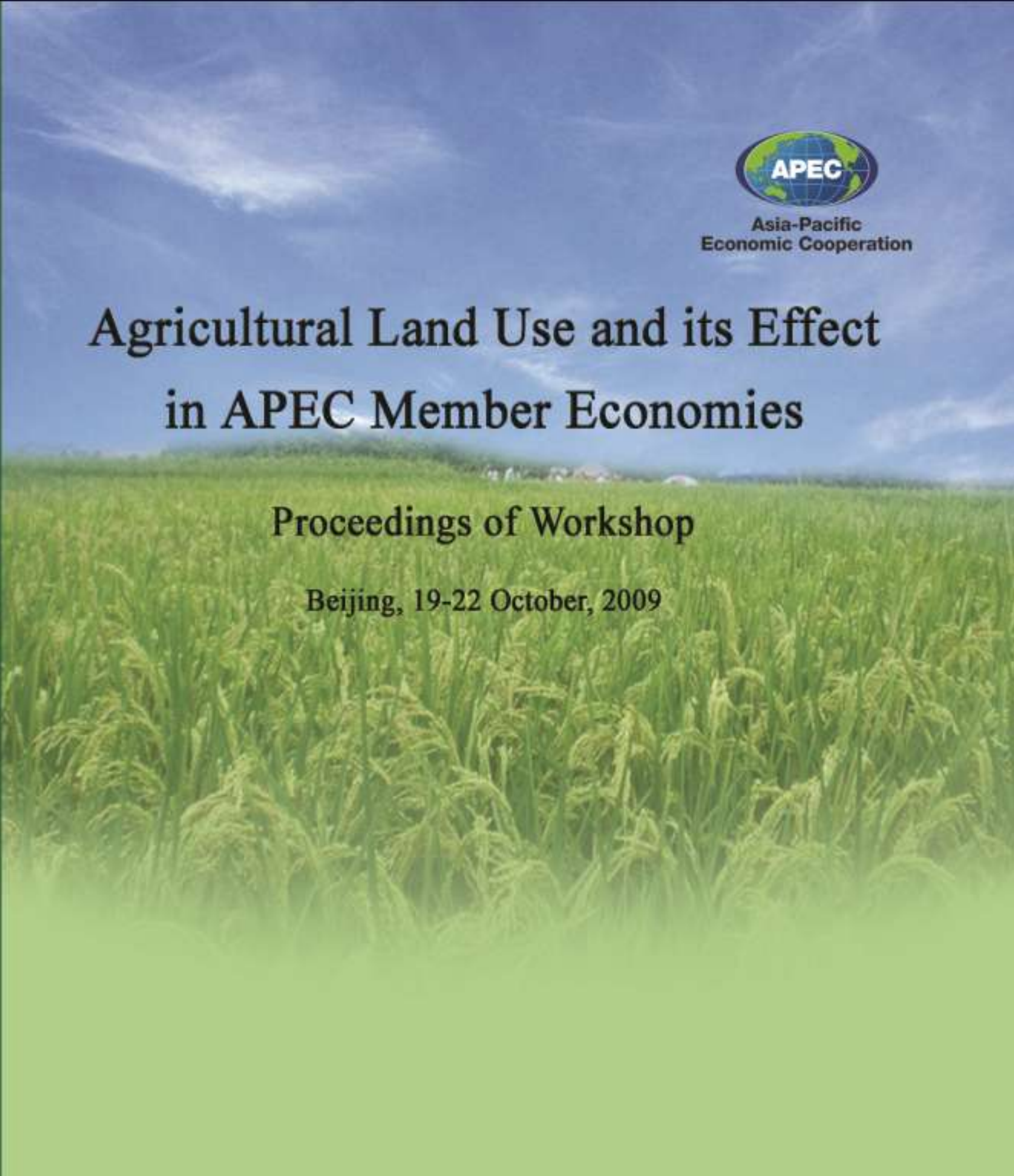

Asia-Pacific
Economic Cooperation

Agricultural Land Use and its Effect in APEC Member Economies

Proceedings of Workshop

Beijing, 19-22 October, 2009

APEC Agriculturala Technical Cooperation Working Group
March, 2010

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CHEN Youqi, HE Yingbin and YU Qiangyi

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March, 2010

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Preface

Sustainable agricultural land use and its effects is one of the hottest issues for economic growth all over the world with no exception of APEC. It has been realized widely that agricultural land management is one of the major factors affecting our environment, due to the fact that agriculture accounted for over 5% of pollution incidents in 2005. Poor agricultural land management results in soil erosion, fertilizer and pesticide run-off that can cause pollution to decrease land productivity and to threaten food security, and climatic change, which is unfavorable to human being, meanwhile good agricultural land management, can reduce these impacts. With APEC members' rapid economic development and huge populations, sustainable agricultural land use is more urgent and the rural environmental problems are more serious according to the present status of APEC economies. Therefore, this paper collection should be particularly valuable in the context of APEC priorities.

In accordance with the 2007 Sydney Leaders Declaration and the outputs of 11th ATCWG Annual Meeting, the "Workshop on Agricultural Land Use and Its Effects among APEC Economies" was held in October of 2009 in Beijing. The workshop aims at improving the level of agricultural land use management and the awareness of the effect of agricultural land use and its change on climatic change and food security. Moreover, organizers expected to enhance realization of sustainable agricultural land use and to strengthen productivity and competitiveness of agro-products in the APEC economies.

Participants were actively involved in workshop deliberations. Presentations, discussions and questions were closely concerned with monitoring and assessment of agricultural land use, the effect of agricultural land use on climate change and food security, the utilization and conservation of agricultural resources, the application of advanced technologies in agricultural land use, regional agricultural land use planning, and public participation and education.

After the meeting, delegates realized to share expertise and advanced technologies on agricultural land use management and to integrate knowledge on how to more rationally and efficiently use agricultural land among APEC member economies. Through the discussion, the APEC distinguished economies strengthened cooperation and exchange of various outputs and knowledge on the effect of agricultural land use and its change on climatic change. Moreover, the participating experts agreed to further linkage and mechanisms of exchange of information affecting sustainable agricultural land use in APEC member economies and to promote sustainable agricultural development in APEC economies.

As a part of the workshop achievements, this proceeding consists of 29 articles, of which some was not presented at the workshop but implemented by editorial committee.

The Publication of this proceeding is encouraged and financially supported by APEC Secretariat, APEC BMC, Chinese Ministry of Agriculture and CAAS, IARRP. I truly express my sincere appreciation to staffs working for this workshop and all the contributors who helped publish this proceedings. I hope that various people in the field of agricultural land use would review this proceedings and that it will contribute to the progress of land use sciences.

CHEN Youqi
Nov., 2009

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Speech at the Workshop on Agricultural Land use and Its Effect in APEC Member Economies

LU Xiaoping
Deputy Director General, Department of International Cooperation, Ministry of Agriculture of China

Distinguished Chairman,
Dear experts and participants,

Good morning.

It is a great pleasure for me to attend the Workshop on Agricultural Land Use and Its Effect in Economies of the Asia-Pacific Economic Cooperation (APEC). Hereon, on behalf of Ministry of Agriculture of China, I would like to extend my warmest welcome and sincere gratitude to all participants.

Chinese Government has always paid high attention to agriculture, and has kept putting agriculture in the first place of economic development, given top priority to well addressing issues of agriculture, rural development and farmers. In the past six decades since the founding of new China particularly three decades since reform and opening-up, China has made unprecedented and magnificent achievements in rural economy, politics, cultural and social undertakings. Regarding supply and demand of main agricultural produces such as grain, we have achieved great historical transition from long-term shortage of supply to general balance with surplus in harvest years. By relying on its own resources, China has succeeded in feeding 21% of the world population with merely less than 9% of the world arable land, laying a solid foundation for China reform, development and social stability, as well as contributing a lot for world agricultural development, global anti-poverty cause and progress of mankind.

Agricultural technology cooperation is a significant component of APEC. Since its creation, Agricultural Technology Cooperation Working Group (ATCWG) has promoted agri-tech cooperation among economies in a pragmatic manner, vigorously advancing agricultural development within the region. Ministry of Agriculture highly valued agricultural cooperation with APEC economies; by capitalizing on this platform, actively strengthen cooperation in agricultural field. The purpose of this Workshop aims at setting up communication platform for APEC economies, discussing new circumstances and new problems arising from land use change in Asia and Pacific region, brainstorming solutions to food security and climate change so as to promote regional sustainable development of agriculture. According to my colleagues, you had an open and free dialogue over the past two days. Centering on farmland use and its effect, the topics involve farmland use monitoring and appraisal, impacts of climate change on farmland use, correlation between farmland use and food security, high technologies for rational use of farmland, regional land use planning and awareness-raising of rational farmland use, among other things, with heated discussion and extensive exchange, the Workshop has served the anticipated purpose.

Chinese agriculture cannot develop without the world and China’s full participation is also indispensable to the world agricultural development. Chinese government will carry on opening-up policy unswervingly and open wider to the outside world in an all-rounded manner and actively engage in agricultural international exchange and cooperation in an even larger scale, a wider range and a higher level. It is my sincere hope that all participants will continue supporting APEC agricultural cooperation and China’s agricultural development. I believe, with the joint endeavor, APEC agricultural cooperation will have a more splendid success.

Finally, I wish you good health and an enjoyable stay!

Thank you.

Remarks at the Workshop on Agricultural Land use and Its Effect in APEC Member Economies

TONG Xianguo

First Secretary of Ministry of Foreign Affairs of China

Distinguished delegates of APEC member economies,

Dear Specialists and Scholars,

Ladies and Gentlemen,

First and foremost, please allow me to welcome you, on behalf of the Ministry of Foreign Affairs of China, to this Workshop on Agricultural Land Use and Its Effect in APEC Member Economies. Golden Autumn is the best season in Beijing. Surrounded by such a beautiful environment, I am sure that all participants will be highly inspired and the workshop will yield a good result through friendly exchanges and discussion.

China has an old saying, "food is the heaven of population". It means feeding and clothing people is the paramount task of a ruler under the heaven. Whoever is capable of solving this heavenly issue, people would accept his rule. Mr. William Petty, a British political economist also said more than three centuries ago, "labour is the father of wealth, while land is the mother of wealth." The combination of the two will create wealth. Apparently, both the ancient oriental people and the western philosopher have a shared understanding on land use, no matter how far they were apart, geographically as well as ideologically.

We, APEC, have 21 member economies. Great majority of which has a fairly large sector of agriculture. Agriculture in those economies not only feeds its population and provides the initial capital accumulation for its industrialization, but also shoulders the task of supplying raw materials to industries and offers the fundamental thrust to sustainable economic development. Most of APEC members take agriculture and optimal land use as the main elements of APEC cooperation to promote regional economic and social prosperity. Furthermore, agriculture and optimal land use are used as an important tool to cope with world food crisis and to ensure food safety. I am certain that this workshop will offer experts and scholars present an excellent platform on which you will exchange views and make common efforts to explore cooperative prospect. From your perspective, you will make full use of this opportunity to study inner-circle issues of changes witnessed in agricultural land use. Building on the findings of your studies, you will contribute your recommendations and advice for the sustainable agricultural development in the region.

Ladies and Gentlemen, now I want to avail myself of this opportunity to give you a brief briefing about the Asia Pacific Economic Cooperation (APEC) and the major work of Agricultural Technical Cooperation Workshop Group in the framework of APEC.

APEC was established 20 years ago this year. The vision was to improve prosperity and well-being in the Asia-Pacific through free and open trade and investment.

To achieve this vision APEC has an Action Agenda that focuses on what we call the Three Pillars:

- Trade and Investment Liberalization
- Business facilitation
- Economic and Technical Cooperation

The importance of the first two pillars to free and open trade is easy to understand. But what many don't know is the emphasis that APEC puts on the third pillar--economic and technical cooperation-or capacity building.

For APEC, capacity building is the scaffolding that allows the other goals to be reached.

APEC's 21 member economies represent 40% of the world's population, 44% of global trade and 54% of world GDP: but within our group there are significant disparities in development and economic and social well-being. As it is know to all, among APEC members there is the most developed economy in the world, as well as the least developed economy. Capacity building is therefore a top priority for APEC because the future prosperity of the region depends on enabling all of our citizens to take advantage of globalization.

Since 1993 over 1,400 capacity building projects have been initiated within APEC.

Right now over 200 such projects are being implemented by APEC's working groups and task forces, at a value of around 14 million US dollars. In 2008, APEC approved 107 such projects worth 8.5 million U.S. Dollars. These projects focused mainly on technical barriers to trade, trade and investment in regional free trade agreements and building productive capacity in the agriculture and energy supply and generation sectors.

Though ATCWG is one of the 16 APEC working groups and task forces, it constitutes an important area of APEC economic and technical cooperation. It undertakes such crucial tasks as green growth, food safety, development of sustainable biomass energy, and sustainable economic development. Ever since 1996 when ATCWG was founded, the working group has made great contribution to the above-mentioned goals. In the 2007 APEC Leaders' Declaration, Leaders stated that "additional capacity building in this area is a priority". The world has limited resources of arable land. However, as the life expectancy maintains growing, the population increases, and industrialization and urbanization, pressure on land use faced by APEC member economies keeps increasing. ATCWG is now confronted by a daunting task. It is still far from its final target. ATCWG will only achieve its aim by way of technical exchange and cooperation, by way of promote agricultural productivity among APEC members. This is the only way that we can thoroughly solve the problems of feeding and clothing our people in the region, and in the end contribute to the world food safety. We are confident that this workshop will surely enhance the APEC member economies cooperation on this field.

I am delighted to know that China was elected the Lead Shepherd of ATCWG in June this year, assuming a role of leadership for APEC agricultural technical cooperation. The ATCWG leadership will be carried out by the Ministry of Agriculture, but the Ministry of Foreign Affairs would like to provide necessary support for the China ATCWG Lead Shepherd, and help him to successfully fulfil the task. We are confident that with the common efforts and support of all ATCWG members, APEC agricultural technical cooperation will land on a new height. Even greater contributions will be made to the food safety of all APEC members.

Last but not the least, I wish the workshop be crowned with a full success.

Thank you.

Speech at the Workshop on Agricultural Land use and Its Effect in APEC Member Economies

WU Changxue

Deputy Director, Division of General Affairs, Department of International Cooperation, Ministry of Agriculture of China

Honorable Chair, distinguished leaders, dear guests:

Good morning!

I’m very happy to attend the Workshop on Agricultural Land use and Its Effect in APEC Member Economies. First of all, I would like to extend the warmest welcome to all participants.

This workshop is held as a follow-up to the declaration of 2007 informal summit meeting of APEC leaders in Sydney that called on people to face up to climate change challenges, the commitment of Osaka Action Agenda to promoting sustainable development among APEC members, and ATCWG agreement in Brisbane to incorporate land management into the priority areas of APEC agricultural cooperation.

There are about 60 participants here at the Workshop, including 22 foreign specialists from 10 APEC members, namely Australia, Canada, Chile, Indonesia, Mexico, the Philippines, Chinese Taipei, Thailand, the United States and Viet Nam, and more than 30 Chinese representatives from institutions, including Institutes of Geographical Sciences and Natural Resources Research of CAS, Chinese Research Academy of Environmental Sciences, Chinese Agricultural University, Beijing Academy of Agriculture and Forestry Sciences, Northeast Institute of Geography and Agroecology of CAS, Hubei University, Hunan Normal University and Tianjin Polytechnic University.

China is committed to agricultural cooperation in the Asia and Pacific region, by on one hand actively participating in the work of ATCWG through the coordination of APEC Secretariat. With the support of all ATCWG members, Mr. Tang Huajun, vice president of CAAS, has been elected as the new Chair, and a special team has been set up to better serve ATCWG members. On the other hand, APEC agricultural cooperation has been given significance and support by the Ministry of Foreign Affairs, Ministry of Finance, Ministry of Agriculture and related authorities. They encouraged and supported agencies to organize workshops or seminars on hot topics and issues of interest to APEC members, which have provided opportunities for member economies to build on communication and cooperation.

In this two-day workshop, there will be intensive and extensive exchange of views over problems and challenges APEC member economies face right now in agricultural land use, indeed providing an opportunity for all members to share and learn, which will be conducive to APEC agricultural cooperation and food security. China has managed to feed 21% of the world's population by less than 9% of world's cultivated land, and has done it self reliantly, which is a big contribution to food security of the world. China will continue to exercise the most stringent arable land protection scheme and use agricultural land on a scientific basis to strive for increase in grain output, in productivity and in farmers' income. APEC economies have accumulated successful experience in terms of agricultural land use, which China wishes very much to capitalize on opportunities like this to take in and replicate into reality in China later on.

This Workshop has got great help from APEC secretariat in making coordination, has got great support from all participating members and agencies, and has been arranged meticulously by the Institute of Agricultural Resources and Regional Planning of CAAS. Thank all of you for your effort.

I'd like to conclude by wishing this workshop a complete success. Wish you a merry and wonderful stay here in Beijing.

Thank you.

Session1:

Monitoring and assessment of agricultral land use

Agricultural Land use Mapping and Decision-Support in Australia

Robert Lesslie, Jodie Smith and Jasmine Rickards
Bureau of Rural Sciences GPO Box 858 Canberra ACT 2601 Australia

Abstract: Land use information has a critical role to play in Australia in developing effective responses to national natural resource management issues involving carbon, water, productivity and sustainability—at national, regional and local levels. This calls for strategic and coordinated collation and delivery of land use information. This paper introduces the elements of a nationally coordinated land use mapping program for Australia – the Australian Collaborative Land Use and Management Program (ACLUMP). Currently, major ACLUMP activities include national-scale and catchment-scale land use mapping, land management practices mapping and measuring and reporting change. A major challenge to the program includes making better use of new and improved national data streams (including statistical collections and remote sensing) and maintaining the currency of information for dynamic land uses. ACLUMP is also investing in developing the technical capacity for the spatial analysis of land use and land management issues and drivers of change. This includes a newly-developed spatial multi-criteria analysis tool — the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S). MCAS-S is designed to assist spatial priority setting, particularly in participatory processes and workshop situations. The tool provides for multiple map display, combination and manipulation of spatial data, and live update of changes - capabilities that enable clear visualisation of the relationships between the spatial data other constraints (including policy goals and stakeholder perspectives).

A National Land use Mapping Program for Australia

The way that land is used and managed has profound effects on social and ecological systems (Figure 1). There is a strong link between changes in land use and environmental, economic and social conditions. Land use information is therefore critical to developing effective responses to natural resource management priorities, including biodiversity protection, sustainable and productive agriculture, water quality and quantity, climate change adaptation, and food security. It can also contribute to risk analysis for pests and disease threats.

In Australia, the role that land use information plays in natural resource management at the national, regional and local level requires nationally coordinated collation and delivery of land use mapping. This has been promoted through the Australian Collaborative Land Use and Management Program (ACLUMP) – a program established and developed by a partnership of Australian and state government agencies with responsibility for agriculture and natural resources management.

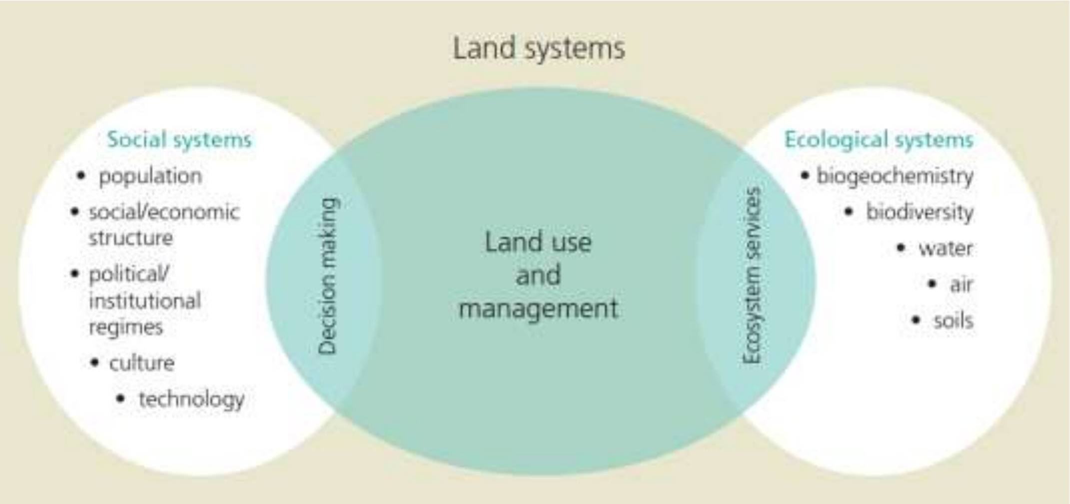


Figure 1 Key relationships in coupled human-environment systems

Adapted from: Global Land Program (2005)

Land use and management is the critical link between ecological systems, social systems and the sustainable use of natural resources. Effective natural resources management requires better understanding of the dynamics of land systems, the consequences of change and a capacity for integrated analysis and modelling.

ACLUMP has promoted the development of nationally consistent land use mapping at 'catchment' and 'national' scales; established technical standards including a national land use classification system – the Australian Land Use and Management (ALUM) Classification; provided web-based delivery to facilitate community access to land use information; and reported on national and regional reporting of conditions and trends. ACLUMP is also developing protocols for detecting and reporting land use change and the classification and spatial representation of key land management practices. These activities are made possible through agreed standards and pooled resources and knowledge.

The term 'land use' is one of a number that describe aspects of the human occupation, use and management of landscapes. ***Land cover*** is the observed physical surface of the earth, including various combinations of vegetation types, soils, exposed rocks, water bodies and human artefacts. ***Land use*** is the purpose to which the land cover is committed, including the production of goods (such as crops, timber and manufactures) and services (such as defence, recreation, biodiversity and natural resources protection). ***Land management practices*** is the means by which a land use outcome is achieved – the 'how' of land use (e.g. cultivation practices such as minimum tillage or direct drilling). ***Land tenure*** is the legal conditions of ownership under which the land is held. Unlike most other national approaches, ACLUMP clearly distinguishes land use from land cover, with its prime objective being the mapping of land use and, more recently, land management practices information.

Land use mapping products

Land use information in Australia is produced at both national- and catchment-scale. national-scale land use mapping (approximately 1:2 500 000 scale) is required for strategic planning and continental modelling, such as national carbon accounting and salinity assessments at the river basin level. national-scale land use mapping is compiled as gridded data at 1 km resolution using a cost-effective procedure that links the growth characteristics of various crops and pastures, time-series satellite data, national agricultural statistics and available spatial data on non-agricultural land use (Bureau of Rural Sciences 2006) (Figure 2).

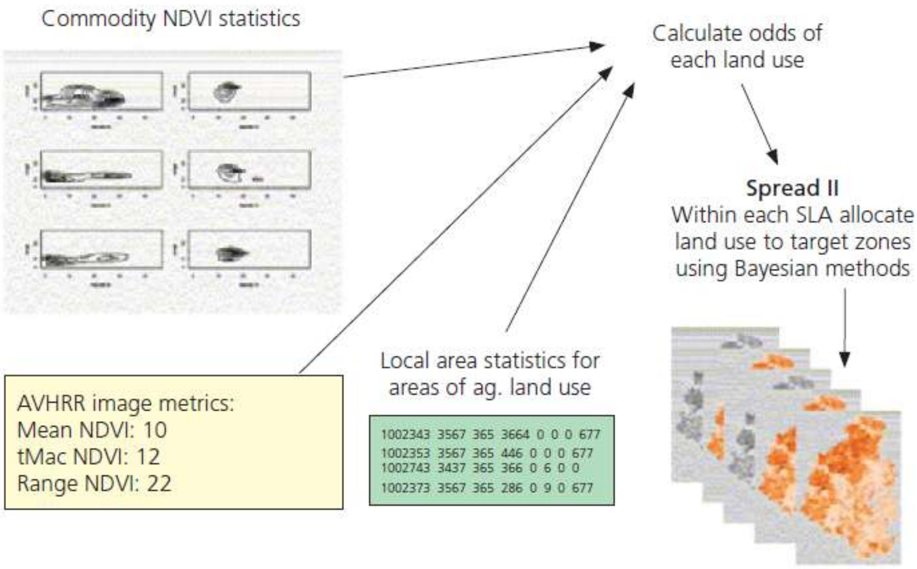


Figure 2 National-scale land use mapping procedure

The mapping process, described by Bureau of Rural Sciences (2006); Lesslie *et al.* (2006), involves:

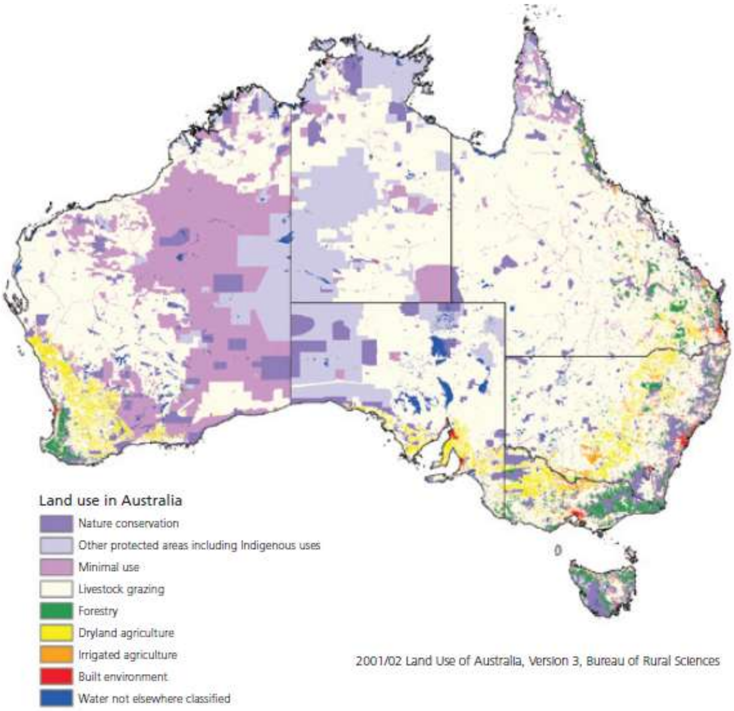
acquisition of NOAA-Advanced Very High Resolution Radiometer (AVHRR) Normalised Difference Vegetation Index (NDVI) annual time series for continental Australia;

compilation of field sites (approximately 1000) for commodity NDVI signatures across Australia;

combination of existing national spatial data sets to produce layers of non-agricultural land uses and mask out non-agricultural land uses from further processing; and

statistical allocation of likely land use classes based on known total commodity areas for local areas from agricultural census data (Bureau of Rural Sciences 2006).

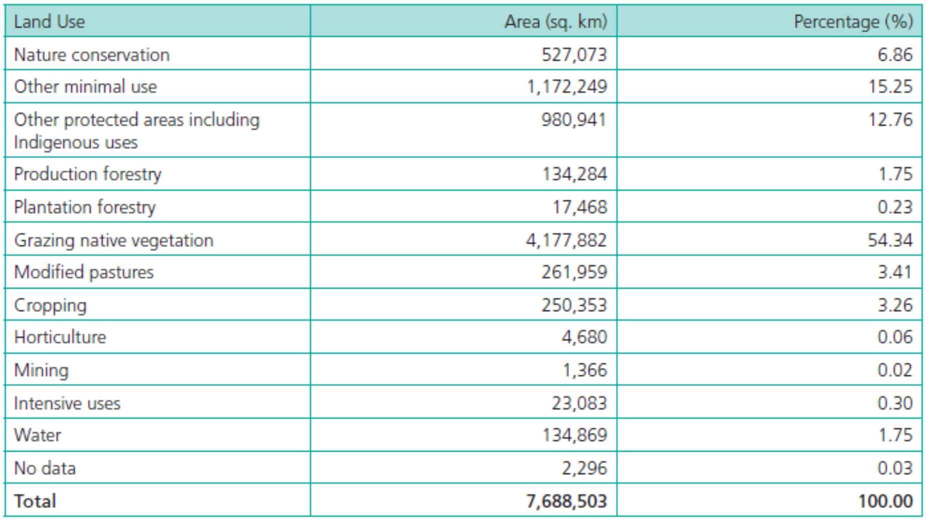
A Bayesian probability method is used to allocate likely land use classes based on statistical characteristics of AVHRR NDVI for commodities defined by the field site data, the time-series AVHRR NDVI data for the continent, and census data about the amount of individual land uses for statistical local areas. Grid cell data layers represent probability surfaces for each mapped commodity or land use type. A single layer is produced containing most likely land uses based on the probabilities of all types mapped. national-scale mapping for Australia (2001/02) is shown in Figure 3.



2001/02 Land Use of Australia, Version 3, Bureau of Rural Sciences

Figure 3   ACLUMP National Land Use map for Australia 2001-02

Jasmine, can you please check that this table is also for 2001/02 so that it matches the map. Email Jodie if you need to find a new table (should be one under V:/projects/landuse_website)



Land Use	Area (sq. km)	Percentage (%)
Nature conservation	527,073	6.86
Other minimal use	1,172,249	15.25
Other protected areas including Indigenous uses	980,941	12.76
Production forestry	134,284	1.75
Plantation forestry	17,468	0.23
Grazing native vegetation	4,177,882	54.34
Modified pastures	261,959	3.41
Cropping	250,353	3.26
Horticulture	4,680	0.06
Mining	1,366	0.02
Intensive uses	23,083	0.30
Water	134,869	1.75
No data	2,296	0.03
Total	**7,688,503**	**100.00**

Catchment-scale mapping (ranging from scales of 1:25,000 to 1:250,000) is also required to address natural resource management issues at the landscape level, such as soil erosion. State and territory partners have the primary role in catchment-scale mapping and data management. Catchment scale land use mapping is produced by combining state land parcel information, public land databases, fine-scale satellite data, other land cover and use data, and information collected in the field. The mapping process has successive stages of data collation, interpretation, verification, independent validation, quality assurance and the production of land use data and metadata.

A major area of new activity for ACLUMP is the classification and mapping of land management practices. The practices adopted by farmers and other land managers have a critical role in mediating the effects of land use on natural resources, particularly soil and water. ACLUMP has developed a hierarchical categorisation system for land management practices and completed pilot land management practices mapping work.

A key initiative in the area of land management practice is the commencement of mapping of characteristic patterns of ground cover maintenance (the frequency and length of bare ground through the annual cycle) in cropping and modified grazing systems. It is planned that this work will commence in 2010 and that outputs will form the basis for ongoing national monitoring and analysis of change in ground cover management under cropping and modified pasture land uses.

The Application of Land use Information

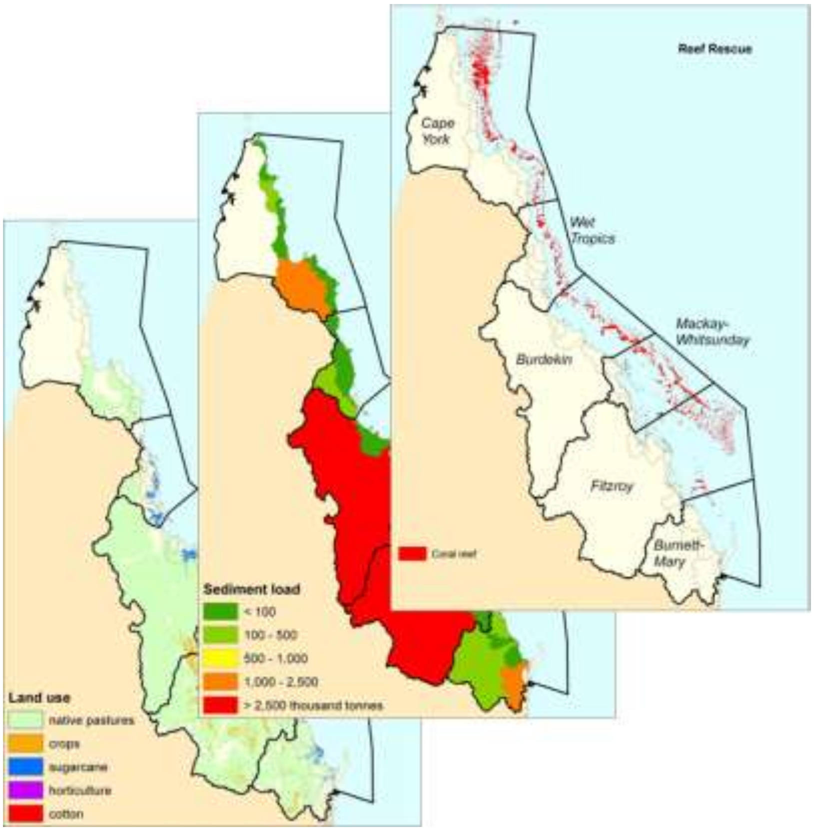
Land use information in Australia is being used in a wide variety of applications. It is being used to help manage catchment salinity, nutrient and sediment problems, assess agricultural productivity and opportunities for agricultural diversification, land value determination, local and regional planning, pest and disease control and emergency response planning.

A recent example of the application of land use mapping is helping plan for improved water quality in the Great Barrier Reef. The Great Barrier Reef is a coral reef system that extends more than 2,000 kilometres along Australia’s eastern seaboard. It is a natural and economic asset of major significance to Australia. The Australian Government is aiming to improve the water quality of the Great Barrier Reef lagoon by increasing the adoption of land management practices that reduce the run-off of nutrients, pesticides and sediments from agricultural land in coastal catchments. The level of sediment, nutrient and pesticide run-off is determined largely by land use and management practices. For example, extensive grazing of rangelands has greatly increased sediment loads and intensive coastal agriculture has greatly increased nutrient loads. As part of ACLUMP, the Queensland Department of Environment and Resource Management has produced land use maps for reef catchments. This information, combined with sediment load modelling and reef asset mapping have helped target investment in improved land management practices (Figure 4).

Challenges

The production of relevant, cost-effective and timely land use and land management information presents a number of technical challenges which ACLUMP is currently addressing. These challenges include the application of sophisticated data integration methods to make best use of the wide range of input data streams (including satellite imagery and statistical collections) which are now available to produce land use information products.

Figure 4: Land use mapping, sediment load modelling and reef asset mapping for the Great Barrier Reef



ACLUMP is also working towards establishing a national system for identifying, mapping and reporting land use change. At the national scale, current investigations are focused on the use of best available modelling methods, coupling time-series satellite image data and agricultural statistics to identify and report on change. At the catchment scale, efforts are focused on methods for identifying change in key catchments and, more specifically, on the use of remote sensing methods to report changes in pasture and cropping land use systems. Mapping the dimensions of land use change presents particular challenges. For example, protocols for reporting land use change in an agricultural context need to be capable of distinguishing the temporal characteristics of farming systems (e.g. rotations) from seasonal variability and longer-term industry and regional trends.

Analysis & Decision-Support

Land use decision-making generally requires the analysis of a wide variety of land use, land management, environmental, social and economic information. It also requires the incorporation of stakeholder opinion, value judgement and policy and management goals. Justifiable decisions depend on the logical and transparent combination and analysis of information. The Bureau of Rural Sciences (BRS) is working with the ACLUMP partnership to develop improved methods and tools for combining and analysing spatial information from a wide variety of sources to support better informed land use and land resources decision-making. A key product in this area is a spatial multi-criteria analysis tool, the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) developed by BRS (Bureau of Rural Sciences 2009).

The MCAS-S tool enables the implementation of spatial multi-criteria analysis (MCA), a method for identifying and evaluating options using mapped information that has wide application in approaching land use and natural resource decision-making. MCAS-S desktop software enables visualisation of map combinations without the need for GIS programming, and it is well suited to the exploration of alternate scenarios by policy makers and stakeholders through its 'live-update' mapping and visualisation capabilities. The example below show how MCAS-S has been used to assist decision-making for land use assessment and natural resource management in Australia. This example draws on a national level assessment of factors affecting the sustainability of extensive livestock grazing in the Australian rangelands (Lesslie *et al*. 2008).

Approximately three quarters of the Australian continent is occupied by rangelands. Rainfall in these areas is generally too low or too variable for dryland cropping or grazing on improved pastures and so land use is dominated by sheep and cattle grazing on native pastures. The benefits of appropriate management of the rangelands include the retention of ecosystem benefits such as biodiversity, storage of carbon, and sustainable and profitable pastoral industries. However, without a sound understanding of the productive capacity of rangeland ecosystems and their sensitivity, environmental pressures such as feral animals and overgrazing can have long lasting negative effects. Grazing in the rangelands can be described as sustainable where economic resilience and stability is combined with the regional maintenance of native species and other ecosystem services.

A spatial multi-criteria analysis completed using MCAS-S was developed to explore these relationships and tensions between competing claims of rangelands natural resources (Lesslie *et al*. 2006). This work was based on the combination of three components: potential productivity, sensitivity of the resource base to livestock grazing, and total grazing pressure. First, relevant input data were combined using MCAS-S functions to produce composite indexes representing the attributes. Primary data input layers were selected and their role in contributing to composite measures examined in a workshop process utilising expert advice. The potential pastoral productivity index was, for instance, developed by the weighted combination of input layers using the logic that potential productivity will generally be greater where landscapes have higher productive potential (forage potential), rainfall is relatively consistent within and between seasons, and there is better access to markets, supplies and labour. The result of a composite index development process for potential pastoral productivity using the MCAS-S tool is shown in Figure 5.

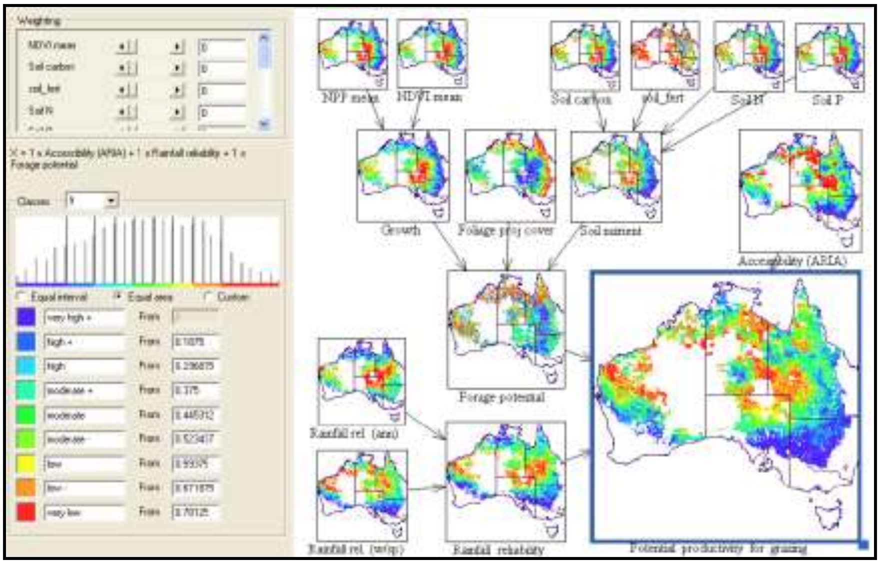


Figure 5: Potential productivity for livestock grazing in the Australian rangelands

Adapted from: Lesslie *et al.* (2008)

The MCAS-S tool was also used to enable exploration of the spatial relationship among derived layers of potential pastoral productivity and the sensitivity of the resource base to livestock grazing. The map layer on the right hand side of Figure 6 highlights locations conditions in the upper right quadrant where there is a coincidence of high potential productivity and high resource sensitivity index values. Locations where other relationships apply can be also be interactively explored using the tool.

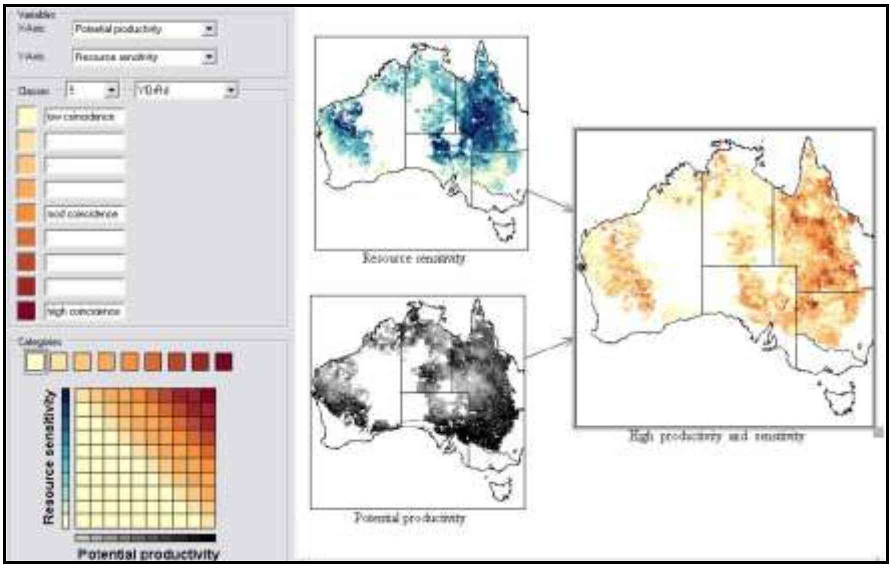


Figure 6: Highlighting locations of high productivity and high sensitivity for grazing in Australian rangelands

Adapted from: Lesslie *et al.* (2008)

Conclusions

In Australia, substantial progress is being made in addressing the demand for land use information and integrated assessment tools to support better informed natural resources management decision-making. To date, ACLUMP has emphasised the development of consistent land use mapping at scales relevant to natural resource management. This adds to established programs producing land cover, tenure and commodity information. Work on the development of data sets and methods for analysing land use change is also progressing, with techniques that couple high temporal resolution satellite imagery and agricultural statistics showing particular promise. Development of the capacity to map and analyse more completely the dynamics of land use and land management in ways that help effectively address major natural resources management issues in Australia such as water management and soil degradation continues to represent a significant challenge.

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An Integrated Modeling Framework to Understand Agricultural Land-Use Changes at a Global-scale

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Abstract: This paper presents an integrated agricultural land-use change model to simulate past and future dynamic changes in sown areas for four major crops at a global scale. This modeling approach, including four core models, was developed under the framework of Action- in-Context (AiC). The crop choice decision model, a Multinomial Logit model was used to model the crop choice decisions among a variety of available alternatives by using a crop utility function. A crop yield model, the GIS-based EPIC model was adopted to estimate the potential yields of different crop types under a given biophysical and agricultural management environment. A crop price model, the IFPSIM model was utilized to evaluate the price of the test crops in the international market. An urban expansion model was constructed to examine the characteristics of urban land expansion and the consequent cropland loss, and to dynamically update the total percentage of land available for agricultural land use. These models were seamlessly linked through data flow and exchange between them, and the dynamic feedback loop between agricultural land-use change and biophysical and socio-economic driving factors was studied. Empirical validation for the model conducted after model construction indicated the reliability of the model for addressing the complexity of current agricultural land-use change and its capacity for investigating long-term scenarios in the future.

Key words: Sown area change, modeling, crop choice decision, yield, global scale

1 Introduction

Over the past few decades, numerous agricultural land-use change models have been developed to understand the dynamics of land-use system (Verburg and Veldkmap, 2005) and to evaluate scenarios to inform policy makers (Solecki and Oliveri, 2004; Kok et al., 2007). These models can be roughly grouped into two categories. One group of models follows a top-down, land evaluation; pattern-oriented approach based on remote sensing and GIS data. This modeling approach generally starts with an analysis of the location suitability for different land uses and allocates the predetermined changes to grid cells primarily based on these suitability maps or based on the condition of neighboring cells. Its unit of analysis is an area of land, either a polygon representing a field, plot of census track, or a pixel as part of a rater-based representation (Castella and Verburg, 2007). In contrast, models in the other category adopt a bottom-up, anthropologic, process-based approach based on household surveys and resource inventory. These models recently have gained popularity in the LUCC scientific community, and use the real actors of land-use change as objects of analysis and as units of simulations, and pay explicit attention to interactions between these “agents” of change. Therefore, they are commonly referred to as actor-based or agent-based models (Parker et al., 2003).

In the modeling of agricultural land-use change, actor-based or agent-based models are often used to understand the agricultural activities or actions such as crop choice, adoption of a new technology, and distribution of agricultural labor forces for individual farmers, households or agricultural organizations at various levels. In this study, following the actor-based modeling approach, a global-scale model of agricultural land-use change was developed. The objects of analysis of this model differs from other LUCC models in that this model specifically simulates the dynamic changes in sown areas of crops occurring in agricultural lands while other models are focused mainly on the simulation of conversions between croplands and other types of land use like forests, grassland and urban areas.

2 Methodology

The general hypothesis of the modeling approach is that the sown area of particular crops is directly linked with human decisions on crop choices for farmland. Land users make decisions about crops for their land based on an understanding of ecological, socio-economic, technological and political factors at local, regional, national and international levels (Duffy et al., 2001). Land use on a regional scale is the sum of the results of decision making at the farm level (Rounsevell et al., 2003). Thus, through capturing the essential features of individual human decision processes on crop choices, it is possible to track and estimate changes in the crop sown areas over time and space (Wu et al., 2007a and 2008a). However, the possibilities of making a living for farmers are broader than agriculture alone. For the sake of simplification, we assumed that farming is the main source of income of the farmers or households; hence, the research question is why households cultivate a certain crop at a certain location and how they adjust their crop choices in response to changes in the coupled human-biophysical systems (Wu et al., 2007b).

The aforementioned assumption can be implemented under the framework of Action-in-Context (AiC) (De Groot, 1992; Overmars et al., 2007a and 2007b). AiC is a methodology designed for the studies that puts human actions, especially in the environmental field, for example crop choice decisions in this case, into context to gain insight in the causes of the actions. The idea of AiC is to start with the actions to be explained, to identify the decision-making actors directly causing this action, then to study the range of options available to the actors and the motivations attached to these options (Overmars et al., 2007a). With that, AiC is a fully actor-based or agent-based framework, which is a logical choice for explanatory work because actors, not systems, are the social entities that cause change directly. A more elaborate description of the deeper analysis can be found in De Groot (1992) and Overmars et al. (2007b).

In this study, the modeling approach followed an integrated structure and was constructed based on five core models and their relationships are shown schematically in Figure 1. The crop choice decision model is a Multinomial Logit model, which was used to model the crop choice decisions among a variety of available alternatives by using an optimization approach. A crop yield model, the GIS-based EPIC model was adopted to estimate the potential yields of different crop types under a given biophysical and agricultural management environment (Tan and Shibasaki, 2003). A crop price model, the IFPSIM model was utilized to evaluate the price of the test crops in the international market (Ohga and Yanagishima, 1996). An urban expansion model was constructed to examine the characteristics of urban land expansion and the consequent cropland loss, and to dynamically update the total percentage of land available for agricultural land use. The crop choice decision model is the main mechanism determining changes in crop sown areas and it is affected by the crop yield and crop price models, which determine directly the crop utilities or profits, as well as by the global cropping systems and the urban expansion model, which provide different crop choice sets to decision-makers or affect the allocation of crop choices. These models are seamlessly linked through data flow and exchange between them.

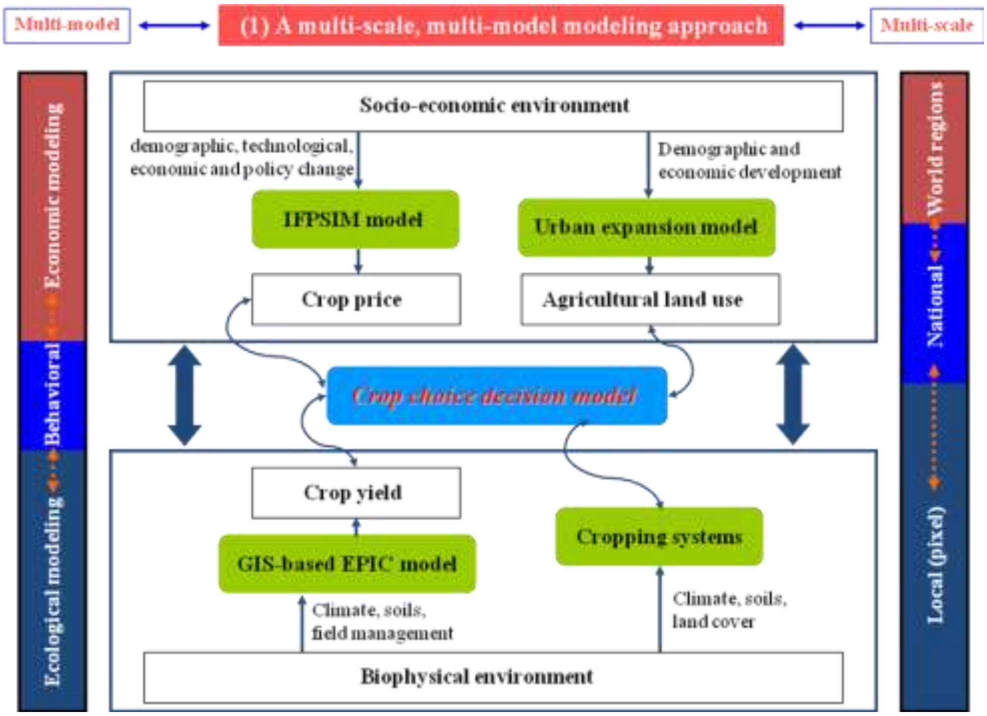


Figure 1. General structure of the modeling approach.

2.1 Crop choice decision model

In this study, a crop choice decision model was developed using discrete choice methods based on Random Utility Theory (RUT) to understand the crop choice behavior of land users (Wu et al., 2007a and 2008a). The RUT is a well-established method for quantifying the preferences of individuals choosing an option from a finite set of potential alternatives. Farmers were assumed to be generally autonomous and to maximize their long-term profits within the constraints of their situation, taking account of uncertainty in prices and yields, which causes farmers on otherwise identical farms to perceive different gross margins for the same crops. We used the term “utility” to describe a mathematical function that expresses the preferences of discrete crop choices of land users in a utility maximizing framework. Using these relative crop utilities, farmers seek to maximize their income by allocating their lands to those crop cultivation activities that they perceive will provide the greatest return or that will carry the least risk. The allocation of land to specific crop types is then translated into the conversion of an area from one crop coverage to another. The utility (U_i) of each possible crop is assumed to comprise two parts:

$$U_i = V_i + \varepsilon_i \tag{1}$$

where V_i is the systematic and observed component of the latent utility for crop i, and ε_i is the random or “unexplained” component.

Because of the random component, scientists can never expect to predict choices perfectly. This leads to the expression for the probability of choice. Assuming that the random error terms are distributed independently and identically and follow the Gumbel distribution, the probability that a crop, i, is chosen for cultivation can be estimated using the Multinomial Logit (Logit) model (Wang et al., 2007; Seo and Mendelsohn, 2008):

$$P_i = e^{V_i} \Big/ \sum_{i=1}^{N} e^{V_i} \tag{2}$$

where i denotes the crop types used for analysis ($i = 1,2,\ldots N$), P_i is the probability for crop type i, and V_i is the observed utility of crop type i, which can be stated as:

$$V_i = a_i + \sum_{j=1}^{M} b_j x_j \tag{3}$$

where a_i is an alternative specific constant for crop type i, j is the number of explanatory variables ($j=1,2,\ldots M$), x is the explanatory variable, and b_j is the coefficient to be estimated for the variable x_j (Mcfadden, 1973).

It is clear from the aforementioned analysis that the impetus for changes in sown crops depends on the difference in their utilities, where a change in crop utilities may drive changes in crop choice decisions, resulting in further changes in crop sown areas over time and space. Therefore, it is very important to select the most appropriate explanatory variables to describe the crop utilities. In general, these variables include biophysical factors (e.g., temperature, rainfall, soil physicochemical properties and topography), demographic factors (e.g., rural population density), socio-economic factors (e.g., farming income per capita, agricultural mechanization, road accessibility and international trade price) and technological factors (e.g., irrigation, fertilizers and pesticides). However, it is not possible to include all of these factors in a LUCC model, especially when modeling land use changes over large areas. Thus, instead of using all of the underlying driving factors, the model generally uses some proximate variables that represent the underlying driving factors (Verburg et al., 2002). Determining the proximate variables is often problematic and an issue of discussion, as there is no unifying theory describing the selection of the most appropriate variables. In this modeling approach, some variables that were highly correlated to others were excluded from the model analysis for the sake of simplification and the elimination of computation redundancy. For instance, crop yield itself is a measure of performance of the crop plant, which is enhanced or reduced by biophysical factors (e.g., temperature, rainfall, soil and topography) as well as by agricultural management practices such as irrigation and fertilizing, therefore crop yield can be used to reflect the impacts and interactions of most biophysical and agricultural management variables. In the construction of this model, four main variables, namely, crop yield, crop price, rural population density and road accessibility, were selected as the explanatory variables for computation of crop utilities (Wu et al., 2007a, 2007b and 2008a).

2.2 Crop yield model

Crop yield, which determines the direct output of farming activities, is likely to have substantial implications for farmer’s crop choices. Changes in crop yield depend on different biophysical and socio-economic factors, of which climate change, increasing CO_2 concentrations and technological development are the most important drivers (Ewert et al., 2005; Stehfest et al., 2007), thus making crop yield difficult to assess.

Process-based models are used increasingly to estimate crop productivity. Of these models, the EPIC model is used by many researchers due to its particular features (Dumesnil, 1993). The EPIC model was initially developed by United States Department of Agriculture, Agricultural Research Service (USDA-ARS) in 1984 with the purpose of understanding the relationship between soil erosion and crop productivity. In EPIC, a general plant growth model with crop-specific parameters is used to simulate the growth of rice, wheat, maize, sorghum and soybean, among others. The EPIC calculates daily potential biomass as a function of solar radiation, leaf area index (LAI), and a crop parameter for converting energy to biomass. The potential plant growth is driven by photosythentically active radiation. The amount of solar radiation captured by the crop is a function of LAI and the amount of solar radiation converted into plant biomass is a function of the crop-specific radiation use efficiency. The daily potential biomass is decreased by stresses caused by water shortage, temperature extremes, nutrient insufficiency and soil aeration inadequacy. The daily potential biomass is decreased in proportion to the severity of the most severe stress of the day. Crop yield is estimated by multiplying above-ground biomass at maturity by a water stress adjusted harvest index (Williams et al., 1990).

The EPIC was originally a site-specific model, and uses a daily time increment to simulate weather, hydrology, soil erosion by wind and water, nutrient cycling, tillage, crop management and growth, and field scale costs and returns. It is thus not possible to use the original EPIC model directly for large-area applications. However, by integrating EPIC with GIS, the EPIC model gains the possibility of estimating crop yields from field level to small or sub-regional scale (Priya and Shibasaki, 2001; Yang et al., 2006). It treats each grid cell as a site and simulates the crop-related processes for each predefined grid cell with spatially distributed inputs. Subsequently, Tan and

Shibasaki (2003) expanded this GIS-based EPIC model to a global level and applied it to detecting crop yields and predicting the effects of future global warming on the yields of major crops at a global level. In their research, the loose coupling approach was used to integrate GIS with the EPIC via data exchange using either ASCII or binary data format between these two packages.

In this study, the GIS-based EPIC model (Version 8120) was used to simulate the potential yields of different crops under given biophysical and management conditions at a global level (Tan and Shibasaki, 2003). Figure 2 shows a brief schematic presentation of the structure of this crop yield model. Running the model simulation requires a variety of input databases to be prepared and processed in advance with the aid of GIS. When all the necessary data were available, crop yields for each grid cell could be simulated for different crops using the GIS-based EPIC. Simulated crop yields for different years were introduced into the crop choice decision model as a basic input variable for the computation of crop utilities.

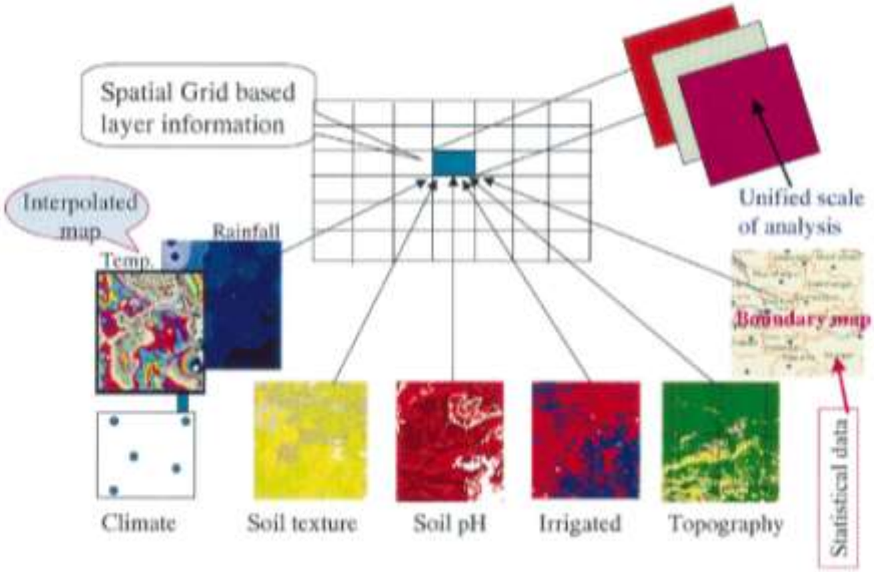


Figure 2. Brief schematic presentation of the GIS-based EPIC model.

2.3 Crop price model

Crop price is another important determinant in human decision-making on crop choices, since it affects the income or returns from the crop types to which farmers may change. In this study, crop price was assessed by a crop price model, the IFPSIM model. The IFPSIM is a multi-commodity, multi-regional and multi-period world agricultural trade and policy simulation model developed and designed on the Ohga Model Building System (OMBS) (Ohga and Yanagishima, 1996). It is a partial equilibrium and interactive model, allowing for the simultaneous determination of supply, demand, trade, stock levels and prices for 14 commodities for 31 regions of the world. A complete description of the regions used in the model has been documented by Ohga and Gehlar (1993).

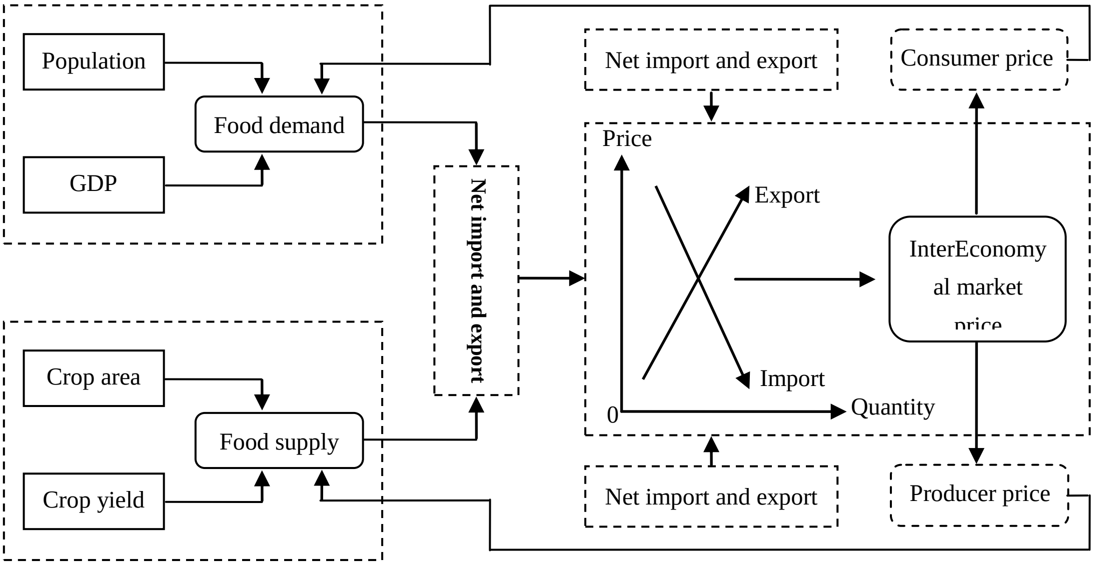


Figure 3. The structure of the IFPSIM model.

Figure 3 presents schematically the structure of the IFPSIM model. Food demand in each region is divided into three kinds: demand for food for human consumption, for livestock and for the production of processed food, and it is described by individual income, population and the consumer purchase price of the crop in question. Food supply in one region is comprised of the supply of crops and the supply of livestock products. The supply of crops is described by crop yields, sown areas and the producer price for each crop. The total food demand or supply in the world is determined from the summation of the demand or supply in each region. In the international market, crop price is determined by the level at which world supply is equal to world demand, where all variables are simultaneously determined, while world market clearing prices are derived by equating the sum of gross imports and the sum of gross exports (Ohga and Yanagishima, 1996). One of important features of the IFPSIM model is that it can deal with changes in demand and supply both inside and outside one region. This is especially important in relation to trends in global trade. Thus, the crop price in one region estimated by the IFPSIM model reflects not only the demand (and supply) of the internal market, but also the demand (and supply) of the external market. The simulation results for crop price were saved as text format data and input into the crop choice decision model for dynamically updating the crop utilities.

2.4 Urban expansion model

Urban itself does not directly influence the crop choices made by land users, but indirectly influence the allocation of crop choices since urban areas are usually surrounded by intensive arable farming and their expansion is often associated with a loss of cropland. Urban land expansion has been perceived as the crucial factor affecting farmland decline because urban development will encroach upon more fertile and productive croplands (Tan et al., 2005). Thus, a global-scale urban expansion model was constructed to examine the characteristics of urban land expasion and to understand the consequent cropland loss and the availability of arable land for crop choices.

Urban land expansion results from land-use change, usually through transformation of agricultural land use into urban land use. The growth of urban may be related to economic, geophysical, and institutional constraints, but demography and economies are the two most important driving factors for urban expansion (Liu et al., 2005; He et al., 2008). Demands for space by humans are the original force for urban expansion. High economic growth may also promote the urban land demands because urban expansion may not happen without economic support (Li et al., 2003). In this study, the elasticity of urban land expansion to urban population growth (Tan et al., 2005), denoted as *E(urb)*, was used to assess the relationship between urban land and urban population growth for individual economies. It is expressed as:

$$E(urb)=\frac{A(i)}{Pop(i)} \tag{4}$$

where *A(i)* is the annual rate of urban land growth of economy *i*, and *Pop(i)* is annual rate of urban population growth of economy *i*.

Using the Formula 4-4, *A(i)* for individual economies can be calculated from *E(urb) and Pop(i)*. According to the economic principle of marginal value, the growth rate of urban land areas would be expected to be less than that of urban population because the new population does not need an entirely new and independent infrastructure system but rather uses existing facilities (Shoshany and Goldshleger, 2002). For most economies, we set 1 to *E(urb)*. However, excess urban land growth relative to urban population increase is also frequently found in many economies worldwide (Li et al., 2003). For example, a ratio higher than 1 was found to be 1.58 in America, 1.62 in India, 1.25 in South America and 1.17 in China (Shoshany and Goldshleger, 2002).

Given the calculated *A(i)* and the initial percentage of urban land (derived from MODIS global land cover dataset), the changes in percentage of urban land for each grid cell can be computed for each simulated period. The simulated results for different years were introduced into the crop choice decision model to dynamically update the total percentage of land available for agricultural land use and allocation of crop choices.

3 Data Preparation

A very large amount of input data, including spatial and socio-economic data, was required in this study (Table 1). Of these data, some were input directly into the crop choice decision model for the calculation of crop utilities while some were used indirectly by the crop choice decision model by being input into the crop yield, crop price and urban expansion models. Some were used only for calibration and validation of the model.

Owing to a large degree of variation in data from sources with different spatial and temporal resolutions, it was necessary to perform a procedure of data reprocessing and standardization. To do this, all spatial data were converted into GIS grid data with a cell size of 6 min by 6 min in a standard GIS software environment (ESRI ArcGIS 9.1), while the socio-economic data were processed and stored as text format data. Additionally, for all spatial data we excluded from the model estimation some geographical regions of the world (mainly those covered by ocean or permanent glaciers) in both the Northern and Southern polar regions. The final test area covered the globe from longitude 180.0 °W to 180.0 °E and from latitude 84.0 °N to 56.5 °S. The C programming language was used to develop the model program, allowing the model to access directly the multiple input data in GIS grid format and text format from numerous sources.

Table 1. Complete set of input data used in this integrated model

Main variable name	Time period	Format	Level of details	Data source
		Crop choice decision model		
Crop yield	1995–2004	Grid	6 min	Simulated with crop yield model
Crop price	1995–2004	Text	Region	Simulated with crop price model
Population density	1998	Grid	30 s	Landscan Global Population Database(http://www.ornl.gov/sci/landscan/)
Road accessibility	1993	Grid	6 min	ESRI DCW database (Digital Chart of the World, http://www.maproom.psu.edu/dcw/)
Global cropping systems		Grid	6 min	Generated by Wu et al. (2007a)
		Crop yield model		
		Weather data		
monthly maximum/minimum temperature, and precipitation	1995–2004	Grid	6 min	IPCC-CGCM1(http://www.cccma.ec.gc.ca/data/cgcm1/cgcm1.shtml)
		Soil data		
depth, percent sand, percent silt, bulk density, pH, percent organic carbon, and percent calcium carbonate	1999	Grid	5 min	Global Soil Data Products (http://mercury.ornl.gov/)
		Management data		
Maximum annual irrigation volume	1995	Grid	30 min	Global map of irrigated areas (http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/global_irrigation_map/index.html)
Maximum annual fertilizer volume	1995	Text	Region	FAO statistical database (http://faostat.fao.org/)

Main variable name	Time period	Format	Level of details	Data source
Crop price model				
Population	1995–2004	Text	Region	World population prospects (http://esa.un.org/unpp)
Economic growth rate	1995–2004	Text	Region	IPCC-SRES(http://www.grida.no/climate/ipcc/emission/)
Urban expansion model				
Percentage of urban land	2001	Grid	6 min	Calculated from MODIS 2001 global land cover dataset
Annual rate of urban population growth	1995-2004	Text	Region	World Urbanization Prospects: The 2007 Revision (http://geodata.grid.unep.ch)
Model validation				
FAO statistical database	1995–2004	Text	Region	FAO statistical database (http://faostat.fao.org/)
MODIS global land cover dataset	2001	Grid	1 km	Boston University (http://www-modis.bu.edu/landcover)
Geographic distribution map of crop areas	2000	Grid	5 min	Department of Geography, McGill University (http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html)

4 Model Validation

An LUCC model is useful if it can predict the future or explain the past (Parker et al., 2003). To validate a model empirically, one may employ either temporally or spatially independent data (Pontius et al., 2004). The first model validation approach used in this study was to compare model estimates with independently recorded historical data at a regional scale. The resulting similarity between predicted and measured values at a regional level can improve our understanding of whether the simulated output is following the trend of a reported aggregate average. Due to the difficulty in collecting data on crop price, this kind of validation was limited to evaluating simulations for crop yield and crop sown area by using a time series of FAO statistical data for the period of 1995–2004.

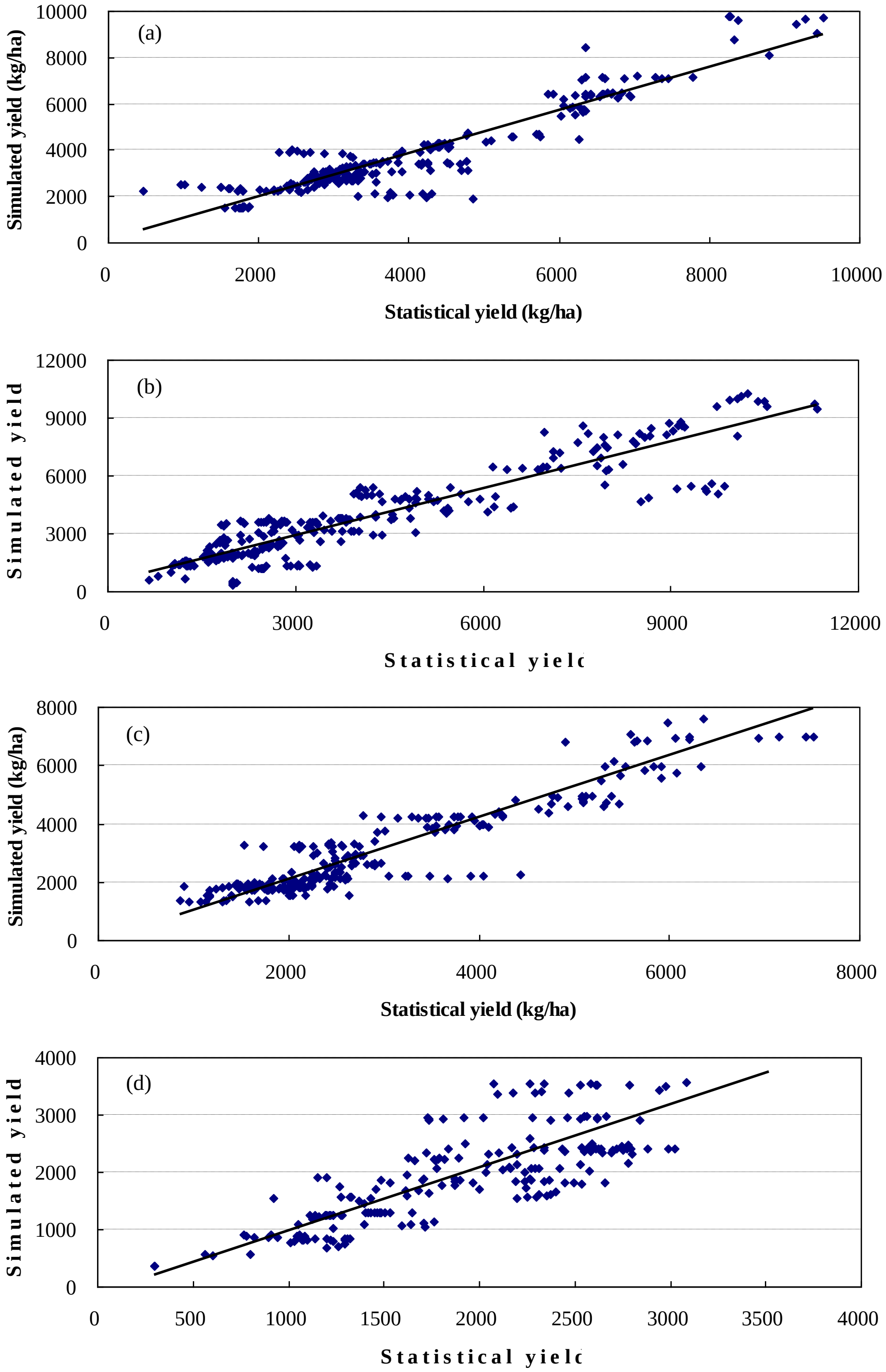
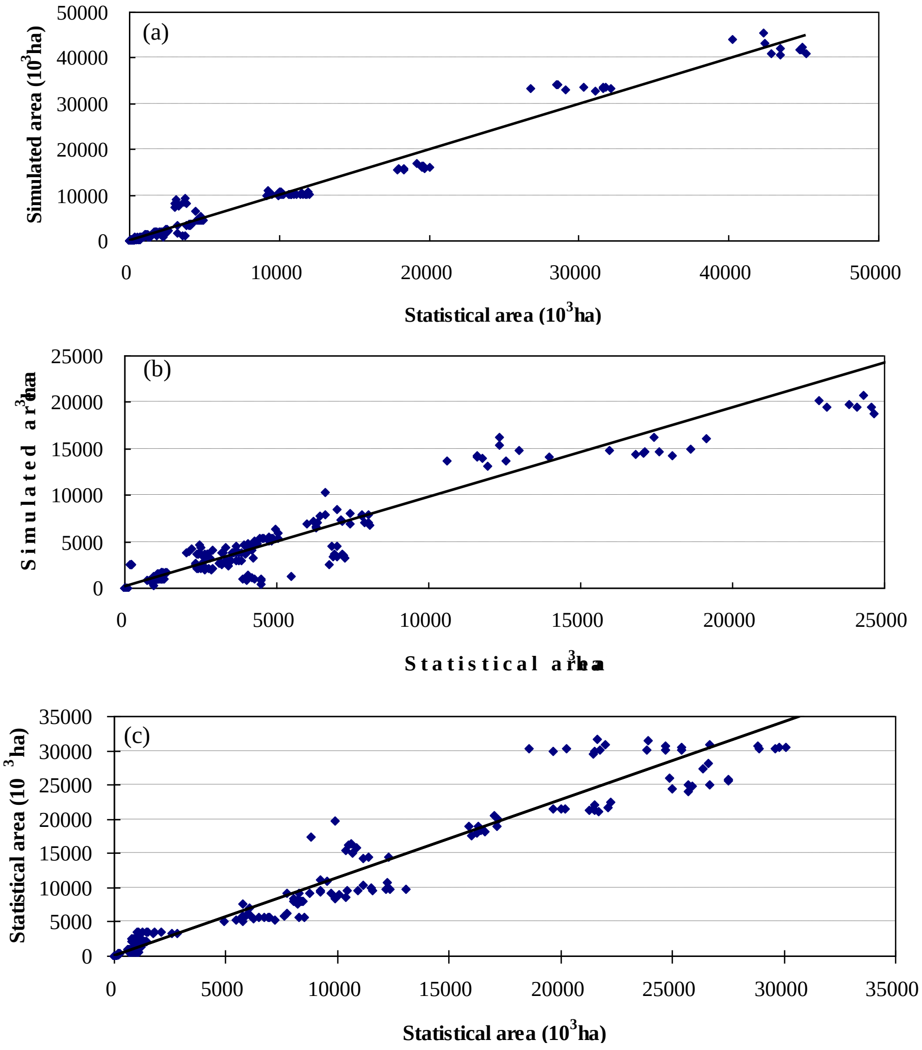


Figure 4. Time series validation of the crop yield model (a: rice; b: maize; c: wheat; d: soybean).

Figure 4 and Figure 5 show a comparative analysis between model estimates and FAO statistical data for crop yield and crop sown area, for four crops. It can be seen that, although there were some places where the model simulation more or less deviated from the reported FAO values, in general the simulated and reported values were similar to each other. The model estimates of crop yield and sown area for rice, maize and wheat had a higher correlation with the corresponding FAO historical data, while those for the soybean crop had a relatively higher deviation from the aggregated FAO data. The main reason for these differences between the simulation and the observed data was possibly the uncertainty in estimations of crop yield made by the GIS-based EPIC model and those of crop price made by the IFPSIM model. The results for soybean in Figure 4-d and Figure 5-d may describe this kind of relationship between the model input and output. Most of the GIS-based EPIC crop parameters established by the USDA were not modified and were applied directly at a global level in this study, which may have resulted in some underestimation or overestimation of crop yields that was then used by the crop choice decision model.



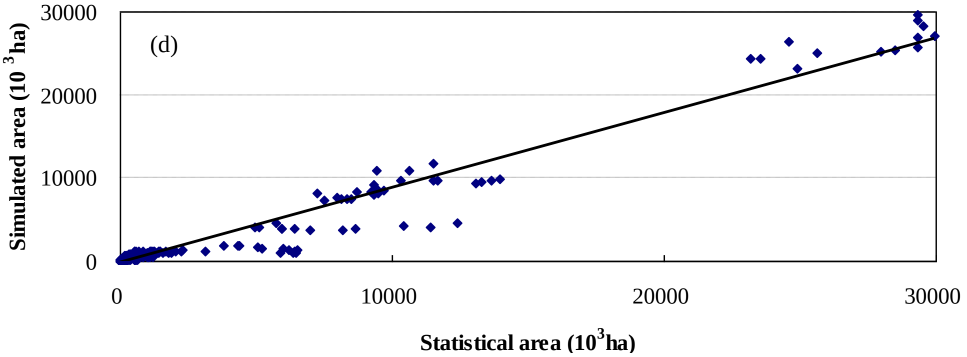
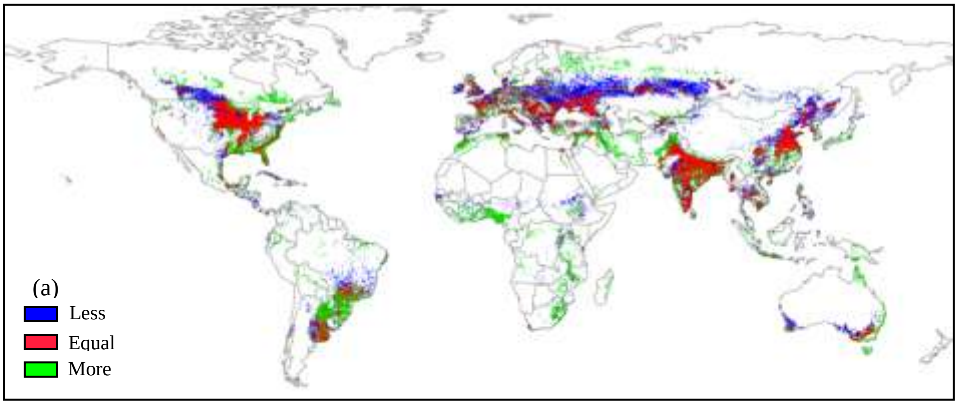


Figure 5. Time series validation of the crop choice decision model (a: rice; b: maize; c: wheat; d: soybean).

However, the non-site-specific nature of the above validation approach has limitations for the crop choice decision model, as a spatially explicit model could evaluate relatively easily the crop sown areas in the correct proportions but in the incorrect locations (Foody, 2002). Thus, another spatial comparison approach was needed to evaluate further the model's simulation of the spatial locations of crop sown areas. In doing so, the MODIS 1 km global land cover dataset in 2001 and the global distribution map of major crops in 2000 produced by Monfreda et al. (2008) were used as reference data for comparing with model-simulated sown areas in 2001.



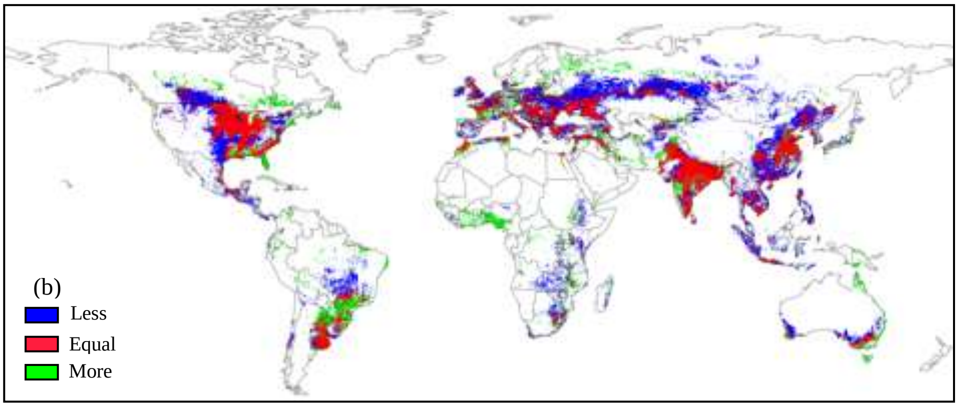


Figure 6. Spatial comparison between the model estimate in 2001 and (a) MODIS dataset; and (b) global distribution map of major crops.

Figure 6 illustrates the comparison between the model-predicted spatial distribution of the four test crops and the MODIS-derived cropland distribution (Figure 6-a), and the comparison between the model estimation and the global distribution map of the same four crops (Figure 6-b). It is obvious that in both cases the model estimates largely coincided with the reference data in the major agricultural regions of the globe, such as China, India, USA and Europe. The discrepancies between them occurred mainly in some regions of North-America, Eastern Europe and Africa. From Figure 6-a and Figure 6-b, it is noticeable that the model simulation was much closer to the global distribution map of these four crops in all regions across the world than to the MODIS-derived data. This was expected, since the spatial distribution map of the four crops generated from the database of Monfreda et al. (2008) consisted only of these four crops, while the MODIS-derived data represented the distribution of global cropland as a whole rather than the individual crops. One of the reasons for the difference between the model estimates and the Monfreda database is that the Monfreda database was produced using the statistical data for period of 1997–2003, and it describes the fraction of a grid cell occupied by major crops. Uncertainties or bias in the reference data can distort the performance of the model validation in some way (Wu et al., 2008b). From the evaluation results described above, it can be concluded that this integrated modeling approach appears to be adequate for the purpose for which it was designed, and it appears to be applicable for the analysis of long-term future scenarios.

5 Discussion and conclusions

This study described the development of a new modeling approach for simulating dynamically changes in the sown areas of four major crops at a global scale. The basic hypothesis was that decisions on crop choices made by farmers mediate the impacts of biophysical and socio-economic aspects on changes in agricultural land use. This basic hypothesis was considered when developing the model, which attempts to establish a dynamic interface of a human–natural environment relationship in an integrated modeling framework. Within the overall model, a Multinomial Logit model was developed to track the decision-making processes of farmers by using a crop utility function. The crop utility was explained by the four independent variables: crop yield, rural population density, road accessibility and crop price. Of these, crop yield, which represents biophysical factors, was simulated from the GIS-based EPIC model and crop price, which represents the socio-economic variables, was estimated by the IFPSIM model. Through data exchange, the crop choice decision model was linked with crop yield and crop price models, and the dynamic feedback loop between agricultural land-use changes and biophysical and socio-economic driving factors was studied.

The empirical validation using data from historical observation and from other studies indicated that the integrated model is reliable for addressing the complicated dynamic changes in agricultural land use at present and that it has the capacity to be used for investigating long-term scenarios and applications in the future.

This bottom-up, process-oriented approach of analyzing the dynamics of LUCC has three main features. First, the objects of analysis of this model differs from other LUCC models in that this model specifically simulates the dynamic changes in sown areas of crops occurring in agricultural lands while other models are focused mainly on the simulation of conversions between croplands and other types of land use like forests, grassland and urban areas. The second feature is that LUCC over time and space results from the complex interactions of a coupled human-environment system. The structure of this coupled model provides important insights into the relationships between different factors contributing to land-use changes, and enables us to understand the process of land-use changes as a system rather than as an isolated set of independent variables (Müller et al., 2004). In this regard, the integrated model can provide a better explanation of systems of land-use changes than could be provided by either of these research approaches applied individually (Evans et al., 2001; Castella and Verburg, 2007). Third and finally, it is characterized by the fact that it models on a global scale. Currently, numerous different models exist that apply at a local, Val or continental scale. Only a few global models of LUCC have been developed and those global model analyses are not typically aimed at investigating LUCC issues, but are aimed at climate change, biodiversity loss and so on (Lambin and Geist, 2006).

The model also contains some uncertainties and there are several caveats that should be kept in mind. First, this analysis assumed that adaptations of crops can take place as needed. For example, farmers can switch from one crop to another as driving factors change. However, this may not be the case if the adjustment requires a heavy capital investment. These adaptations will not be instantaneous and they may also take farmers a long time to make (Seo and Mendelsohn, 2008). Second, it used a simplified modeling approach and was based on a few assumptions about the driving factors behind land-use changes. Some other causes, e.g., policy change (Van Meijl et al., 2006), technological development (Verburg et al., 2006) and social preferences (Serneels and Lambin, 2001), which may also have a great influence on changes in crop sown areas, were not taken into account in this study. Large changes in these omitted factors may alter the results. Third, the model focuses on four major crops and does not consider new crops that might get introduced into the crop choices. The model therefore underestimates the likely substitution available in the crop choices. Future studies should address these issues and provide ever more accurate measures of crop choices made by farmers.

Acknowledgment

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Cultivated Land Quality Change and Engineering Countermeasures in Northeast China

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Abstract: This paper carried out cultivated land quality evaluation in Northeast China based on GIS. It also studied cultivated land quality changes in last ten years from the perspective of the temporal and spatial points. The causes of this change were analyzed. The engineering control measures were proposed to improve the quality of cultivated land.

Key words: cultivated land quality change; GIS; Northeast China

1. Introduction

Good cultivated land quality is the basic guarantee of food production. Regional differences in land quality and timely changes affect regional food security. Northeast China (Provinces of Heilongjiang, Jilin and Liaoning） is an important grain production base in China, which has an irreplaceable strategic position and role in the layout of the national economy. However, due to natural and man-made factors, soil fertility of cultivated land has declined especially in the organic matter content of arable land by reclaiming the initial 8-12%, down to the current 1.5-2.5%. The comprehensive grain production capacity is suffering a potential threaten. Therefore, accurately and timely monitoring changes in the quality of cultivated land is the basic work for the development of grain production and ensuring food security in Northeast China.

In this study, the quality evaluation of cultivated land in the Northeast region was conducted based on GIS technology. Combined with the Second Soil Survey data carrying out in 1980's of the last century as well as cultivated land change digital maps in 1993 and 2003, the spatial and temporal changes in quality of cultivated land were studied. Reasons for the change were analyzed. Finally, the measures to improve the quality of cultivated land were put forward from an engineering perspective.

1. 1 The Study Area

The Northeast region spans the latitudes 14°50′ between 38°43′ to 53°24′ with length of 1,600km from south to north, and across the longitude 19°40′ between 115°20′ to 135 °with length of 1,400 km from east to west. It adjacent to North Korea in the west, Russia and Mongolia in the north, Inner Mongolia of China in the east and Bohai sea in the south. Thus the Northeast region in the natural landscape has shown significant features of the cold wet especially in climate and soil composition.

The northwest, north and east of the Northeast region are higher than the middle and south in topography. Most of cultivated lands locate on the middle of the Northeast plain. TheNortheast region is a temperate continental monsoon climate. Annual average temperature is of -2~10.2℃ with -27.8~-4.9℃ in January and -27.8~-4.9℃ in JulyThe annual precipitation is 243~1072mm, most of the regions in between 450~850mm decreasing gradually from the southeast to northwest. The rainy season is from June to September accounting for 70% precipitation of a year. The soil type in Northeast China is cold wet forest and meadow grassland soil with dark-colored soil surface and rich organic matter or humus content. Therefore, it is well known as one of the world's three main areas of fertile black soil zone. Zonal soils include brown coniferous forest soil, dark brown forest soil, black soil and chernozem soil with mostly large contiguous area of distribution. Non-zonal soil such as the white slurry soil, meadow soil and swamp soil are often associated with zonal soils. Due to increase in area under rice cultivation, paddy soil area is expanding gradually.

The Northeast region has jurisdiction over 35 cities, one autonomous region and 164 counties with population 110 million and a total area of nearly 8 hundred thousand square kilometers（See Figure 1). The Northeast region is an important grain production base with 16.6% of the economy's arable land, about 10% of the grassland and 40% of the forest. Its total grain output was 14.9% of the economy’s total grain output in 2003. The grain per capita was 622.16kg, which was higher than the national average of 250kg. Grain supply accounted for one-third of the economy.

Fig.1 Location of the study area

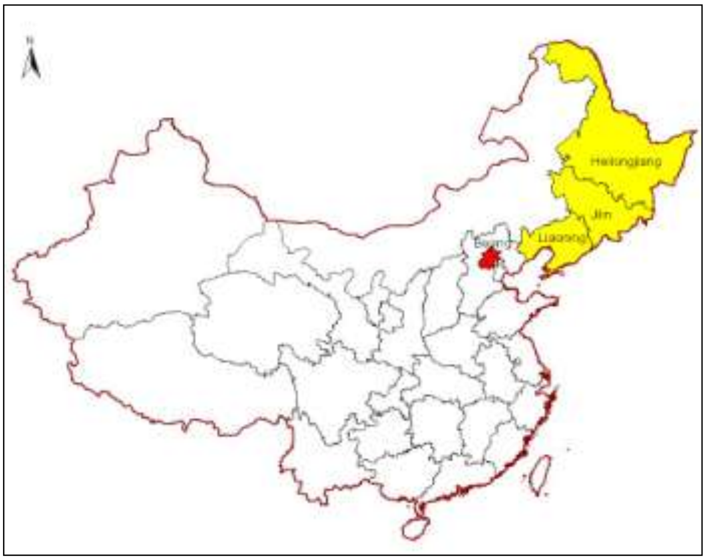
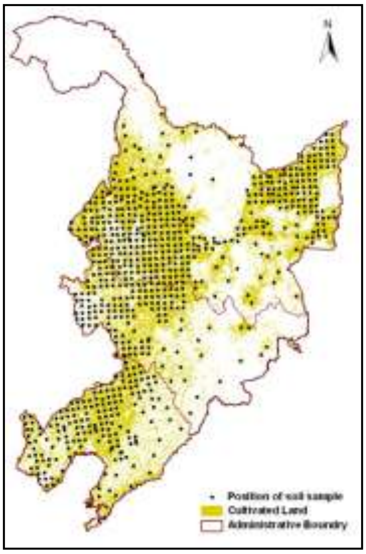


Fig.2 Distribution of soil sampling points



2. Quality Evaluation of Cultivated Land and Change Analysis

2.1 Basic data

The basic data for evaluation and change analysis included digital map on administrative divisions, vector data of land use TM images interpretation in 1993 and 2003, DEM, as well as natural resources data such as precipitation and natural disaster, socio-economic statistical data such as irrigation area, sowing area of grain, fertilizer scalar, rural labor, plastic film usage, power consumption from 1990 to 2003. The data also included the Second Soil Survey data in 1980’s of the last century (including soil types, soil nutrient content, etc.).

In order to get newer soil nutrient contents data, we carried out soil sample collection and investigation in the Northeast region of cultivated land at the beginning of 2005. By using uniform fabric mesh point mode with the sampling interval of 10km × 10km (see Figure 2), a total of 750 soil samples with 0~20cm surface were collected, and investigated data at the same time on crop types, crop yields, fertilizer application, cropping systems, agricultural facilities and so on. Data on soil nutrient status such as PH, organic matter, nitrogen, phosphorus, potassium, soil salinity were analyzed in laboratory by using the Available Soil Nutrient Method (ASI).

2.2 Quality Evaluation of Cultivated Land in 1993 and 2003

This research was based on GIS technology. At first, the evaluation indicators were selected and converted to raster layers with certain grid size. Then, using a weighted overlay method in GIS generated cultivated land mass index. At last, the degrees of cultivated land quality were made by using the method of sub-indices sub-function.

Indicators

Cultivated land is an eco-economic system made by the natural ecosystem and socio-economic system through technical inputs and human labor process. Therefore, the factors that affect the quality of cultivated land include not only natural factors such as climate, topography, parent materials, vegetation and hydrology, but also socio-economic factors such as various types of cultivated land input, land use patterns and agricultural land infrastructure construction.

Through consideration of land evaluation studying results at home and abroad, and consulting 23 experts in geography, land resource science, soil science, agriculture, economic management, environmental science and the Northeast region research institutions, cultivated land evaluation quality system was built combined with grain production in Northeast China's history and environmental characteristics (Tab.1). Index weights were based on expert scoring obtained through the Delphi method.

Table 1 Cultivated land quality evaluation index

Index	Weight	Factor	Weight
natural resource and environment	28.42	elevation	10.22
		slope aspect	9.90
		slope	16.40
		precipitation	23.23
		≥10℃ accumulation	27.24
		disaster rate	13.01
soil	30.75	PH	13.13
		organic matter	28.35
		available phosphorus	13.72
		available potassium	13.13
		alkali-hydrolysable N	15.53
		topsoil salinity	16.13
infrastructure	10.83	irrigation level of assurance	74.15
		roads as access to degree	25.85
social economic input	30.00	mechanization	23.82
		the amount of chemical fertilizer per mu	37.50
		plastic film usage	20.83
		electricity in rural areas	17.85

2.2.2 The formation of single-factor evaluation layers

Indicators of soil organic matter, available nitrogen, available phosphorus, available potassium, soil salinity and meteorological data for precipitation sites in quality evaluation index were point data. Therefore, the study used Kriging interpolation in ArcGIS to generate the 1km × 1km raster maps.

Indicators of cultivated land irrigated area, sown area of grain, fertilizer scalar, rural labor and plastic film usage, power consumption and total power of agricultural machinery were based on county-statistics. Therefore, these indicators in 1993 and 2003 were calculated to get the average data firstly. Then these attributes were connected to the county-level administrative division maps in ArcGIS to form vector and then converted into a 1km × 1km raster maps.

Road accessibility index layer formation process was the use of straight line calculation command to calculate the distance from the farmland to the road and then generate 1km × 1km road accessibility raster map. Slope map and aspect map were derived from DEM data through the slope commands.

2.2.3 The formation of integrated factors evaluation layers

Quality evaluation of cultivated land used weighted overlay method to get result. General formula of calculation was as follows:

$$S = \sum_{i=1}^{n} WiPi$$

Where S is the total evaluation index value, W is for the i indicator weights, P is for the i indicator value. The land mass quality index layer of the Northeast region was made by using raster weighted overlay command in the ArcGIS. The resulting layers of cultivated land quality in 1993 and 2003 were extracted based on cultivated land-use maps in the Northeast region. The cultivated land quality index was divided into five grades by using breakpoint method in ArcGIS (see Fig.3 and Fig.4). The lower the grade is, the higher the quality is.

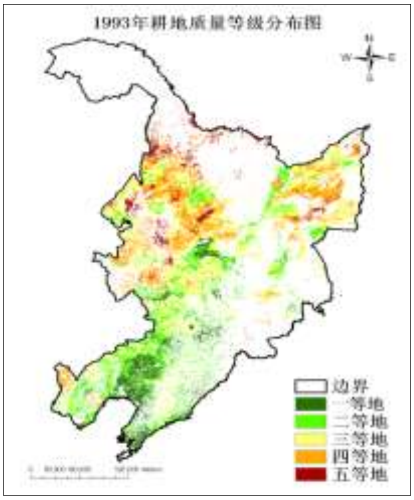


Fig.3 Distribution of cultivated land quality grade in 1993

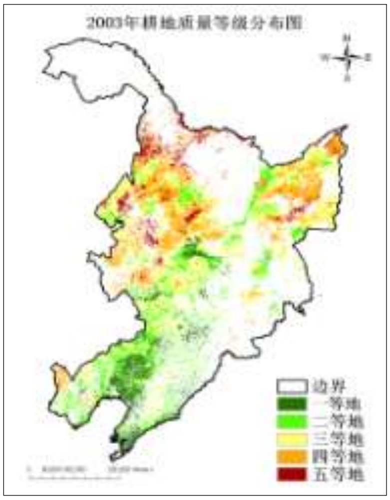


Fig.4 Distribution of cultivated land quality grade in 2003

2.3 Result Analysis

2.3.1 Quality Status of cultivated land in 1993 and 2003

Table 2 showed that the third-class quality covered the largest area of the cultivated land accounting for 32.91% in 1993, and then followed by second-class and four-class accounting for 25.38% and 24.61% respectively. The five-class quality of cultivated land covered the smallest area accounting for 5.81%. In 2003, the third-class quality still covered the largest area of the cultivated land. But the percentage had changed to 32.91%, and then followed by the four-class quality accounting for 25.74%. The five-class quality of cultivated land also covered the smallest area accounting for 6.91%. Thus, the quality of cultivated land in the Northeast region was in the middle and upper levels.

Tab.2 The quality of cultivated land in 1993 and 2003 in the Northeast region

Unit: million hectares

Quality grade of cultivated land	1993		2003		Change	
	Area	Rate%	Area	Rate%	Area	Rate%
1	2.77	11.30	2.76	10.42	-0.01	-1.02
2	6.23	25.38	6.33	23.95	0.10	5.36
3	8.08	32.91	8.72	32.98	0.64	33.88
4	6.04	24.61	6.81	25.74	0.76	40.50
5	1.43	5.81	1.83	6.91	0.40	21.27
Total	24.56	100.00	26.45	100.00	1.89	100.00

From the spatial distribution, the first, second and third-grade cultivated lands were distributed more in Liaoning and Jilin provinces. The fourth and fifth-grade cultivated land were distributed more in Heilongjiang province. The first and second-grade cultivated land were mainly distributed in the central plains of the agricultural area, the western hilly agricultural area, the eastern mid-level agriculture and forestry area and the coastal agricultural areas. The third-grade cultivated land was mainly distributed in the western plains of agricultural-pastoral areas and Sanjiang Plain. The fourth and fifth-grade cultivated land were mainly distributed in the western plains of agricultural-pastoral areas, the north of Changbai Mountain agricultural-forest areas, the north of Daxinganling and Xiaoxinganling forests and the center of Nunjiang plain.

2.3.2 Analysis of cultivated land quality changes

Quality grade maps of cultivated land in 1993 and 2003 were overlaid and analyzed through GIS software (see Tab.2 and Fig.5). The results showed that the first-class quality of cultivated land area was reduced to 19.3 thousand hectares accounting for 1.02% of total cultivated land changes. Other grades of cultivated land showed an increasing trend, of which the four-grade cultivated land area increased 764.3 thousand hectares accounting for 40.50% of the total, followed by the third and fifth-grade cultivated land area with increase of 639.4 thousand hectares and 401.4 thousand hectares accounting for 33.88% and 21.27% of the total cultivated land change respectively.

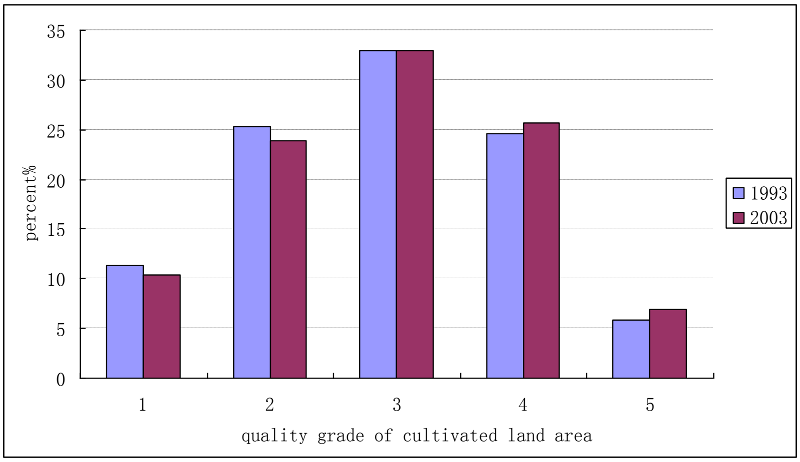


Fig.5 Proportion of cultivated land quality distribution in 1993 and 2003 in the Northeast region

Areas of all grade quality of cultivated land in Heilongjiang Province showed an increase. Among them, the four-grade land increased the area of the largest of 702.5 thousand hectares, followed by third grade with an increase of 664.5 thousand hectares. The fourth and fifth-grade quality of arable land in Jilin Province showed an increase of 17.4 thousand hectare and 36.5 thousand hectares. Others showed decreasing trend, of which the third-grade reduced the largest number of 14.6 thousand hectares. Except for the four-grade quality of cultivated land in Liaoning Province increased by 6.5 thousand hectare, others showed a decreasing trend. The second-grade quality of cultivated land reduced the largest number area of 94.3 thousand hectares (see Tab.3).

Tab.3 Quality of cultivated land area change in the Northeast region of China

Unit: thousand hectares

Quality grade	Heilongjiang	Jilin	Liaoning
1	31.7	-9.0	-10.2
2	230.1	-9.1	-94.3
3	664.5	-14.6	-13.0
4	702.5	17.4	6.5
5	349.4	36.5	-0.3
Total	1978.2	21.2	-111.3

3 Change Analysis of Soil Organic Matter of Cultivated Land

Organic matter content is an important indicator of soil fertility. This study also carried out comparative analysis of organic matter between the survey data and soil organic matter content data of the Second Soil Survey conducted in 1980's of 20th century to reflect changes in the quality of cultivated land from another perspective.

The spatial distribution of soil organic matter in the Northeast region was obtained from soil sampling points by using GIS-Kriging method. And then, the spatial distribution of soil organic matter of cultivated land in 2005 and 1980's of 20th century were obtained by overlaying cultivated land use map in 2003 to make comparative analysis of changes in organic matter (see Tab.4, Fig.5, Fig.6 and Fig.7).

Results showed that the areas of soil organic matter contents of 4-8% and 3-4% covered more with a total area of cultivated land 34.07% and 24.09% in 1980's of 20th century. While the areas of soil organic matter contents of 4-8% and 1-2% covered more with a total area of cultivated land 29.73% and 26.04% in 2005. In more than 10 years, the content of 4-8%, 3-4% and >8% have reduced 4.34%, 4.31% and 2.95% of the total area of cultivated land sharply. While the area of organic matter content less than 2% of cultivated land has increased.

Tab.4 Soil organic matter changes in the Northeast region

Organic matter content%	The proportion of total arable land%		Change
	1980's of 20th century	2005	
<0.6	1.06	1.47	0.41
0.6-1.0	4.56	7.74	3.18
1-2	18.00	26.04	8.04
2-3	14.99	14.95	-0.04
3-4	24.09	19.78	-4.31
4-8	34.07	29.73	-4.34
>8	3.23	0.28	-2.95

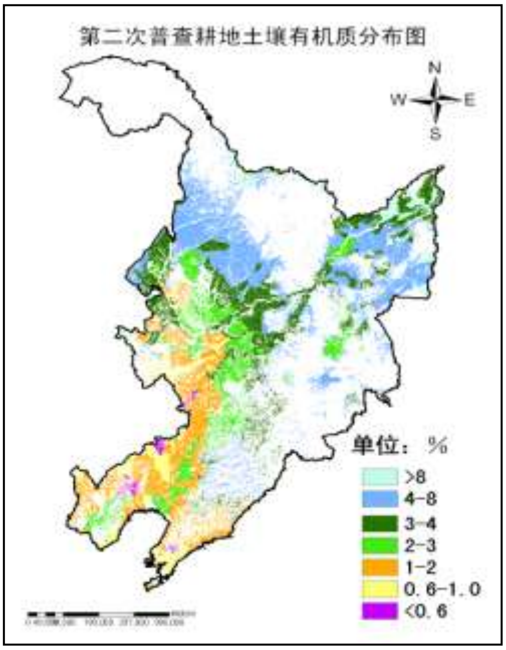


Fig.5 Distribution of cultivated soil organic matter in 1980's of 20th century

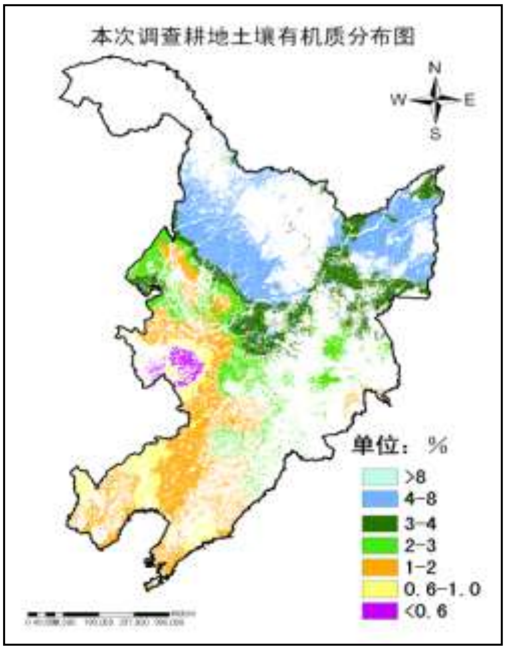


Fig.6 Distribution of cultivated soil organic matter in 2005

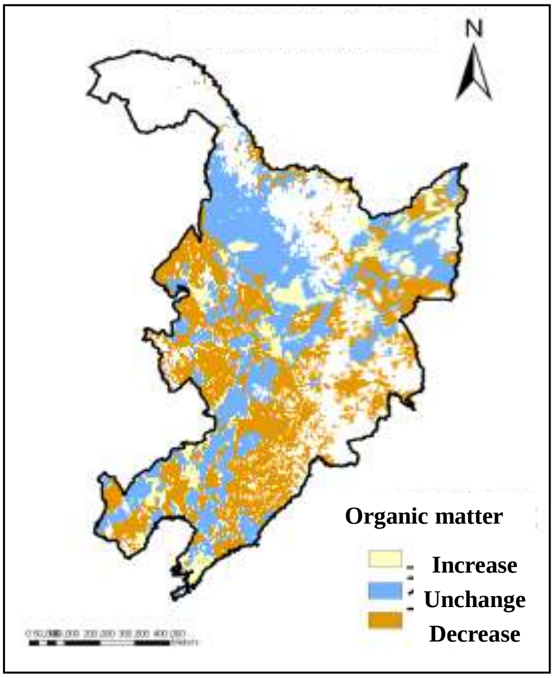


Fig.8 Distribution of 10 year's organic matter change in cultivated land

4. Reason Analysis of Cultivated Land Quality Changes

(1) Due to land use conversion

Over the past decade, land use structure has undergone an obvious change in the Northeast region of China, which is one of the reasons for the quality changes of cultivated land.

Table 5 and Table 6 showed that reduction of cultivated land of the first-grade quality was mainly construction land occupation and returning farmland to forest, accounting for 50.8% and 21.8%. Reduction of the second-grade land was mainly returning farmland to forest, accounting for 60.3%. Reduction of the third-grade land was mainly occupied by returning farmland to forest and construction land, accounting for 37.3% and 24.0%. Reduction of the fourth-grade land was mainly destruction of returning farmland to forest and abandoned, accounting for 37.9% and 26.8%. Reduction of the fifth-grade land was mainly destroyed in returning farmland to forest and abandoned, accounting for 30.8% and 19.3%.

Among the increase in cultivated land, increase of the first-grade quality was mainly unused land exploration and back forest to farming, accounting for 34.7% and 34.3%. Increases of other grade land were attributable to back forest to farming, unused land development and back grassland to farming.

Tab.5 Reduce the movement of different quality levels and the proportion of cultivated land

Grade of cultivated land quality	Construction occupied%	Back farming to forest%	Back farming to grassland%	Water development %	Abandoned and ruined%
1	50.8	21.8	6.7	11.6	9.1
2	16.8	60.3	8.7	9.5	4.7
3	24.0	37.3	19.2	10.0	9.5
4	14.1	37.9	10.7	10.5	26.8
5	16.4	30.8	19.3	10.7	19.3

Tab.6 Increase the movement of different quality levels and the proportion of arable land

Grade of cultivated land quality	Back building to farming%	Back forest to farming%	Back grassland to farming%	water development %	Unused land development%
1	14.4	34.3	8.7	7.9	34.7
2	2.3	38.8	23.0	4.6	31.3
3	0.4	34.5	37.1	2.2	25.7
4	0.2	33.2	34.5	1.3	30.7
5	0.1	56.1	26.1	0.9	16.9

(2) Due to soil erosion

Soil erosion is another reason for the quality changes of cultivated land. For example, according to the third soil erosion announcement of Jilin Province, water erosion area accounted for 61.78% of the total and wind erosion area accounted 38.22%. Six thousand large-scale erosion ditches have formed and have eroded over 81,600 ha of cultivated land, an annual loss of 550 million kilograms of grain, equivalent to 440 million Yuan. Soil erosion has also led humus layer of black soil to significant thinning from 60 cm to 70 cm 60 years before down to 20cm to 30cm, the average annual loss of about 0.4cm to 0.5cm surface black.

Causation by soil erosion is not only due to natural factors such as climate, but also irrational land utilization by human, in which human factors play a major role. For instance, the average annual rainfall in Jilin province is about 500 mm, and 70% of the rainfall concentrated in July to September. Water erosion can easily occur. Another reason is that it is more wind in spring and the period of most scarce ground vegetation. After snows melt, the ground bare. The role of freezing up made the soil structure becoming loose and prone to wind erosion. Soil erosion by human factors are mainly steep land reclamation, lacking of land keeping as well as unreasonable farming. Most farmers used small tractor to shallow plowing, which cause the capacity of soil water storage and permeable decline and exacerbate soil erosion.

（3）Due to emphasis on chemical fertilizers, but contempt organic fertilizers

As the content of soil organic matter in the Northeast region is higher than other places of China. Farmers usually have a small investment on the land, obtain more from land rather than re-raise. The areas of green manure and leguminous crops have become less and less, which are not well implemented crop rotation and fertilize soil. Furthermore, farmers apply more chemical fertilizers to get high yield. Organic fertilizer application rate has fallen steadily. Soil nutrient composition has made imbalance, resulting in soil quality decline.

5 Cultivated Land Engineering Measures for Quality Improvement

(1) Land consolidation project

Land consolidation project include carrying out large-scale land reclamation and the implementation of fields, water, roads, forest integrated management to increase cultivated land areas and to build a high standard farmland in order to increase food supply capacity.

(2) Farmland conservation and nurturing project

Carrying out construction projects of organic fertilizer application, the low-yielding farmland improvement, dry farming and conservation tillage and shelterbelt construction can improve agricultural production conditions and gradual restore soil fertility of cultivated land in order to improve the quality of cultivated land.

(3) Ecological restoration project

In order to prevent soil erosion in sloping land, ecological shelterbelt need to be developed to form small watershed management system. Rehabilitation and reconstruction of vegetation can improve agricultural production conditions and ecological environment.

(4) Farmland water conservancy project

Widespread adoption of water-saving irrigation technology, complete transformation of the existing irrigation works and equipped with irrigation and drainage facilities can increase irrigation areas to further enhance the arable land disaster resilience capabilities. Reinforce dangerous reservoirs, building and maintenance embankments and dam can provide effective protection for arable land.

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A Neural Network Method for Retrieval of Land Surface Temperature and Emissivity from ASTER1B Data

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Abstract: The accuracy of RM (radiance transfer model)-NN (neural network) for separating land surface temperature (LST) and emissivity from AST09 (the ASTER Standard Data Product, Surface leaving radiance) is very high, but it is limited by the accuracy of atmospheric correction. This paper continues to use the neural network and radiance transfer model (MODTRAN4) to directly retrieve land surface temperature and emissivity from ASTER1B data, which overcomes the difficulty of atmospheric correction in previous methods. The retrieval average accuracy of land surface temperature is about 1.1 K, and the average accuracy of emissivity in bands 11~14 is under 0.016 for simulated data when the input nodes are the combination of brightness temperature in bands 11~14. The average accuracy of land surface temperature is under 0.8 K when the input nodes are the combination of water vapour content and brightness temperature in bands 11~14. Finally, the comparison of retrieval results with ground measurement data indicates that the RM-NN can be used to accurately retrieve land surface temperature and emissivity from ASTER1B data.

Keywords:Land surface temperatue, emissivity , Neural network, ASTER data

1 Introduction

Land surface temperature (LST) and emissivity are two important key parameters which control the physical, chemical, and biological processes of the Earth. ASTER data has five thermal infrared bands which can be used to obtain detailed maps of land surface temperature and emissivity. The standard algorithm for retrieving land surface temperature and emissivity from ASTER1B data is a combination of radiance transfer based atmospheric correction (Palluconi *et al.*1999) and temperature/emissivity separation (TES) (Gillespie *et al.* 1998). The accuracy of this algorithm depends on the empirical relationship between emissivity values and spectral contrast, compensation for reflected sky irradiance, ASTER's calibration, and atmospheric compensation (Gillespie *et al.* 1998, Mao *et al.* 2008). Liang (2001) proposed an optimized algorithm to separate land surface temperature and emissivity. Mao *et al.* (2008) also utilized the neural network to separate land surface temperature and emissivity from standard product AST09 (ASTER level-2). The accuracy is very high, but the three algorithms (Gillespie *et al.* 1998, Liang 2001, Mao *et al.* 2008) are all based on atmospheric correction which influences the retrieval accuracy in application. Sobrino *et al.* (2007) made an evaluation for the accuracy of AST09 standard products in an agricultural area in Spain, which indicated that some part of retrieval results in AST08 product is higher than *in situ* ground temperature.

Mao *et al.* (2008) used the RM-NN to separate land surface temperature and emissivity after making atmospheric correction for ASTER1B data, so the accuracy is influenced much by atmospheric correction. In this study, based on previous work (Mao *et al.* 2008), we first make a further analysis for neural network to retrieve land surface temperature and emissivity from ASTER1B data in section 2, and an example for application and evaluation in section 3.

2 Modtran Simulation and NN Retrieval Analysis from ASTER1B Data

The derivation of the algorithm for LST and emissivity retrieval is based on the thermal radiance of the ground and its transfer from the ground through the atmosphere to the remote sensor (Mao *et al.* 2005). Atmosphere has important effects on the received radiance at remote sensor level. After some simplification (Mao *et al.* 2008), the radiance transfer equation for remote sensing of LST can be depicted as:

$$\begin{aligned} B_i(T_i) = {} & \varepsilon_i(\theta)\tau_i(\theta)B_i(T_s) + [1-\tau_i(\theta')][1-\varepsilon_i(\theta)]\tau_i(\theta) \\ & B_i(T_{ia}) + [1-\tau_i(\theta)]B_i(T_{ia}) \end{aligned} \tag{1}$$

where T_s is land surface temperature, T_i is the brightness temperature in channel i (i =10~14) at sensor, $\tau_i(\theta)$ is the atmospheric transmittance in channel i at viewing direction θ (zenith angle from nadir), and $\varepsilon_i(\theta)$ is the ground emissivity in channel i at viewing direction θ, $B_i(T_i)$ is the radiance measured by sensor, $B_i(T_s)$ is ground radiance, T_{ia} is the effective average atmospheric temperature in channel i. θ' is the downwelling direction of atmospheric radiance. In equation (1), there are three unknowns (one band emissivity, land surface temperature, effective average atmospheric temperature) in one equation. So the equations can not be resolved and other conditions must be found out, which is a typical ill-posed retrieval problem. On the other hand, the individual thermal band transmittance ($\tau(\theta)$) is also an unknown which is a function of the water vapour content and other absorption gas (Mao *et al.* 2005, 2007, 2008). Although the effective average atmospheric temperature (T_{ia}) varies with the wavelength-dependence of the water vapour absorption, which is mainly determined by the water vapour content and the surface air temperature at two meter height above the ground (Mao *et al.* 2007,2008). For one land surface type, five emissivity unknowns can be made as one because the emissivity is almost constant for thermal band (Mao *et al.* 2007, 2008). The local linear relationship between emissivities in bands 10~14 can be built, but the relationship is more complicated than the analysis in (Mao *et al.* 2007, 2008), which may make the solution unstable for general mathematics method because the approximated error can be transferred to other parameter when we solve retrieval equations.

In contrast to conventional methods, NN does not require that relationship between the input parameters and the output parameters be known, which determines the relationship between the inputs to the network and the outputs from the networks directly from the training data (Mao *et al.* 2008). To train and test neural network, the radiance transfer model MODTRAN (Berk *et al.* 1987) is applied to generate the training and testing data set. The scheme is like as figure1. According to spectral curve, the detail information of data used can be referred to spectral database (URL: http://speclib.jpl.nasa.gov). We use every band emissivity (about 80 kinds of land surface type) in bands 10~14 as input parameter of MODTRAN4. The range of land surface temperature is from 270K to 320K with step size 10 K, and the near surface air temperature (at 2 m height) is arbitrarily assumed from 273 to 310 K with step size 3 K and 5 K. The range of atmospheric water vapour content is from 0.2 gcm^{-2} to 4 gcm^{-2} with step size 0.5 gcm^{-2}, and atmospheric profile of Midlatitude summer is used for simulation. These simulation data sets can be viewed as reference data from a known ground truth.

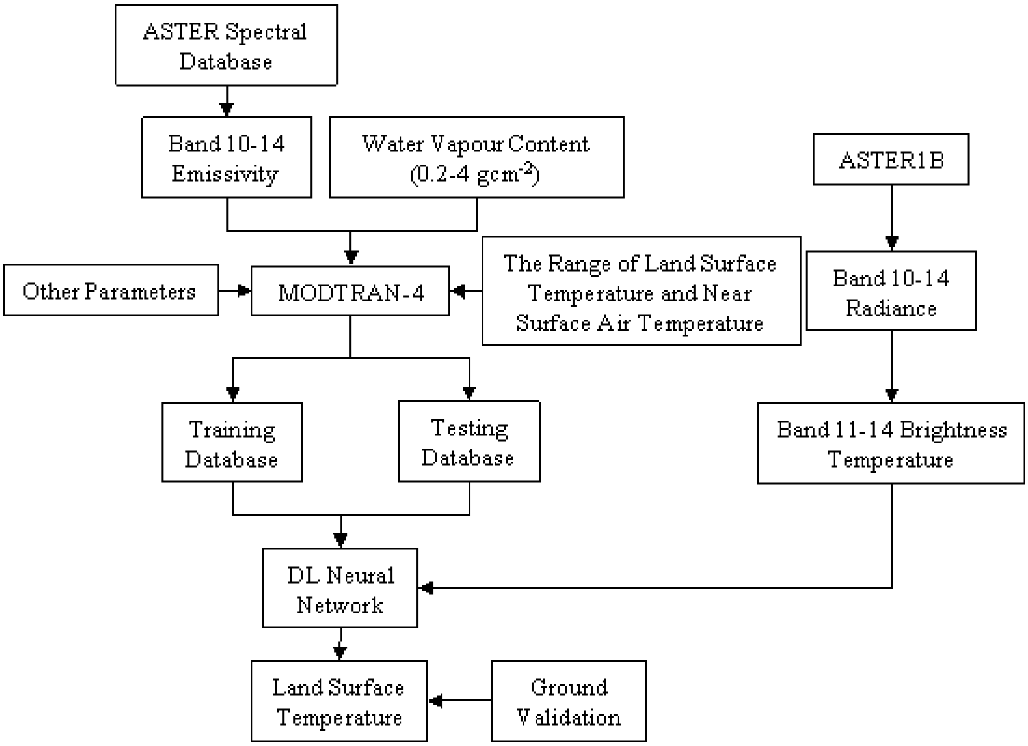

Figure 1 The scheme for retrieving land surface temperature and emissivity from ASTER1B data

In this study, we select the dynamic learning neural network (DL) (Tzeng *et al.*1994) to retrieve land surface temperature and emissivity. The dynamic learning neural network (DL) is different from general neural network. The dynamic learning neural network (DL) (Tzeng *et al.* 1994) uses the Kalman filtering algorithm to increase the convergence rate in the learning stage and enhance the separately ability for highly nonlinear boundaries problem. The initial neural network weights are set to be small random numbers (-1, 1). The Kalman filtering process is a recursive mean square estimation procedure. Each updated estimate of neural network weight is computed from the previous estimate and the new input data. The weights connected to each output node can be updated independently. DL quickly achieves the required rms error in just a couple of iterations, and the result obtained by NN is very stable. So the root error threshold is often set to be $10e^{-3}$ and the epochs of iteration is two. The more introduction can be referred to (Mao *et al.* 2007, 2008, 2009, Tzeng *et al.* 1994). The detail scheme is as follows.

1) Dividing randomly the simulation data into two parts. The training data is 7977 sets and the testing data is 2149 sets.

2) Training and testing neural network. We have four groups to analyze the retrieval results.

2.1 The first group

The input nodes of neural network are brightness temperature in bands 11~14(T_i, i =11/12/13/14), and output nodes are the land surface temperature and four emissivities. The size of two hidden layers is first set as 10-10 with the step size 10-10. The step size is changed with 50-50 when the size of two hidden layers is set as 100-100. After trial and error, the size of two hidden layers with 700 nodes each is good in this study. The part of detail test data sets information can be referred to table 1.

Table 1 The summery of retrieval error (4-5)

Hidden nodes	LST		EM 11		EM 12		EM 13		EM 14	
	R	SD	R	SD	R	SD	R	SD	R	SD
100-100	0.99	2.37	0.808	0.02	0.727	0.021	0.255	0.014	0.265	0.012
200-200	0.992	2.2	0.901	0.017	0.842	0.014	0.52	0.013	0.512	0.012
300-300	0.995	1.68	0.923	0.014	0.8	0.019	0.567	0.011	0.579	0.01
400-400	0.996	1.46	0.936	0.013	0.842	0.014	0.565	0.012	0.56	0.011
500-500	0.997	1.33	0.941	0.012	0.841	0.016	0.539	0.013	0.545	0.013
600-600	0.997	1.37	0.938	0.013	0.851	0.015	0.513	0.013	0.518	0.014
700-700	0.997	1.28	0.943	0.012	0.86	0.015	0.555	0.013	0.545	0.014
800-800	0.997	1.27	0.945	0.012	0.855	0.015	0.544	0.014	0.531	0.015

R: Correlation coefficient; SD: Standard deviation of the fit

Figure 2 is comparison between the retrieval results (Tr) and truth of land surface temperature (Tg), and the average error($\frac{\sum_{i=1}^{n}|T_t - T_r|}{n}$) of LST is under 1.1K. The average error of emissivity is under 0.011, 0.015, 0.014 and 0.016 in bands 11~14, respectively.

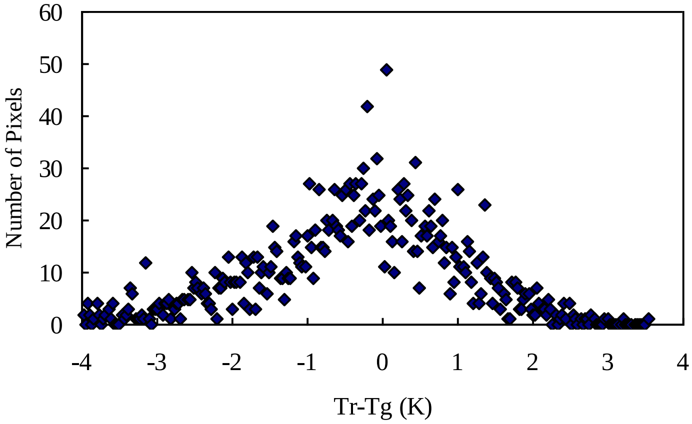

Figure 2 The histogram of difference between land surface temperature retrieved (Tr) by NN and ground temperature (Tg) (4-5)

2.2 The second group

The input nodes of neural network are brightness temperature in bands 10~14(T_i, i=10/11/12/13/14), and output nodes are the land surface temperature and five emissivities. After trial and error, the size of two hidden layers with 300 nodes each is good in this study. The part of detail test data sets information can be referred to table 2.

Table 2 The summery of retrieval error (5-6)

Hidden nodes	LST		EM10		EM 11		EM 12		EM 13		EM 14	
	R	SD	R	SD	R	SD	R	SD	R	SD	R	SD
100-100	0.991	2.37	0.756	0.016	0.829	0.023	0.724	0.02	0.193	0.012	0.176	0.01
200-200	0.993	2.12	0.822	0.018	0.913	0.018	0.795	0.02	0.482	0.015	0.557	0.011
300-300	0.994	1.91	0.874	0.016	0.913	0.019	0.862	0.016	0.618	0.011	0.611	0.01
400-400	0.99	2.59	0.849	0.017	0.915	0.018	0.759	0.02	0.552	0.011	0.574	0.012
500-500	0.994	2.03	0.858	0.016	0.94	0.015	0.836	0.019	0.538	0.014	0.555	0.012
600-600	0.989	2.64	0.883	0.014	0.94	0.015	0.762	0.023	0.47	0.017	0.544	0.013
700-700	0.993	2.17	0.883	0.015	0.94	0.015	0.834	0.019	0.561	0.014	0.605	0.013
800-800	0.993	2.06	0.872	0.015	0.937	0.015	0.84	0.018	0.584	0.014	0.59	0.014

R: Correlation coefficient; SD: Standard deviation of the fit

The average error of LST is under 1.6 K, and the average error of emissivity is under 0.015, 0.016, 0.017, 0.014 and 0.014 in bands 10~14, respectively.

2.3 The third group

The input nodes of neural network are water vapour content and brightness temperature in bands 11~14 (T_i, i=11/12/13/14), and output nodes are the land surface temperature and four band emissivities. After trial and error, the size of two hidden layers with 800 nodes each is good in this study. The part of detail test data sets information can be referred to table 3.

Table 3 The summery of retrieval error (5-5)

Hidden nodes	LST		EM 11		EM 12		EM 13		EM 14	
	R	SD	R	SD	R	SD	R	SD	R	SD
100-100	0.99	2.46	0.819	0.02	0.721	0.019	0.517	0.013	0.576	0.01
200-200	0.997	1.35	0.924	0.015	0.838	0.016	0.614	0.012	0.632	0.011
300-300	0.998	1.09	0.923	0.016	0.872	0.015	0.648	0.013	0.66	0.012

400-400	0.998	1.16	0.925	0.015	0.853	0.016	0.576	0.013	0.6	0.012
500-500	0.999	0.86	0.945	0.013	0.895	0.014	0.67	0.012	0.659	0.013
600-600	0.999	0.85	0.946	0.012	0.883	0.015	0.641	0.012	0.666	0.012
700-700	0.999	0.88	0.95	0.012	0.878	0.015	0.658	0.013	0.686	0.012
800-800	0.999	0.84	0.949	0.012	0.889	0.014	0.681	0.013	0.696	0.012

R: Correlation coefficient; SD: Standard deviation of the fit

The average error of LST is under 0.8 K, and the average error of emissivity is under 0.011, 0.015, 0.013 and 0.012 in bands 11~14, respectively.

2.4 The fourth group

The input nodes of neural network are water vapour content and brightness temperature in bands 10~14 (T_i, $i = 10/11/12/13/14$), and output nodes are the land surface temperature and five band emissivities. After trial and error, the size of two hidden layers with 600 nodes each is good in this study. The part of detail test data sets information can be referred to table 4.

Table 4 The summery of retrieval error (6-6)

Hidden nodes	LST		EM10		EM 11		EM 12		EM 13		EM 14	
	R	SD	R	SD	R	SD	R	SD	R	SD	R	SD
100-100	0.99	2.51	0.751	0.016	0.83	0.024	0.713	0.022	0.418	0.015	0.417	0.012
200-200	0.994	1.95	0.79	0.015	0.82	0.023	0.725	0.021	0.233	0.012	0.279	0.01
300-300	0.994	1.91	0.775	0.015	0.869	0.018	0.737	0.018	0.392	0.018	0.424	0.014
400-400	0.996	1.58	0.808	0.02	0.909	0.018	0.79	0.021	0.576	0.016	0.557	0.016
500-500	0.979	3.63	0.54	0.038	0.765	0.031	0.572	0.038	0.445	0.025	0.505	0.017
600-600	0.998	0.95	0.896	0.013	0.901	0.018	0.911	0.012	0.725	0.01	0.77	0.008
700-700	0.997	1.29	0.876	0.014	0.886	0.019	0.845	0.016	0.683	0.012	0.713	0.011
800-800	0.998	0.98	0.889	0.013	0.912	0.017	0.888	0.013	0.683	0.01	0.731	0.009

R: Correlation coefficient; SD: Standard deviation of the fit

The average error of LST is under 0.9 K and the average error of emissivity is under 0.013, 0.015, 0.013, 0.011 and 0.01 in bands 10~14, respectively.

Compared from four groups above, the highest accuracy is group three when the input node parameters are the combination of water vapour content and brightness temperature in bands 11~14. The second is group four when the input node parameters are the combination of water vapour content and brightness temperature in bands 10~14. The third is group one when the input node parameters are the combination of brightness temperature in bands 11~14. The last is group two when the input node parameters are the combination of brightness temperature in bands 10~14. Three conclusions can be obtained. One is that land surface temperature and emissivity can be directly retrieved from ASTER1B data. The second is that band 10 has little contribution for retrieval result, and the main reason is that the transmittance of band 10 is very low and the emissivity in band 10 is very different from other four bands. The third is that the retrieval accuracy can be improved if atmospheric water vapour content is made as one input parameter of neural network, though the average difference is just 0.3 K if we do not make the water vapour as one input node parameter. The water vapour content can be accurately retrieved from MODIS data and Microwave data, but the resolution is so coarse relative to ASTER data that the matching is a problem. So we think that the group three is the best selection in application if the water vapour content can be obtained, and the group one is also a good choice which is more applicable in real use.

3 Evaluation and Application

In order to further make an example in application, the Harbin is selected as study region, which is in Heilongjiang province, China. The image (2005/9/9) combined by ASTER bands 3, 2, 1 can be referred to Mao *et al*. (2008), which mainly includes city, river, village, cropland and pond/swamp. Four band brightness temperatures ($T_i, i = 11,12,13,14$) of ASTER1B data are used as four input nodes, and land surface temperature and four emissivities are output nodes. The retrieval result of land surface temperature is like figure 3.

By comparing the spatial distribution of land surface temperature with AST08 which showed in Mao *et al*. (2008), it could be found that land surface temperature in figure 3 is higher than AST08 mostly. The most retrieval result in city in figure 3 is about 1 K higher than in AST08 product. The retrieval result by NN in crop land and bare soil is about 2 K lower than AST08. The largest relative error is about 4 K on the water surface of river and the pond/swamp. The accuracy is about 0.7 K relative to AST08 if we make a regression revision. The difference between emissivities retrieved by NN and AST05 shows that the emissivity of bands 11~14 retrieved by NN is mostly higher than AST05. We can deduce that the emissivities (AST05) are underestimated by TES, so some part of the land surface temperature (AST08) is overestimated. The differences between retrieval result by NN and ASTER standard product may be due to 1) The TES is based on atmospheric correction. The validated TIR surface leaving radiance product (AST09) provides an estimate of the total radiance leaving the surface including any reflected sky component and an estimate of the sky irradiance for each of the five ASTER TIR bands. This product corrects the radiance measured at sensor for the effects of atmospheric transmission, path radiance and scattering using atmospheric profile information derived from NOAA and MODIS (TERRA) by assimilation models. The accuracy of the product is dependent on the amount of water vapour in the atmosphere and the accuracy of the source of the atmospheric profiles used in the correction procedure. On the other hand, the matching is also another problem because the resolution of MODIS is so coarse relative to ASTER data. Sobrino *et al*. (2007) made an evaluation for the accuracy of ASTER level-2 thermal-infrared standard products of an agricultural area in Spain, which indicated that the AST08 product is higher than *in situ* ground temperature. Mao *et al*. (2008) used neural network to retrieve land surface temperature and emissivity from AST09, and the retrieval result is also higher than *in situ* ground temperature. These show that the main reason is the influence of atmospheric correction error. 2) The temperature and emissivity separation (Gillespie *et al*. 1998) relies on an empirical relationship between spectral contrast and minimum emissivity, which are determined from laboratory and field emissivity spectra. The empirical relationship makes the equalization of the number of unknowns and measurements, so that the set of Planck equations for the thermal radiances measured by ASTER can be inverted. Essentially, the empirical relationship is used to scale the emissivity spectra properly. However, it is inaccurate for surfaces of low spectral contrast, such as water, vegetation, and some soils, since in these cases the spectral contrast is dominated by measurement error (Sobrino *et al*. 2007).

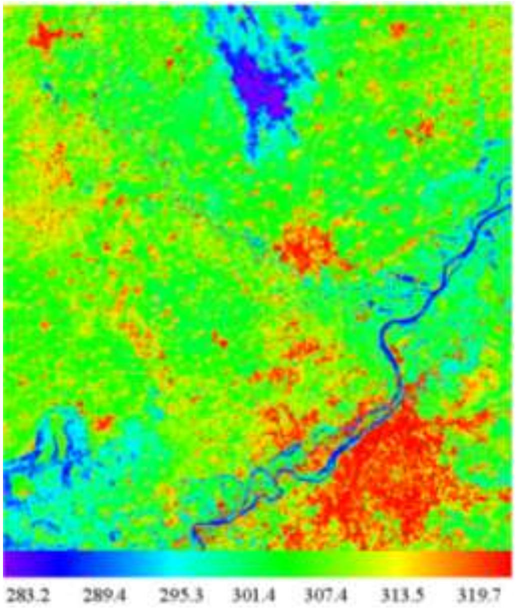

Figure 3 LST Retrieved by NN

It is very difficult to obtain the *in situ* ground truth land surface temperature and emissivity to evaluate the retrieval result. Generally speaking, land surface temperature and emissivity vary from point to point on the ground. The ground measurement is generally point measurement, and the difference is about 1 K (even 1.5 K in some place) when we put the thermometer in different orientation for same position. On the other hand, ASTER observes the ground at different angles, and precisely locating the pixel of the measured ground in ASTER data is also a problem, so the ground measurement is maybe different from measurement at satellite sensor. Since there are so many difficulties in obtaining ground truth data, validation with the use of ground truth data is quite difficult. We just obtain four points data of land surface temperature measured by soil thermometer from meteorological branch in Harbin, Suihua, Zhaodong and Anda city. On the other hand, the project 973 of China made ground measurement in Xiaotangshan and provided a data set of land surface temperature in two sites (116.448E and 40.182N, 116.447E and 40.177N) from May, 2004 to July, 2004 (Mao *et al*. 2007, 2008), which is obtained by T107. T107 is a temperature sensor consisting of a thermistor encapsulated in a cylindrical aluminum housing (URL:http://www.oznet.unimelb.edu.au/t107.html). We get an ASTER image in this region and extract two pixels from ASTER data through the longitude/latitude. The comparison between retrieval result by NN and *in situ* land surface temperature is like as figure 5, and the average accuracy is about 1.6 K. As we all know, the influence factor for ground emissivity measurement is too much, especially for mixed pixel. In fact, the comparison result of testing data in table 1-4 can show the accuracy of RM-NN because the simulation data can overcome the measurement error. We will make more field measurement and the more comparison analysis will be reported in future. On the other hand, another advantage of the NN is that the retrieval accuracy can be improved by compensating some training data (Mao *et al.* 2008).

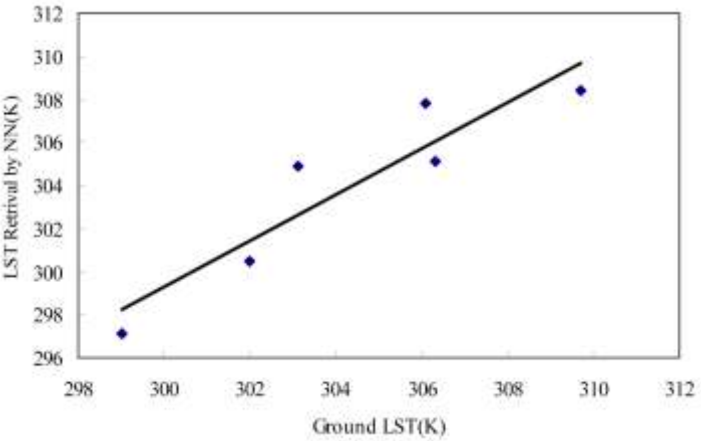

Figure 5 Validation Results

4 Conclusion

This work examines the combined use of thermal emission model (MODTRAN4) with neural networks to perform parameter retrieval from ASTER1B data. The retrieval analysis indicates that ASTER band 10 has little contribution for retrieval result, and the main reason is that the transmittance of band 10 is very low and the emissivity in band 10 is very different from other four bands. The average error of LST is under 1.1K when the input nodes are the combination of brightness temperature in bands 11~14. The average error of LST is under 0.8 K when the input nodes are the combination of water vapour content and brightness temperature in bands 11~14. These indicate that the accuracy can be improved if the water vapour content is made as input parameters, and the retrieval result is not very sensitive for water vapour content because the average difference is just 0.3 K if we do not make the water vapour content as one input parameter. The water vapour content can be accurately retrieved from MODIS data and Microwave data, but the resolution is so coarse relative to ASTER data because the matching is a problem in real use. So the combination of four band (11~14) brightness temperatures is the good selection in application. Finally, we gave an evaluation in application and the analysis indicates that the retrieval result by NN is average lower than the ASTER stand product (AST08). The comparison between retrieval result by NN and *in situ* land surface temperature shows that the average accuracy is about 1.6 K. The combination of radiance transfer (MODTRAN4) and NN makes it possible to directly retrieve land surface temperature and emissivity from ASTER1B data. A suggestion is that retrieval algorithm should be built based on different training database according to the different region (altitude, latitude and longitude).

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The Study of Applying Hyper-spectral Remote Sensing Technology in Soil Moisture Monitoring

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Abstract: Precision agriculture need information on surface soil moisture fast and timely. Because of high-resolution and multi-band in spectral, hyper-spectral remote sensing can be used to detect slight differences in soil moisture, which has reference value on the provision of timely, accurate and fast information on soil moisture content. Taking black soil in Jilin Province of China as the research object, this paper analyzed soil hyperspectral characteristics and extracted parameters by using a series of methods such as spectral differentiation, feature-band extraction and multiple stepwise regression analysis. The relationship between soil moisture and soil spectra was analyzed combined with soil moisture laboratory measurement. Five models were used to quantitative inversion in order to seek soil moisture monitoring by applying hyperspectral remote sensing. The conclusion was as follows: ①in the below field water holding capacity condition, the sensitive bands of black soil spectral reflectance and its reciprocal and logarithmic transformation mainly focused in 400-470nm, 1950-2050nm and 2100-2200nm. The highest correlation coefficient between laboratory spectral data and soil moisture reached to 0.89 at 2156nm. ②The best prediction model of black soil moisture content by using hyperspectral remote sensing was $Y=22.16+26278.2x_{1328}-47785.1x_{1439}-201.42x_{1742}+49306.34x_{2156}$, $x=(\lg R)'$, Y representing soil moisture content (%), coefficient of determination was 0.931.

Key word: hyper-spectral remote sensing，soil moisture，soil spectral reflectance

1 Introduction

Precision agriculture needs information on soil moisture quickly and timely at the plot level. Traditional soil moisture measurement methods, such as oven dry, neutron moisture meter and tenometer are based on soil samples. Although the precision are higher, but the time cycle is long, measurement conditions are harsh and can not obtain the soil moisture data quickly. Multi-spectral remote sensing images such as TM and SPOT have only several bands. For example, TM image has only 7 bands with lower spectral resolution of average 137nm. It is suitable for soil moisture monitoring on the large-scale areas, but has higher error on block-level monitoring. Hyperspectral remote sensing with high spectral resolution (10nm) has dozens or even hundreds of spectral bands in the visible and near-infrared ranges. It can obtain information quickly on surface soil reflectance spectra, forms a continuous spectral curve and detects slight changes in soil surface water content. Those provide a new technical means in the dynamic monitoring soil moisture and also provide an important theoretical support for the development of precision agriculture.

The theory of hyperspectral remote sensing to monitor soil moisture is using reflectivity method mainly in the visible and near infrared ranges to establish relevant quantitative indicators inversing soil moisture content according to the principle of soil spectral curve changes with soil water content changes. There were many studies on the best band scopes for soil moisture inversion by hyperspectral remote sensing. Bowers and Hanks carried out spectra study on different soil types in different moisture content under laboratory environment. Results showed that the soil reflectance spectra have three absorption bands at 1400 nm, 1900 nm and 2200 nm. The band of 1900 nm was the characteristic band to soil moisture and could estimate soil moisture content by the soil reflectance spectra in this band. But they did not give a concrete model. Scientists analyzed three water absorption spectrums in 1430-1450nm, 1620-1650nm and 1920-1940nm, and pointed out that the soil moisture content could be obtained based on soil reflectance value. Wang Jing measured 175 soil samples of water content, obtained spectral data in laboratory simultaneously. The regression model predicting soil moisture in bands of 1423nm, 1524nm and 1746nm was established. Wang Changzuo put forward that the ideal band of soil moisture inversion was 1950-2250nm in natural light conditions according to the research of four different irrigation zones in Xiaotangshan agricultural demonstration base of Beijing. He Ting established quantitative relationship between laboratory measurement of spectral data and soil moisture content for 129 loessal soils and sandy soils. Through relevant comparison of peak position of absorb characteristic and soil moisture content, he pointed out that 1450nm absorption peak was more sensitive than the 1925nm in prediction of soil water content. There were few studies on soil moisture retrieval models by using hyperspectral remote sensing. Hummel studied change patterns of undisturbed soil reflectance spectra in the saturated water content, 0.033Mpa, 0.1Mpa, 0.33Mpa, 1.5Mpa and dry soil moisture conditions at different depths in the laboratory, and carried out soil moisture inversion using multiple linear regression method. Liu Weidong measured ten different types of soil surface moisture, and used the relative reflectivity, the first derivate reflectivity and finite difference method to predict soil moisture contents. Results showed that methods of the reflection of the first derivate reflectivity and finite difference could predict soil moisture content.

Based on previous studies, it can be found that the soil moisture prediction model was set up mostly through the study of spectral characteristics of different soil types. As soil spectrum is strongly affected by soil parent material, organic matter, moisture and other factors and has spectral characteristic differences between different soil types. It may be errors to predict a particular type of soil moisture content by using one model. Therefore, taking black soil as study object, this paper analyzed correlation relationship between soil moisture and soil spectral curve. Soil moisture inversion equation was set up through spectral characteristic parameters in order to find the potential of fast method of measuring black soil moisture by using hyperspectral remote sensing.

2 Data Acquisition and Processing

2.1 Soil sample collection and processing

As soil spectrum was detected and analyzed in the lab, uniformed spatial distribution of soil properties did not be taken into account when collecting soil samples in the field. By choosing black soil with corn planting and relatively flat field, the study collected 63 soil samples with a depth of 0-20cm (seeing Figure 1). After air drying, picking out intrusion and fine grinding, soil samples were over 2mm aperture sieve, full mixed and filled into containers to be tested. 10 soil samples with similar organic matter contents were divided into 20 equal portions by each and were placed in small metal boxes with a radius of 5 cm and deep of 1.5cm. Followed by inject different amounts of water with interval 1ml and then placed 2 hours. After free water on soil surface disappeared, soil spectral measurements were carried out and obtained different soil reflecting spectrum curve shapes under different soil water content. Soil moisture contents were obtained through oven drying method in the lab.

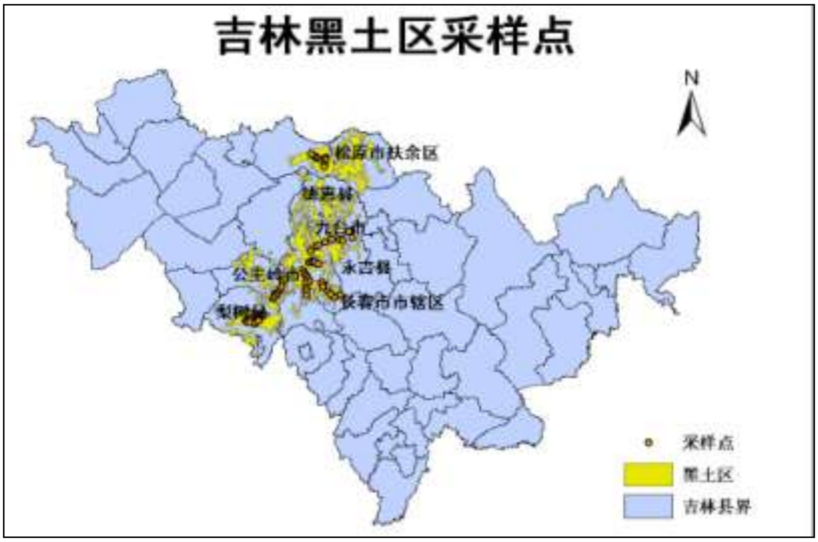


Figure 1 The distribution map of sampling point of black soil in Jilin Province

2.2 Soil reflectance spectra measurement

Soil reflectance spectra measured in the dark room using ASD FieldSpec FR spectrometer. Its spectral range is 350-2500nm. The spectral resolution between 350nm to 1000nm is 3nm with sampling interval of 1.4nm. The spectral resolution between 1000nm to 2500nm is l0nm with sampling interval of 1nm. According to Zhou Qing’s study result, 200W halogen lamps were placed on both sides of soil sample with 15 °zenith angle and 30cm away. The probe was placed 8 ° field angle and 15cm vertically at the top of target. A white board with 75cm × 75cm was used for standardization. One sample was measured 10 times, and an average soil spectral reflectance was obtained. To eliminate high-frequency noise, this study adopted He Ting’s results about 9 point weighted moving average method to smooth noise of high-spectral reflectance data.

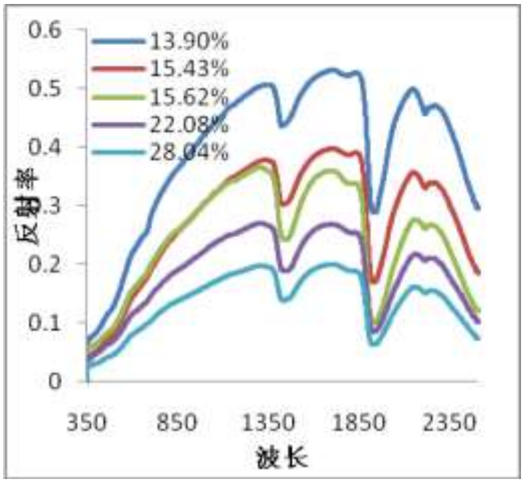
2.3 Spectral reflectance of soil moisture inversion

The aim of spectral analysis is to use parameters to characterize main features of the spectral curve and describe characteristics of a spectral absorption band. Based on analysis of spectral reflectance characteristics, the study used mathematical transformation models of logarithm, reciprocal, the first derivate differential, logarithm of the first derivate differential and reciprocal of the first derivate differential to analyze correlation between character parameters of soil spectral curves and soil moisture content. Statistical analysis methods were used for soil moisture inversion reflectivity.

3 Results and Discussion

3.1 The relationship between soil moisture and soil spectral curve

Many studies have shown that soil reflectivity will decrease with increase of soil moisture content under the field capacity. When soil moisture content reaches the field capacity above, soil reflectance will increase with increase of soil moisture. This study measured the soil moisture capacity of 38.64%. There were 4 soil samples greater than 38.64% and 28 samples less than 38.64%. Figure 2 and Figure 3 showed same results.



Fiure 2 Spectral curve at low-level moisture

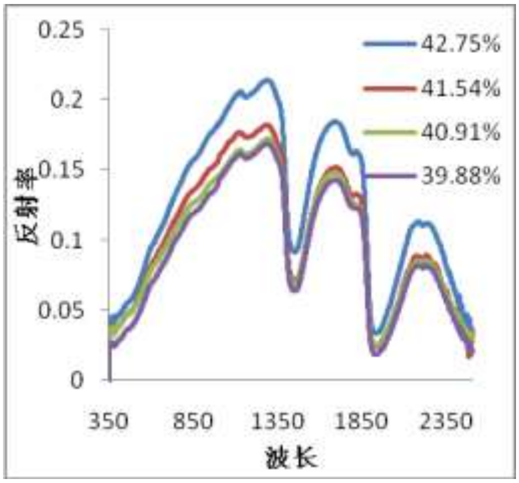


Figure 3 Spectral curve at high-level

moisture

3.2 Soil spectral analysis

The spectra curves of soil samples varied mainly at the location and depth of water absorption offset. The moisture absorption peaks located near 1400nm, 1900nm and 2100nm. The spectral reflectance between 350-1300nm had a monotonic increase in an upward trend with wavelength increase. The soil spectral reflectance curve became flat in 1500-1800nm and increased monotonically again in 1900-2100nm. It showed decrease trend in 2200-2500nm. Thus, the soil spectral curves can be divided into seven sections. Those were 350-1300nm, 1300-1450nm, 1450-1700nm, 1700-1900nm, 1900-2100nm, 2100-2200nm and 2200-2500nm (seeing Figure 4).

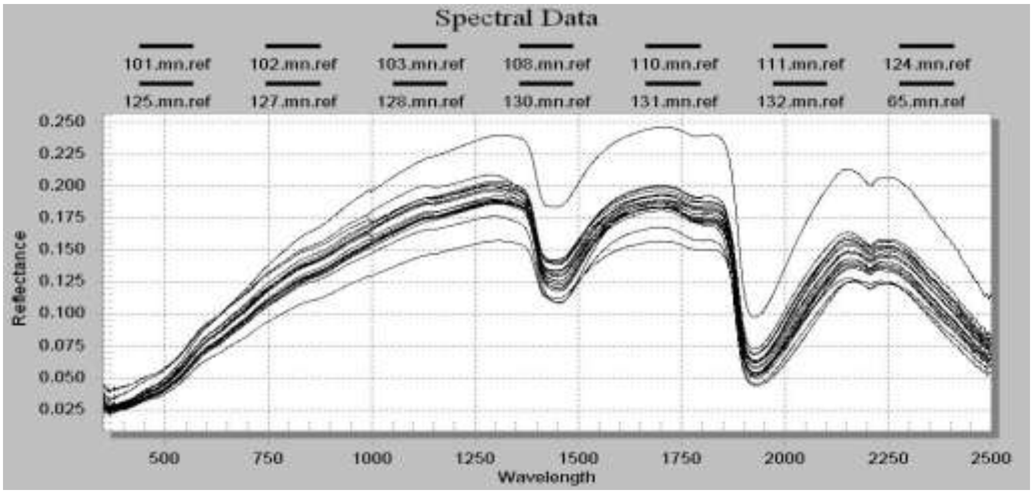
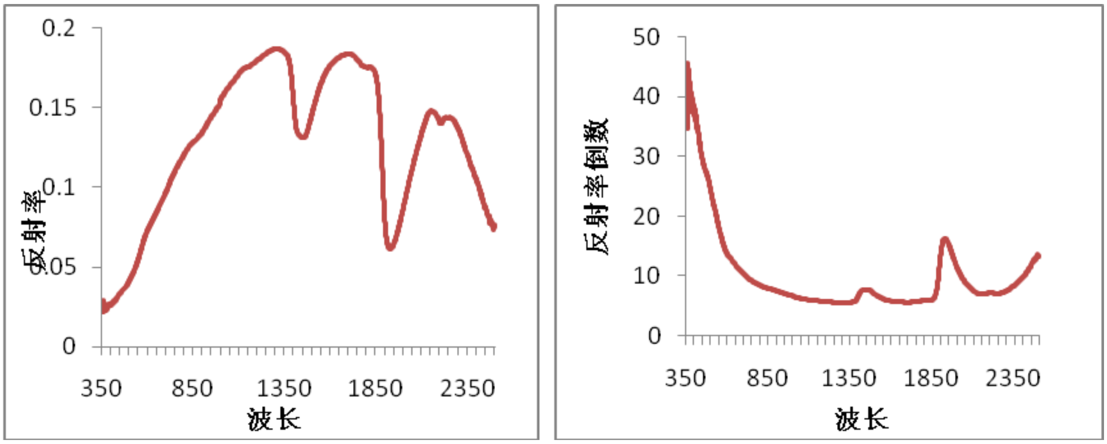


Figure 4 Soil spectral curves

3.3 Soil spectral reflectance transform and correlation analysis of soil moisture

To find soil moisture-sensitive spectral indicators for soil moisture inversion, the study analyzed the relationship between soil moisture contents and soil reflectivity. Except that, mathematical transforms of soil reflection rate were made through models of the reflectivity of the reciprocal 1/R, reflectance logarithmic lgR, the first derivate differential reflectivity (R)', the reciprocal of reflectance of the first derivate differential (l/R)' and reflectance logarithmic of the first derivate differential (lgR)' in order to calculate the correlation coefficient with soil moisture content (seeing Figure 5).



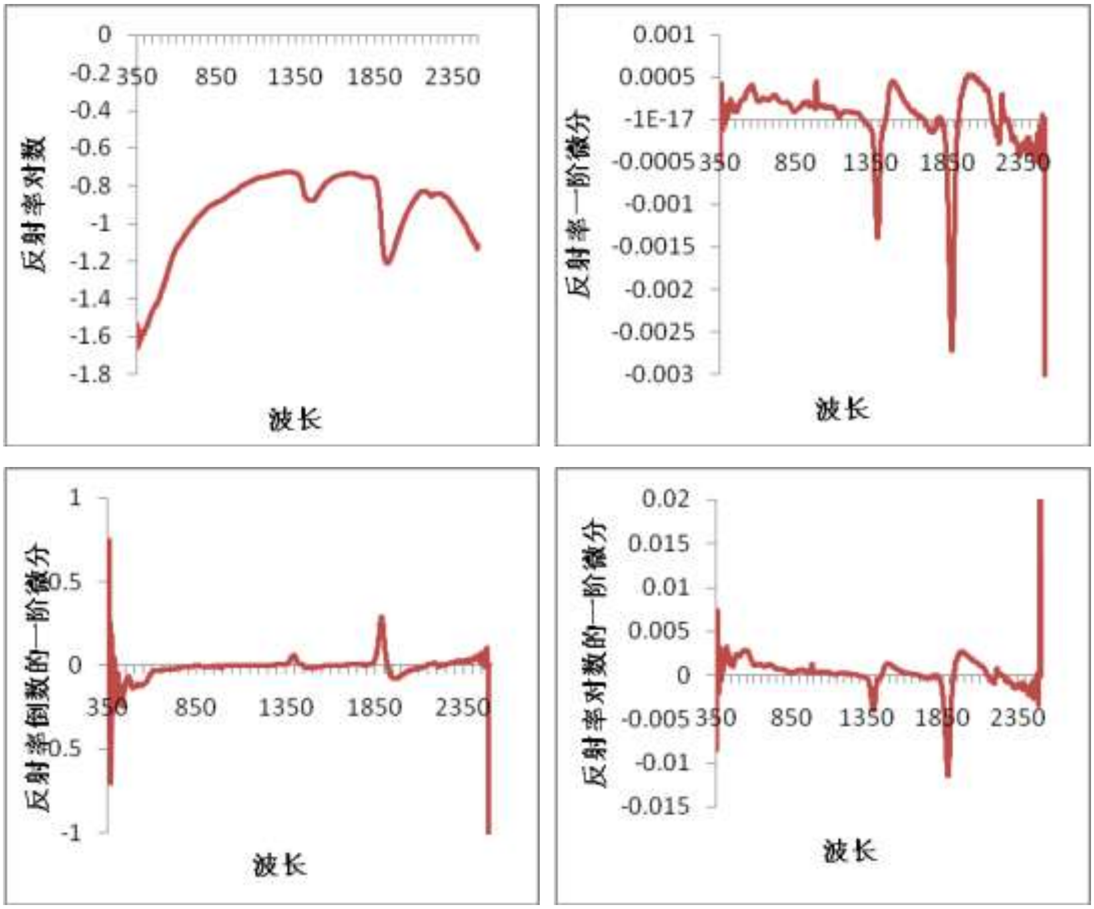


Figure 5 Worked soil spectral curves

Results showed that the relationship of reflectance and soil moisture was positive correlation in 350nm- 950nm and negative correlation in 950nm-2500nm. 401nm (r^2=0.55), 1460nm (r^2=-0.6), 2102nm (r^2=-0.63), 2469nm (r^2=-0.67) and 1978nm (r^2=-0.68) with the largest correlation coefficient in each band section were selected as sensitive bands. The relationship between reciprocal of reflectance and soil moisture content was negatively correlated in the range of visible band, while showed positive correlation in 1000-2500nm. The correlation coefficient curve of the first derivate differential reflectivity changed greatly. Bands of 1415nm, 1544nm, 1749nm, 1830nm and 2156nm were chosen as characteristic parameters. For the correlation curve of reflectance logarithmic of the first derivate differential, soil moisture-sensitive bands were concentrated in the near-infrared range and the correlation coefficient was 0.8 above. Bands of 2156nm, 2050nm, 1591nm, 1830nm and 1749nm were selected as sensitive bands for soil moisture content inversion (seeing Figure 6 to Figure 11, Table 1).

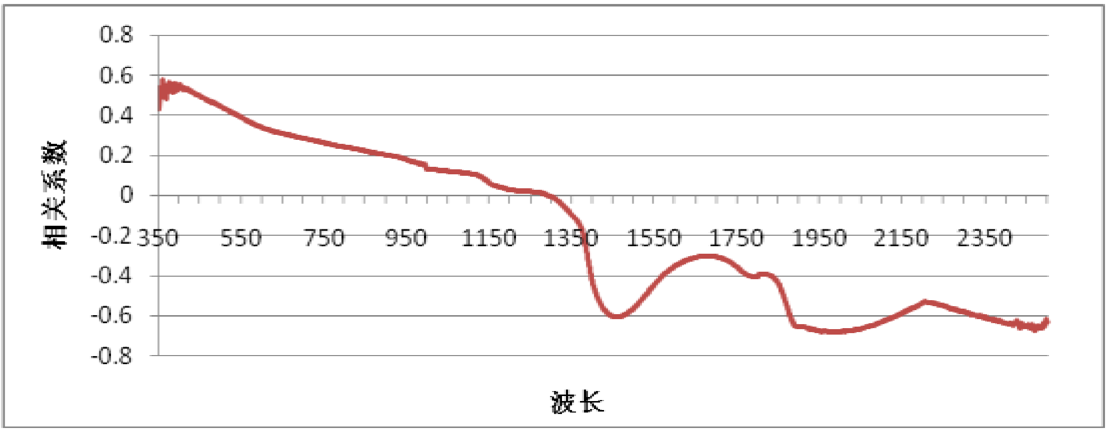


Figure6 The correlation coefficient between the reflectivity mean and the soil moisture

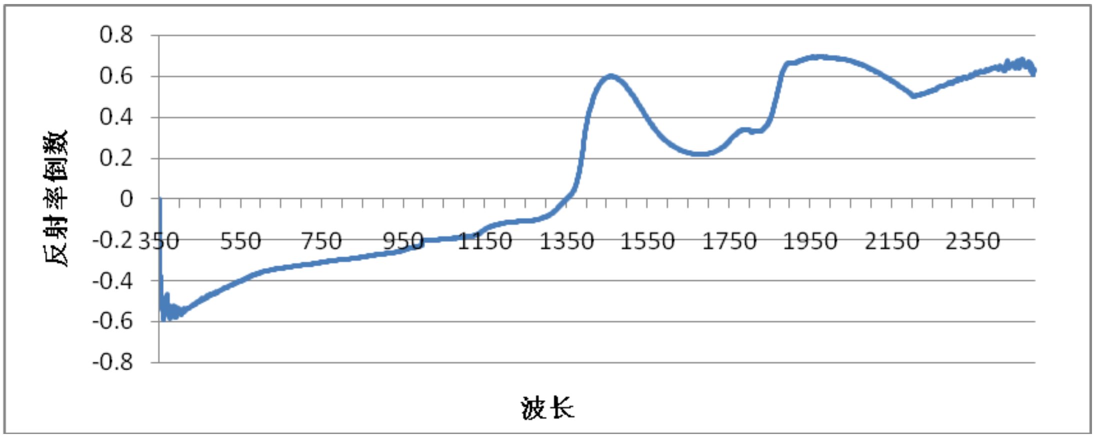


Figure7 The correlation coefficient between the reciprocal reflectivity and the soil moisture

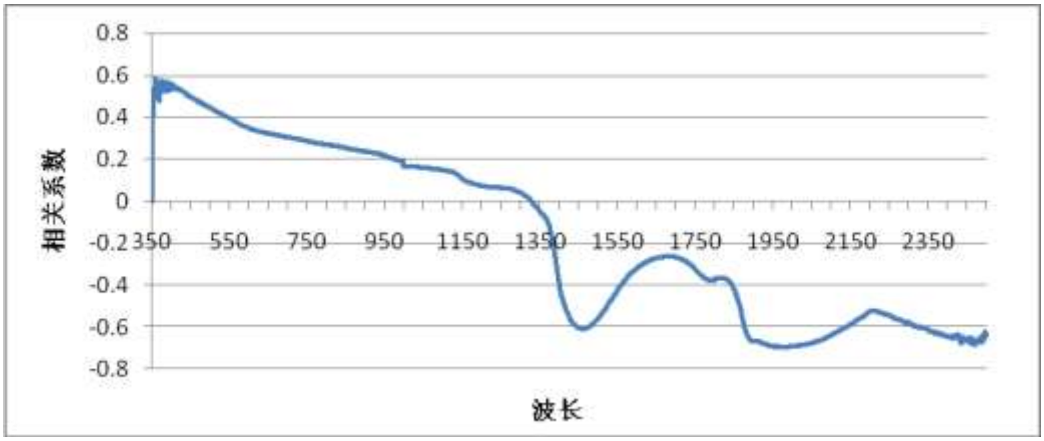


Figure 8 The correlation coefficient between the logarithmic reflectivity and the soil moisture

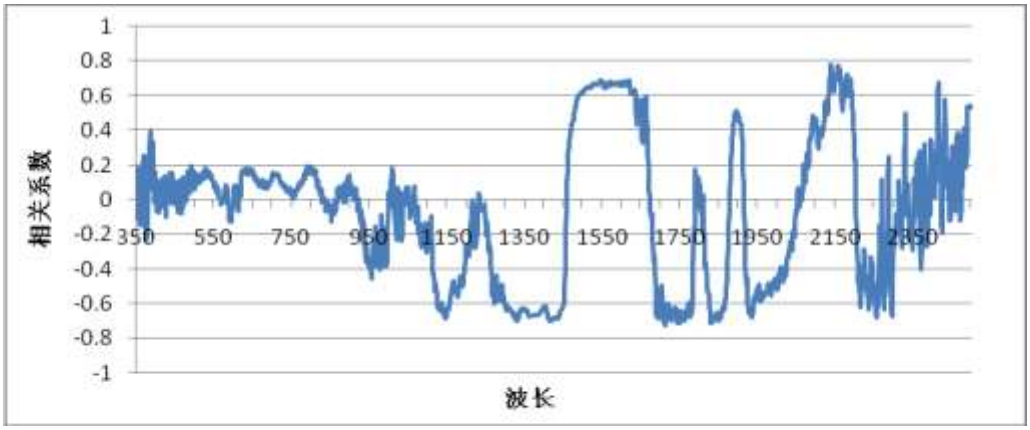


Figure 9　The correlation coefficient between the 1st derivated reflectivity and the soil moisture

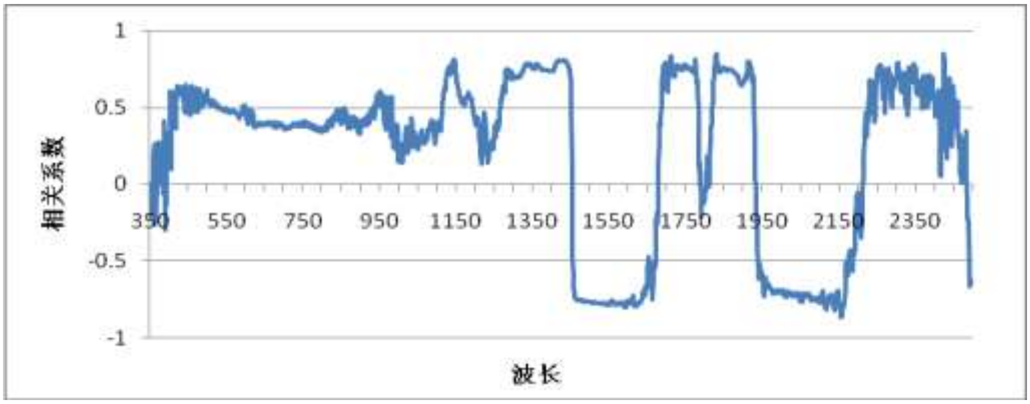


Figure 10 The correlation coefficient between the reciprocal 1st derivated reflectivity and the soil moisture

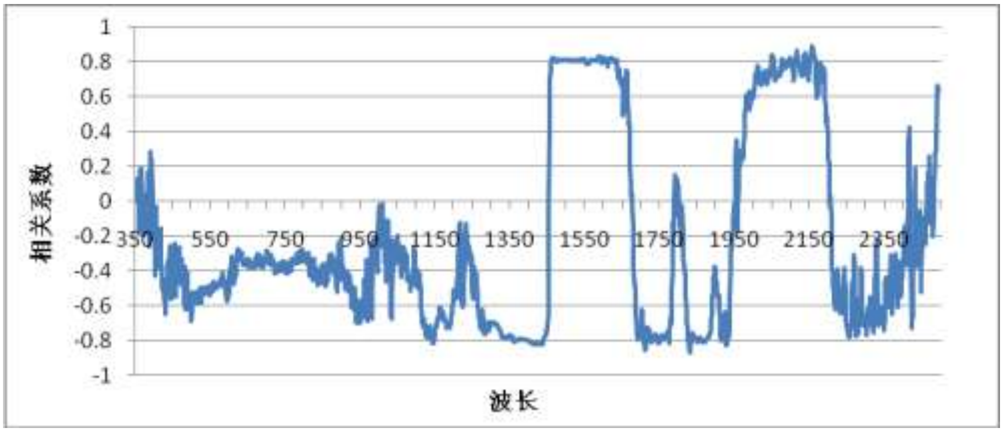


Figure 11 The correlation coefficient between the logarithmic 1st derivated reflectivity and the soil moisture

Table 1 Peak value and band position of the correlation coefficient between different transformation and soil moisture

Transformation method	Band position	Correlation coefficient
spectral reflectance	401	0.55
	1460	-0.60
	1978	-0.68
	2102	-0.63
	2469	-0.67
the first derivate reflectivity	1415	-0.70
	1544	0.68
	1749	-0.71
	1830	-0.71
	2156	0.74
the logarithmic of the first derivate reflectivity	1591	0.83
	1749	-0.81
	1830	-0.86
	2050	0.83
	2156	0.89

3.4 The establishment of the reflectance of soil moisture inversion model

Multiple regression analysis were carried out for the selected spectral characteristics parameters from the soil reflectivity, the first derivate reflectivity and the logarithmic of first derivated reflectivity with larger correlation coefficient with soil moisture to establish predicting models of soil moisture and reflectivity bands (seeing Table 2 to Table 4). The inversion model with the largest determination coefficient R^2 was selected as the predicting model of the black soil reflectance and soil moisture content. Where, Y is the soil moisture content (%), x is the reflectance value of band (%).

Table 2 Stepwise regression analysis outcomes of the reflectivity and soil moisture

Soil samples	Regression	R^2	Number of samples
FY001	$Y=26.997-310.195X_{1978}+708.140X_{401}$	0.581	20
FY005	$Y=24.394-297.851X_{1978}+495.37X_{2150}$	0.513	20
JT002	$Y=22.491+54137.6X_{401}-795.8X_{2150}$	0.476	20
JT006	$Y=30.674-496.86X_{1978}+916.708X_{2156}$	0.574	20
JT007	$Y=50.419+46436.8X_{401}-261.744X_{1978}$	0.631	20
LS010	$Y=46.728-708.14X_{2156}$	0.491	20
LS011	$Y=29.514+5432.1X_{451}+216.78X_{1978}-376.432X_{2150}$	0.526	20
LS014	$Y=32.166-263.181X_{1978+}394.76X_{2139}$	0.547	20
LS024	$Y=27.821-435.786X_{1831}+893.271X_{2059}$	0.683	20
LS028	$Y=30.547+496.259X_{1425}-372.916X_{2150}$	0.439	20

Table 3 Stepwise regression analysis outcomes of the 1st derivate reflectivity and soil moisture

Soil samples	Regression	R^2	Number of samples
FY001	$Y=28.399+157740.4X_{2156}$	0.56	20
FY005	$Y=25.734+254372.6X_{2156}$	0.603	20
T002	$Y=22.961+734264.1X_{2156}$	0.549	20
JT006	$Y=24.376+211325.1X_{1831+}75436.1X_{2152}$	0.639	20
JT007	$Y=30.174-457630.8X_{1431}+297631.4X_{2156}$	0.742	20
LS010	$Y=42.371-2611370.6X_{1324}-43276.8X_{1776}+163796.5X_{2156}$	0.776	20
LS011	$Y=20.961+753436.5X_{2156}$	0.496	20
LS014	$Y=26.359+143765.3X_{2156}$	0.554	20
LS024	$Y=32.178-27638.1X_{451}-273067.5X_{1451}+275947.1X_{2156}$	0.617	20
LS028	$Y=26.717+324678.5X_{2156}$	0.639	20

Table 4 Stepwise regression analysis outcomes of the reciprocal 1st derivate reflectivity and soil moisture

Soil samples	Regression	R^2	Number of samples
FY001	$Y=28.79+52599.78X_{2156}$	0.794	20
FY005	$Y=24.73-37918.4X_{1798}+73829.6X_{2156}$	0.726	20
JT002	$Y=39.637-72463.5X_{2156}$	0.674	20
JT006	$Y=22.163+26278.2X_{1328}-47785.1X_{1439}-201.418X_{1742}+49306.34X_{2156}$	0.931	20
JT007	$Y=52.525-37696.8X_{451}-27793.6X_{1328}-39425.6X_{1821}+49536.4X_{2156}$	0.769	20
LS010	$Y=50.117-35694.2X_{475}-22619.9X_{1824}-19723.9X_{2139}-19140.8X_{2334}$	0.716	20
LS011	$Y=42.729-423161.3X_{1326+}32476.5X_{2078}$	0.847	20
LS014	$Y=32.417+26738.4X_{1832}-49736.6X_{2156}$	0.847	20
LS024	$Y=28.642-32496.5X_{2139}$	0.713	20
LS028	$Y=30.963-45728.9X_{1457+}4392.781X_{2156}$	0.801	20

Table 2 to table 4 showed that the best model for predicting black soil moisture content was the regression equation of the logarithmic of the first derivate reflectivity with four reflectivity bands of 1328nm, 1439nm, 1742nm and 2156nm as independent variables. The regression equation was as follows.

$$Y = 22.16 + 26278.2\, x_{1328} - 47785.1\, x_{1439} - 201.42\, x_{1742+49306.34}\, x_{2156}$$

Where, $x = (\lg R)'$, Y for the soil moisture content (%). The determination coefficient was 0.931.

4 Conclusion

(1) Hyperspectral remote sensing technology can obtain nano-scaled soil spectral reflectance, and can reflect slight differences in soil properties. Those can be used in soil moisture remote sensing monitoring.

(2) Below field capacity conditions, the sensitive band of black soil spectral reflectance and its transformation of reciprocal and logarithmic were mainly in 400-470nm, 1950-2050nm and 2100-2200nm, of which band of 2156nm had the highest correlation coefficient of 0.89 to the soil moisture content.

(3) The best black soil moisture predicting model by hyperspectral remote sensing *is:* $Y = 22.16 + 26278.2\,x_{1328} - 47785.1\,x_{1439} - 201.42\,x_{1742} + 49306.34\,x_{2156}$, where $x = (\lg R)'$, Y for the soil moisture content (%). The determination coefficient is 0.931.

(4) Soil spectral detection was carried out in the laboratory, which eliminated a number of interferences from natural and human. Therefore, it need more work on spectral data analysis comparison between field and laboratory to establish an accurate spectrum of soil moisture inversion model.

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Regional Land Suitability Assessment for Tree Crops Using Remote Sensing and GIS

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Abstract: Shouyang County which partly locates on the Loess Plateau suffers severe soil and water erosion and is characterized by ecological vulnerability and semi-arid climate. Land suitability evaluation for tree crops is very significant for agricultural production in the ecologically vulnerable regions of semi-arid zone. The authors applied a upscaling approach to carry out land suitability for the four local tree crops of apple, pear, jujube and hawthorn under the traditional cultivation senario. The upscaling was implemented in a land form hierarchy which was composed of land unit, land facet and land site at three spatial levels. The IAO land suitability evaluation model for crops was revised by appling a meteorological revision index. The results showed that a polarized phenomenon occurred, which means that the most suitable class (S1) and the most unsuitable class (N2) were predominant in acreage percentage for all the four tree crops in the study area. We proposed that cropland use policies should pay more attention to putting more investment for agricultural production in the suitable regions. It is necessary to balance the relationship between the livelihood of local farmers and environmental protection to maintain a healthy and stable ecosystem.

Key words: Land suitability assessment; upscaling; tree crops; land unit; revision index; semi-arid

1 Introduction

The process of land suitability evaluation is the appraisal and grouping of specific areas of land in terms of their suitability for a defined use (Zonneveld 1989). Agricultural suitability mapping involves identifying land use patterns and assessing whether the current use is the most feasible both economically and environmentally. The final goal of the mapping is to provide the politicians and decision makers with a land evaluation tools in a final digital geographic database that can constitute a basis for a rational land use planning and a sustainability assessment.

Since land suitability is very significant for scientific research and policy-making, numerous studies have concentrated on this field. The American Ministry of Agriculture first issued a land potential classification system in 1961 and Canada, Britain, Australia, Japan and former the Soviet

Union follow the suit to evaluate the land through land investigation (SHI *et al.* 2007). FAO issued "A Framework for land evaluation" which not only implemented land evaluation but also focused on land suitability for special use in 1970s (FAO 1995). With the rapid development of remote sensing and GIS technologies, statistics theory, systematic theory, ecological theory and dynamic simulating model, the land suitability entered a new era. The remote sensing technique has been widely applied for collection of terrestrial features and so many journalists put forward land use change trend models for land suitability evaluation based on GIS techniques (Bouma 1998). Landscape methods were incorporated into land suitability evaluation and natural change of landscape could be quantitatively identified through statistics (Ahmed and Dent 1997). The results of the dynamic simulating models could consist of a part of main land unit database (Batjes 1996). Systemic methods such as AHP, Delphi, fuzzy mathematics, linear planning, optical allocation and neutral network were also applied in the identification of land suitability classification and weighing values (Du *et al.* 2001; Liu *et al.* 2006; Chen *et al.* 2007; Wang *et al.* 2008). In addition, in recent years, ecological methods, for instance Land eco-economical suitability evaluation based on niche fitness, were generally introduced to evaluate land suitability (Yu and He 2008). No matter what new technologies were adopted in land suitability evaluation, the update of methods for identifying weighing values and suitability classification is always most concerned; however, there are still the two problems needed to be solved which are as follows: (1) the evaluation was implemented at a certain spatial scale supported by data at the same scale, but the more accurate data at larger scales were not used; (2) the evaluation mapping results was too fragmented to be practical for policy-maker.

In the light of the deficiencies in the land evaluation, this study seeks to achieve three objectives: (1) to evaluate land suitability in a typical region characterized by ecological vulnerability and semi-arid climate from practical management point of view; (2) to apply a up scaling method to deliver the accurate information at larger scale to the evaluation model at the mapping scale; (3) to revise and improve the IAO land suitability model by the meteorological revision index. We therefore expect this study can offer policy-makers some preliminary recommendations to ensure the sustainable use and management of croplands.

2 Methods

2.1 The study area

Shouyang County (112°46'-113°28'E, 37°32'-38°5'N) is situated at the eastern part of Shanxi Province (Fig.1). The altitude ranges from 813 m to 1756 m with the three kinds of landforms: mountain, hill and valley. The middle region, covering 41.1% of the total area of the whole county, locates on the Loess Plateau hills and valleys, terraced mesas. The total area of this county is 2,112km^2 with a total population of 220,000 inhabitants and most of people depend on crop products to live. Shouyang County has a long agriculture history and there is a total area of 66,430 ha for agricultural use, of which only 1,900ha is irrigated by wells and river water. Due to scarcity of precipitation and concentration of rainfall in summer, the study area strongly suffers soil and water erosion. The disadvantage natural phenomena such as aridity, flooding, frosting, hailstone and sandstorms sometimes occur; hence, the physical surrounding of the county is fragile.

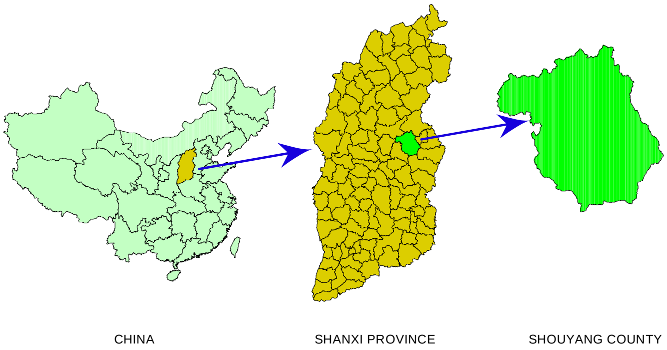

Fig. 1 the sketch map for the location of Shouyang County in China

2.2 Methodology

2.2.1 The evaluation and mapping unit

To evaluate land resources which are a complex and adaptive system, it is not possible to simply consider the affecting factors in an individual aspect and an integrated methodology which takes into consideration land attributes such as climate, geology, geomorphology, soil, land use and over and their interactions from holistic view of the landscape is inevitably necessary. Therefore, the Land evaluation and mapping unit needs to be identified with full consideration of all the relevant land attributes: the land unit is a basic geographic cell which is classified according to soil type, landform, land use and cover and geological type simultaneously, and the characteristics of each land attributes for one land unit classification are homogeneous at a certain spatial scale. Land facets, which are also composed of land sites, can describe Land unit and land unit, land facet, and land site spatially form a hierarchical land system. Land facets identified in terms of land use and over, landform and soil type is also a homogeneous unit from a management point of view and they are composed by a combination of land sites with at least one homogeneous land attribute. The smallest holistic unit is land site which has homogeneous land attributes; and meanwhile, site information concerning land attributes is acquirable through records (including data of landform, soil profile and land use/over) by selecting the sampling points to do field survey. Land sites must be described as exactly as possible, as it is basis for land suitability evaluation. In this land system, the uniqueness of land attributes of land unit, land facet and land site closely corresponds to spatial scale.

Assuming that one or different land sites can describe a kind of land facet and one or different kinds of land facets can describe a kind of Land unit, a single value for each land attribute of a kind of land unit could be obtainable by up scaling the same land attribute data of the different land sites. Every land site describes a certain acreage percentage of a land facet. The final value of each land attribute of each land facet comes from the addition result of the multiplying of the same land attribute values of land sites by the corresponding weighing values. The weighing value of each land site depends on acreage proportions of land sites in a land facet. A lowest acreage threshold of five percent was set for disregard the smaller land sites. The up scaling procedure from land facet to land unit follows the suit as well.

2.2.2 Land suitability model

The knowledge of the land production capacity and its potential is an essential precondition to plan a better land use and, as a consequence, to promote agricultural and economic development. The land production capacity is limited by a set of the affecting factors such as climate, soil, water availability, landform, and cropping management. Once the affecting factors are identified, crop productivity could be advanced by the improvement of these factors.

The land suitability evaluation for each crop was implemented by using an improved method, which is originally from the IAO method based on FAO guidelines for land suitability evaluation of crops. The IAO method consists in homogenizing the characteristics of land attributes and assigning a suitability rating for each land characteristic. The database of landform and soil parameters, which are from records obtained during the field survey, was established. To obtain a unique value of the established parameters for each record, a different analyzed depth (control section) is used. Soil data are then averaged in terms of the single horizon depth with respect to the considered control section. The land suitability index for each record (Si) is calculated from the individual ratings in the following mathematical formula:

$$S_i = A \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \frac{E}{100} \times \frac{F}{100} \times \frac{G}{100} \times \frac{H}{100} \qquad (1)$$

Where *A* is the rating of drainage; *B* is the rating of soil depth; *C* is the rating of soil slope; *D* is the rating of texture; *E* is the rating of surface coarse fragments; *F* is the rating of CaCO3; *G* is the rating of electric conductivity; *H* is the rating of pH. The final value for land suitability evaluation is then ranked from zero (worst) to 100 (best) (Ongaro 1998);

In the IAO method, if the study area is at small spatial scale such as county scale, the parameters of meteorological factors were considered as homogeneousness. However, the meteorological factors do affect crops production from the practical perspective of view. If the amounts of temperature and precipitation in the study area could not meet the needs of crops growth, the difference between potential value and actual value of the meteorological factors could decline land suitability for crops growth. Thus, this article applies the philosophy of the water stress index widely used in the research field of crop drought to establish a meteorological revision index, which is shown in formula (2) to improve the land suitability index:

$$R_i = \frac{T_i}{T} \times \frac{P_i}{P} \qquad (2)$$

Where R_i is the meteorological revision index, T_i is the actual effective accumulated temperature for a kind of crop during growth phase (℃ d); *T* is the effective accumulated temperature (≥10℃) for the same crop to grow in good condition (℃ d); P_i is the actual water-supplied amount during the growth phase (m^3ha^{-1}); P is the water-needed amount for the same crop to grow in good condition during the growth phase (m^3ha^{-1}). In addition, the improved land suitability index is expressed in formula (3):

$$S = S_i \times R_i \tag{3}$$

Where S is the improved land suitability index and the land suitability classes are shown in table1.

Table 1 Index values for the different Suitability classes

Suitability Class	Index	Description
S1	>60	Highly Suitable
S2	45-60	Moderately suitable
S3	30-45	Marginally suitable
N1	15-30	Almost unsuitable
N2	<15	Unsuitable

2.3 Data collection and processing

2.3.1 Materials

Thematic maps such as the geological map and the soil map both at a scale of 1: the Shanxi Agriculture Remote Sensing Centre produced 500,000 in 1985. To perform the photo-interpretation, 71 infrared aerial photos obtained in 2000, at a scale of 1:50,000 with nine different flight lines were used and they were very useful for drawing the preliminary land unit map and supporting the satellite images interpretation. A Landsat ETM+ image of July 1st, 2000 with radiometric correction and georeferenced information for drawing preliminary land unit map, fieldwork and other relevant analysis was acquirable from the digital database of the Shanxi Agriculture Remote Sensing Centre. The Digital Elevation Models with a spatial resolution of 90 meters, which was very useful for geomorphologic analysis, were downloaded from the NASA web site http: //www.jpl.nasa.gov. The meteorological data such as temperature and precipitation values during the period 1984-2000 came from the Shouyang Meteorology Bureau. The references concerning local agricultural production and crops growth were collected from the local agriculture bureau and internet. In order to complete the land suitability evaluation, fieldwork including digging soil profile to record soil characters, visually observing land use/cover to record landscape information and obtaining the landform information was done. A GPS (GARMIN GPSMAP 76S) with an accuracy lower than 15 meters and RMS 95% was used to store, during the fieldwork, records coordinates and ground control points (i.e. crossroads).

2.3.2 Data processing

The Landsat ETM+ image was made FCC 432 fusion with panchromatic band for land use/cover identification. During the preliminary phase, digital data were collected from many sources such as aerial photos, satellite images and from the available digitized hardcopy map. The boundary of the study area was defined according to the administrative border of Shouyang County. The aerial photos, the ETM+ FCC 432 composite with panchromatic band and other thematic maps such as geology and soil maps were input into the GeoVIS software, which could simultaneously display four screens for the same geographical location to digitize the preliminary Land unit map. All the data collected during the fieldwork, both from the field samples and GPS, were used to fill the database and to correct and refine the preliminary Land unit map. The annual accumulated temperature and precipitation values for 17 years from 1984 to 2000 were averaged and stored in the dataset.

3 Results

3.1 Land unit map and its legend

An analysis of geomorphologic aspects of the study area based on the information acquired from the ETM+ image and aerial photographs was implemented to identify the three main landscapes: the rocky substrate, the Loess Plateau and the valley system. The Loess Plateau area was divided into two parts of northern and southern regions according not only to geographical criteria, but also to morphological observations. In addition, it was observed that the southern plateau was characterized by higher and steeper hills than the northern one, reflecting different litho logy; meanwhile a loess cover thicker than the southern one characterized the northern plateau where the litho logic substrate was mainly outcropped. The land cover was classified according to the Eiten methodology and the Land Cover Classification System (Di and Jansen 2000).

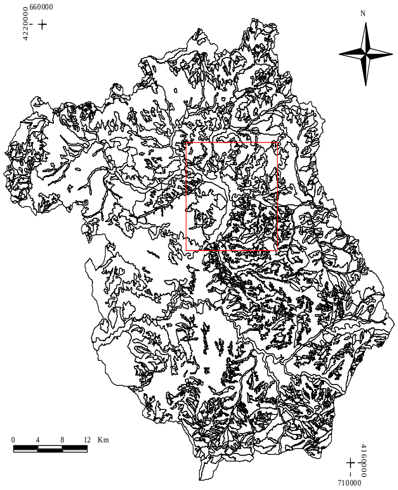

Fig. 2 Preliminary land unit map

Through the integrated analysis of the aerial photos, the ETM+ imagery FCC 432 bands composition and the NDVI image derived from ETM+ imagery by visual interpretation method, fourteen land use/cover types were summarized. In addition, five types belonged to natural vegetation, which was described applying the dominance role during digitizing preliminary land use map, five in human-influencing areas and the others represented by mixed classes. In case of mixed unit, the adopted criteria was that the cover of each one of the considered facet must be higher than 20% in size. The soil classification of the study area and detailed description of the soil groups identified in the field has been provided according to the World Reference Base for Soil Resources (FAO 1995). For each group, the list of sub units, reflecting the secondary paedogenesis process that affects significantly the primary properties of the soil, was also set combining field-collected and laboratory data. The soil legend and the soil map were derived from this list and the legend was organised applying a distinction among pure soils, predominant soils and association of soils. Based on the analysis mentioned above, the preliminary land unit map was available (see figure 2).

Table 2 Land unit legend

Geology	Landform	Land use/cover	Land Unit	Soil
Limestone, shale with sand	Very steep mountains	Thicket	1	Association of Calcaric Cambisols and Chromic Luvisols and Eutric Leptosols
		Low forest with closed scrub	2	Predominance of Calcaric Cambisols with Leptic Cambisols
		Open to closed scrub and forest plantation	3	Association of Eutric Leptosols and Endoleptic Cambisols
		Open to closed scrub	4	Predominance of Calcaric Cambisols with Paralithic and Calcaric Leptosols
		Annual rainfed crops	5	Calcaric Cambisols
Sandy deposit with gravel	Gently sloping summit surface (Yuan)	Annual rainfed crops	6	Calcaric Cambisols
		Irrigated tree crops	7	
	Dissected gently sloping surface	Annual rainfed crops	8	
		Forest plantation	9	
	Strongly dissected sloping surface	Annual rainfed crops and open to closed scrub	10	Association of Calcaric and Chromic Cambisols and Calcaric Fluvisols
	Terraced rolling hills	Open scrub	11	Predominance of Calcaric Leptosols with Calcaric Cambisols
		Open scrub and forest plantation	12	Association of Calcaric and Chromic Cambisols and Calcaric and Hyperskeletic Leptosols
		Annual rainfed crops and open scrub	13	Calcaric Cambisols with Chromic Cambisols and Calcaric and Hyperskeletic Leptosols
		Open scrub and annual rainfed field crops	14	Predominance of Calcaric Cambisols with Eutric and Chromic Cambisols
		Forest plantation and open to closed scrub	15	Calcaric Cambisols with Eutric Cambisols

Geology	Landform	Land use/cover	Land Unit	Soil
Grey-yellow quartz sandstones and quartz shale	Residual gently sloping summit surface (*Yuan*)	Annual rainfed crops	16	Calcaric Cambisols
	Steep hills	Open to closed scrub	17	Association of Calcaric and Chromic Cambisols and Calcaric and Hyperskeletic Leptosols
		Open scrub	18	Association of Calcic Luvisols and Calcaric Cambisols and Calcaric Leptosols
		Annual rainfed crops and open to closed scrub	19	Calcaric Cambisols with Chromic Cambisols
		Annual rainfed crops and open scrub	20	Predominance of Calcaric Cambisols with Calcaric and Hyperskeletic Leptosols
Gravel sandy alluvial deposits	Alluvial plain	Grassland on temporarily flooded land	21	Calcaric Fluvisols
		Annual rainfed and irrigated crops	22	
		Forest plantation	23	
	Colluvial valley bottom	Annual rainfed crops	24	Association of Calcaric Fluvisols and Calcaric Cambisols
		Water body	W	
		Quarry	Q	
		Urban	U	
		Other area	M	

In terms of the field observations (totally 70 records), the preliminary landform and geology legend were not modified; instead, in the rocky mountainous area, where greater differences related to the land cover description were found, a revision of the preliminary map was necessary. The Land units characterized by anthropic influence were kept as in the preliminary map; on the contrary, areas covered by natural vegetation were completely modified. Map changes were realized by taking into account record information and using ground control points collected during the fieldwork for this purpose.

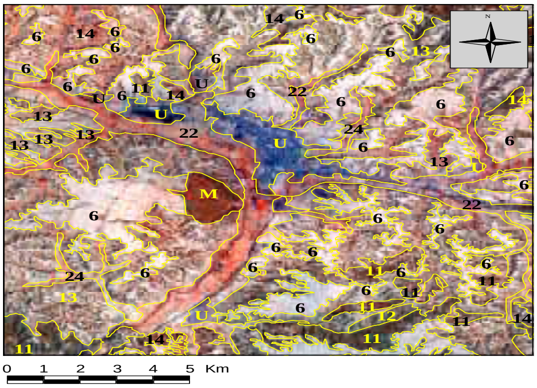

Fig. 3 Land unit map

After this revision, the acreage percentages of land facets were computed for the description of land units. Sometimes the different types of land facets had very slight differences and they were merged (McDonald et al. 1998). After the relevant analysis, eleven different facets were recognized. The final land unit legend was in the following table 2 and the final land unit map was drawn at a scale of 1:50,000 (figure 3).

3.2 Land suitability assessment results for tree crops

Through the above-mentioned method, suitability maps for apple, pear, hawthorn and jujube were obtained. In order to have a better comprehension about the suitability of different Land units/culture, the following chart was prepared (Table).

Table 3 Suitability class for tree crops

Suitability class	Apple	Pear	Jujube	Hawthorn
Highly suitable	5,8	5,8	-	-
Moderately suitable	6,9,10,13,16,20	15	-	-
Marginally suitable	7,15,19	6,9,10,16,20	5,8,15,22	5,6,9,10,13,16,20,22,23
Almost unsuitable	3,18,22,24	3,7,13,18,19	3,6,7,9,10,13,16,18,19,20,24	3,7,8,15,18,19,24
Unsuitable	1,2,4,11,12,14,17,21,23	1,2,4,11,12,14,17,21,22,23,24	1,2,4,11,12,14,17,21,23	1,2,4,11,12,14,17,21

It is very important to stress that, since the adopted model was mostly validated for temperate and Mediterranean areas, some results seem a little unmatched either the theory or the ground truth as, for instance, in unit 1. In this unit, apple and pear suitability results S1 even if this unit is in very steep mountain area usually unsuitable for apple or pear. So after checking the second dominant result (N2) and third one (N1), N2 was be given manually as the final class to this unit. Generally speaking, slope and drainage are the main limiting factors for the chosen tree crops. The mountain areas (Land units 1 to 4) are very unsuitable for these tree crops, except Land unit 5, belonging to the mountain terraces. It can also be noticed that, on Loess Plateau and arenaceous reliefs with loess covered areas, all the units covered by scrub result unsuitable because of the steep slope. Increasing the slope, water flows down faster and the soil cannot retain enough water for the plants. The decrease of soil depth is also a very important limiting factor for growing.

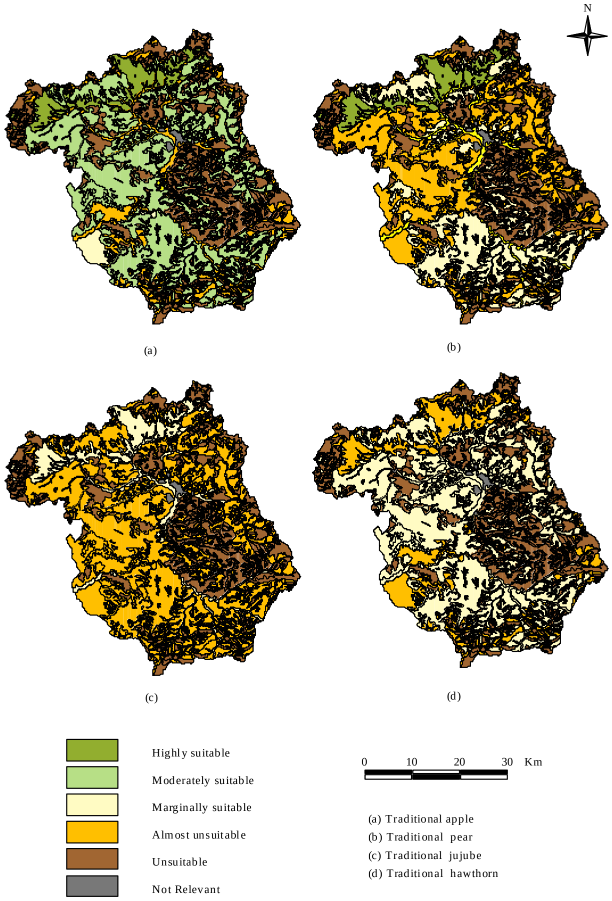

Fig. 4 Suitability map for tree crops

On cultivated areas, it should be pointed out that the slope degree recorded during the fieldwork considers the absolute slope of the facet that the terrace belonged to, instead of the slope of the terrace itself. This brought a problem to the results of evaluation (Land units 4, 14).

As described in the previous chapter, the study area is in semi-dry mild continental monsoonal climate. Because of the lack of water and precipitation, drainage is another parameter to be considered, especially on terraces, Loess Plateau and river valley, where it plays a more important role than on the steep mountain area.

According to specific moisture requirements of each tree crops, different Suitability classes were given out. For an easy understanding of the result, the classes were grouped in this way: suitable

(S1, S2, and S3), potentially suitable (N1), unsuitable (N2). The following chart shows the suitability results for the analyzed cultures (Table).

Table 4 Suitability order for the tree crops

Suitable	Apple, pear, jujube, hawthorn	Unit
Completely suitable	S1, S2, S3	5
Completely unsuitable	N1, N2	1,2,3,4,11,12,14,17,18,21,24
Mixed suitable	S1, S2, S3, N1, N2	6,7,8,9,10,13,15,16,19,20,22,23

Apple: about 56% of total area is suitable, most of these units are in the Loess Plateau with gently sloping surfaces or terraces, and 14% is potentially suitable with some changeable limiting factor such as inadequate drainage. Due to the slope and soil depth constraints, 30% is unsuitable for apple, which is spread in terraced rolling hills (Liang) and mountain areas.

Pear: in general, the study area is not suitable for pear crop because of its requirement of deep soil.

Hawthorn: pH and soil depth can almost satisfy the requirements of hawthorn resulting suitable in the 52% of the study area, while texture influences the results severely. The potentially suitable areas are almost located in the units where rainfed crops and forest plantation are present now with a cover of 17%. Steep mountains and rolling hills are unsuitable (30%) due to the slope and the coarse fragments.

Jujube: soil depth and pH fit the needs completely, while the slope and texture are still the main constraints for growing. The result shows that 58% of the study area has the potential suitability.

4 Discussion

The Loess Plateau is a unique geographic unit characterized by soil erosion and low fertility. In China, the loess plateau occupies a large area in central and northern parts of its territory. The conflict between inhabitants' agricultural activities for living and economic purposes and ecological vulnerability has been a hot issue for academy and decision-makers. Soil erosion was very intensified by agricultural activities, and there are so many projects to develop sustainable agriculture in the study area now. The results of the study aimed at promoting the reduction and abandonment of the less productive farmlands such as many highly eroded and difficultly accessible terraces and balancing the relationship between the livelihood of local farmers and environmental protection to maintain a healthy and stable ecosystem.

This article applied an up scaling method to evaluate land suitability for crops based on land units drawn before field survey. Through the hierarchical land system of land unit, land facet and land site, the evaluate results not only embody the accuracy but also are to be used for policy-maker because of homogeneity in one unit. With respect to the up scaling method, the philosophy is quite similar to object-oriented idea in the computer science, which means that all the things are generalized to many basic constitutive components and different comprehensive combinations of components could describe a concrete thing. The organization of such hierarchical land system was very effective and efficient for economical purpose during field survey and assuring the accuracy of the up scaling of land site data to land unit.

In equation (1), the rating of drainage in fact has been assumed as the most important affecting factor for crop evaluation, meanwhile the rest affecting factors are considered as equal in weighing. In the past evaluation methods, soil properties predominate in the affecting factors list and the meteorological data are always neglected since its homogeneity at a relatively small spatial scale such as county level. However, the insufficiency of accumulated temperature and precipitation certainly results in the decrease of agricultural production and soil moisture. Thus, the temperature and precipitation are used as the meteorological revision index for the land evaluation in this article. The meteorological revision index is meaningful to the comparison of the evaluation results between the different regions since its widespread applicability. Both deficit and excess of meteorological factors could no doubt bring out unfavourable results for crops growth, so the meteorological revision index is better suitably utilized for the arid and semi-arid regions short of water. In this article, authors made the land suitability evaluation for crops just considering the natural affecting factors, but not neglecting the involvement of socio-economic elements. We do not accept the thinking that the more comprehensive aspects to be considered, the more accurate results will be. In fact, land suitability evaluation should base on natural factors assessment and guide human activities.

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Efficiency Analysis of Agricultural Land use Based on DEA Method ——a Case Study Among APEC Economies

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Abstract: Data envelopment analysis (DEA) is a useful method to evaluate the efficiency and productivity of a number of producers which consume multiple inputs to produce multiple outputs. Agricultural land use is actually an input-output system for food production. The paper evaluates the efficiency of agricultural land use, and concludes that1. The whole region still has room to increase land output based on current input level. 2. Arable land area is the last factor to cause input redundancy. Sufficient arable land area is important for food production. 3. Agricultural labors should be liberated from agricultural sector. 4. Artificial material input such as fertilizer and machinery plays an important role in agricultural land use system.

Keywords: DEA, agriculture land use, efficiency evaluation

1 Introduction

With the ongoing climate change, population explosion, industrialization and urbanization, agriculture land use is facing serious challenges. On one hand, urban sprawl brings a sharp shrinking of arable land area, which will make the total food production decline, even though the unit yield is increasing due to the advanced agriculture technology and additional agricultural input; on the other hand, a series environmental issues including land degradation, soil contamination and frequent drought caused by climate change, combined with other problems such as population explosion and changes of dietary structure, make the food security situation increasingly difficult. So how to understand the efficiency of agriculture land use and to increase food production is becoming more and more important.

Agriculture land use is a complicated production system, and its efficiency is essentially related to regional natural condition and input of production factors. So the assessment of agriculture land use efficiency should comprehensively consider the resource endowment, capital investment, labor input, technology application, and so on. A general understanding is that, regional difference of agriculture land use efficiency is inevitable; because natural condition, economic strength and developing stage are differ from region to region. However, this difference provides us another way to understand agriculture land use efficiency. In this paper, the author makes a horizontal analysis on agriculture land use efficiency among APEC economies using the C^2R model of DEA.

2 Study area

Asia-Pacific Economic Cooperation, or APEC, is the premier forum for facilitating economic growth, cooperation, trade and investment in the Asia-Pacific region.

APEC has 21 members - referred to as "Member Economies" - which process of approximately 40.5% of the world's population, 43.3% of the world's arable land area, produce about 52.1% of the world's total food production, and account for approximately 54.2% of world GDP and about 43.7% of cereal trade. The region includes a lots of major food trade economies such as, Australia, Canada, China, Japan, Korea, Thailand, Viet Nam.

Within the Asia-Pacific region, food security is always a priority among all levels. Concerns about food security and the increase in prices of various agricultural products are the result of a confluence of individual factors. Prospective long-term factors such as population growth and global climate change may be the primary reasons, however, other problems such as structural adjustment, technology application, resource utilization as well as investment would never be underestimated its effect. So choosing the Asia-Pacific region as the study area will have great importance.

3 Methodology

Data envelopment analysis (DEA), first introduced by Charnes et al. (1978), is a non-parametric, linear programming technique, commonly used to evaluate the efficiency and productivity of a number of producers which consume multiple inputs to produce multiple outputs. A typical statistical approach is characterized as a central tendency approach and it evaluates producers relative to an average producer. In contrast, DEA is an extreme point method

compares each producer with only the "best" producers. Extreme point methods are not always the right tool for a problem but are appropriate in certain cases. In DEA, techniques are used to “envelop” the observed input – output vectors as tightly as possible. One main advantage of DEA is that it allows several inputs and several outputs to be considered at the same time. In this case, efficiency is measured in terms of inputs or outputs along a ray from the origin.

In the DEA methodology, a producer is usually referred to as a decision making unit or DMU. Each DMU $_j\{ j=1, 2, 3\ldots n\}$ usually uses a set of inputs (resources) to secure a set of outputs (products), which can be described by a vector of outputs $\mathbf{y}_{rj}\{ r=1, 2, 3\ldots s\}$and a vector of inputs $\mathbf{x}_{ij}\{ i=1, 2, 3\ldots m\}$. In the method originally proposed by Charnes, Cooper, Rhodes (1978, so called CCR or C^2R model), the efficiency of the DMU$_{j0}$ is defined as follows.

Model 1. Output oriented - CRS model

Max h

s.t.

$$\sum \lambda_j x_{ij} + S_i^+ = x_{ij0} \qquad \forall i$$

$$\sum \lambda_j y_{rj} - S_r^- = h y_{rj0} \qquad \forall r$$

$$S_i^+, S_r^- \geq 0 \qquad \forall i, \forall r$$

$$\lambda_j \geq 0 \qquad \forall j.$$

If h^* is the optimum value of h, then DMU$_{j0}$ is said to be Pareto efficient iff h^*=1 and the optimal values of S_i^+& $S_i^+$are zero for all i & r.

Model 2. Input oriented - CRS model

Min ϕ

s.t.

$$\sum \lambda_j x_{ij} + S_i^+ = \phi x_{ij0} \qquad \forall i$$

$$\sum \lambda_j y_{rj} - S_r^- = y_{rj0} \qquad \forall r$$

$$S_i^+, S_r^- \geq 0 \qquad \forall i, \forall r$$

$$\lambda_j \geq 0 \qquad \forall j.$$

Assume that $\Phi^*$is the optimum value of φ. DMUj0 is said to be Pareto efficient iff Φ^*= 1 and the optimal values of S_i^+& $S_i^+$are zero ($\forall i, r$).

The output oriented method means no other DMU or combination of DMUs exist which can produce at least the same amount of output as DMU $_{j0}$, with less for some resources and/or no more for any other resources, while the input oriented model describes how efficiently resources have been utilized to produce the output of each DMU.

In trying to evaluate the agriculture land use efficiency, we mainly focus on the combined relationship of land use input and output. From the perspective of food security, the output of agriculture land use system usually represented by crop yield, rather than livestock products and forest production. However, the factors of input generally refer to natural resource, labor, capital, technology, institution, information, management etc.

This study, to apply the DEA method, each APEC member economy (18 of 21, excluding Chinese Hong Kong, Chinese Taipei) is regarded as a DMU. Meanwhile, due to the difficulty in quantification, the following indicators are chosen as input factors to avoid complexity: arable land area, agricultural population, share of irrigated land, total fertilizer consumption, and number of tractors and threshers. Similarly, to simplify, the cereals production was defined as land use output. Table 1 shows the value of each indicator among the 18 APEC economies

Table1. The input / output data of agricultural land use in APEC member economies (2006)

	Arable land area	**Agricultural population**	**Irrigated land area**	**Total fertilizer consumption**	**Land capital stock**	**Tractors and threshers**	**Total cereal production**
	(1000 ha)	**-1000**	**(1000 ha)**	**(tones)**	**(US$ million constant)**	**(Number)**	**(1000 tonnes)**
Australia	47715	851	2546	1903522	26923	381720	19229
Brunei Darussalam	2	2	1	64	22	82	1
Canada	45113	684	850	1787267	30573	812034	48577
Chile	1350	2334	1900	609302	9931	63450	3566
China	138634	838873	56333	55925569	318549	1940876	444065
Indonesia	22000	91878	4500	4062241	58215	352000	66066
Japan	4343	3457	2543	1761376	19369	2844665	11742
Korea, Republic of	1619	2864	859	599294	4369	323800	6647
Malaysia	1800	3614	365	1609851	9261	0	2234
Mexico	24500	21072	6300	1652609	52178	343000	32155
New Zealand	915	335	555	418417	5216	79605	805
Papua New Guinea	250	4604	-	17138	1708	1750	11
Peru	3650	7501	1198	339892	6477	14600	4163
Philippines	5100	30852	1428	542670	15241	66300	21409
Russian Federation	121574	12764	4513	1517330	76119	607870	76866
Singapore	1	4	-	10746	3	108.3	1
Thailand	15200	28047	4986	1797235	39207	592800	33201
United States of America	170530	5590	22700	25278756	354580	5115900	338513
Viet Nam	6348	55909	3000	2027794	15619	393576	39648

Source: FAO Statistical Yearbook 2007-2008

Table2. Result of DEA analysis of agricultural land use in APEC member economies

	Efficiency summary	Summary of input slacks					
		Arable land	Labor input	Irrigation	Fertilizer	Capital stock	Machinery
Australia	0.727	12096.643	0	631.835	100399.11	0	0
Brunei Darussalam	0.396	0	0	0.34	0	7.919	25.594
Canada	1	0	0	0	0	0	0
Chile	0.913	0	0	1462.92	317494.25	6369.361	0
China	0.93	0	141894.682	22188.6	39115612	0	0
Indonesia	0.917	0	0	0	1844281.1	7157.383	0
Japan	0.927	0	0	1117.79	643101.07	8486.035	2214867.6
Korea, Republic of	1	0	0	0	0	0	0
Malaysia	1	0	0	0	0	0	0
Mexico	0.86	0	0	3338.07	0	15591.775	0
New Zealand	0.368	0	0	133.64	89660.539	1178.584	8197.831
Papua New Guinea	1	0	0	0	0	0	0
Peru	0.829	0	176.033	691.219	0	1536.494	0
Philippines	1	0	0	0	0	0	0
Russian Federation	1	0	0	0	0	0	0
Singapore	1	0	0	0	0	0	0
Thailand	0.871	0	0	2236.18	0	5959.413	212507.77
United States of America	1	0	0	0	0	0	0
Viet Nam	1	0	0	0	0	0	0

3 Result

According to the Tab 2, there are 9 DMUs: Canada, Korea, Malaysia, Papua New Guinea, Philippines, Russia, Singapore, the U.S. and Viet Nam reached the perfect efficiency score. In contrast, the efficiency score of Brunei Darussalam and New Zealand is relatively low, which is 0.396 and 0.368 respectively. The rest of the DMUs' score centralized in 0.75-0.95, indicating that there are more or less of the input redundancy existed among those economies.

Redundancy analyzes:

(1) Arable land. Australia is the only one that redundant in quantity of arable land. Definitely, Australia holds plenty of land resource and possesses high arable land per capita, making it possible to adopt conservative tillage. Therefore, most of the cropland has got the possibility to be lied fallow. Ostensibly, the superabundant land input failed in bringing the extra food production, but actually, it is a good way to protect the soil fertility therefore to promote sustainable agriculture.

(2) Labor. Apparently, China has the great input slack in agricultural labor input. The problems partly due to its huge population, however, the over high ratio of agricultural population is much more important. According to the origin population data of FAO yearbook, there are over 830

million people (about 63% of the total population) live in the Chinese rural area. It’s inevitable that Chinese population will grow continually, what should we do is not only in population control, but also in structure adjustment. Liberating more and more people out of the agriculture sector, will not only promote China’s industrialization and urbanization, but also improve the production efficiency of agriculture.

(3) Fertilizer, capital stock and machinery. The three indicators can be regarded as the major artificial input of materials. From the summary of input slacks, it’s easy to find that Japan has the high redundancy existing, especially in machinery. It means that Japan made great effort to guarantee cereal production by the large scale of investment in artificial material input. However, Japan’s relatively high efficiency score shows that even if the artificial input redundancy is existing (not necessarily, the result is just according to data envelopment analysis), the output deficiency was not effected dramatically. That is to say increase in artificial input will raise the landuse production; even through the marginal efficiency is diminishing.

4 Conclusion

The mean value of efficiency score is 0.88, with 9 DUMs didn’t reach their optimal efficiency. The fact suggests that there are plenty room for the whole region to increase land output based on current input level, especially for those 9 economies with imperfect efficiency. It’s also can be comprehended as the region is possible to save more agricultural resource with no production decline.

Arable land area is the last factor to cause input redundancy, so the quantity of agricultural land especially the quantity of arable land is the basic foundation to ensure landuse output. Sufficient arable land area is not only the key factor for food production, but also provides the possibility to develop conservative tillage, which is the ideal way to protect the soil fertility and conserve the natural resources.

The overfull agricultural population makes no extra contribution to agricultural production, so a large number of agricultural labors should be liberated from agricultural sector (as China). The situation is that industrialization and urbanization is the best way to create non- agriculture employment, but it will inevitably occupy more and more farmland. So how to handle the dilemma is really a big question, a practicable solution is that to rationalize the land use planning within the framework of cultivated land protection system.

Artificial material input such as fertilizer and machinery plays an important role in agricultural land use system (as Japan). It is a possible measure to raise the landuse production by increase in artificial input; even through the marginal efficiency is diminishing. However, the overuse of fertilizer will not only bring input redundancy, but also cause some environmental problems such as soil hardening, land degradation and water eutrophication. So the utilization of fertilizer should be scientifically designed, how to use, and to what degree.

5 Discussion

The study area covers a large region with various types of climate, topography and fragmental land distribution, and the population scale, land area economic development are differed from economy to economy. Inevitably, adopting DEA to evaluate the efficiency of agricultural land use in large scale with input- output data will cause low accuracy.

Besides the natural condition, the fluctuation of land production is greatly influenced by technology input, policy and institution. Due to the difficulties in data availability, this study only considered the input elements of capital and labor; however, it didn’t involve the effect caused by those factors. In future studies, it’s necessary to think about how to quantize and integrate the effectiveness of policy and technology into the DEA system.

The effect of land use is comprehensive, so the output of agricultural land use should not be limited in food production or crop yield. Multi-output including economic benefit, ecological benefit and social benefit of agricultural land use is supposed to be considered in further studies.

An innovative framework would be that: to acquire a matrix of the efficiency value by the use of DEA method with the panel data (input as well as output) of the region, so that the efficiency of each DUM will be represented in time series. Using the time series data, a regression analysis can be conducted to understand and forecast the changing trend of agricultural land use efficiency in each DUM. However, how would the new method be effective, and to what extent, will be validated in my future studies.

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Spatial Variability of Nutrient Properties in Soil of Jilin Middle Plain

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Abstract: Spatial distribution of soil middle-elements and microelements in the middle plain of Jilin province were investigated using geostatistics and geographic information system (GIS) techniques. With various processing methods, including logarithmic transformation, excluding outliers and Box-Cox transformation, the available Ca, Mg, B, Cu, and Zn contents were evaluated with normal distribution. The result shows that Box-Cox transformation is applied in order to achieve normality in the data sets of available Ca, Mg, Cu, and Zn while excluding outliers were employed in the data set of available B to dampen the effect of outliers. Geostatistical analyses were carried out, including calculation of experimental variograms and model fitting, and then the distribution patterns of these soil nutrients elements were plotted. Semivariogram analysis showed that these soil nutrient elements were moderately spatially dependent in a given range.

Keywords Soil properties, Spatial variability, Geostatistics, GIS, Northeast China

Introduction

Spatial variability of soil properties is inherent in nature. And it always exists whether it is observed in large-scale or small-scale A better understanding of the spatial variability of soil nutrients is important for refining the agricultural management practices and for improving sustainable land use. Quantification of soil spatial variability is important in ecological modeling, environmental prediction, precision agriculture, and natural resources management

Soil surveys provide a map of different soil orders, together with a record of measured observations for each sampling locations. However, for a large scale soil property map it is not practical to measure soil properties for locations Although spatial distribution of soils provided by soil surveys is sufficient to make decisions for land use, more detailed information is needed in order to set up models to simulate chemical fate and transport, as well as for precision farming programs. Geostatistics is a technology for estimating the soil property values in non-sampled areas or areas with sparse sampling It Provides a set of statistical tools for a description of spatial patterns, quantitative modeling of spatial continuity, spatial prediction, and uncertainty assessment Geostatistical techniques incorporating spatial information into predictions can improve estimation and enhance map quality.

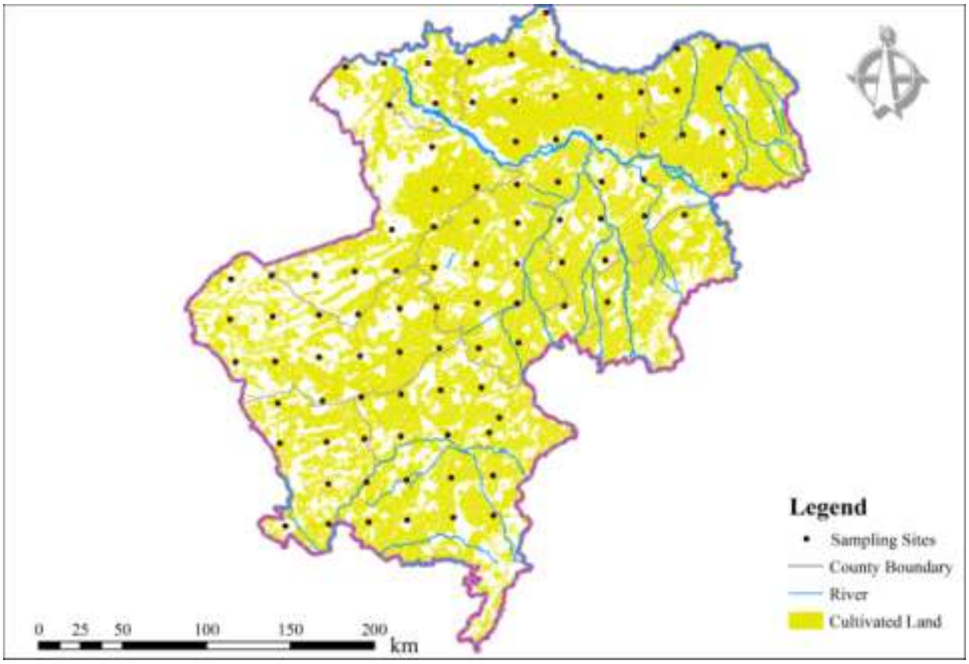
Although standard geostatistical techniques have been suitable for describing the spatial distribution of soil and successfully analyze spatial variability of soil properties, most applications were estimated in small-scale areas or on a field scale with little work being done in large land areas or soil regions. And also considerable interests have been generated in assessment of the macro elements (N, P, and K et al.) of agricultural soils, while less study about the middle-element and micro-element.

In this study, classical statistics and Geostatistics analysis methods, in combination with geographic information systems (GIS), were used to study the spatial variation characteristics of several soil properties. The objectives of this study were to map soil properties and provide a scientific basis for cultivated land evaluation which is targeting at improving soil quality in this region and analyzing the effect on grain production from the cultivated land quality change.

Materials and Methods

Study area

The study area (123°06′～127°06′E, 42°49′～45°32′N) is located at the middle part of Jilin Province, Northeast China(see Fig.1.) . This area has an altitude below 200m with an area of 45973 km^2, among which cultivated land account for 61.9%. This region has been the major grain production areas in Jilin Province.



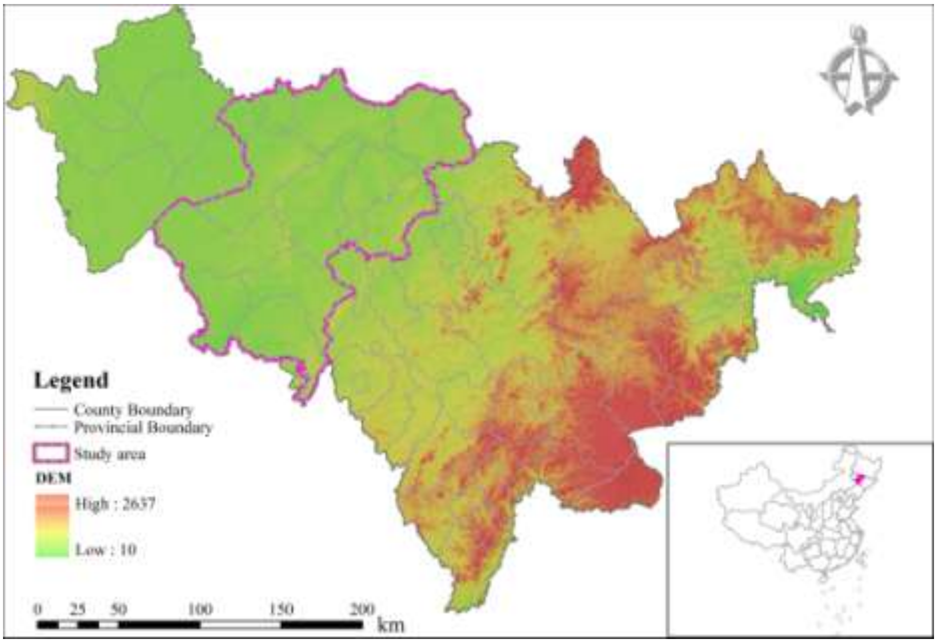


Fig. 1. Location map of study area and soil sampling sites in Jilin Province, Northeast China (n = 68).

The study area is characterized with a temperate, semi-humid continental monsoon climate. The mean annual temperature is about4-5℃and the average annual precipitation is 500-600mm. The average of sunshine each year is between 2200-3000h. The frost-free period is about 130-145d. The soils are largely comprised of black soil (Luvic Phaeozem, FAO), chernozem (Haplic Chernozem, FAO), meadow soil (Eutric Vertisol, FAO), aeolian soil (Arenosol, FAO) and paddy soil (Hydragric Anthrosol, FAO).

Soil sampling, processing, and analysis

In the May of 2005 over the entire arable crops region a total of 70 soil samples from the plow layer (0-20 cm) at an approximate interval of 30 km were collected. Global position system (GPS) was used to determine the sampling locations. Soil samples were air-dried and ground to pass through a 2-mm sieve. The amount of available soil calcium (Ca), magnesium (Mg), boron (B), cuprum (Cu) , zinc (Zn) in each sample were determined by the ASI systematic approach which is high efficiency, fast analysis and high accuracy by using the complete sets of equipment and systematic techniques and procedures.

Classical statistics and geostatistical analysis

Some main statistical parameters, which are generally accepted as indicators of the central tendency and spread of the data, were analyzed. These include description of the mean, standard deviation, variance, coefficients of variation (CV) and extreme maximum and minimum values. To decide whether or not the data followed the normal frequency distribution, the coefficients of skewness and kurtosis were examined These statistical parameters were calculated using EXCEL 2003 and SPSS 11.5.

Geostatistics is a spatial analytical method developed based on classical statistics. Semivariogram of Geostatistics was conducted to test the spatial autocorrelation within the data of soil properties that was not interpreted by classical statistics. Compared with classical statistics, it can be more easily combined with GIS and associate the spatial patterns with the ecological processes.

Prior to geostatistics analysis, the spatial distances of the soil sampling locations must be determined. Soil sampling locations were input into ArcGIS software, in which the latitudes and longitudes were transformed to X- and Y-coordinates with distances in meters.

Geostatistics uses the semi-variogram to quantify the spatial variation of a regionalized variable, and provides the input parameters for the spatial interpolation method of Kriging The semi-variogram is half the expected squared difference between paired data values *z(x)* and *z(x+h)* to the distance h, by which locations are separated

$$r(h) = \frac{1}{2}E[z(x) - z(x+h)]^2$$

For discrete sampling sites, such as sampled in our study, the function is usually written in the form:

$$r(h) = \frac{1}{2N(h)}\sum_{i=1}^{N(h)}[z(x_i) - z(x_i + h))]^2$$

Where $z(x_i)$ is the value of the variable z at location of x_i, h the lag and $N(h)$ the number of pairs of sample points separated by h. For irregular sampling, it is rare for the distance between the sample pairs to be exactly equal to h . That is, h is often represented by a distance band.

The experimental variogram is calculated for several lag distances. This is then generally fitted with a theoretical model, such as spherical, exponential, and Gaussian models. The models provide information about the spatial structure as well as the input parameters for the Kriging interpolation.

Kriging is considered as an optimal method of spatial prediction. It is theoretical weighted moving average:

$$\hat{z}(x_0) = \sum_{i=1}^{n}\lambda_i z(x_i)$$

Where $\hat{z}(x_0)$ is the value to be estimated at the location of x_0, $z(x_i)$ the known value at the sampling site x_i and n is the number of sites within the search neighborhood used for the estimation. The number n is based on the size of the moving window and is defined by the user. Kriging is different from other methods (such as inverse distance weighting), because the weight λ_i is no longer arbitrary. The weights depend on the parameters of the variogram model and the sampling configuration and are decided under the conditions of unbiasedness and minimized estimation variance.

Results and Discussion

Descriptive statistics

Variability of soil property can be described by average, standard deviation (SD) and coefficient of variation (Cv). Among them, Cv is the most discriminating factor. When Cv is <10%, the property shows low variability; and if Cv is more than 90%, it shows great variability The characters of soil variability are shown in Table 1. All the Cvs are between 10% and 90%. This indicates that available Ca, Mg, B, Cu, Zn are moderate variability in the study area.

Table 1 Classical statistics result for soil middle-elements and microelements in Jilin Middle Plain

Variable	Sample	Mean(mg/L)	Variance	Skewness	Kurtosis	Cv
Available Ca	68	3100.22	1395.02	0.82	0.45	45.00
Available Mg	68	418.23	254.59	1.02	1.08	60.87
Available B	68	1.64	0.79	2.62	13.70	48.38
Available Cu	68	2.18	1.13	1.34	1.63	51.99
Available Zn	68	1.34	0.92	2.34	6.76	68.28

We also analyzed the quantitative parameters of the probability distribution and the significance level of the Kolmogovorv-Smirnov test for conformance to a normal distribution for the variables the available Ca, Mg, B, Cu, and Zn contents with various processing methods, including logarithmic transformation, excluding outliers and Box-Cox transformation.

Table 2 Classical statistics result for available Ca, Mg, B, Cu, Zn (soil middle-elements and microelements concentrations) and their K-S test after different data processing methods

Variable	Treatment method	Mean (mg/L)	S.D	Minimum (mg/L)	Maximum (mg/L)	Skewness	Kurtosis	K-S P
Available Ca	Original data	3100.22	1395.02	837.65	6741.45	0.82	0.45	0.56
	Excluding outliers	3100.22	1395.02	837.65	6741.45	0.82	0.45	0.56
	Logarithmic transformation	7.94	0.47	6.73	8.82	-0.31	-0.18	0.73
	Box－Cox	25.72	3.46	17.76	32.86	-0.02	-0.30	0.85
Available Mg	Original data	418.23	254.59	96.00	1297.60	1.02	1.08	0.11
	Excluding outliers	415.16	244.90	96.00	1088.65	0.79	0.04	0.10
	Logarithmic transformation	5.85	0.63	4.56	7.17	-0.12	-0.91	0.53
	Box－Cox	7.92	1.12	5.75	10.37	-0.02	-0.91	0.59
Available B	Original data	1.64	0.79	0.25	6.05	2.62	13.70	0.13
	Excluding outliers	1.60	0.62	0.25	3.45	0.50	1.19	0.80
	Logarithmic transformation	0.39	0.49	-1.39	1.80	-1.12	4.13	0.09
	Box－Cox	0.46	0.54	-1.09	2.55	0.17	3.59	0.34
Available Cu	Original data	2.18	1.13	0.65	5.90	1.34	1.63	0.13
	Excluding outliers	2.17	1.10	0.65	5.25	1.22	1.06	0.16
	Logarithmic transformation	0.66	0.48	-0.43	1.77	0.24	-0.29	0.86
	Box－Cox	0.60	0.42	-0.45	1.50	0.01	-0.26	0.92
Available Zn	Original data	1.34	0.92	0.30	5.40	2.34	6.76	0.03
	Excluding outliers	1.31	0.81	0.30	3.95	1.77	3.32	0.05
	Logarithmic transformation	0.13	0.56	-1.20	1.69	0.38	0.58	0.81
	Box－Cox	0.09	0.54	-1.36	1.43	-0.01	0.57	0.89

The K-S showed that available Ca, Mg, Cu, and Zn didn’t exhibit a normal distribution in this study area. They couldn’t pass one-sample Kolmogovorv-Smirnov (K–S) test at a significant level ($p < 0.05$) and could not be directly used in the analysis of variation function. Therefore, the Box-Cox transformation is applied in order to achieve normality in the data sets of available Ca, Mg, Cu, and Zn while excluding outliers were employed in the data set of available B to dampen the effect of outliers.

Geostatistics Analysis

The semivariogram for Availabe Ca, Mg, B, Cu, and Zn are shown in Fig. 2. Key parameters of the remaining semivariogram are given in Table 3. Their optimal theoretical models were gaussian, circular, exponential, exponential, and gaussian model, respectively.

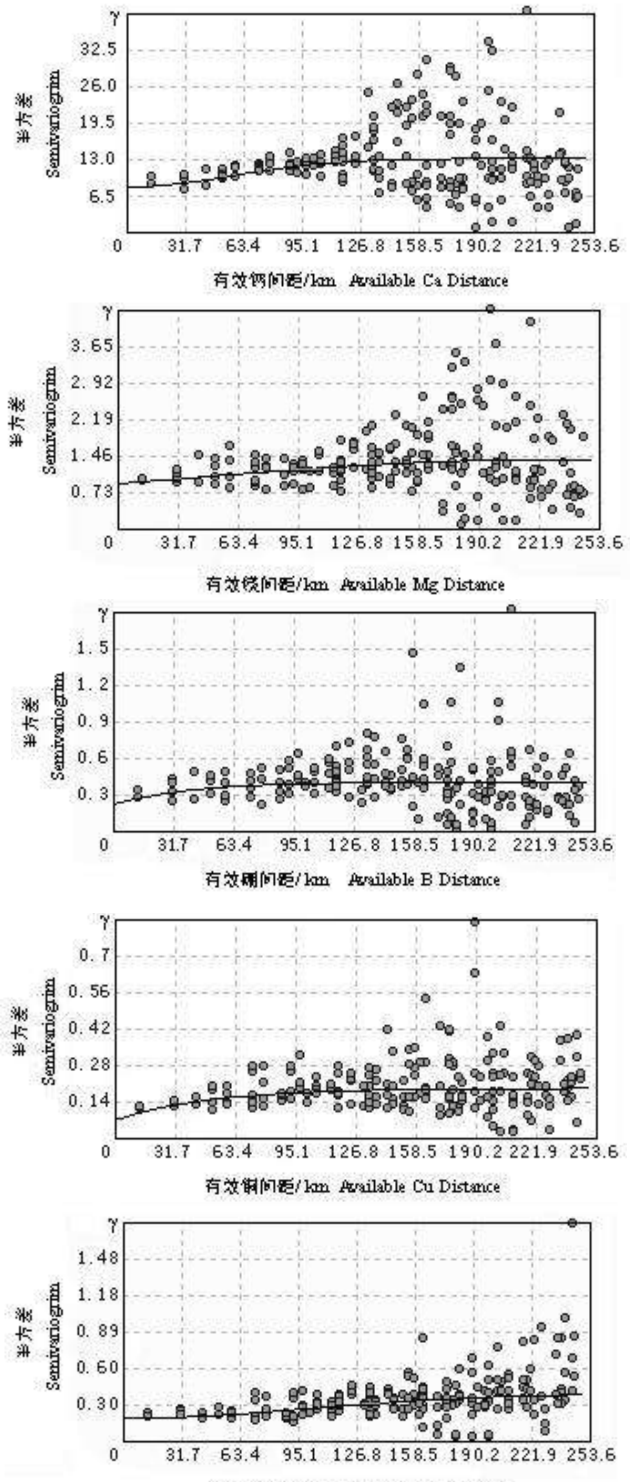


Fig.2 Experimental semivariograms with fitted models for Available Ca, Mg, Cu, B, and Zn of Jilin Middle Plain in Northeast China

Table 4 Parameters of the variogram model for soil middle-elements and microelements

Variable	Model	Nugget	Sill	Nugget/Sill(%)	Range(km)
Available Ca	Gaussian	8.15910	13.20850	61.77	139.95
Available Mg	Circular	0.91492	1.37586	66.50	191.84
Available B	Exponential	0.22133	0.40829	54.21	118.46
Available Cu	Exponential	0.07068	0.19343	36.54	146.88
Available Zn	Gaussian	0.18815	0.39051	48.18	247.07

The range of the semi-variograms was the distance at which semi-variance attained the maximum value (sill), and the sill approximately equaled the same variance (Journel and Huijbergts, 1978). The range expressed as distance could be interpreted as the diameter of the zone of influence that represented the average maximum distance over which a soil property of two samples was related. At distance less than the range, measured properties of two samples became similar with decreasing distance between the two points. Thus, the range provided an estimate of areas of similarity. The zones of influence for available Ca, Mg, B, Cu and Zn were approximately from 118.46km to 247.07km. These distances stood for the minimum distances on the average, at which maximum variation occurred, and were larger than the distances among sampling locations.

These studies proved that soil properties displayed spatial autocorrelation, and that structural factors, such as parent material, terrain, and water table, as well as random factors, such as fertilizer application, crop planting, and soil management, codetermined soil properties (Goovaerts, 1997). The relative degrees of < 0.25, 0.25-0.75, and > 0.75 could be used to describe the proportion of the spatial structure (nugget/sill) that showed strong, moderate, and weak spatial autocorrelation, respectively. This proportion of spatial structure determined the ratio in which random factors induced spatial variability (Cambardella et al., 1994). With regard to available Ca, Mg, B, Cu and Zn, the values for nugget/sill are more than 0.25 but <0.75, and indicate that they have moderate spatial autocorrelation, suggesting that random (including farm practice) and structural factors codetermined them (Table 4).

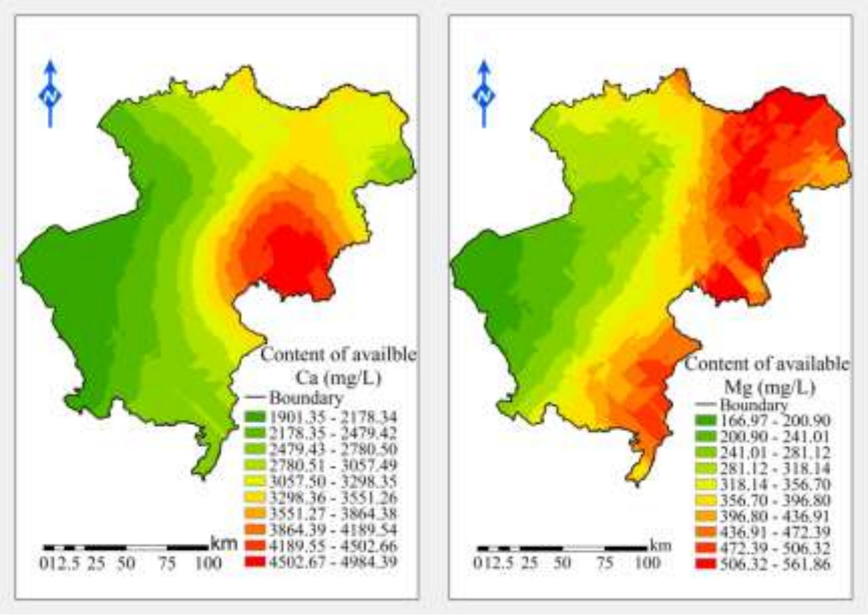
Spatial distribution of the five soil nutrients

Kriging was used to convert point soil samples into continuous fields of soil properties. The parameters of geostatistics obtained above were used for Kriging to produce an interpolation map of the five soil nutrients in soils of the study areas. A search region of 12 nearest-neighbours was applied. For the spatial interpolation, a cell size of 1km×1km was chosen to divide the study area into a grid system. The final result of this spatial interpolation process was shown in Figure 4. The available Ca content had a large spatial variability, namely, it increased from west to east with the distribution of vertical stripe. The soil with high available Ca content is found in the middle part of the study area, which mainly lied in Jiutai county, Dehui county and Nong’an county. And the major soil type is black soil and meadow soil in high available Ca content areas.

The available Mg content in soil showed a downward trend from east to west, while the high-value areas are mainly concentrated in the rive infested areas, and along the direction of the river the available Mg content is gradually reduced. Such regions are distributed in meadow soil and black soil of Yushu county, Dehui county, Jiutai county and the southeastern of Gongzhuling and Lishu county.

However, for available B and Cu, there was no obvious visual trend. There are a number of high-value areas scattered patches in this area, and patch size and shape is of significant differences in spatial distribution. The nutrient content is still follow the distribution of the gradient from high to low, in which area with high available B content is mainly distributed in the west of the study area, the soil type in these regions are mostly chernozem and meadow soil; and the distribution of available Cu content in general was related to altitude, the regions with higher elevations in eastern part had the higher available Cu content than that in the western regions with low elevation. And there have been a number of high-value areas locally affected by random factors, these high-value areas are mainly distributed in the northeastern and southeastern part of the study area.

The spatial changes of soil available Zn content had more regularity. It showed ladder-like decline from southeast to northwest. The west part of the study area had the lowest available Zn content. While the regions with high available Zn content located in the northeastern, where the soil type is chernozem, calcareous meadow soil, wind sand. It is contrary to the truth that soil type in these regions should have the lower available Zn content, so we could determine that the random factors make these regions with higher available Zn content. Long-term application of nitrogen fertilizer, phosphorus and potassium fertilizer can increase the soil available Zn contentIt was found that the eastern part of the study area is the major corn-producing areas, the application of large quantities of nitrogen fertilizer and phosphorus fertilizer containing Zn resulted in the imbalance of the input and output of Zn in the ecosystem, the input section is greater than the output part.



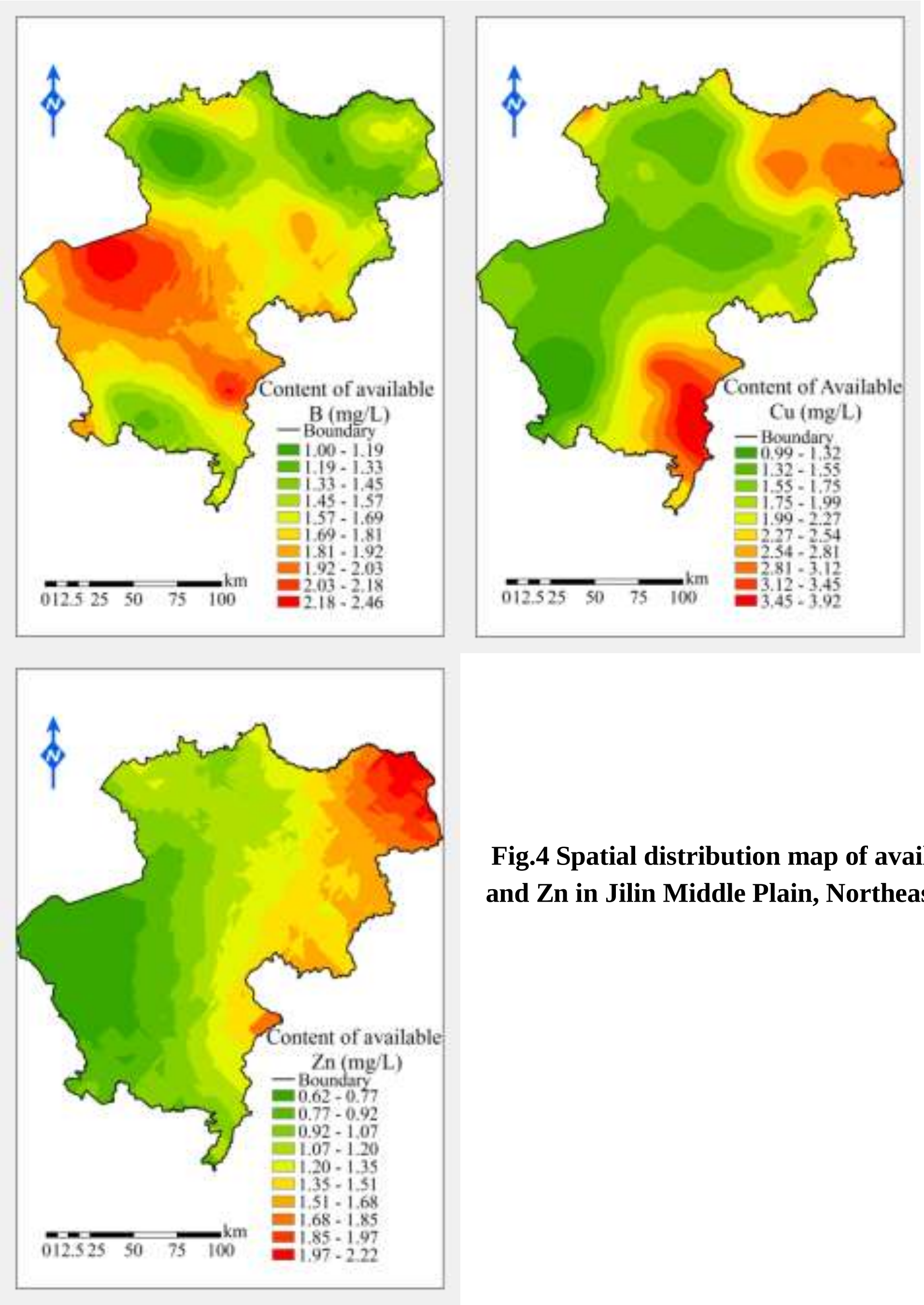


Fig.4 Spatial distribution map of available Ca, and Zn in Jilin Middle Plain, Northeast China

Conclusions

All the soil properties, namely, available Ca, Mg, Cu, B, and Zn, had spatial autocorrelations. The classic statistical analysis showed that all soil properties had moderate variability with 0.1≤CV≤0.9. While the geostatistical analysis results showed all soil nutrients had moderate spatial correlations with the nugget/sill ratio of 0.25-0.75 that random and structural factors codetermined. In addition, kriging could successfully interpolate all soil nutrient content. In general, then, the geostatistics method on a large scale could be accurately used to evaluate spatial variability of soil medium elements and micro elements in Jilin Middle Plain of Northeast China.

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Multiple Cropping Index from Spot NDVI Time Series Using Wavelet Transform

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Abstract: Multiple Cropping Index(MCI) is directly related to food security and the utilization efficiency of cultivated land. SPOT VGT NDVI time series data sets are not non-stationary and present short-term, seasonal and long-term variations. MCI from SPOT VGT NDVI in 2007 using Wavelet Transform (WT) has been implemented. Applying Wavelet Transform to denoise the multi-temporal remote sensing data, we can easily judge cropping pattern by smoothed NDVI values. At the same time, four mother wavelets have been compared and COIFLET has a better result. The study has proved the wavelet transform is an effective denoising tool for time series data. The MCI of the study area has a good consistency with the existed studies.

Keywords: Multiple Cropping Index (MCI), Wavelet Transform (WT), SPOT VGT, Huang-Huai-Hai Plain

1 Introduction

Cultivated land is one of land use pattern which is the main source to provide food to human being. It is directly related to food security and has an important impact on environment and social development progress. With the promotion of urbanization, industrialization of economies, cultivated land resources is sharply decreased，which enables food security a hot topic in the international community.

Multiple cropping is a cropping pattern which refers to two-season or more crops in the same field within one year or a production year(LIU, 1992; WANG, 2005). Multiple Cropping Index (MCI) can be calculated by: the total area of crops/ total area of cultivated land × 100%. From 1986 to 1995, China's multiple cropping index increased by 9.7% and increase re-sowing area of 8.5 million hm^2. Annual output of grain reached 24.1 billion kg which is accounting for 36.5% of the total grain output during the same period (WANG, 2005). As a simple cropping pattern, multiple cropping can not only effectively make full use of land resources to increase food production and ensure food security, but can increase farmers' income, reduce income disparities and promote social development.

Generally, researches on multiple cropping index are base on statistics data such as investigation data, statistical Yearbook and so on (CHEN, 1994; YANG et al., 2000; Biswas et al., 2006).

Comparing with conventional ways, it is a new way to extract multiple cropping index by time series remote sensing data. Currently, the development of effective methodologies for the analysis of multi-temporal data is one of the most important and challenging issues for the remote sensing community (Bruzzone et al., 2003). The time series remote sensing data are mostly based on low-, medium-resolution remote sensing satellite. The data is vulnerable to environmental impacts and is very difficult to identify surface features. In particular, Normalized Difference Vegetation Index (NDVI)-based time series are fundamental to the remote sensing of vegetation phonology and to extract numerical observations related to vegetation dynamics (Pettorelli et al., 2005; Tucker & Sellers, 1986).

During the crop growing process, NDVI is not a fixed value which will fluctuate by different stage of crop growing such as higher value in heading period, lower value in regreen stage. Recovering the crop growing process is a very important step for studying on multiple cropping index by NDVI values. However, NDVI has been disturbed by a variety of factors such as the atmosphere, clouds, fog and so on. In order to remove the noise or mutation, smoothing the time series NDVI data is necessary.

Different smoothing techniques are used to monitor vegetation dynamics from multi-temporal data (Beatriz Martínez et al., 2009). In summary, there are two categories: (i) statistical methods such as the algebraic method (ZHANG, et al., 2003; Beck et al., 2006; WU, et al., 2009; PENG et al., 2006), maximum synthesis method (WU, 2008), curve fitting (GU, 2003; CHEN et al., 2004; Jönsson et al., 2004) and so on; (ii) spectral-frequency techniques such as Fourier transform (FAN et al., 2003; Lin et al., 2006; Canisius et al., 2007), wavelet transform. Wavelet transform has been a relatively new smoothing method of data since 1980 which has been used to characterize crop phenology (Sakamoto et al., 2005) which has been proved that wavelet transform has better effect than Fourier in Japan as well as to determine changes in the expansion and intensification of crops (Galford et al., 2008).

This paper is based on previous research, using wavelet transform to smooth multi-temporal data in Huang-Huai-Hai plain, north of China, monitoring and comparison the multiple cropping index.

2. Data description

2.1 The study area

Huang-Huai-Hai Plain is located in the North China which includes the plain of the Yellow River, Huai River and Hai River. The total area is of 387,000 square kilometers [GONG Yuan, 1985]. The region includes Beijing, Tianjin, Hebei, Shandong, Henan, Jiangsu and Anhui. Huang-Huai-Hai Plain is very flat in topography and generally less than 50 meters above sea level. It has rich cultivated land in natural resources and accounts for about 1/6 of the total cultivated area of China. Huang-Huai-Hai Plain has the monsoon climate and has good light and heat conditions that annual average temperature is 13.0℃, average annual radiation is 5 370 MJ·m-2 and frost-free days is 175-220d. The precipitation of Huang-Huai-Hai Plain is from 500 mm to 800 mm, and 60-80% of annual precipitation is mainly in June to September. So, it is an appropriate agricultural area and also one of the major grain producing areas in China. The total area of crops and grain crops has 3 743×104 hm^2 and 3 057×104 hm^2 respectively. The main crops include winter wheat, maize and cotton whose production account for 56%, 37.5% and 38% of national total.

This study selected areas in Beijing, Tianjin, Henan, Hebei and Shandong. The region has typical characteristics where it has mainly a crop or two crops a year and is more favorable for wavelet transform to smoothing the time series remote sensing data.

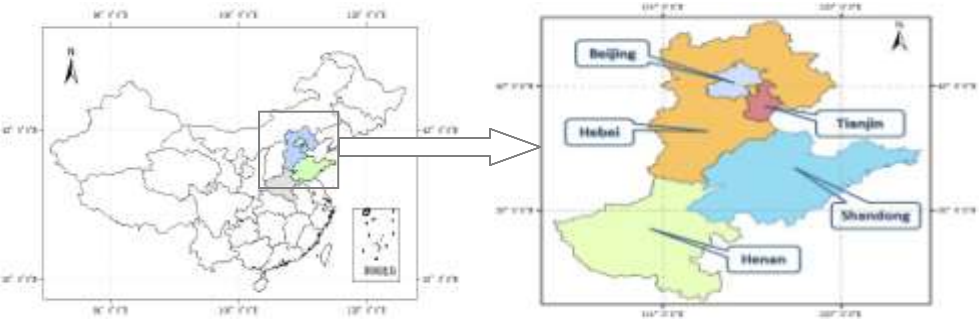


Figure 1. The study area

2.2 Data

2.2.1 NDVI data sets

The study used NDVI data comes from SPOT VGT-S10 (synthesis) NDVI products, whose NDVI composites at full resolution of 1 km are generated from the atmospherically corrected P products (surface reflectance corrected for molecular and aerosol scattering, water vapor, ozone and other gas absorption) through maximum value compositing(Holben, 1986). Then set the NDVI value from -1 to -0.1 to -0.1 and converted the YDN value range from 0 to 250 by the formula YDN = (JNDVI +0.1)/0.004 (MA, 2007). The data can free download from the website: http://www.spot-vegetation.com/. The time of the study is from January to December in 2007 and has 36 scenes SPOT VGT images.

2.2.2 Land use map

In the study, land use data sets come from China's land resources and environmental raster database in 2000 whose spatial resolution is 1km×1km. The data which is a resolution of 30m of the Landsat TM/ETM data covering the whole economy was made by artificial interactive image interpretation to 1: 100 000 land-use map and then vector-raster conversion. The study will extract NDVI value related to cultivated land data, smooth time series data and calculate multiple cropping index. In order to reduce the file size and favorable image manipulation operations, the original NDVI data will be transformed from float to unsigned binary.

3 Theoretical background

3.1. The wavelet transform (WT)

Basically, the idea of the wavelet transform (WT) is the decomposition of a signal at different spatial or time scales onto a set of basis functions. For the sake of brevity and clarity the theory is presented in the time dimension. The set of basis functions, $\{\psi_{a,b}(t)\}$, can be generated by translating and scaling the so-called mother wavelet, $\psi(t)$, according to (Daubechies, 1992)

$$\psi_{a,b}(t)= \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right), \ a > 0, - \infty < b < \infty$$

where a is the scale parameter which adjusts the dilation of the wavelet and b determines the location of the wavelet ($a, b \in R$ and $a \neq 0$). The mother wavelet is translated in the time domain to select the different portions of signal, and dilated and contracted to analyze different scale variations (Bruce et al., 2001). The wavelet $\psi(t)$ satisfies two basic properties: (i) $\int_{-\infty}^{+\infty} \psi(t)dt = 0$ and (ii) $\int_{-\infty}^{+\infty} \psi^2(t)dt = 1$ which mean that this function oscillates around zero and is localized in a finite-width interval. Therefore, both conditions lead to a small wave or wavelet. However, a third condition is required from a practical view: (iii) $\psi(t)$ must satisfy the admissibility condition (Daubechies, 1992). This property allows the reconstruction of a function from its continuous wavelet transform. The requirements (i–ii–iii) guarantee that the original signal can be recovered by integrating over all scales and locations, a and b, and that the energy in a time series is preserved in the transform.

3.1.1. Continuous wavelet transform

A continuous wavelet transform is used to divide a continuous-time function into wavelets. Let the signal f(t) be a real-valued function in the time dimension. Its continuous wavelet transform (CWT) with respect to the wavelet basis function, $\psi_{a,b}(t)$, can be defined as

$$W(a,b) = \int_{-\infty}^{\infty} \varphi_{a,b}(t)f(t)dt = \frac{1}{\sqrt{a}}\int_{-\infty}^{\infty} \varphi_{a,b}\left(\frac{t-b}{a}\right)f(t)dt$$

where $\psi(t)$ is a continuous function in both the time domain and the frequency domain called the mother wavelet and represents operation of complex conjugate. For each scale, the result of the WT is a set of coefficients associated with different locations. For a uniquely defined scale a_0 and location b_0, a coefficient is obtained for that specific point. If the spectral component of the signal around location b_0 is comparable to the wavelet defined at the scale a_0, the wavelet coefficient will have a relatively large value. This is repeated for other combinations of band a (i.e. other basis functions) resulting in the decomposition of the signal into time-scale space. The wavelet coefficients can be interpreted as proportional to the differences between temporally adjacent averages of portions of a time series. This physical interpretation has rendered the WT useful for evaluating how stable such averages are over time.

3.1.2. Discrete wavelet transform

An alternative approach when dealing with discrete signals is to define discrete wavelet transform (DWT) specifically adapted for sampled values. Let the discrete signal be a vector of N observations $f(t_i)$, i=1, ..., N, where $t_i=t_0+i\Delta t$, t_0 is an offset, and Δt is the sampling period. The DWT can be thought as dyadic sampling of W(a,b), in which the mother wavelet is scaled by powers of two, $a=2^j$ and, within a given scale, translated by integers, $b=k2^j$, where k is a location index that runs from 1 to $2^{-j}N$ and typically indicates where the non zero portion of each wavelet basis vector occurs. The signal resolution is defined as the inverse of the scale $1/a=2^{-j}$, and the integer j is referred to as the level. As the level and the scale decrease, the resolution increases and the smaller and finer components of the signal can be accessed. The index j runs from 0 to J, where J is the total number of scales used, and the physical scale associated with the *j*th set is $s_j=\Delta t2^j$. Thus, a discretely scaled and translated wavelet is expressed as

$$\psi_{(j,k)}(t) = 2^{-\frac{j}{2}}\psi(2^{-j}t - k)$$

and the DWT coefficients of f(t) can be obtained from

$$W_{(j,k)} = W(2^j,k2^j) = 2^{-\frac{j}{2}}\int_{-\infty}^{\infty} f(t)(2^{-j}t-k)\,dt, \quad = 0,1,2,\ldots, \quad k \in Z$$

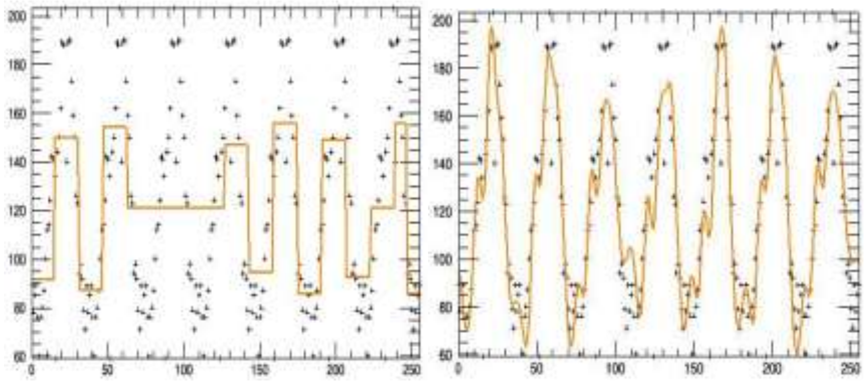
4 Experimental procedure

4.1 Data regulation

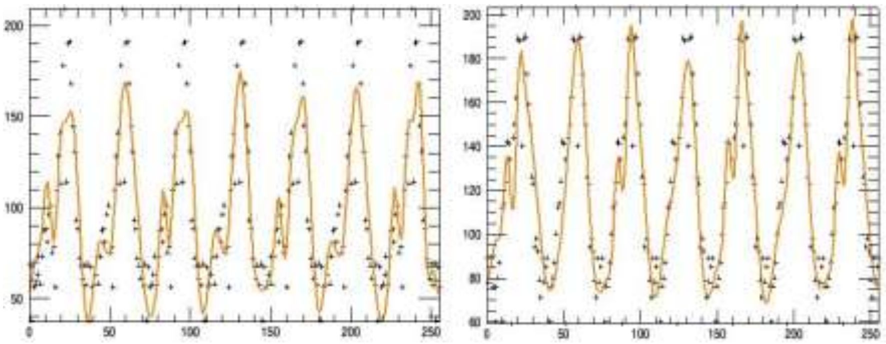
The number of elements in the input data array should be a power of 2 for wavelet transforms. In order to build an input array with 2^8 elements, a year's NDVI data continuously and recursively to fill the array in observational date order. Missing or abnormal data were linearly interpolated. At last, the elements from the 144th to the 179th which are 36 elements to reflect the crop change in one year is regarded the smoothed time profile of NDVI.

4.2 Choosing the mother wavelet

The procedure has implemented in Interactive Data Language (IDL). IDL provide four wavelets to denoise multi-temporal data which are COIFLET, DAUBECHIES, HAAR and SYMLET. In order to choose the better mother wavelet, there are some ground reference points to test. According to the result, COIFLET is the best mother wavelet which can denoise multi-temporal data and it is coincide with the existed research.



HAAR DAUBECHIES (order=12)



COIFLET(order=4) SYMLET(order=11)

Figure 2. Comparison of smoothing results of four mother wavelet

4.3 Cropping pattern identification

In the study region, cropping pattern is mostly one crop and two crops whose characteristic is very clear. This is convenient for analyzing the cropping pattern. Peak value is main basis to judge the crop pattern which is identified by two-difference algorithm. Additionally, if peak value less than 40% of max peak value, it is not regarded a peak value. According to the smoothing result, it is respectively counted as one crop and two crops when the smoothing NDVI curve has a peak value and two peak values.

5 Result and discussion

5.1 Validation with the existed study

According to the data procedure, there is an ideal result with wavelet transform to denoise multi-temporal SPOT VGT NDVI. Comparison with the existed study which use different smoothing ways to assess the MCI in the region, wavelet transform which is a time-frequency new way can also apply to the similar research and has a better result.

Table 1. Comparison of different research results

	A	B	absolute error	C	absolute error
Beijing	149.26	130	19.26	137	12.26
Tianjin	152.385	132	20.385	137.25	15.135
Hebei	156.731	143	13.731	159.25	-2.519
Shandong	171.475	159	12.475	176.25	-4.775
Henan	187.874	183	4.874	191.75	-3.876

＊The result comparsion of the different study. A,B,C is respectively the result of the study base on SPOT VGT NDVI using wavelet transform in 2007(In this study), MODIS/EVI using decision-tree in 2005 (ZUO) and SPOT VGT NDVI using HANTS (FAN).

In Hebei, Shandong and Henan, the MCI are between the existed studies. However, the MCI is larger in Beijing and Tianjin. More analysis will be in the future study.

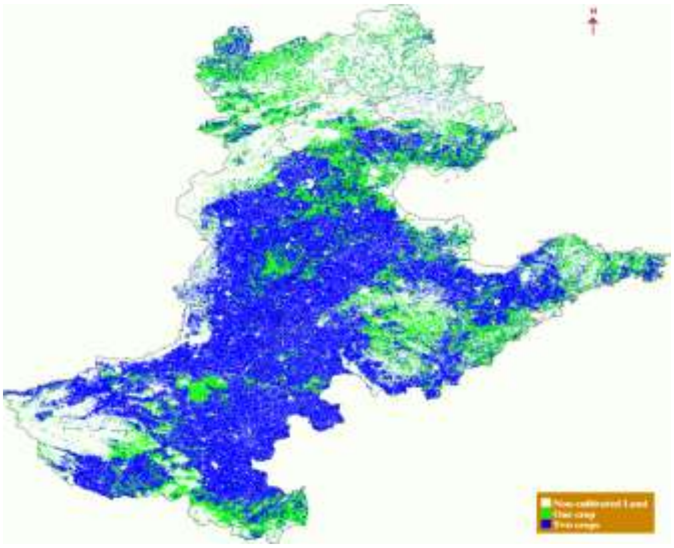


Figure 3. MCI distribution map in Huang-Huai-Hai Plain

5.2 Detection the cropping pattern

The resolution of SPOT VGT NDVI is 1 km×1 km. It is not a high resolution, especially for some areas where it has some small building. For the forest or other vegetations, it is very difficult to identify crops will result the errors. Though Huang-Huai-Hai Plain formed by alleviation and height above sea-level is very low, the mixed pixel effect and topography may affect the spectral characteristics in satellite image. MODIS data with a 500-m resolution has a higher discrimination than SPOT VGT and NOAA/AVHRR (ca. 1.1×1.1 km) which offers an advantage in determining regional MCI. The better and the longer time series remote sensing data will be applied to the further studies.

6 Discussion

The study applied wavelet transform to denoise the multi-temporal remote sensing data and have proved wavelet transform have a better result. Smoothing time-series NDVI can easily identify the peak value and judge cropping pattern. In the study, different mother wavelets have different results which are good or bad. Comparing with ground reference points, the COIFLET has been chose which also give a better smoothing in whole region. As a newer smoothing way, it needs more studies to validate.

Although there are some ground reference points, the statistic data of the whole region is not been included. The validation of statistic data is not used in the study. Additionally, there are some regions that exit other cropping patterns such as intercrop, mixed cropping and so on. It is very difficult to discriminate in remote sensing data. In the near future, together with the higher resolution remote sensing data and the smaller region will improve the accuracy of the study.

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Session2:

Agricultral land use and its effect on climate change and food security

Land Use and Land Cover Change in Heilongjiang Province and Its Impact on Food Security

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Abstract: Based on analysis of food security and its determining factors in land use in China, this paper presents land use status quo and land use change in Heilongjiang during 1993-2003 and makes an in-depth study about impacts on grain production and food security, thus offers corresponding countermeasures and suggestions for ensuring food security.

Key words: land use change; food security; impact; Heilongjiang

With the development of human society, land use change and its effects have become the frontier and hot field for global change researches, strongly affecting not only global biodiversity but also national and regional food security. Grain output has kept increasing gradually since the founding of new China, reaching historical high level of 512.3million tons in 1998. However the following six years witnessed decreasing or stagnant state in grain output, with the output falling to 430.695 million tons in 2003, which was close to the same level in early 1990's(446.243 million tons in 1990). Thus, food security in China has become increasingly highlighted. Impacted by output decrease, grain prices were out of seven-year downturn in later half of 2003 and began to rise, by May 2004 grain price has increased by 30%, national authorities at different levels and rural households have dipped into their grain reserves to fill the gap. Statistic data showed a decline tendency in national grain reserve, staple food reserve for rural and urban residents and commercial reserve for grain-processing facilities. In particular, during that period most of urban residents gave up reserve practice, while many grain-processing facilities resorted to purchasing as need instead of two or three-month stockpile. Hence the principal contradiction of food security spread to whole society, altering from staple food to fodder grain. Fortunately grain output began to rebound in 2004, reaching 469.47million tons in 2004 and 484 million tons in 2005 respectively, an increase of 9.0% and an increase of 3.1% year on year respectively. The reason why grain production in China varied greatly has to do with the effects of various factors including farmland resource, water resource, eco-environment, cropping structure adjustment, population, grain consumption for industry purposes, grain circulation, incomplete grain reserve system, import-export trend of grain, institutional factors, non-economic factors and international factors. Particularly land use change should be basic factor for food security, and determines national and regional grain production and supply capacity in a large degree.

The entire landmass in Heilongjiang is about 450,000KM^2, taking 4.9% of the national total. Total provincial population was 38.15 million with population density by 84.8 persons/KM^2, lower than national average level of 134.6persons/KM^2, therefore per capita land resource is comparatively rich. In terms of topography, the plain area, hilly area and mountainous area cover 37.0%、35.8% and 24.7% of the provincial total land respectively. Total provincial grain output reached 25.123million tons in 2003, contributing 5.83% to national output. The provincial unit yield of grain hit 3096.0kg/ha^2 with per capita grain availability by 658.5kg，much higher than national average of 362.2kg/capita and minimum subsistence baseline of 400kg/capita set by government. Therefore, it is significant theoretically and practically to study impacts of land use change on grain production, which is closely bound up with the grain production and food security for Heilongjiang Province and whole China at large.

1. Land use Status and Land use Structure Change

According to remote sensing survey, land use and its change is featured with the following in Heilongjiang Province in recent decade (see Table 1 for detail): (i) High proportion land use, poor land resource reserves. Land use proportion hit 92.25% in 2003 while the proportion of unutilized land was barely 7.75%. (ii) Different types of land use experienced different changes. Farmland increased remarkably, land for construction slightly; plantation, woodland and forest and grassland decreased by a big margin, unutilized land and water areas reduced considerably over the same period, especially for unutilized land by 21.33%. (iii) In terms of acreage, farmland was second to amount of plantation and woodland by land use type, making it 37.43% of total land in 2003, increasing 251.49×10^4 KM^2 with rate of increment by 17.46% during 1993—2003.

Table 1 Changes in land use structure in Heilongjiang during 1993-2003

Type of land use	1993		2003		Acreage in 2003 compared with that in 1996	
	Acreage (10,000 KM^2)	Proportion in total (%)	Acreage (10,000 KM^2)	Proportion in total (%)	Increments (10,000 KM^2)	Rate of increment (%)
Farmland	1440.56	31.83	1692.08	37.43	251.49	17.46
plantation, woodland(forest)	2164.92	47.83	2059.10	45.54	-105.82	-4.89
Grassland	280.56	6.20	230.76	5.10	-49.79	-17.75
Construction land	90.38	2.00	92.45	2.04	2.06	2.28
Water body	104.41	2.31	96.32	2.13	-8.10	-7.75
Unutilized land	445.51	9.84	350.48	7.75	-95.03	-21.33

Data source: remote sensing and image interpretation

2. Variation Trend of Grain Production

Over years grain output (see Figure 1) has kept growing in Heilongjiang in general, this paper tries to analyze variation trend from three periods, that is period 1993-1995 with annual average output by 25.07 million tons, period 1996-1999 by about 30 million ton, and period 2000-2003 by 26.63million tons. Regarding grain sown area (see Figure 2), it declined slightly by 61200 ha from 7.5576million ha in 1993, then picked up continually to 8.0985 million ha in 1999, till reached the peak of 8.534 million ha in 2001, and stabilized at the level of 8.1 million ha or so. Grain yield increased from 3163.4kg/ha in 1993 to historical level of 3916.5kg/ha in 1996, then leveled off at level of around 3700kg/ha for next three years, remained stagnant at around 3100kg/ha during 2000-2003 except minor height of 3547.4kg/ha in 2002. These demonstrated that grain output was closely associated with yield; sown area kept increasing in general with fluctuation, yet the margin of fluctuation was narrow.

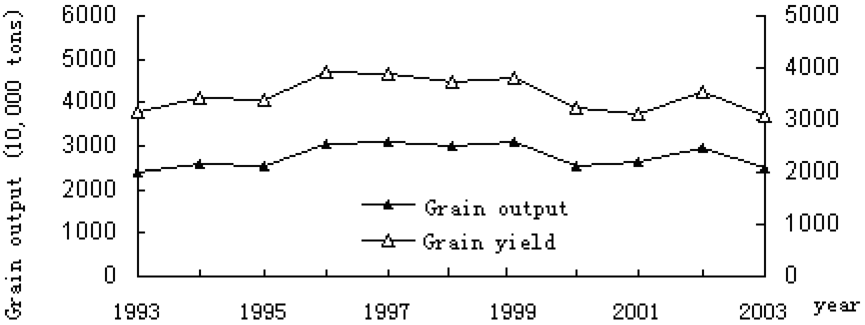

Fig.1: Changes in grain output and yield in Heilongjiang in 1993-2003

3. Food Security Analysis for Heilongjiang Province

3.1 Grain production factors and other relevant resources

3.1.1 Grain production factors

There are many factors affecting grain production, mainly including natural resource factors and social-economic factors. (i) Natural resources factors. Natural resources factors include quantity and quality of arable land, water conservancy and others, besides temperature and precipitation. They shape potential of natural resources for food and agricultural production, and the dynamic variation of the potential could be measured by ecological stock. An increased ecological stock indicates that the potential of natural resources is rising and vice versa. (ii) Social-economic factors. Various forms of rural infrastructure fall into this category, involving, inter alia, farmland infrastructure, agricultural science and technology and dissemination system, degree of mechanized operation in agriculture, agricultural input supply, development of quality varieties and fine breeds and storage facility. These constitute economic potential for food production, and are enhanced gradually with the growth of economy. In addition, policy factor plays a remarkable role in current food production in China.

3.1.2 Analysis of relevant resources

Heilongjiang is located in continental monsoon climate area of temperate and frigid zones. Annual mean temperature is from -4℃ to 4℃, decreasing from south to north with average temperature difference by 8℃.It is hot in summer. Annual average precipitation is 400-600mm; precipitation mainly concentrates on period of June-September, taking about 60-80% of the annual total. With long sunshine hours and adequate water and thermal resources, it’s suitable for crop production. Heilongjiang covers an area of about $45\times10^4KM^2$, accounting for 4.9% of national land total. Farmland and woodland and forest reached 11.771 million ha and 24.276 million ha respectively, being the first in China. Unutilized land, reclaimable waste land and pastureland cover 4.843million ha, 1.438 million ha and 2.409 million ha respectively, ranking third, second and seventh national wide respectively, thus, Heilongjiang is an important agricultural, forestry and livestock bases in China. Per capita possession of farmland was 0.44 ha in 2003, 4.4 times of national average level of 0.10 ha, and higher than world average level of 0.25ha. Total amount of water resource is 85.9 billion M^3 in Heilongjiang, taking 2.7% of national total, even lower than northwest level of 6% in national total. Water possession of per mu farmland is 460 M^3, which is barely 23% of national average. Water availability per capita is 1451 M^3, representing 60% of national average. In addition, water resource distribution is uneven temporally and spatially with abundant water resource in east and west mountainous areas and shortage in plain areas. In total, comparative abundance in various resources has laid a good foundation of land and material for sustainable development of agriculture in Heilongjiang.

3.2 Correlation analysis between land use change and grain production

3.2.1 Impacts of land use change on grain production

Quantitative change in land use types affects grain sown area via quantitative change in farmland, thus exerts influence on grain output. This can be expressed in term **land use dynamic degree** with the following formula:

$$K=(U_b-U_a)/U_a\times(1/T)\times100\%$$

Where, K represents dynamic degree of a certain land use type over certain period; U_a and U_b represent the quantity of a certain type of land use at beginning and end of the study period; T represents study session. When T is set by years, then the value of K represents annual change rate of a certain type of land use over study period. Figured out from above formula, annual change rates of farmland and land for construction were 1.59% and 0.21% respectively in Heilongjiang during 1993-2003, while the annual change rates of plantation and woodland, pastureland, water area and unutilized land were -0.44%, -1.61%, -0.70%, and -1.94% respectively during the same period. Farmland increase mainly derived from conversion of other types of land use and increase of newly reclaimed farmland in Heilongjiang. However a prominent problem emerged in the period, that is, at aggregate level, the amount of previous high-quality farmland has decreased; moreover, the superiority of higher farmland availability per capita has been attenuating gradually due to population growth.

Ensuring minimum quantity of cereal sown area is a significant guarantee for grain output. With the increase of farmland, sown area for crops has increased (see Figure 2), with peak of 9.9892 million ha in 2001. Cereal sown area has kept increasing of fluctuation in general with peak of 8.534 million ha in 2001. The proportion of cereal sown area to crop sown area averaged 86.9%, 87.8% and 84.1% respectively during period 1993-1995, period 1996-1999 and period 2000-2003 respectively. Consideringgrain output mentioned above, obviously there did existed correlation between cereal sowing area and grain output. In the meantime, driven by economic interest, cereal sown area decreased gradually while sown area of other crops kept increasing after 2000.

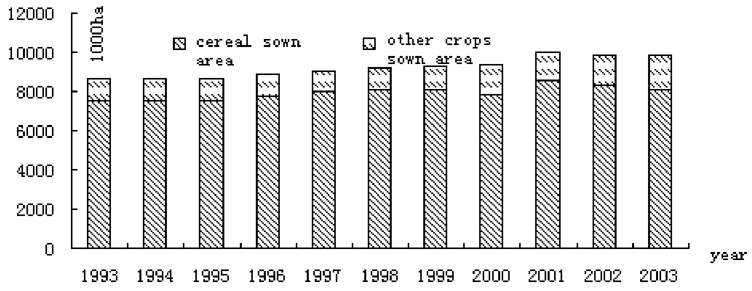

Fig.2 Changes of crop planting in Heilongjiang in 1993-2003

Fig.2 Change of crop planting in Heilongjiang in 1993-2003

3.2.2 Impacts of land use degree change on grain production

Land use degree is usually reflected by multiple-cropping index which is a significant factor affecting output. The multiple-cropping index decreased from 97.0% in 1993 to 83.3% in 2003 during ten years since 1993. This showed that land use intensity decreased despite of quantitative increase in farmland in Heilongjiang. This is partially due to increase in sown area of economic crops particularly those with longer growing season which decreased relatively the opportunity for multiple-cropping.

3.2.3 Impacts of agricultural input on grain production

Modern agriculture is featured with high input, a distinct character comparing with conventional agriculture. Agricultural input mainly includes total power of farm machines, rural electricity consumption, chemical fertilizer consumption, effective irrigated area and mechanized-operation area. The per hectare availability of total power of farm machine and electricity consumption showed an increasing trend during 1993-2003, increasing from 1.37KW to 21.84 KW for the former, and increasing from 254.42 KW to 313.18 KW for the latter. There was also a growing tendency basically for the proportion of irrigated area to total sown area, from 11.71% in 1993 to

22.17% in 2003. The per hectare application of chemical fertilizer (see Figure 3) also showed a tendency of increasing with fluctuation, specifically, increasing from 115.8 kg in 1993 to peak level in 1998, then decreasing to 128.2 kg in 2003. That is to say, annual average chemical fertilizer application featured three periods, 122.3 kg/ha for Period1993-1995, 134.4 kg/ha for Period 1996-1999 and 128.4 kg/ha for Period 2000-2003. All these demonstrated an evident correlation between fluctuation of chemical fertilizer application and fluctuation of cereal yield. However, in general, chemical fertilizer application per ha in Heilongjiang is even lower than that in lower chemical fertilizer consumption area (177.5kg/ha). Moreover chemical fertilizer application was uneven spatially; particularly newly-increased farmland consumed no chemical fertilizer or less. Furthermore, due to improper farmland utilization and management practices, the cultivated soil in Heilongjiang faced challenges such as serious degradation, decline in contents of soil organic matters, Nitrogen and Potassium, increase in content of Phosphor and relative density of soil, decrease in water retention and available moisture capacity of soil.

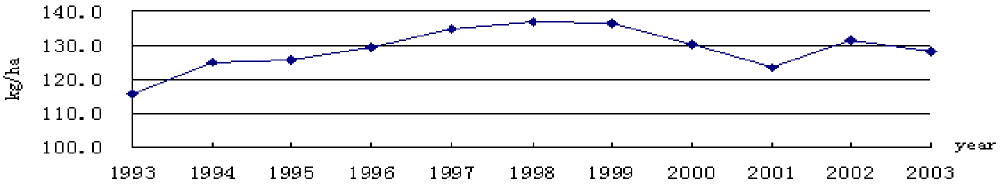

Fig. 3 Changes of chemical fertilizer consumption per unit area in Heilongjiang in 1993-2003

4. Conclusion and Discussion

（1）Land use rate was 92.25% in Heilongjiang in 2003, farmland and land for construction have increased while other types of land use decreased markedly particularly for unutilized land, woodland and forest and grassland comparing with 1993. The main contributors for increased farmland were woodland and forest, grassland and swampland under the category of unutilized land, and the amount of increased dry land was more than that of paddy field. The amount of previous farmland converted into other types of land use (mainly residential land, grain-for-green land and abandoned land) was lower, land for construction mainly stemmed from dry land and middle-coverage grassland in conventional farming regions. Large amount of woodland and forest were converted into cropland, plantation expended by a big margin stimulated by market economy and comparative advantage. A majority of grassland decreased has been converted into cropland and minority of it has been converted into woodland and other types of land use. Due to the trend that it is getting drier in Northeast China, water area decreased, part of water bodies such as lakes shrank in size, or even became saline-alkaline land, grassland or paddy field. The unutilized land reduced as a result of conversion into cropland especially utilization of swampland. Heilongjiang is the primary distribution region of wetland in China; there are large areas of swampland in Sanjiang Plain, daxing’anling and xiaoxing’anling regions. Due to lack of understanding in role and ecological value of swampland, coupled with inappropriate policy guidance, swampland lost or degraded seriously over the period and was converted into paddy field, dry land and grassland.

（2）Farmland quality tended to decline in 1996 in Heilongjiang, and in particular this trend was comparatively evident after 1999. This maybe resulted from less attention paid to soil fertility building of increased farmland, which led to higher proportion of low and medium-yield land(63%) in Heilongjiang, thus affects general quality of farmland and yield.

(3) Farmland kept growing in size; cereal sown area maintained increasing with slight fluctuation. Yet the proportion of cereal sown area to crop sown area has decreased to 84.1% in period 2000-2003, lower than the corresponding level of 86.9% in period 1993-1995 and level of 87.8% in period 1996-1999. In terms of land use degree, multiple-cropping index of farmland fell from 97.0% in 1993 to 83.3% in 2003. The proportion of unutilized land dropped to barely 7.75% in Heilongjiang, leaving less room in land reserves to be utilized.

5. Countermeasures and Suggestions for Food Security

There are two approaches to ensure food security in Heilongjiang. Firstly, to safeguard minimum farmland resource required for food production and to pay close attention to farmland quality which is more important than the former. Secondly, to improve grain yield. In essence improving yield is closely associated with farmland quality. Only by earnestly protecting farmland quality, can we achieve higher yield level to guarantee food security while maintaining certain sown area required. For this end we would like to recommend the following measures to be taken:

（1）To establish Farmland Protected Area System and implement Land Use Regulation System. Efforts should be made to strictly implement ***Law of the People's Republic of China on Land Administration,*** intensify land use regulations, regulate the conversion of quality farmland into non-agricultural use, and further improve farmland protection system. Equal attention will be paid to both quantity and quality in farmland protection, and dynamic equilibrium of farmland should be taken into account.

(2) To optimize land use structure and improve land productivity. Currently a host of problems have arisen in land use field in Heilongjiang, ranging from lower land productivity, irrational land use structure to blindly expansion in farmland scale while neglecting land quality. It’s time to stop the practice of only pursuit of farmland scale by encroaching on other types of land use. Instead, in light of nature of land use and ecological and environmental conditions, adhering to land suitability principle, allocation of land resources should be optimized based on overall and rational planning to bring into full play the advantage and potential of different land resources. Thus the farmland, woodland, pastureland and other types of land use are kept at a rational ratio, as a result, land resources’ productivity has been improved.

(3) To increase input and improve farmland productivity. Agricultural input particularly chemical fertilizer input played a significant role in grain output growth. The proportion of effective irrigated area reached 22.17% in Heilongjiang in 2003, higher than the level of 11.71% in 1993, yet much lower than the level of 32.3% for Jilin and the level of 33.4% for Liaoning. In addition, the capacity to mitigate natural disasters of farmland was lower. Therefore, great attention should be paid to soil

fertility conservation of increased land and upgrading of low and middle-yield farmland, at the same time, basic farmland construction should be intensified. While stabilizing farmland scale, measures will be taken to improve multiple-cropping index of farmland and output rate per unit area so as to increase food production by water conservancy, basic farmland construction, supporting infrastructure, improving farming system and readjusting crop mix.

(4) To implement land consolidation to improve utilization rate of land resources. Land reserves should be reclaimed rationally, land consolidation scheme should be carried out for existing land resources to improve utilization rate of farmland.

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Land Utilization and Agricultural Development in Viet Nam

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Abstract: Viet Nam is an agricultural economy with more than 86 million people (2008), living an area of 32.924 million ha, in Southeast Asia. By 2008, the national gross income was 1,144,015 billion VN dong. National economic sectors are contributed by 20.3% of agro-forestry and aquaculture, by 41.6% of industry and by 36.1% of services. Agricultural production is playing an important role in the national economic development and food security. From imported rice, Viet Nam imported rice in early 1980's year and become the second exported rice economy, after Thailand. Food production has a great progress with production of 6.1 million tons in 1955, and increased up to 14.4 M. tons in 1980 and 43.3 M. tons in 2008.

Thanking to the changing in policies and land law after year's 1980 to gain these fruitfulness. From the self consumption and self-supply economic system, since 1980, Viet Namese Government changed new policy and strategies to develop national economic. "New rethinking" policy was issued to give up "the self consumption and self supply economic" and access into "Marketing economic rule". The land resources are exploited for agriculture by 9.42 M. ha (28.5%), for 14.8 M.ha of forestry in 2008. Food production is most priority, so that rice lands increased from 7.3 M.ha in 1995 to 8.4 M.ha in 2008.

However, agricultural lands, particularity, rice culting lands are getting big problem. Due to industrialization, urbanization and construction, agricultural lands are moving to non agricultural lands. From 01/7/2004 to nowadays, 750,000 ha were withdrew to set up more 29,000 non agriculture projects, 80% of which was agricultural lands. Up to 1 January, 2008, 4.1 million ha of paddy lands is remained. Period of 2000-2007, paddy field was reduced by 361,935 ha. Main reasons to reduce the agricultural lands are industrialization, urbanization, sport (golf), infrastructure building… In addition, the climate change (as drought, degraded lands, …) causes a large cultivating lands become waste land . These factors are hard challenge to save 4 million ha of rice lands as planned to get 31 million tons of rice by year 2010 for meeting the national food security and economic development.

1 Introduction

Viet Nam is a developing economy in South-East Asia with narrow land but high population density. Statistic by 01 January, 2008, the natural area of Viet Nam is 331,150.4 km^2 and population is 86.21 million people, averaged by density of 260 people/km^2. GDP was 1,144,015 billion VN

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dong, including 23,188 billion VN dong of agricultural and aquaculture production, 475,681 billion VN dong of industry and 43,146 billion VN dong of service sectors in 2007.

Agriculture plays an important role for Viet Nam on the way to go on the monetization and industrialization period. So that, agricultural development is survival national task to ensure food security and create the sustainable base for the national monetization and industrialization.

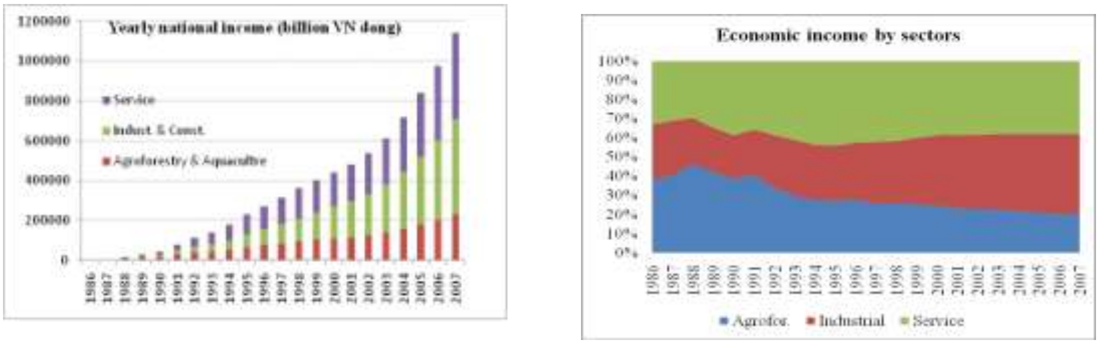
2 Agricultural and Food Prodcution

2.1 Agricultural production

Viet Nam is an agricultural economy. Difficult economic situation maintained until the end of year's 80. Going on year's 90, national economic situation become brighter. Figure 1a show that yearly economy production, fast increasing during 20 years. Since year's 80 to the end of year's 90, Viet Nam's agriculture has obtained a great progress due to re-structure and applying innovative technology. Total production was 599 billion VN dong (1986), 41,955 billion VN dong (1990). It increased up to 441,646 billion VN dong (2000), 839,211 billion VN dong (2005) and 1,144,015 billion VN dong (2007). In comparison, the gross income in 2007 was increased by 3.6 times in 1997 and 398,6 times in 1987 and agro-forestry and aquaculture production was increased by 2,9 times and 1997, respectively.

In period of 1989-1998, agricultural production has been increased by speed rate of 4,3%/year; food income was averaged by 23.08 million tons/year (increased by 1 million tons/year). Rice production has been being continuously increased in last 10 years and in 1989 Viet Nam first time exported rice and become the second rice exported economy in 1997. Vegetables, coffee, rubber, tea, cachewnut, black pepper was increased in both production and export turn over. Animal husbandry such as cattle, meet production, eages and milk were increased. Aqua cultural cultivation was enhanced in both production and export turn over in last 10 years with 20% per year and reached to 11 billion USD per year.

In last 10 years, national economy was fast increasing. Total income was obtained by 313,623 billion VN dong in 1997 up to 1,144,015 billion VN dong in 2007. In this period, income of industrial and service sectors were quickly increased. Industrial income was obtained by 100,595 billion VN dong in 1997 and 132,202 billion VN dong in 2007, and income from service sector was 475,681 billion VN dong and 436,146 billion VN dong, respectively (Figure 1a).



a b

Figure 1. Yearly national income (a) and economic income by sector (b)

The naional economic income is divided by 3 sectors (agro forestry-aquaculture, industrial and service). Before 1990, agro forestry and aquaculture component was develolped in increasing trend (38% in 1986 to 46,3% in 1988). From non food security and imported food economy, Viet Nam has become exported rice economy, so that since 1990’s year, national economic components have been moving from agriculture to industrial and service components. The economical sectors contributed to the GDP are 20.3% of agroforestry and aquaculture, 41.6% of industry and 36.4% of service sector, in 2007 (Figure 1b).

Cultivation and livestock directly produces the products for people. In last 10 years, agricultural production has quickly been increased. The Figure indicated that cultivation sector was more important role in national economic development than others. Agricultural sector include 3 sub components (cultivation, livestock and service). The total income from plant cultivation component was 4.4 times and 28.7 times higher compared with livestock and service component, respectively, in year 1990. It was obtained by 3.9 times and 31 times higher than livestock and service component, respectively, in year 2000. The service component was not being paid attention by grower and policy maker, in the past. At that time, agro-forestry productions were maintained by self consumption and self- supply economic system. Since 1980, Viet Namese Government changed new policy and strategies to develop the national economic. “New rethinking” policy was issued to give up “the self consumption and self supply economic” and access into “Marketing economic rule”.

There are about 12 million households and 9.4 million ha of cultivated land in whole economy, averaged by 0.7-0.8 ha per household, equal to 0.3ha per man labor or 0.15 ha per capita. Potential of agricultural land in economy is estimated by 10-11 million ha, in which, annual crop area is about 8.1 million ha (5.4 million ha can be used for rice cultivation and 2.3 million ha for perennial crops). At present, agricultural land resources are used by 65%, including 5,6 millions ha of annual crops and 0.86 million ha of perennial crops, 0.33 million ha natural grass field and 0.17 million ha of water surface.

Other potential lands for agriculture can be accounted by slopping and degraded land in the mountainous region. It is estimated by 44% of the northern mountainous regions and 79% of mountainous middle regions. The potential lands unexploited for cultivation are accounted by 76% in the western highlands and 34% in south-eastern region. The large agricultural regions are red river delta in the north and cuu long river delta in the south. Where land used for agricultural production was accounted by 93% in red river delta and 82% in cuu long river delta. The remain lands are mostly problem soils such as acid sulfate soils, saline soils and swap lands which required the advanced irrigation systems and improvement.

Table 1. Cultivated lands by crop group (thousand ha)

Year	Total	Annual crops			Perennial trees		
		Sub total	Cereals	Industrial crops	Sub total	Industrial trees	Fruit trees
1990	9040.0	8101.5	6476.9	542.0	938.5	657.3	281.2
1995	10496.9	9224.2	7324.3	716.7	1272.7	902.3	346.4
2000	12644.3	10540.3	8399.1	778.1	2104.0	1451.3	565.0
2005	13287.0	10818.8	8383.4	861.5	2468.2	1633.6	767.4
2006	13409.8	10868.2	8359.7	841.7	2541.6	1708.6	771.4
2007	13555.6	10894.9	8304.7	846.0	2660.7	1821.7	778.5

Source: General statistic department, 2008

Agricultural production in Viet Nam is multiform with different crop groups. Since 1998, Viet Namese Government increases the agricultural production by giving land use right direct to farmers. In addition, self decision in agricultural production promotes the famer's enthusiasm to explode the waste lands to cultivate, resulting the cultivated lands are increasing. In last 17 years, cultivated lands were increased from 9,040 thousand ha to 13,555.6 thousand ha (1.5 time). At that period, cultivated lands increased by 1.3 times or annual crop, 2.8 times for perennial crops. The big change happened since year 2000. By changing from planning subsidized economic to the marketing economic oriented to socialism, commodities production was increased. In annual industrial crops such as peanut, soya been, cotton, increased at the higher rate than food crops, (1.3 times for food crops and 1.6 times for industrial crops).

2.2 Food production

Employing the land for agricultural production has been increasing over time. Table 1 shows that land use was increased in agricultural section in period of last 53 years. Total cultivated lands ware 4.7 million ha (M.ha) in 1955, increased upto 7.1 M.ha in 1990.84 M.ha in 2005 and 8.5 M.ha in 2008. The food production is increasing from 4.7 M ha in 1955 to 7.1 M.ha in 1990 and 7.4 M ha in 2008. The total food production is 6.1 M tons in 1955; 21.5 M.tons in 1990 and 39.6 M.tons in 2008. The average food was 430.3kg/capita/year in period of 1996-2002, increased to 540.5 kg/capita/year (by 1.95%) in period of 2002-2006, and 503 kg/capita in 2008.

Period of 1976-1986, food production was yearly increased by 3%, with 18,4 millions tons in 1986, but 1987 it was loe down to 17,6 million tons. So that, average food reduced from 301 kg/people to 282 kg/people. Due to better weather conditions and changing in management rules, agricultural production was better progress. Food income was obtained by 19.6 million tons in 1988 and 21.4 million tons in 1989. In GDP, agricultural products contributed by 50% (1988), 2 times higher than industrial products, while population pressure is getting higher and higher, resulting cultivated lands going down. It was 0.19 ha/capita in 1955 down to 0.12 ha/capita in year's 80 and 0.10 ha/capita in 2008 (Table 2).

Table 2: Land use for agricultural production in Viet Nam for 50 last years

Year	Cultivated area (M.ha)	Average area (ha/capita)	Food production (M.tons)	Population (M.people)	Food income (kg/capita)	Rice yield (ton/ha)
1955	4,7	0,19	6,1	25,1	244	1,42
1975	5,6	0,12	11,6	47,6	244	2,14
1980	7,0	0,13	14,4	53,7	268	2,09
1985	6,8	0,11	18,2	59,7	305	2,78
1990	7,1	0,11	21,5	65,7	325	3,21
1995	7.3	0,11	26.1	72.0	363	3.69
2000	8.4	0.10	34.5	77.6	444	4.24
2005	8.4	0.11	39.6	83.1	476	4.48
2008	8.5	0.10	43,4	86.2	503	5.22

Rice production

Rice cultivation is a long standing and traditional production of Viet Nam and playing an important role in food production, agricultural and economical development in Viet Nam. Rice areas are distributed in whole economy. Rice production contributes on rate of 37% of total agricultural income and 26% of exported agricultural products in period of 2000-2004.

In the northern part, rice is mainly cultivated in 2 crops per year (spring rice and summer rice). In central and southern parts, rice can be grown one more season, (3 crops per year). Red river delta and cuu long river delta is main rice regions, where rice covers on 2/3 cultivated areas and produced by 70% of total rice production in economy.

In the Red river delta, rice is dominantly planted on the fluvisols, alluvial soils. Rice based cropping systems are rice-rice, rice-corn, rice-rice–potato/sweet potato, rice-rice corn/ bean, rice –rice-vegetables (tomato, cabbage, ..). In cuu long river delta, rice based cropping systems are rice-rice, rice-rice-rice. In addition, rice is also cultivated in mix farming system such as rice –fish, rice –shrimp.

Due to application of new technology in rice production such as new variety, soil management, important policies to develop the agriculture (location of land use right to farmer/ household and reduce the land tax for farmer…), rice production in Viet Nam has been being increased yearly in both area and productivity. Period of 1990-1999: rice area was enhanced from 6 millon ha in 1990 to

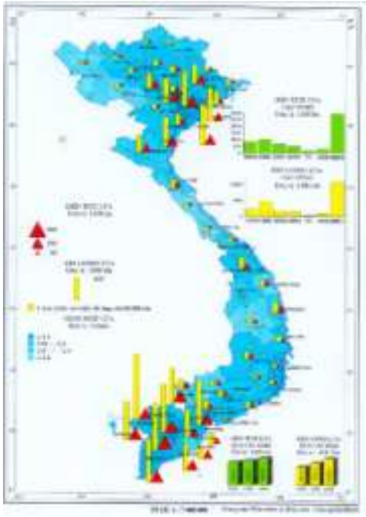


Figure 2. Rice distribution in Viet Nam

7.66 millon ha in 1999, production was increased by 7.2%/year. Period of 2000–2007, rice area reduced frequently from 6.7 million ha to 7.4 million ha. However, rice production increased from 32.5 million tones (2000) to 35.9 million tons (2007).

In 2008, rice area is increased to 7,4 million ha and production was obtainted by 38.6 million tons, (General statistic year book 2008). In 1989, the first time Viet Nam exported rice of 1.4 million tons with 310 million US$ of export return. Afterward, food production is continuously increasing. Exported rice amount in 2005 was 5.3 million tons with export return of 1.4 billion US$,*(N.D. Bich,http://vietbao.vn/Kinh-te/Xuat-khau-gao-Tra-gia-cho-su-qua-da/ 30156413/87/)*.

World Bank forecasted that food income of Viet Nam will reduced about 5 tons in 2030. Increasing of insect and deases while technology in rice cultivation is still not good enough are the main reason for failure crop.

Based on the investment and application of innovative technologies in cultivation, rice yield will be increased by 1%/year and reach to 5% in year 2015, so expected average yields (quintal/ha) will be 51.7 (2010), 55.1 (2015), 57.1 (2020) and 58.2 (2030). To meet the food requirement in futer, rice production was planned in Table 3.

Table 3. Oriention on rice production in Viet Nam

Year	Land area (million ha)	Rice cultivated area (million ha)	Expected rice yield (quintal/ha)	Expected production (million tons)
2010	4.0	7.2	51.7	38.0
2015	3.8	7.0	55.1	39.7
2020	3.7	6.9	57.1	41.0
2030	3.5	6.8	58.2	45.0

Source: Vu Nang Dung, Hoang Tuan Hiep, 2009

Population is 86 million people at 01 January, 2008. By forcasting, in few next decades, population of Viet Nam will be yearly increased with rate of 1-1.2%, it will reach to 100 million in 2020 and 120 million people in 2030. Average of grain food is accounted by 470 kg/capita/year in 2010 and 390 kg in 2020. national food reserve needs 1.3 million tons/year from current time to 2010, 1.5 million tons in period of 2010-2015 and 2-2.5 million tons behid 2020. So that, food requirement of Viet Nam is estimated for 2010 to 2030. In food crops, cereals including rice and maize are common and rice is biggest crop (Table 4).

Table 4. Food requirement of Viet Nam to 2030 (million tons)

Target	Year 2010	Year 2015	Year 2020	Year 2030
Total requierment	47.0	50.3	53.2	58.3
1. Maize	6.0	8.0	9.0	10.0
2. Rice (total):	31.1	32.1	35.2	37.3
2.1. For variety	1.1	1.0	1.0	0.8
2.2. For animal & loss	7.0	7.5	8.5	9.0
2.3. For processing	0.3	0.5	1.0	1.0
2.4. For humam and reserve	22.7	23.1	24.7	26.5
3. Cassava	8.5	9.0	10.0	10.0
4. Sweet potato	1.4	1.2	1.0	1.0

Source: Vu Nang Dung, Hoang Tuan Hiep, 2009

3 Land Resource and Utilization

3.1 Land resources of Vetnam

Total natural area of Viet Nam consists of more than 32 M ha. Based on soil map (1/1,000,000), soil types in Viet Nam are classified by 13 main soil groups as in Table 2. Low lands in delta include 5 groups (1-5), covering on an area of 7.425.700 ha (23%). Arenosols (AR) are located in a long coustal provinces (Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien Hue, Ninh Thuan and Binh Thuan provinces). Arenosols are characterized by sandy and urca texture, very poor nutrient and dry. Sandy fraction consist of 80-90% while, clay content is around 5%. Salic fluvisols (FLS) is formed from sea sediments or affect by flooding of saline sea water.

Sloping lands include 8 groups with 25,667,393 ha (77%). The largest group is ferasol soils which covers on 48.3%, the second group is humud ferrasol group. Those soils distribute on upland area with high slop. The large lands with low fertility are distributed in the central northen part. Viet Nam is dived by 9 bio-ecological regions with different landscap and soil types. Fluvisols are main lands for food crop production (rice, maize…). Fluvisols almost distribute in river deltas such as Cuu Long river in the south and Red river in the north. Red river delta: there are most fertile soils which are mostly derived from red river alluvial deposition. Red river delta has higgest population densty with 19654.8 thousand people in 2097.3 thousand ha of natural land or 802.6 thousand ha of cultivated land, (2008). Cuu Long river delta covers on the natural area of 4060.2 thousands or 2560.6 thousands ha of cultivated land with population of 17695 thousand people. There are ore than 3 million ha of saline of acid sulfate soils in Cuu long river delta.

Table 5 Soil classification of Viet Nam

Main soil group	%
Total	100
1. Arenosols	1.41
2. Salic fluvisols	5.94
3. Thionic fluvisols	5.17
4. luvisols	0.55
5. Haplic acrisols	9.48
6. Black arid soils	9.83
7. Semi arid black soils	0.21
8. Histosols	1.05
9. Ferasol soils	48.27
10. Humic ferasols	11.20
11. Alisols	0.50
12. Leptosols	1.34
13. Podzolic	5.04

A large lands with low fertility are distributed in the central northen part. The most fertile soils are fluvisol in the north (Red river delta – 600,000 ha and other rivers in the central part – 260,000 ha), where is facing to high population preasure.

In the central north part, hilly and mountanuous soils consist of 80%, left area is low lands, alluvial soils, sandy marine soils and sandy duns. These areas usually get big problems caused by critical weather conditions. So that, crop production usually falls in the difficulty for growth and yielding.

Coastal central region, from Quang Nam to Thuan Hai, is 4.5 million ha. Of which, there are 30% of low land used for rice cultivation. But, rain is smallest, estimated by 800 mm/year. That is reson for agricultiural production usually implements one crop per year with low benifte.

Figure 3. Soil map of Viet Nam

Western highland covers on an area of 5.5 million ha with elevation of 100n above sea level. In this region, rice is cultivated on an area of 211.1 thousand ha by year 2008, (General statistic book, 2008). This region is most suitable for perennial crops such as coffee, tea, ruber and fruits. Coffee is welknown and grown on about 7000 thousand ha.

There are 770,000 ha cultivated lands in the Souhtern east region, of which rice lands occupied on 307.9 thousand ha. This region is suitable for ruber, fruit trees. Cuu long river delta consists of 4.06 million ha. There is largest rice area in Viet Nam with nearly 3.9 million ha and production of 38.7 million tons in 2008. However, there, flooding usually happen on about 1-1.2 million ha in 2-4 months. Acid sulfate soil is estimated by 40%, 700 ha of saline swamp is a suitable for shrimp cultivation.

3.2 Land use change in Viet Nam

3.2.1 Current land use

Land use in Viet Nam is presented in Table 6. Data showed the land use situation in whole coutry and by different ecological regions in 2008. The total natural area is 32,924.1 km^2. Of which agricultural lands occupy on 28.43% of the total natural area.

Table 6. Curent land use in Viet Nam (to 01/01/2008) (thousand ha)

Region	Total area	Agriculture land	Forestry land	Special use land	Residential land
Whole economy	33,115.0	9,420.3	14,816.6	1,553.7	620.4
1. Red river delta	2,097.3	802.6	445.4	277.6	129.4
2. Middle mountain	9,543.4	1,423.2	5,173.7	259.3	105.6
3. North Central coast	9,589.5	1,758.3	5,069.7	451.4	169.9
4. Central highlands	5,464.0	1,626.9	3,122.5	142.0	43.5
5. South East	2,360.5	1,248.7	668.4	189.4	61.9
6. Cuu Long river delta	4,060.2	2,560.6	336.8	234.1	110.0

Source: Decision No1682/QD-BTNMT,26 Agurst, 2008. Ministry of resources & environment

In agricultural lands, the annual crops consist of 19%, three times larger than the perennial crops. The annual crops include rice, maize, sweetpotato, peanut, soyabean and vegetables cuntivated on flate lands in delta. On upland soils, anuual crops include maize, cassava, some vegetables. Largest agricultural land is in cuu long riverd delta. There are the most rice cultivation in both area and production. The forestry land is estimated by 44.74% of natural national area. The most area is covered by natural forest. Forests are density concentrated in the mountainous northern and middle regions.

The forestry land is estimated by 44.74% of natural national area. The most area is covered by natural forest. Forests are density concentrated in the mountainous northern and middle regions. Potentional lands are allocated in unused land sector. Un-used land, river and rock mountaints are estimated approximately 44.74% in whole economy. It shows a high potential to exploit in future for national economic development.

3.2.2 Changing in land use and agricultural land

The total cultivated lands are more than 24 million ha, of which agricultural lands are more 9 million ha. Viet Nam government is increase to change agriculture production from home consumsion, self supply to food production oriented to marketing rule. Then, land use for agricultural production is changing in trend of annual crop lands miving to perennial crop lands. Annual crop area gradually reduces by time. It was 6372.9 thousand ha in 2005, 6348.2 thousands ha in 2007 and 6309.6 thousand ha in 2008. While perennial crop land was quickly increased from 3045.5 thousand ha in 2005 to 3110.7 thousand ha in 2008. On the bare lands, Viet Namese Government issued policies to increase the re-forestation the whole economy. Due to high population pressure, shifting cultivation and "slash and burn" in the mountainuous regions are still common happen, causing the deforestation. In order to regreen, forestry and aquacultural lands are increasing by time, (Table 7).

Table 7. Variation of agricultural land use *(thousand ha)*

Item	2005	2007	2008
Total area	24,822.6	24,997.2	24,997.2
1. Agriculture	9,415.6	9,426.3	9,420.3
1.1. Annual crops	6372.9	6348.2	6309.6
1.2. Perenial crops	3045.5	3088.0	3110.7
2. Forestry	14,667.4	14,816.6	14,816.6
3.Aquaculture	952.6	728.6	1052.6

Agriculture of Viet Nam is facing to a number of problems. Recent years, rices was extremely attacked by insects, pariticularary *Nilaparrvala lugens*, causeing the crop failures. Insects are the main factor to make the rice yield and production reduced. Additionaly, food lacking is happening in many counties in the world, let the rice price enhancing. So that, rice will become scare and non food security will be threated in future.

Ministry of agriculture and rural development indicated that population of Viet Nam will be 130 people and need about 36 million tons of rice. In order to reach that target, Vetnam should keep at leats 3 million ha for 2 rice cultivation to get 6 million ha of cultivated rice per year. To reach the most effectiveness in land utilization for agriculture, land use planning for 2010 and 2020 was issued in Table 8.

Table 8. Land use planning for agriculture production upto 2010 and 2020 (1,000 ha)

Item	2007	2010	2020
Total area	24,696.0	26,220.0	26,971.0
1. Agriculture	9,436.2	9,239.9	9,472.0
1.1. Annual crops	6,348.2	6,583.0	5,758.0
1.2. Perennial crops	3,088.0	2,656.9	3,714.0
2. Forestry	14,524.2	16,243.7	16,540.0
2.1. Productive forest	5,672.5	7,702.5	6,622.0
2.2. Protection forest	6,766.3	6,563.2	4,468.0
2.3. Special use forest	2,075.5	1,978.0	3,450.0
3. Aquaculture	715.1	700.1	911.0
4. Salt land	14.1	20.7	18.4
5. Other agricultural lands	16.5	15.6	30.2

3.3 The factors cause changing in land use and agricultural production.

3.3.1 Population pressure

Viet Nam has been trying to control the birth rate. However, increasing rate of population is still high, compared with other economies in South-east Asia.

Table 9. Population in Viet Nam (thousand people)

Region	1995	2000	2005	2006	2008	People/ km^{2,} 2008
Economy	71,995.5	77,635.4	83,106.3	84,136.8	86,210.8	260
1. Red river delta	17,078.4	18,055.2	19,107.5	19,318.9	19,654.8	933
2.North Middle mountain	9,522.9	10,204.8	10,838.6	10,970.9	11,207.8	118
3.North central coast	17,201.2	18,307.9	19,367.2	19,494.8	19,820.2	207
4. Western highlands	3,384.8	4,236.7	4,757.9	4,854.9	5,004.2	92
5.South Central coast	17,201.2	18,307.9	19,367.2	19,494.8	19,820.2	543
6.Cuu long river delta	15,531.9	16,344.7	17,256.0	17,400.1	17,695.0	436

National population is incseasing by time (71,995.5 M people in 1955; 77,635.4 M people in 2000 and 86,210 M people in 2008). Population density is un-equal in each region in economy. In mountain area and west highlands are most small density. In urban area and deltas are more density, particularly in Red river delta. In 2008, average density was 260 people/km^2 for whole economy, 933 people/km^2 for red river delta and 436 people/km^2 for Cuu long river delta, (Statistical year book 2009). More details by ecological regions in the economy are presented in Table 9.

Viet Nam population was forcasted by 100 million people in 2010 and 120 million in 2020. Due to the increasing of population, food and other consumption requirments will be enhanced at a big rate. In order to meet the food security in county, food production mush be enhanced in both cultivating area and intensive level. Intensive cultivation include the application of good quality and high yield varieties and advanced technologies.

3.3.2 Urbanization and industrilization

The goal of Viet Nam is to escape from developing economy group with national low income before 2010 and become an economy with model industry in 2020. Land used for industry has been shafly being increased. As planned for period of 2006-2010, in economy, industrial lands is estimated by 100,469ha; 49,152 ha higher than that in 2005. In face, there was 57,903 ha, acounted by 01 January, 2007 (Vu Nang Dung, Hoang Tuan Hiep, 2009).

Farmer sociation reported that changing of land use purpose in agricultural land is frequently increased. In Hanoi, there are large lands were withdrew for non agricultural projects: 733 ha for 159 in 2001; 1,003 ha for 194 projects in 2002; 1,424 ha for 260 projects in 2006 and 1,980 ha for 280 projects in 2007.

Requested by the industrilization, urburnization and development of infrastructure, there are about 200,000 ha of agricultural land withdrew to change into non agricultural lands. In the main point of agricultural region, Binh Duong province has 16 industrial zones with 3,270 ha and industrial – service conjugate zone with 4,190 ha has ben beeing implimented, (Thu Trang, 2005). Expanding Ha Noi city is typical example in urbanization needing more land for contruction (brid, roard, housing, ...).

Dr. Nguyen Van Banh has anounced on the changing in land use and problem for food production in future being caused by moving quickly the agricultural land to non agricultural land for industrial developement. Due to this reason, agricultural lands are being excaped by 70,000 ha for industrial construction.

Viet Nam, since 2001 up to nowdays, about 300,000 ha rice land has been replaced for industrial zones. That is the potential high risk for food security when cultivation lands reduced and population increased, while crop yiedls is limited.

Ministry of natural resources and environment reported that there are 4.1 million ha of rice lands, of which 3.1 million ha of paddy rice, accouted by 01 Agurst, 2008. Period of 2000-1007, rice lands were reduced by 361,935 ha. Of which, there are 71% from red river and Cuu long river deltas. Lossing lands are estimated by 51,705 ha/year, that is reason for 400-500 thousand tons of rice lost and affected on the livehood of at least 1000,000 households/year.

Transport and contruction and trading Ministries informed that from nowdays to 2020, land for infrastruction’s development is very big requierment. If the rate of land moving the agricultural lands to non agricultutral lands keft as the same 7 last years, 672,000 ha of agricultural lands would be lost by year 2020 and total paddy rice lands would be remained about 3.4 million ha. (http://udc.vn/home/index.php?option=com_content&view=article&id=51: phasellus-ut-).

3.3.3 Policy relating to land utilization

Management mechanism plays an importal role in the agricultural development. Viet Nam has gone through the different periods to find out the innovative land management rules for economic development. Particularity, period of 1981-1985, Viet Names Government gave up the subsidized and administrative management structure to go into the marketing mechanism oriented to socialism. This period, agricultural production is stable developed. The agricultural production was gaint a great progresss. The increasing in food production was estimated by 27% in food income, by 23% in rice yield and by 62.1% in are of annual industrial crops, compared with previous period. Food production is enhanced by rate of 5%.

In the last 17 years of renovation (1996-2002), Viet Namese Party and Government have issued many policies to encourage development of agriculture and rural economy in the direction of linking goods production to market. One of these policies is Law on Land with many important contents was ratified, in which there was an important content; Government allocated land use to households and industrial for their long use with 5 rights: conserving, transferring, rentting, inheriting and mortgaging. The existence of Law on agricultural land use with lower tax rate than agricultural tax hoped to reduce contribution of farmer and encourage households to effectively utilize agricultural land. In December 1996, an important policy, which relate to industrialization and modernization of agriculture and rural area was issued. This policy is to promote the agriculture development. Other hand, investment for agriculture was increased by 50% of budget in 1999.

The most important to develop agriculture is application of the fixed price contract. This policy gives a contractual agreement to farmer in land use in 15 years. However, fixed price in contract is not changed in every 5 years. At the same time, government also incareases to develop household's economic which was forbiden in the past. In addition, the propicious weather in period of 1988-1990, food production got a great progress and good results. Rice production was increased an average of 2 million tons/year. At the same time, increasing of production is not only in food crops but also in industrial crops, fruit trees and husbandary.

3.4 Climate change

Agro-forestry and aquacultural production has been being fall in difficulties bcause of green house effect is raising the air temperature, thaw ice, sea water leven, harmfull rain, windstorm and flood tide and complete climate change. Generally, climate changes are very complex happen in trend to increase the longer the more serious change such as air temperature, very demaging cold, flood tidle, (*INFOTERRA VN (Xl by ministry of agro-forertry and rural requirmentBộ NN&PTNT, 27/5/2008)*.

FAO informed that in 2008, climate change has been being effected on the human lifes on the world and the hungers were estimated by 1 billion, 100 million people and 100 million people higher than that in 2007 due to the world financial crisis, (To Van Tuong, 2009, http://www.vncold.vn/Web/Content.aspx?distid=1915).

Addtionaly, hunded thousand ha of land are being serious degraded and desertificatio. Partial desertification happens on 7.85 million ha, distributing on western highland pleatau, western north and Long xuyen quadrangular, **(**Quang Thuan, 2004). Economic loss was estimated by 125 billion US$ per year, (Khong Loan, *http://www.tuoitre.com.vn/Tianyon/PrintView.aspx?ArticleID=319151&ChannelID=2)*.

Flooding usually happens from May-June to september-October in Northern part, from June-July to October-November in Northern central part, Octber- December in Southern celtral part, June – Dember in Western highlands and July – December in Southern part.

Red river delta, two extremely strong floods happened in Aurst 1945 and augurst 1971. They demaged many dames and dyes in many provinces. There were additionaly flooding in year's (1913, 1915, 1917, 1926, 1964, 1968, 1969, 1970, 1986, 1996, 2002...).

In the central parts, big flodding happened in year's (1964, 1980, 1983, 1990, 1996, 1998, 1999, 2001, 2003,…) and in Cuu long river denta, harmfull flooding happned in year's (1961, 1966, 1978, 1984, 1991, 1994, 1996, 2000, 2001,…).

4 Summary

Viet Nam is an agricultural economy with narrow land and density population. Agricultural production is being developed and obtained a great progress in recent years, contributing about 20-40% of GDP. The land resources are exploited for agriculture of 9.42 M. ha (28.5%) and forestry of 14.8 M.ha in 2008. Food production is most priority, so that cultivated rice lands are increased from 7.3 M.ha in 1995 to 8.5 M.ha in 2008. Food production has been increaded from 6.1 million tons in 1955 to 43 million tons in 2008, averaged by 224 and 503 kg/capita/year, respectively.

However, agricultural production is facing to big problem. From 01/7/2004 to nowadays, 750,000 ha ware withdrew to set up more 29,000 non agricultural projects, 80% of which was agricultural lands. Period of 2000-2007, rice fields was reduced by 361,935 ha. Main reasons to reduce the agricultural lands are industrialization, urbanization, sport (golf), construction.

In addition, the climate change cause a large cultivating lands become waste land as drought, degraded lands… Natural calamities are also a reason for hard challenge to save 4 million ha of rice lands as planned to get 31 million tons of rice by year 2010 for national food security and economic development.

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Applying High Technology to Enhance Agricultural Land Protection and Rational Utilization

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Abstract: Under the guidance of agriculture resources ideology with scientific, rational and sustainable utilization, this paper introduced application of agricultural land protection by using modern information technologies in China. It also analyzed and discussed three key technologies about land use issues — obtaining farming land change information, implementing land consolidation and drawing up land use planning.

Key words: 3S technologies; land consolidation; image segmentation; land use planning; ecological footprint

0 Introduction

Land is one of the fundamental conditions for agriculture. Agricultural land is an important national resource. The properties of limited, vulnerability, irreplacebility and non-renewable determined that agricultural land must be protected and rationally utilized especially for cultivated land. It is a comprehensive national systems engineering which not only need a high-tech support, but also have strict legal protection.

China has vast land area. But the cultivated land has only 121 million hectares with 0.081hm^2 for per capita and is only 30% of the world's cultivated land per capita. Since the reform and opening up, China's national economy is keeping a high-speed growth of an average 9% annual. All fields in the national economy need a great deal of cultivated land to develop and some of cultivated land had been returned to forestland because of the policy of returning land from farming to forestry for the ecological protection. The quantity of cultivated land dropped significantly at an average annual rate more than 330,000 hectares despite some of wasteland were reclaimed. Sharp drop in cultivated land area year by year has been a major threat to national food security.

To control the tendency of the significant decrease of cultivated land, China has made and implemented a series of policies to strictly protect cultivated land. These actions have achieved good effect. The modern information technologies mainly remote sensing, global position system and geographic information system (3S) play an important role in applying cultivated land protection policy. Those provide not only the reliable scientific basis to make agricultural development strategies and macro-control policies, but also timely accurate information for policy implementation.

1 Obtaining the Agricultural Land Change Information

3S technology is a modern spatial information technology which can obtain a large area of ground information with fast, accurate and multi-resolution. Its advantages are essential to acquire agricultural resource management. Therefore, agriculture has being one of the main fields of 3S application. Through nearly 30 years of technological development, 3S technology in China has been widespread and profound application in agriculture. China has applied 3S technology successfully to carry out land resources survey including agricultural resources and acquired a large number of land resource data including many inaccessible areas in Tibet, Xinjiang, Qinghai. Furthermore, using 3S technology has achieved five kinds of crops yield estimation—wheat, corn, cotton, soybeans and rice, and has achieved nationwide agricultural situation forecast which is released once every 10 days including drought, flood and crop growth. In order to protect cultivated land, China has established land use monitoring around 50 large and medium cities which will obtain 2m resolution remote sensing data once a month to provide scientific basis for the implementation cultivated land protection policies.

Nowadays, 3S technology application is transforming from obtaining basic geographic information data to the change information including ground feature characters information. According to the research, the annual ground surface change information only accounts for about 10% of the overall information. That is to say, most of the massive data which we obtain everyday are duplicated information. It is a new subject for 3S technology to how to effectively compare the new data with the old data to acquire change information, including the geometry changes and character changes of the ground features.

Primary methods of ground surface change information detection can be divided into three types, that is visual interpretation, pixel-based detection and object-oriented detection.

The visual interpretation can give full play experience and knowledge of experts and integrated the information of image space, texture, structure, shape and other information, so it can get very high accuracy. However, the visual interpretation will be time-consuming. When using high-resolution remote sensing images, the results of the visual interpretation can be regarded as “true value” of testing interpretation effect images.

The pixel-based detection method can be divided into pre-classification comparison and post-classification comparison. The basic idea of pre-classification comparison method has two steps: (1) geometric matching and radiometric correction for two scene images; (2) comparing each pixel of the image one by one with overlay analysis techniques. The main analysis methods include the difference method, ratio method, vegetation index method and principal component analysis (K-L analysis). Its key technology is to determine a reasonable threshold. Because the value is very difficult to adapt each pixel of the image, it has influential to the detection effect. For the post-classification comparison method, it classifies every multi-temporal image, and then compare with the classification result with overlay analysis. This method can use all kinds of image classification techniques, such as supervised classification and unsupervised classification. Its test results depend on classification result of two images, therefore it will affect the accuracy of detection.

The object-oriented detecting method is a new technology to remote-sensing image processing. Its key technology is image segmentation. Segmented images based on geometric image features, spectral features and texture features. There are many segmentation methods. One of them is Watersnake method which is developed by combined the watershed segmentation method with the Snake segmentation method, and it has a strong technical advantage in the international and has been already developed several software applications. Remote Sensing of the Chinese Academy of Sciences has also developed its own software using the method and applied to the ground surface information changes detection.

Obtaining agricultural land changes can now be identified for $4m^2$ surface features change (such as SPOT-5 images) and the accuracy could be up to 90%. There are a lot of researches come out for detecting the land quality changes such as land desertification and rocky desertification.

2 Land Consolidation and Agricultural Resources Rational Utilization

China's cultivated land resources is extremely poor compared with 1.3 billion peoples. Reclaimed arable land area is very limited, which is only 2.6% of the present cultivated land and mostly located in remote areas having high development costs but the little value. The only way to improve the situation of cultivated land resources scarce out is to raise the land utilization, that is, expand farmland from the collation of present agricultural land and increase the efficient use of cultivated land area.

Since the reform and opening up, China has carried out a new land use policy—diving farmland to household. In the rural area, every people including an infant would get a share of farmland. But the quality of the farmland is not uniformity and resulted in much more intensified fragmentation of rural land. There are too much farmland plots such as riser of terrace**,** ditches, roads and ponds area. According to national land resources survey, the area of China's riser of terrace is up to 187 million mu, more than one times of medium-level intensification of the international community. The area of China's ditches is 73 million mu, more than 1.5 times. The area of China's field of road is about 100 million mu, more than 2 times. Direct loss of cultivated land achieves 3-10%. Correspondingly the grain cost per ton will increase 115 Yuan and production efficiency will decline 15%. It can be seen that there is a great potential from land consolidation to increase cultivated land area and has a great growth space to land output efficiency.

The fundamental way out for developing agriculture is intensification and large-scale of agricultural production. Land consolidation can not only improve effective land usage, but also create prerequisites for the intensive and large-scale agricultural production. In recent years, China has invested 100 billion Yuan every year for land consolidation whose aims are save land, expand cultivated land and improve land output efficiency.

Land consolidation is a comprehensive land projects which includes land consolidation addresses exploration and selection, broken block merger, construction sites demolition, land reclamation, land leveling, soil improvement, agricultural planning and implementation. Apparently, geo-information acquisition and analysis is the core technology of land consolidation such as the high geometric resolution image interpretation and analysis techniques, high-precision farmland mapping techniques and terrain analysis techniques.

Land consolidation sites exploration and selection need high geometry resolution images. Vegetation index (VI) measurement during crop growth period is one of the fundamental basis of location choose by remote sensing. Farmland and the surrounding vegetation index higher, the economic value higher in this region.

Land consolidation sites exploration and land leveling are related to mountain slope measurement and analysis. Mountain slope measurement exist problems of spatial information uncertainties. The spatial information uncertainty refers to different descriptions information at different scales. Because the mountain is a random complex surface, every point has a slope. A natural slope of the gradient is actually the average slope gradient of all points. In the land consolidation, what scales to measure the various points of the gradient of slope, and how the maps scale measurement of the mountain slope regardless of the data for the DEM or contour map, are problems need to be addressed. Scale maps decided the mountain slope measurements and the accuracy of estimating the amount of excavation works. A reasonable choice maps scale is essential for the implementation of land consolidation. It shows that 1:5000 or 1:2000 scale digital contour map, $4 \times 4\ m^2$ DEM data are suitable for land consolidation projects and meet the needs of the general area.

In Yunnan, Guizhou and Guangxi, the southern provinces of China, land rocky desertification problem is serious. Land is covered by stone. Mellow soil which is suitable for cultivation becomes scarce resources in those areas. The local government implemented a policy that the arable layer of soil should be stripped out to set up a "soil bank" for reclamation in areas close to rocky desertification of arable land use when it was developed to the construction. This solved the lack of soil problems effectively.

Land consolidation provides conditions for agricultural production industrialization and large-scale preparations. The Chinese government is implementing an agricultural policy to encourage farmers to voluntarily organize themselves through land shares and the establishment of agricultural cooperatives in order to break the boundaries of individual plots, and solve the terraces fragmentation problem.

Practices have shown that land consolidation can receive double effects in land saving and production increasing. After land consolidation in some areas, corn production could increase 17%, wheat 18% and rice 4%. The farmers significantly reduced the amount of investment and jobs. Medium and large farm machinery played work efficiency.

3 Strict Control of Land Use and land Use Planning

Cultivated land protection is the core of land management in China. The fundamental reason for arable land scarcity is that people use land irrationally. Management and control of people's land development acts and land use approach are fundamental measures to protect arable land. The legalization of land use regulation is the land use planning.

Land use planning is a governmental action and is a guidance to implement the land use management for governments at all levels. Land use planning is a kind of fixed-time regulations, which is the rational land use program for the economy or a region to play maximum land efficiency in accordance with the principles of sustainable economic growth. Scientific establishment and strict implementation of land use planning have strong relationship with agricultural land protection for sustainable use and agriculture healthy development.

Land use planning is a science, but also an art. Development and implementation of land use planning needs the support of modern information technology including 3S technologies. Remote sensing technology provides the status of spatial information of land use and information on land quality and attribute. The Global Positioning System provides accurate land spatial position information. Geographic information system provides technological mean on storage and analysis of spatial and attribute information.

Land use planning is a national or a regional economic development strategy in the implementation of land-use layout program. Land use planning is made from top to bottom, that is, from the national, provincial (city), regional, and county levels respectively. It can be roughly divided into the following five steps:

(1) According to the national or a regional economic development strategies, as well as a land-use programs of a top level to determine land use objectives for the planning area.

(2) Evaluating implementation of the last round of planning; identifying gaps in achieving land-use goals according to national economic development strategies of current round of planning, summing up experiences of implementing the plan.

(3) Predicting the trend of population development, and need and demand forecasting for the various types of land in the planning period.

(4) Carrying out land-suitability assessment, such as crop cultivation, residential land, industrial development zone, cultural and educational development zones, tourism development zones.

(5) Based on results of land suitability evaluation, conducting regional districting according to the principles of maximizing benefits of economy, social and ecology, determining the content of each regional focus on the development, giving indicators of all kinds of land use.

Implementation of the above five steps need the support of information technology, especially 3S technology.

Land use planning is a necessary means to achieve sustainable development. Based on resources status for the planning area, as well as various aspects of economic development, calculation the economic development of the land carrying capacity and giving to sustainable development at a reasonable valuation are important elements for the land use planning. In this regard of recent years, a large number of research results have attracted international attention including "Ecological Footprint Analysis" research methods.

‘Ecological footprint’ concept and calculation method was brought forward by the Canadian ecological economist Willam Rees and Wackernagel in 1996. Their basic idea is that human being must consume a variety of products, resources and services in order to survive. The amount of items of final consumption can be traced back to eco-productive land providing the required consumption production of raw materials and energy. Therefore, all consumption in theory can be converted into the corresponding productive land area. In certain technical conditions, to maintain consumption levels of a substance in an area necessary for the continued survival of population need ecologically productive land area, namely the ecological footprint. The ecological footprint is as "a footprint left on earth by a giant foot loaded of people and their creatures of city and factory". This is the demand of human to the nature. The land area providing to human being for the usage is called the supply of the ecological footprint, which is a measure of the ecological carrying capacity.

Ecological footprint analysis focuses on the calculations of ecological footprint demand and supply. When a region's ecological footprint demand is greater than the supply, it appears ecological deficit. When a region's ecological footprint demand is less than the supply, it appears ecological surplus. Ecological deficit shows that the population load of this area exceeds its ecological capacity. To meet its population living standard under the existing consumer demand, the region must import lack the resources from outside to balance the ecological footprint, or by depletion of natural capital to make up for revenue shortage of the supply flow. This has showed that the regional development pattern is in a non-sustainable state. On the contrary, ecological surplus indicates that the region's economic and social development is within the scope of natural ecological system of the region and the consumption pattern has relative sustainability.

The significance of the ecological footprint analysis quantitatively gives status of regional economic development sustainability. If the region's economic development is not sustainable in what aspect and what indicator has an important guiding role for the national macroeconomic regulation and control, especially in land-use management.

Land use planning for the next decade is being developed in China. With the support of modern information technology and a number of new ideas including the use of "ecological footprint" analysis, this work is going on scientifically and practically. At present, some provinces and cities have completed land use planning. Land use planning at county level is being launched gradually. Land use planning has an important significant for the effective protection of agricultural resources and support of agricultural production.

4 Conclusion

Agriculture is the basic of the national economy. The agricultural land is the support conditions for agriculture development. Farmland protection has a particularly important significant of sustainable economic growth for the most populous economy like China.

Protection and rational use of agricultural land need support of information technology, especially 3S technology. Land consolidation and land planning are effective ways for efficient and rational use of land by the support of information technology. In the implementation of land consolidation and development of land use planning, we must constantly update our ideas and use new technologies in order to safeguard agriculture sustainable development.

Agricultural Land Use and Its Effect in Thailand

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Introduction

Agriculture in Thailand is varied and differs in terms of activities in each region or locality, particularly in the way farm cultures and traditions have been handed down through the generations. Each region has clear social and economic differences. The agriculture of the Central region around the Chao Phraya river basin differs from the farm culture of the Northeast, and from that of the North and South of Thailand.

The history of Thai agriculture and the role and importance of the agricultural sector at the present time are briefly discussed. Data on geography and climate, agricultural/natural resources and basic agricultural production, processing and marketing infrastructures are presented, followed by the performance of past development efforts, production and marketing of important agricultural commodities, socio-economic condition of farmers.

Thai agriculture has had a long evolution in Southeast Asia. The development of farming has gone hand in hand with the growth of the Thai economy, ever since Thai people first appeared in the land called Suwannaphum. Agriculture is important and affects the livelihood of most of the population. Not surprisingly, agricultural activities have been honored and closely observed all through Thai history. Agricultural activities in Thailand are strong and consolidated. The agricultural sector has progressed in many areas, including management of water resources, land development, horticulture, animal husbandry, fisheries, agri-business, and agricultural industries and cooperatives. Thai people have made their living in agriculture for several generations. The old proverb states that ‘agriculture is the way of life in Thai society.

In the period of globalization, the importance of agriculture to Thailand and the world can be pointed out as follows.

1. Thailand is a major food producing economy capable of producing to feed approximately 250 million people, more than four times the current population of economy. Thailand is the exporter of many agriculture goods to the world. These include rice, maize, sugarcane, cassava, natural rubber, canned pineapple and black tiger prawn.

2. Exports of agriculture food and products are an important source of revenue and foreign exchange earnings. For example, in 2002, agriculture exports accounted for 25% of total export values and increased to 26% of the total in 2003.

3. Since Thailand is a producer and exporter of several agriculture food and farm products, the economy has therefore an important role in international markets. Thai agriculture commodities helped support downstream industries in developed and developing economies.

4. The majority of Thai population is still connected with agriculture and with agriculture-related downstream industries. Thai people are expanding in the fields of agri-business, agro-industry and food production for export to world markets.

5. National policies which promote investment in infrastructure development contribute to the production of agro-industrial exports. The investment in food industries will continue, and be come supplier for the world's kitchens.

6. Thailand's natural resources enable it to produce an over abundance of agriculture commodities. However, this puts pressure on the economy's land, forests, coastal areas, and other water resources. The problem of deteriorating natural resources is now apparent. The agriculture sector is called upon to adapt to changing social needs while responding to growing environmental concerns.

Topography and Climate

1. Topography

Thailand is situated on the Indochina peninsula at latitude of about 5' 37' and 20' 27" north, and a longitude between 97' east and 105' 37" east, just above the equator. The shape is as resembling an ax or dipper. With an area 51.4 million hectares, Thailand is the third largest economy in the Southeast Asian region, after Indonesia and Myanmar. (The Southeast Asian region includes Indonesia, Myanmar, Thailand, Malaysia, Viet Nam, the Philippines, Lao PDR, Cambodia, Brunei and Singapore.). And border of economy are as follows;

In the north, Thailand shares borders with Myanmar and Lao PDR. The northernmost point of Thailand is Mae Sai district in Chiangrai province.

In the south, Thailand shares a border with Malaysia. The southern most point is Betong district in Yala province.

In the east, Thailand shares a border with Laos PDR. The eastern most point is Na Poh Klang commune, Kohng Jiem district, in Ubon Rachathani province.

Thailand borders Myanmar on west. The westernmost point is Mae Kohng commune, Mae Salaeng district, in Mae Hong Son province.

2. Regional Classifications

Thailand has 6 geographical regions. These include a central region with 22 provinces; a western region which covers 5 provinces; the eastern region which includes 7 provinces; the northeast, with 19 provinces; the north, with 9 provinces; and the southern region, which has 17 provinces. Altogether, Thailand has 76 provinces and topographical characteristics of each region are as follow;

The north is characterized by mountain ranges composed of the Daen Lao range, the Tanon Tongchai range the Phi Bphan Nam range, and the Luang Prabang rage. All of these ranges comprise the origins of various rivers which, flowing down through valleys, forests, hills, plateaus, and foothill plains feed the Mekong and Chao Phraya river.

The northeastern region is mostly a high plateau which sloped downward from the west and the south toward the east. On the western side of the plateau are the Petchabun and Dong Phaya Yen mountain ranges. Along the southern side of the plateau are the San Kampaeng and Panom Dong Rak ranges. These hold the watersheds of the Mun and Chi river, which flow east toward the Mekong river.

The central region is largely composed of a vast and fertile floodplain. The Chao Phraya river is the major waterway. In the West, the mountains are a continuation of mountain ranges from the north and Myanmar which the most important ones are the Tanaosri and the Tanon Tongchai ranges. The Graben basin is a valley formed by an up life of the earth’s crust.

The eastern region is characterized by low mountains and rolling plains. The plains are interspersed with low hills which are the watershed of short rivers flowing from north to south toward the Gulf of Thailand. The coastline nearby and around the gulf resemblance the environment of the gulf and composes of small and large islands, e.g., bays of Sathahip, Udom, and Pattaya, and the islands of Sri Chang, Chang, and Kut among others.

The southern region has unbroken mountain ranges running from north to south. The Tanaosri range in the west is bordered on both sides by narrow coastal plains. While the eastern coastal range in the south is an emerged coastline, the plain along the western coastline is submerged

3. Climate

The so-called Koppen climatic types, which are based on amount of rainfall and temperature, describe Thailand as having three major climatic areas influenced by the southwest and northeast monsoons. A tropical Savannah climate covers the economy from the far north to the northern part of Prachuab Kirikuan province, affecting the northern, and the northeastern and central regions. When the southwestern monsoon arrives, the weather is wet. It rains continuously. During the northeast monsoon, the weather is dry and cool. These areas are lightly forested, grassy plains.

Moist Rain Forest Climate: There are rain forests all along the eastern coast in the south, from Chumporn down to Naratiwat province. This area receives both the southwest and the northeastern monsoons. In summer, it is influenced by the southwest monsoon and in winter by the northeast monsoon. It rains heavily all year round in the Southern region, with an average of more than 2,500 mm annually. The average temperature can rise above 20 degrees Celsius. The natural vegetation is dense rain forest.

Monsoon Rain Forest Climate: The climate is hot and humid in the monsoon regions along the western coast of the southern region through Ranong, Pangna, Phukhet, Krabi, Trang and Satun, and the eastern region, i.e. Rayong, Chantaburi and Trat. The average rainfall, as well as the vegetation, resembles the rain forest area.

Seasons and Temperatures: Since Thailand is located in the path of the monsoon, the economy has three seasons. Summer or hot season begins in mid-February and lasts till mid-May, about 3 months. The weather becomes very hot and dry, especially in April, which is the hottest month. During this period, the sun moves past the equator toward the northern hemisphere, directly toward Thailand. The northern and northeastern regions, the west and central regions, all have long periods of hot weather. The average temperature is from 33-42 degrees Celsius. The southern region is influenced by the sea's climate along both coasts, making the weather cooler with some rain. The average temperature is 28 degrees Celsius

Rainy season begins in mid-May and goes on till mid-October, around 5 months. It rains throughout the economy. The southern region has more rain until November due to the northeastern monsoon's influence, which comes across the Gulf of Thailand, bearing moisture, during this period. During the seasonal change from mid-October to mid-November, the waning of the southwestern monsoon and the arrival of the northeastern monsoon creates a trough, which tends to make the weather violent and capricious.

Cold season begins in mid-October and lasts till mid-February, about 4 months. Chilly weather is experienced in the north, west, and northeast. The lowest average temperature is around 18 degrees Celsius. However, the central and eastern regions are only mildly cold, averaged around 21 degrees Celsius. In the south, especially on the eastern coast, there are heavy rains early in cold season. The climate is comfortably cool because of ocean breezes. The average temperature in cold season in the south is about 26 degrees Celsius.

Production of Major Agricultural Products

Thailand is one of the main exporters of agricultural products. Many of these products exported to global markets. The value of agricultural exports from Thailand is about 26% of the economy's total export values. The major markets for all agricultural exports, i.e. about 70% are ASEAN economies, Japan, the US and the European Union. Some information of main agricultural products is described about area, production and market as follow;

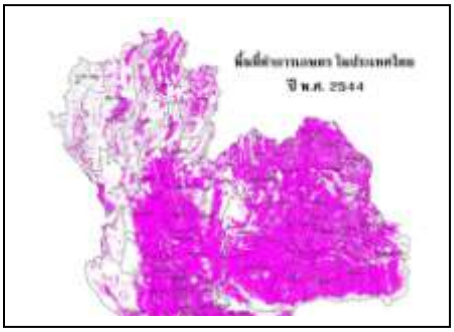
Rice

Rice is the food of half the world's population, which people have been cultivating rice for 5,600 years. Rice is the essential foundation of Thai society the source of Thai culture in its various aspects. This is truly a rice-based culture, rooted in rice cultivation as the FAO precisely pointed out in its slogan for the year 2004 as "Rice is life". When the economy developed and flourished, step by step, the production of rice was no longer just for consumption, but also for sale. Rice then became a product to be marketed abroad to earn more income for the economy.

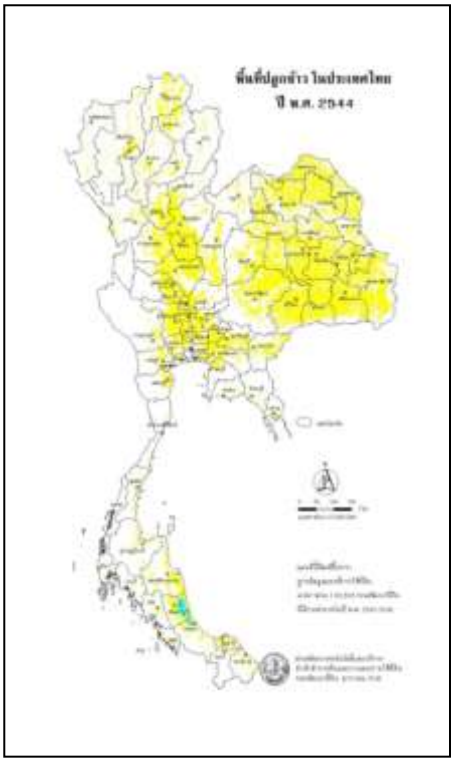
Rice is the major cash crop, grown just about everywhere in the economy, especially in the Central region, the North and the Northeast. In 2007 rice cultivation in Thailand covered around 11.23 million hectares, more than 50% of the total agricultural area. About 9.18 million hectares were devoted to growing major crop. The second crop was given only about 2.05 million hectares. About 32.1 million tons of paddy were produced for the first or major crop, 80% or 23.31 million tons.

The second crop represented around 20%, or 8.79 million tons.

Thailand has been and remains one of the biggest rice exporter. From 1999 to 2002, Thailand provided about 30% of the rice in world markets. In 2007, the economy exported 9.19 million tons of rice.



Agricultural land (20.85 m.ha)



Rice cultivation land (10.17 m.ha)

Cassava

Cassava originated in South America and spread from there throughout the world, In Thailand cassava was first cultivated in the south before spreading to the other regions. There are two types of Thai cassava. The bitter kind, which is called man paen, has high starch content. It is used to make cassava flour, cassava pellets and shredded cassava. The other type is called sweet cassava. It yields less flour than the bitter type, and has less hydro-cyanic acid. It boils faster and soften more completely, making it more suitable for direct consumption in sweets. Many familiar products made form cassava are MSG (monosodium glutamate), tapioca, sweeteners, biodegradable containers, citric acid and ethanol.

Today, the Northeast is the biggest producer of cassava. About 0.8 million hectares are under cultivation, around 50% of the economys’ whole area devoted to this crop. About 14.29 million tons of cassava is produced in the northeast. The central and northern regions rank second. The planted are about 0.3 million hectares, with production of 9 and 3 million tones, respectively. The whole area of cassava plantation in Thailand is 1.18 million hectares, with total production of 26.92 million tons. However area on cassava has steadily decreased since 1997. However, Thailand government set the target within 5 years (2010-2015) to intensively increase yield of cassava from

22.5 to 31.25 ton/hectare.

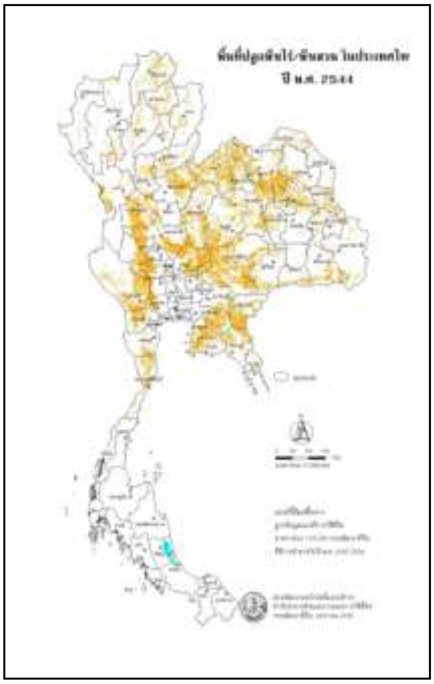
Approximately 22-25% of the total cassava production is for domestic consumption. And 17 -18% is consumed in powdered form. This is used industrially in food processing, in sweeteners, paper textiles, for example another 5-6% is processed as animal feed. The products take various forms as pellets, shredded, or as tapioca.

Sugarcane

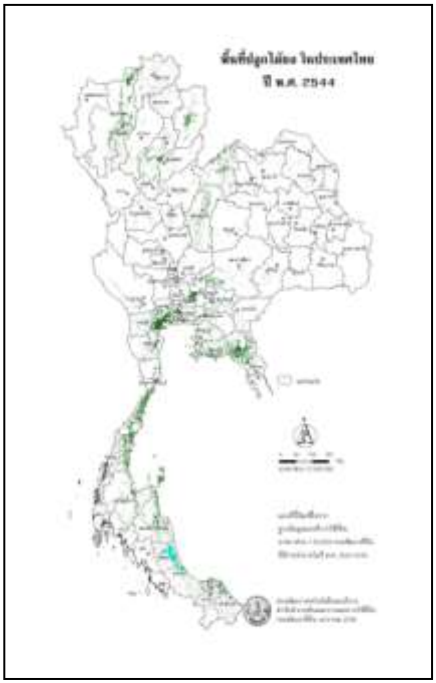
Sugarcane is the raw material from which sugar is obtained through processing. The first stage of processing yields brown sugar. Further processing results in its crystalline form. Unbleached crystals are popular nowadays, in addition to processed white sugar. Sugarcane is also an important raw material in the production of ethanol. In this case the Thai government has established the target to intensively increase yield of sugarcane from 63.69 to 93.75 ton/hectare within 5 years.

The cultivation of sugarcane increased steadily throughout 1987 to 2007. In 2007, about 1.01 million hectares were used for sugarcane plantation and produced about 64.37 million tons. Most of the area (0.48 million hectares or 40%) is in the northeast and about 30 million tons of sugarcane were produced. Next are the central and northern regions. The central region used to be the biggest producer of sugarcane. Today it has a bit smaller area planted in cane than the Northeast. The Central region produces about 22 million tons. The north has around 0.24 million hectares under cane cultivation to produce approximately 12 million tons.

Today, Thailand ranks the second in sugar exports to world markets. In 2007 Thailand exported 2.09 million tons. Moreover, raw sugar now becomes the raw material for ethanol production.



Crop cultivation land (4.36 m.ha)



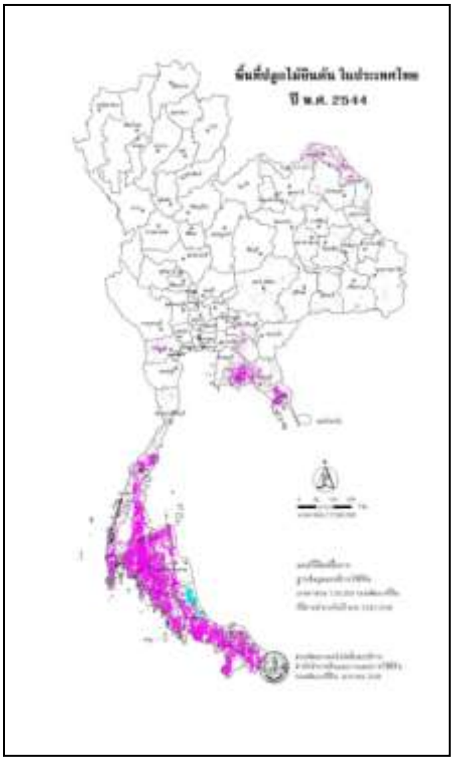
Fruit tree land (4.58 m.ha)

Para-Rubber

Para-Rubber is quite a big tree. It was indigenous in South America and were taken to be cultivated in Asia and Africa. In Thailand, para-rubber was firstly brought from Malayu into the economy to be planted in Kantang, Trang province since 1900. By 1908, rubber was also being grown in the Eastern region in Chantanburi province. Para-rubber cultivation later expanded to every part of the economy.

Para-rubber has been developed as an important cash crop for Thailand, in production and exports. The para-rubber cultivated areas cover 2.46 million hectares and produce 3.02 million tons. Most para-rubber are grown in the south and east. The government planned to expand para-rubber, plantation in 14 provinces of northeastern part about 0.12 million hectares are focused as well as in the north, where approximately 50,000 hectares have become para-rubber area in 7 provinces. Based on agriculture zoning and production as the primary criteria, the Ministry of Agriculture and Cooperatives selected suitable areas for planting para-rubber. Several projects were evaluated and promoted with an objective of increasing the income and stability of farm families.

As the exporter of rubber in world markets, Thailand earns more from exporting rubber and rubber products than from any other agriculture export. In the year 2007, Thailand exported totally 2.97 million tons of rubber and rubber products.



Tree plantation land (4.14 m.ha)

Resident area (0.74 m.ha)

Oil Palm

Before 1977, the cultivation of oil palm in Thailand was relatively limited. After the commercial plantations expanded from 0.11 million hectares in 1977 to 0.31 million hectares in 2002, and 28-fold increase in 25 years. In 2007, area of oil palm plantation increased to 0.51 million hectares. The south and the east are the major cultivation areas where the climate is hot and humid oil palm thrives in such conditions. Palm oil price is rather low when compare to other vegetable oils and has a variety of uses. Industrially, palm oil can be processed for consumption or use in food preparation in the production of margarine. Palm oil can also substitute such other kinds of vegetable oils as coconut oil.

Krabi has the largest growing area. About 38% of the total cultivated area of the province is planted oil palm. Other cultivated areas are in Surat Thani, Chumporn, Satun and Trang. Nowadays, oil palm plantations have expanded to the eastern part of the economy in Rayong and Chonburi. Since oil palm gives a better return than para-rubber or rice, as a result, farmers tend to grow more and more oil palm. Besides, the global warming is become a big concern of among economys, the Thai government, in response to that, enhances to increase both area and yield of oil palm to be the source of biofuel, and launches the 5-year-strategy plan (2010-2015) to increase oil palm yield from 16.2 to 18.75 ton/hectare.

Palm oil in Thailand is mainly consumed within the economy. Even the price of palm oil in the world market is very competitive, only some are exported. Domestic consumption of palm oil is scattered through different groups of consumers. It is directly consumed as cooking oil (65%) and is used in other industries (35%) to produce food, soap, pharmaceuticals and cosmetics. It is also used in the tanning and food industries, and to make lubricants for textiles and smelting machinery.

Agricultural Land Resources

1. Land use in agriculture

Thailand covers an area of around 51.4 million hectares. In 1997, forest areas covered 25% of the economy’s land area of which 41% were agricultural holding land. Non-agriculture land including cities, rivers, highways, airports, etc., occupied about 34% of the total. However, Thailand’s use of land resources has changed slowly over the years. In the past 40 year period, the economy’s forest area reduced from about 58% to 25%. Forested areas have been transformed to serve the purposes of agriculture and housing to create water reservoirs and to accommodate various infrastructure projects. Area devoted to agriculture has expanded about twofold. At the same time, areas being used for other than agriculture have expanded by more than 50%. However, in 2007 rice paddies accounted for 49% of the economy’s agriculture holding land. Field crops accounted for 21% fruit-trees and timber for 22%, housing for about 3% and vegetable and flower gardens, pastures and idle land etc., altogether accounted for about 5% of the total agriculture land area.

North: mountainous ranges with abundantly forest resources surround the upper north, while the lower area is a high plain. In lower north area, lowlands are mainly occupied by paddy field, and uplands by maize, beans and cotton. Suitable climatic condition to farming in the upper north provides farmers with a high potential for crop diversification. A number of nontraditional crops, particularly vegetables, cut flowers and fruits, have widely grown, which supported the upper north as an important exporter of such crops to the economy and world market.

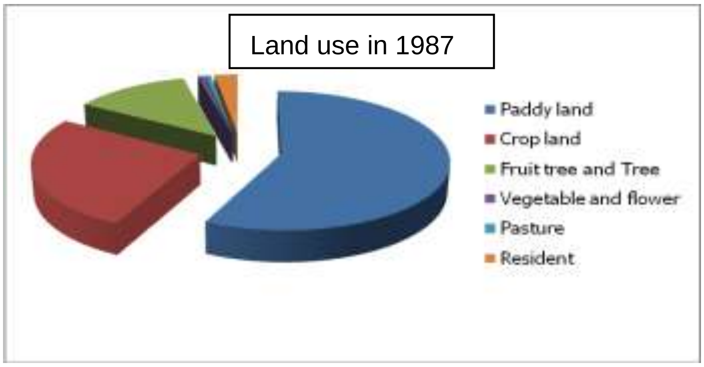
Northeast: northeast is the least natural resource endowment of the economy. Soils are low fertility and a large scale salinity area and erratic rainfall with long drought period limit the farming potential. Irrigated area is limited, only 10 percent of total farm land area of the region. Paddy land has occupied most lowland while cassava and sugar cane have mainly occupied the upland cultivated areas.

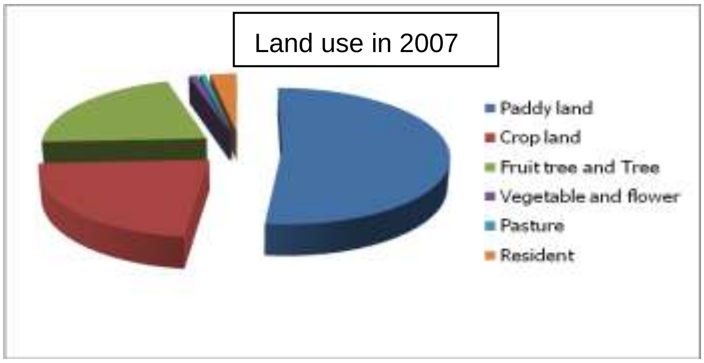
Central: lowlands are mainly occupied by rice fields, while uplands are mainly occupied by cassava, maize and sugar cane fields. Fruit trees and rubber plants have been mainly grown in coastal areas. The booming of shrimp export during the earlier 1990 heavily converted mangrove forests along seacoast to shrimp farming area. Agricultural production, particularly vegetables and flowers in low lands are highly diversified and intensified due to overwhelmingly advantageous factors of the region. Industrial land use has highly been agglomerated in and around Bangkok, its vicinity provinces and eastern coastal zone.

South: with the limit of lowland and high plain, most upland crops have been planted in hilly and mountainous areas. Uplands and hilly areas are mostly occupied by rubber and oil palm. Meanwhile, lowlands are covered by rice. Since the year 1990, substantial mangrove forest areas along the peninsular have been converted to shrimp farming, mostly by illegally occupation. Diversification of crop has been markedly apparent in fruit trees.

Agricultural land use changes in Thailand from 1987 to 2007

Land use types	1987	1992	1997	2002	2007
Agricultural land	20,992,420	21,128,193	20,977,217	20,942,722	20,846,515
Paddy land	11,547,067	11,013,699	10,671,304	10,419,915	10,168,180
Crop land	5,353,213	5,247,202	48,16,193	4,485,647	4,359,995
Fruit tree and Tree	2,559,919	3,335,915	386,1125	4,261,881	4,580,263
Vegetable and flower	120,553	141,076	1537,89	190,131	197,910
Pasture	133,987	119,954	114,983	142,241	181,133
Resident	502,445	553,848	560,884	584,432	577,600





The main cause of changing land use in Thailand is the increasing population, economic expansion, demand and supply of market, including price of products. Especially in field crop (cassava and maize), farmer utilized their upland for both crops depend on price of product. The farmer try to make the best possible use of their own natural resources to produce enough food for domestic consumption, and earn foreign exchange by exporting agricultural products as well.

Land use problems arise out of utilization and ownership. Unwise use of land has led to problems of soil erosion and degradation. Soil becomes leached out and infertile when soil surface was not covered by plant or residue, and some area faced the problem about saline soil, acid and acid sulfate soil, or has a low buffer capacity. In mountainous and slopping areas the soil is sandy or loamy and should not be used for agriculture without regard for conservation practices. This type of soil is not suitable for farming. At the same time, good farmland should not be wasted on non-agricultural purposes. In terns of ownership, there are various problems such as inadequate or total lack of ownership rights, landlessness. Tenancy and the renting of land lead to problems, as does the hoarding of idle land by individuals.

The government has policies and plans for various programs and projects aiming at proper land utilization, conserving soil and water, and improving deteriorated soil. The important measure is to implement agricultural zoning according to soil properties and land suitability. Financial and tax measures can be used to protect agricultural land, distribute land rights, and covert land asset-to-capital for farmers in order to use it more efficiently.

2. Assessment of land use

The information of the land use is essential for a number of planning and managing activities. The existing land use patterns, because their strong influence on how land can be used in future, become a crucial factor in deciding as to how land development, management and planning activities should be undertaken. Therefore, the information classification and the mapping of the land use is very important. The land use has to be planned and determined by all levels of the agricultural sectors. Satellite remote sensing is widely accepted as a technique to study land use and land cover changes. The use of satellite data for compiling the data of the changes of land cover is becoming a substitute for data derived from time consuming in ground survey. Better assessment of the changes of land cover by using digital analysis of remote sensing satellite data can help decision makers to develop effective plans for the management of land. The following analysis will quantify the changes that can be primarily observed with the use of available satellite images. Finally, the observed changes will be analyzed in combination with other sources of data in an attempt to offer causal explanations for the changes of land use. Most of the natural resources are directly or indirectly related to the surface cover in a given locality. Therefore, to maintain harmony among sustainable resources and socio-economic needs, land cover and land use studies should be dealt with care.

The assessment of land use and land cover is one of the most important factors for planning and managing activities concerning the use of land surface on this earth. Remote sensing techniques have improved mapping and interpretation of data as a means of understanding and effectively managing the present resources for sustainable development. The land classification and the stages of overlaying the results for three periods of time for the purpose of figuring out the areas which had caused the changes of the use of land during the last 23 years are in the focus. It was found that from 1981 around 95% of the total land was composed of agricultural areas for growing rice, different kinds of fruit and perennial trees, while less than 5 % of the land in the urban or the community areas was reserved for agriculture. For the use of land from 1995 to 2004, it was found that the urban and the community areas enormously expanded while the agricultural land and forests apparently decreased. According to the analytical interpretation by using supervised classification in the years 2000-2004, most of the areas around 75% were made up of cultivated areas, such as rice, crops and the output of the interpretation was very close to that of the visual interpretation.

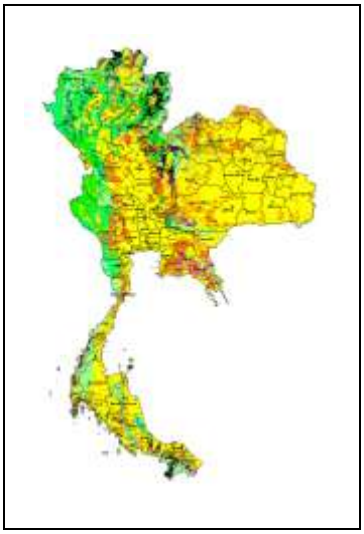
Nowadays, Land Development Department (LDD) accessed the digital data from SPOT-5 and LANDSAT-5, incorporated with aerial photo and ortho photo, applied with Geographic Information System (GIS) program. In 2000 LDD launched GIS to analyze land use zoning in 255 watershed areas. Establish soil suitability map at the scale of 1: 50,000 and the recommendation of appropriate soil management and follow up present land use to set up the national plan. Moreover, LDD established land suitability map for brackish water shrimp farming at the scale of 1: 250 000 in 41 provinces and a map of proper area for brackish water shrimp farming in coastal area at the scale of 1: 50 000 in 25 provinces. In the matter of GIS development, a government agency has developed its own computer network and linked data between its headquarters and local sites. As a result, farmers and the local staff will be able to use the data to solve their problems by one stop services. Moreover, in case of farmers and local staff potential development, the government agency has conducted training courses for the local staff as well as volunteer soil doctor and farmers to improve their efficiency in using high technologies to solve land use problems.

Management of Agricultural Land

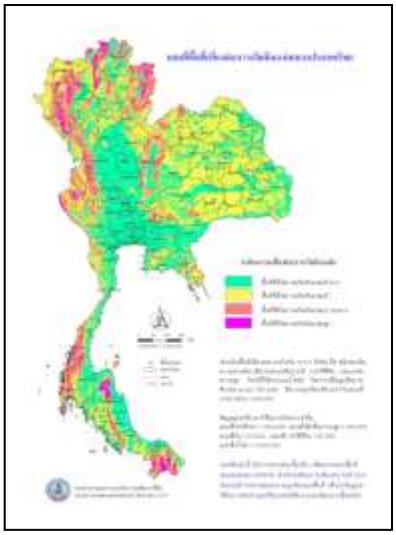
1. Soil and water conservation measures

Soil and water conservation measures are extremely important for arable area in the economy of which main occupation of the people is agriculture such as Thailand. This is due to losses of soil nutrients mainly by erosion process on the nuded area with no soil conservation measure applied.

Consequently, no more soil nutrients left for plant growth as erosion process go on continuously for a long period of time. This will result in poor crop production at the long last. It is not possible to exploit the land for producing crop anymore. The operation of soil conservation on upland and highland is being done by regional service centers throughout the economy. The soil conservation practices have been implemented both mechanical and vegetation measures. The most common of the former of soil conservation measure in the field terrace has been widely used in low slope area. Bench terrace is less common measure. Hillside ditches seem to be more potential. At present, various types of mechanical with vegetation practices are implemented.



Soil erosion map (LDD, 2002)



Land slide risk map (LDD, 2002)

Depletion of fertility in cropland is brought about by the combined action of many factors such as the removal of large amount of nutrient materials by annual cropping, losses of soluble constituents through leaching processes, and by the rapid rate of organic matter decomposition as a result of microbial activity in cultivated soils. In addition, the process of erosion is now recognized as one of the most serious forces in the rapid depletion of fertility and productivity of cultivated land. Moreover, the pattern of crop cultivation in upland and highland, such as the intertilled crops afford little protection to the soil so that erosion has proceeded. Rowcrops production especially on highly eroded land year after year without proper soil conservation, therefore cause serious erosion then the land will become unproductive.

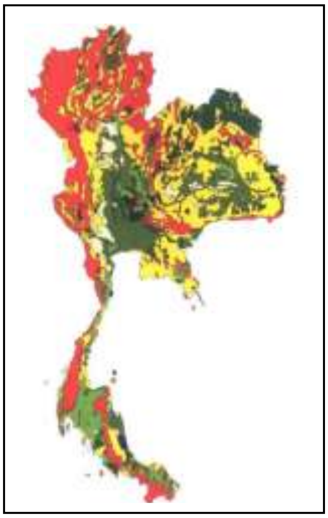
Soil conservation projects have been implemented for nearly 40 years. At their inception in the early 1960, soil and water conservation stations and units were set up throughout the economy, especially in the north and northeast where erosion was very serious. Initially, terracing was introduced as a free service to farmers, linked with ploughing their fields without charge. Farmers were willing to accept the new methodology due to the free ploughing service. Later they removed the terraces because of the reduced cultivation area. Today, however, some farmers have come to realize the long term benefits and accept some soil and water conservation measures and adopt them in their lands (especially in the north). The obstacles to accomplish such activities may be due to the lack of basic data and information needed for establishing appropriate soil conservation measures, local extension staffs do not allow for sufficient contact with farmers, approaches to farmers has been inappropriate measures, and the lack of adoption of soil and water conservation.

2. Organic matter and waste products

Some 36 million ha (70%) of total area can be classified as deteriorating areas with unfertile soils and limited plant nutrients. Similarly is approximately 31 million ha (60%) of lands are classified as areas facing a serious problem of low level of soil organic matter. Soil degradation is caused by loss of soil organic matter including the failure of implementation to maintain satisfactory organic matter levels. Soil organic matter plays a major role in soil functions and quality such as a source of nutrients, promotion of favorable soil physical condition, soil biotic population and plant nutrients absorption. These beneficial effects to soil organic matter imply that the maintenance of satisfactory level of organic in soils is essential for sustainable soil management. Organic recycling for soil improvement project was set up to serve the resolution of farmers poverty in rural area of Thailand. The project was conducted in 1982 until the present. Its implementation consists of training, program in compost making for farmers, field demonstration and extension of compost making and also green manure application and its seed production, and some research activities on organic fertilizers as well.

Organic fertilizer is recommended to increase crop yields. Some experimental results conducted in eastern and northeastern Thailand showed that the application of organic fertilizer combined with chemical fertilizer would appropriately raise the crop yield. Compost can reduce environmental problems due to agricultural waste and industrial waste products by means of recycle processing from raw materials to organic fertilizer, reduces burning of rice straw in paddy fields and decreases bad odor, insects and pathogens from organic garbage, diminishes environmental problems from various kinds of industrial waste such as bagasse, distillery waste, filter cakes from sugar factories and wastewater from canneries. Making compost from water hyacinth can solve water pollution due to concentrations of water hyacinth clogging canals, rivers and other waterways. Compost can maintain the balance of environmental ecology system.

Saline soil map (LDD, 2005)



Soil organic matter map (LDD, 2000)

3. Saline soils management

Improvement measures are mostly applied in slightly and moderately saline areas. Adopted technology packages, e.g. salt-tolerant plant varieties, compost, organic matter, green manure, and soil amendment are used to improve soil properties and increase yields. Then 2 major measures as prevention and improvement or reclamation were implemented in salt-affected areas.

Prevention and reclamation measures are used in strongly saline soils areas. In the Northeast where strongly salt-affected soils occur, biological control as reforestation which include screening of suitable salt-tolerant varieties of plants with deeper rooting system and high consumptive use of water are recommended to prevent spread of soil salinization. These plants have been grown in recharge areas to reduce amount of excess water that percolated to the water table. This lowers the saline groundwater table to the depth that capillary rise will not bring saline water up to the soil surface. Reforestation minimized salt-affected area in the project site by a proportion of 5:1.

In the coastal areas where saline soils are formed from marine or brackish water sediment and subjected to inundation of sea water or brackish water during high tide, constructing of dykes or polders has been recommended to prevent the encroachment of sea water or brackish water and to leach salts from root zone with rainwater or water of lower salt concentration.

Environment becomes important in terms of soil salinization problems. Although inappropriate landuse such as salt-making and brackish water shrimp farming give farmers high profit, they can cause serious impact on adjacent areas and the environment. This includes the reduced capacity of the land to provide long term economic value, the increased investment cost and the problem of soil and water management. In the northeast, inland saline soils are constantly expanding. Inappropriate land use results in soil salinization from the movement of saline water, and reduction of arable land and forest areas.

4. Integrated land resource with area participation

Develop systems of technology transfer and public relation, land development service, soil data, and land utilization for the target group. Technology transfer will be done through the centre of agricultural technology transfer of each sub district: giving soil data, developing arable land for sustainable agriculture. Each activity will be conducted by using GIS technology.

Develop land information and GIS systems throughout the economy as one-stop service centers; improvement of working system and development of capacity building by: supporting private sector and educational institutions to participate in government activities; and training government officials to use new technologies of administration, technique and operation concerning their job; reorganization by decentralizing some of officers to work in local area to support and strengthen the work of the local stations. The development plan also emphasizes on the balance between the utilization and the rehabilitation of natural resource which leads to sustainable natural resource utilization. It is expected that, in the year 2006, soil erosion problem area will be decreased at least 0.8 million hectares, and the area of acid soil, saline soil as well as low fertility soil will be rehabilitated at least 1.6 million hectares.

Agricultural land use often results in land degradation and the reduction of productivity. Degradation of land results in loss of current income and increase the risk and also threaten prospects for economic growth. Despite relatively low average return to agriculture, the costs of degradation, and thus the benefits of conservation, are substantial. However, there are methodological problems in estimating cost and benefit of soil and water conservation on regional or national level.

In order to gather participation from communities, LDD has established a unit called “Soil Doctor” to help farmers afford and apply the new technology in soil and water conservation and soil improvement in their fields. So that farmers can make better use of their land area, increase their income by increasing crop production, preservation and improve soil quality. In addition, soil and water conservation demonstration villages have also been set up as the pattern for farmers to adopt on their land. LDD has launched participation project on training of agriculturist, information technology services to small districts, to increase of agricultural productivity and the development of soil and water resources in rural areas. Participation from farmers and local people is required in such projects especially on the part of spreading the recommendations and information of LDD. “Soil doctors” have been established since 1995 in order to increase the efficiency of the activities of LDD. All soil doctors are volunteers, who are in charge of coordinating of land development among farmers in the village, transferring new technology to their neighbors and participating in some activities of LDD. They are all volunteer and representatives of LDD in their villages who give farmers a better understanding of soil management and follow up land development practices. They also are trained how to use soil maps (1:50,000) by LDD and show farmers the soil distribution suitable for various crops using soil map and some posters. With the soil NPK test kit, they are able to examine soils on farms around their villages, and give local farmers basic recommendations about fertilizer management. They are the messengers in distributing the information about land development from LDD to the villagers, and sometimes transferring messages regarding land use problems from the farmers to LDD. According to farmer’s requests, LDD constructed demonstration plots to solve problems of saline soil and acid soil, gave information on methods about a better use of organic fertilizer and provided some seeds for soil conservation.

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Study on Impact Evaluation of Regional Arable Land Change on Food Crops Productivity

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Abstract: This research is innovative in such aspects as research content, method and so on. Authors took Northeast China as study area, with the help from “3S” technology and based on spatial and temporal land resource data, agricultural statistics data and considering the natural and socio-economic factors. And, this paper analyzed the impact of cultivated land change on the grain production capacity within this region in terms of cultivated land quantity, cultivated land quality, crop structure etc. The natural resources, cultural structure and social-economic conditions among different regions may have great difference, the natural and social-economic factors will have different influence on the grain-production in different regions, and this proves that it is important to manage cultivated land resources based on regionalization. In the last few years, the peasants have increased the input amount on the cultivated land, such as the fertilizer and the plastic film, this caused the different influence on the cultivated land quality in the Northeast China. Under the above-mentioned background, this paper analyzed the cultivated land quality information in the Northeast region. The method was to explore the natural quality grading and utilizing quality grading on cultivated land respectively through the natural quality grading indicators and utilizing quality grading indicators system. Then we divided the whole region into high-yield cultivated land, medium-yield cultivated land and low-yield cultivated land based on grain yield per unit, correlation was analyzed between natural quality grading of land and grain yield per unit area, also between utilizing quality grading of land and grain yield per unit area through GIS method. In a word, this paper can provide help to sustainable utilization and management of cultivated land resource in this area, and give the useful method for the similar research.

Key words: Cultivated land change; cultivated land quality; grain productivity; GIS; northeast China

1. Introduction

The cultivated land resource is the foundation for human beings' existence and development. The quantity and quality changes of cultivated land resource will inevitably cause the fluctuation of food supply. When in a certain region with the same environment background, same social economic development level, and the same technology conditions, the cultivated land use change would influence the food production capacity mainly in such aspect: the acreage, the environment, and the level of food production. The demand for agricultural products is increasing due to the growing population, so the food production and the food security become a hot issue that was concerned by the government as well as the academe here in China. Therefore, to analyze the quantity and quality changes of the current regional cultivated land resource, and to research the influence of food production caused by cultivated land use change would make important theory and real meaning.

There were so many profound and comprehensive researches on the dynamic monitoring of quantity change of cultivated land resource abroad, and the researches on assessment of cultivated land resource had made great progresses. In general, cultivated land resource assessment had developed to the “resources value management assessment system integrated with human and land”, which comprehensively considered the natural, economy, and society. That was no longer being bounded in the research on the land’s natural state, such as: measuring the acreage and the production of the cultivated land, researching soil properties, surveying fundamental productivity and so on. Some quantitative studies on the quality changes of cultivated land limited to the qualitative description, because it was difficult to acquire the data, or because the cost was really high. Some were based on the sufficient soil nutrient monitoring data to make quantitative evaluation to the changes on regional soil fertility, still lacking the quantitative evaluation on the spatial distributing change of comprehensive quality of cultivated land. Regarding the arable land use change, studies in Europe and America focus on quality of land and influence of food production caused by ecological environment change. Meanwhile, some of the domestic studies paid more attention to influence of food production caused by arable land change in quantity. However, the quantitative studies on the influence of regional food production caused by the integrated quantity and quality changes of cultivated land are comparatively less. On the research methodologies, there were a lot of domestic studies made use of the statistic data to do the correlation analysis between grain production, grain yield per hectare and cultivated land area, grain planting area. However, the research fruits are still not deep enough to reveal the correlation between the spatial distributing change of cultivated land and the food production capability. This paper takes the northeast China as example; making use of the advantage of the “3S” technology, acquiring the cultivated land data of temporal and spatial variation by the use of remote sensing technology, exerting the ability of spatial analyze of the GIS, then combining with the agriculture statistical data, creating a assessment system of cultivated land which has different indicators, to study the influence of food production capability caused by the quantity and quality changes of regional cultivated land. The main aim of this paper is to make further study on the sustainable utilization and administration of regional cultivated land, to establish the scientifically rational food production developing plan, to improve the theory and method of regional cultivated land resource assessment, then to provide reference for similar studies in other areas.

2. Study Area

Northeast area (including Liaoning, Jilin and Heilongjiang provinces) lies between 38 °43' to 53 ° 30' northing, and 115 °20' to 135 °easting. The total area is $79.18\times104km^2$, with a total population of 1.05×10^8. Being surrounded in three sides by big mountains, about 55.8% of the area is plain. The area locate in the temperate zone with continent monsoon climate, winter is long and dry with the extreme low temperature; summer is short ,but warm and rainy, that is to say rain in hot season. In the major agricultural areas, the annual accumulated temperature(≥10 ℃) is 2200~3600℃, the average annual precipitation is 400-1000mm, and the total water resources is 973.2×10^8m3. The northern and eastern have sufficient water resources, but the south and western is in short of water resources. There is an alternative variation in high and low water period. The illumination resources is abundant, the total amount of radiation per year reaches as high as 4100~5400MJ/ m^2, which is suitable for crop production. The 16.55% of the total cultivated land of China lies in this area, the soil is mainly composed by black soil type, such as black soil, meadow soil, chernozem, planosol, and dispersed with some bog soil, dark brown soil and paddy soil. Cultivated land in northeast area mainly distributed in Sanjiang Plain, Songnen Plain of Heilongjiang province, and north part of Songliao Plain of Jilin province, as well as some platform that located in front of the mountain. The institution of grain plant is food-soybean rotation with one crop per annum. The area is an important agricultural production base in China, also is a region with the highest rate of per capita grain and commodity grain.

The trend of cultivated land conversion was obvious in northeast area these years. The natural factors, overreclamation and exorbitance of resource development have made serious loss of soil and water, decrease of some part of the black soil resource, decline of the soil fertility. The food production is affected by such changes in a certain extent.

3. Materials and Methods

3.1 Data collection

This paper uses the administrative division data, the harvesting data of yield per unit based on household survey, the land use data in 1993 and 2003 based on TM images, and natural environment data of DEM, slope, slope orientation, precipitation, hazard rate, as well as social economic statistic data. All the data are come from the “database of resource and environment of northeast area”, the outcome of the “assessment and early-warning of the influence of regional cultivated land change in China”, supported by scientific research institution social welfare of Ministry of Science and Technology of China.

3.2 Field Soil Sampling and Analysis

This research is basing on the data of the secondary soil survey and the data of soil fertility monitoring, considering the distributing character of soil type and topographical pattern, adopting the sampling method of reticular uniform in 2005, with the 10km×10km sampling interval, using the GPS to position the sample’s field location, then adjusting the sample’s field location according to the soil map of northeast area and actual conditions of topography and geomorphology, supplementing samples properly in the hill and mountainous region or between different soil types, to make the representative more comprehensive in the space. Every sample was selected according to the method of agrochemical samples, choosing 3-5 spots in an area diameter of 10m, by the quarter method. The research has acquired the total amount of 742 spots in the 0-20cm surface soil mixed samples, then recorded the samples' actual coordinate of latitude and longitude, soil type, crop type, crop yield prediction, fertilizing management, cropping system, topography and geomorphology, irrigation condition, farmland facilities. The survey asked the local farmers to give qualitative descriptions to the condition of the cultivated land of sampling area as well as non-sampling area, then ranking according to the quality, using it as the basis to test the grading result.

Soil nutrients system evaluation method (ASI) was adopted to study the soil samples, then to acquire the chemical tests data of soil nutrient, such as pH, organic matter, nitrogen, phosphorus and potassium, soil salt content.

3.3 Data Processing

The study use Kriging method of GIS and the new Co-Kriging method to generate a 1000m×1000m spatial distribution map which contains the information of pH, organic matter, nitrogen, phosphorus and potassium, soil salt content and precipitation, based on the surveyed sampling soil fertility data and the meteorological stations' precipitation data.

Limited to the soil sampling method, the space contributing data of soil fertility acquired by the use of Kriging method, which was just mentioned above, cannot totally reflect the land's real condition, so we adjusted it by the use of geomorphological type data and soil type data. Take the organic matter as example to illuminate the main process of correction of soil type data: (1) Overlay the 1:1,000,000 soil type figure with the sampling distributing map, calculating the average value of the soil organic matters of the samples which were located in a single soil type patch, then to generate the raster data of average value of the soil organic matters in 1000m×1000m, based on different soil type (hereinafter referred to as layer1); (2) Overlay the soil type figure with the soil organic matter spatial distribution map acquired by Kriging method, to generate the raster data of average value of the soil nutrient, based on different soil type (hereinafter referred to as layer2); (3) Using the spatial analysis module of GIS, calculating the ratio of layer1 and layer2, to generate the ratio distribution map (hereinafter referred to as layer W); (4) Multiplying layer W with the soil organic matter spatial distribution map acquired by Kriging method, to generate the adjusted spatial distribution data of soil organic matter. The correction of landform data is the same with the process mentioned above, Take the organic matter as example to illuminate the second correction after the soil type adjustment: (1) Using GIS to calculate the average value of the soil organic matters of the samples which were located in a single geomorphological types patch, then to generate the raster data of average value of the soil organic matters in 1000m×1000m, based on different geomorphological type (hereinafter referred to as layer A); (2) Overlay the scanned geomorphological type maps with the soil organic matter spatial distribution map acquired by Kriging method, to generate the distributing map of average value of the soil organic matters, based on different geomorphological type (hereinafter referred to as layer B); (3) Using the spatial analysis module of GIS, calculating the ratio of layer A and layer B, to generate the ratio distribution map (hereinafter referred to as layer P); (4) Multiplying layer P with the soil organic matter spatial distribution map acquired by Kriging method, to generate the adjusted spatial distribution data of soil organic matter.

Using the social and economic statistic data such as irrigation area, grain crop sown area, fertilizer input, rural labor, used amount of plastic film, rural electricity consumption and nationside power consumption etc. that based on the “database of resource and environment of northeast area” to calculate the indicators such as guarantee degree of irrigation of each counties(irrigation area/ grain crop sown area), fertilizer input per Mu(fertilizer input/ grain crop sown area), mechanization degree(rural labor/ nationside power consumption), used amount of plastic film per Mu, rural electricity consumption per Mu and etc; Link the attribute data and the county administrative division to generate vector data by GIS, then transfer it to raster data in 1000m×1000m. Using the average value of rural electricity consumption, mechanization degree, fertilizer input per Mu, used amount of plastic film, to reduce the instability brought by the annual fluctuation of each indicators. Applying the social economic input data of each soil samples acquired by field investigation record, the geomorphological type data and the soil type data to adjust the average social and economic raster data of each county, the correction method is the same as above, so it is unnecessary to go into detail.

Acquire the slope map and aspect map in 1000m×1000m from DEM. Hence, all the raster data are 1000m×1000m, so we can assess the quality of cultivated land by the evaluation unit of 1000m×1000m.

3.4 Methods

This paper analyzed the quantity change of the cultivated land in this decade; then made assessment on the natural quality, utilization quality, comprehensive quality of cultivated land respectively, with the comprehensive consideration on natural and social factors. The paper analyzed the relationship between unit area grain yields with natural quality and utilization quality, studied the special distributing changes of cultivated land’s quality that caused by the quantity change of the regional cultivated land; and finally, analyzed the influence of food production capability caused by the comprehensive action of cultivated land use changes.

Table1 cultivated land natural grading indicators and their weight

Indicator layer	Weight of indicator layer Q_i	Single index A_j	Weight of single index P_j
Natural environment	40.62	AltitudeA_1	11.18
		Aspect A_2	10.83
		Slope A_3	17.95
		Precipitation A_4	25.42
		Accumulated temperature($\geq 10^{o}C$) A_5	29.81
Soil	43.93	Hazard rate A_6	14.24
		pH A_7	14.37
		Organic matter A_8	31.02
		Available P A_9	15.01

Indicator layer	**Weight of indicator layer Q_i**	**Single index A_j**	**Weight of single index P_j**
		Available K A_{10}	14.37
		Available N A_{11}	16.99
		Surface soil salt content A_{12}	17.66
Infrastructure	15.45	Guarantee degree of irrigation A_{13}	81.14
Total	100		300.00

According to "assort and grading regulation of national agriculture land use", an industry standard promulgated by the Ministry of Land and Resources 2001, and based on the fundamental productivity, utilization and cultivated land's comprehensive quality, this paper created indicators systems of cultivated land, including natural quality, utilization quality and comprehensive quality. Applying the division method of yield grade, divided the cultivated land into high yielding land, medium yielding fields and low yielding fields, which was based on the yield per unit area, then to analyze the relationship between unit area grain yields with natural quality and utilization quality.

This paper composed the natural quality with natural environment, soil and infrastructure, composed the utilization quality with social economic input and administrator factors, when created the indicators system of natural quality and utilization quality. Based on referencing internal and overseas researches, combined with the characteristic of the area and the experts' opinion, and under the principle of dominance, region, universality, spatial variability and maneuverability, the research confirmed 13 indicators concerns natural environment, soil and infrastructure which will influence the quality of cultivated land (according to table 1). The study using the grey relevant degree method to analyze relationship between unit area grain yield and the fertilizer input, effective irrigation area, used plastic film amount, when selecting the social economic indicators, and use the mechanization degree, fertilizer input per Mu, used amount of plastic film per Mu and rural electricity consumption to compose the indicators system of assessment of cultivated land use quality (according to table 2).

Table2 cultivated land utilizing grading indicators and their weight

Single index B_n	**Weight W_n**
Mechanization degree B_1	23.82
Fertilizer input per Mu B_2	37.50
Used amount of plastic film B_3	20.83
Rural electricity consumption B_4	17.85
Total	100.00

The cultivated land's comprehensive quality is integrated by cultivated land's natural quality and utilization quality (according to table 3).

Table3 cultivated land comprehensive grading indicators and its weight

Indicator layer	Weight of indicator layer
Natural quality of cultivated land	70
Utilization quality of cultivated land	30

The paper applied the Delphi method to confirm the indicators' weight of cultivated land's natural quality and utilization quality. In order to acquire a better assessment result, 23 experts in different research field such as soil science, agronomy, agricultural economic management, geography, regional economics, ecology, environmental science were invited to weight the indicators. According to the experts' opinions, combined with the referencing internal and overseas researches, as well as the characteristic of cultivated land use in northeast area, a final weighted indicators system of natural quality and utilization quality assessment of cultivated land use in northeast area were acquired. The weight of comprehensive cultivated land was calculated by the combined contribution rate of natural quality and utilization quality.

Applying the comprehensive index method to standardize the assessment element data by GIS:

$$S = \sum_{i=1}^{n} W_i P_i$$

The indicator layers of natural quality, utilization quality and comprehensive quality of cultivated land, which covers the completely northeast area, were acquired. Using the natural breakpoint method of ArcGIS, combined with experts' advices, data of unit area grain yield, as well as the distribution of the value of each assessment factors to do the adjustment, then to divide the comprehensive indicator layer into 5 levels(according to table 4). The graded distribution maps of natural quality, utilization quality and comprehensive quality of cultivated land 1993 and 2003 were acquired respectively, by the superposition and extraction with the cultivated land data from the cultivated land use data in 1993, 2003, and the graded distribution maps mentioned above.

The grade of natural quality of cultivated land mainly reflected the difference of natural condition and infrastructure of the cultivated land. The first grade is the high stable yield farmland, which have the high fundamental productivity and almost no limiting factor. The second grade have the comparatively high fundamental productivity but with some of the limiting factors, such as limited irrigation conditions in Liaoning province; soil salinization in Jilin province, the low accumulated temperature and frequent natural disasters in Heilongjiang province. The fundamental productivities of third grade, forth grade and fifth grade were decreased systematically, they were limited by one or more factors, such as accumulated temperature, slope, soil nutrient, soil salt content, natural disasters, irrigation conditions and so on. It calls for us to make effort to improve its imperfections.

The quality grade of cultivated land use mainly reflect the different yield increasing effect which caused by factors of input and administration. The input and administration level of the first grade to the fifth grade were decreased systematically.

The comprehensive quality of cultivated land reflects the comprehensive productivity of regional cultivated land, with the combined effect of natural quality and utilization quality of cultivated land. The unit area grain yields in this decade were: 5225.82 kg/hm^2 in the first grade, 4780.23 kg/hm^2 in the second grade, 4277.12 kg/hm^2 in the third grade, 3515.46 kg/hm^2 in the forth grade, 2364.08 kg/hm^2 in the fifth grade.

Using the GIS software to calculate the correlation coefficient between unit area grain yields and natural quality and correlation coefficient between unit area grain yield and utilization quality, then to analyze the relation between natural quality, utilization quality and unit area grain yield. Overlay the graded data of comprehensive quality of cultivated land in 1993 and 2003 by GIS, to analyze the spatial distribution feature of comprehensive quality of cultivated land.

Table 4 Grading standards of natural grading land, utilizing grading land and comprehensive grading land

Graded cultivated land	Natural grading land	Utilizing grading land	Comprehensive grading land
First grade	>0.60	>0.77	>0.56
Second grade	0.49~0.60	0.58~0.77	0.45~0.56
Third grade	0.39~0.49	0.41~0.58	0.34~0.45
Forth grade	0.28~0.39	0.23~0.41	0.23~0.34
Fifth grade	<0.28	<0.23	<0.23

The assessment based on: (1) the influence on grain planting area caused by quantitative change of cultivated land; (2) the variation analysis of unit area grain yield in high, medium and low yielding land, (3) the influence on total yields of grain caused by quantitative change in the inner of the high, medium and low yielding land, (4) the influence on food production capability caused by the comprehensive effect of quantity and quality spatial distributing change of cultivated land. These are the basic steps: The first step was based on cultivated land use change monitoring and the analysis of spatial distribution change of comprehensive quality of cultivated land caused by cultivated land quantitative change, acquiring the unit area grain yield of this recent three years near the samples by household survey, regarding the average yield of this three years which near the soil samples as the sample’s unit area grain yield, using ArcGIS to form the map of unit area grain yield; then taking average of yield of the sample which contained in one cultivated land grade, to calculate the average yield of each cultivated land grade. The second step used the agriculture statistic data, to calculate the average unit area grain yield of each county in this decade, using the average unit area grain yield of each county to acquire the special distribution map of unit area grain yield, transfer it in into the raster data in 1000m×1000m, then to calculate the average unit area grain yield of each area. The third step combined the data acquired by household survey and the agriculture statistic data, to adjust the average unit area grain yield of each cultivated land grade, then acquire the final average yield. The final step was to analyze the change of total grain yields in northeast area, by the cultivated land use change data of each grade and the average unit area grain yield of each cultivated land grade.

4 Results

The cultivated land in northeast area have increased from 2455.9×$10^4$$hm^2$ in 1993 to 2644.7×104hm^2 in 2003, the increased area was 188.8×$10^4$$hm^2$, the new increased account for 7.69% of the total cultivated land. Although the total amount of cultivated land have increased in this decade, but the situation was differed from these three provinces. Liaoning province has decreased the cultivated land from 585.4×$10^4$$hm^2$ in 1993 to 571.4×$10^4$$hm^2$ in 2003, the decreased area was 14×$10^4$$hm^2$; Jilin province has decreased the cultivated land from 609.1×$10^4$$hm^2$ in 1993 to 589.3×$10^4$$hm^2$ in 2003, the decreased area was 19.8×$10^4$$hm^2$; Heilongjiang province has increased the cultivated land from 1261.4×$10^4$$hm^2$ in 1993 to 1484.0×$10^4$$hm^2$ in 2003, the increased area was 222.6×$10^4$$hm^2$, the new increased account for 17.64% of the total cultivated land.

The analysis reflects that there was obvious regional difference in the cultivated land use change in northeast area. The increased area mainly distributed in the east of the Sangjiang Plain, the west of the Songneng Plain, and the mountain area in the Daxing'an and Xiaoxing'an Mountains in Heilongjiang province. The decreased area mainly distributed in the mountain area in southwest Liaoning province, plain area in middle Liaoning province, and the Songneng Plain in Jilin province. And the general trend is obvious that increase in north but decrease in south.

The natural quality and the comprehensive quality in the research region are mostly at the middle or high middle level, the cultivated land inputs are mostly at the middle or low middle level(according to Table 5, Table 6). The spatial difference of cultivated land was obvious due to the spatial difference of the natural quality, input, and production conditions in each region. Generally speaking, the plain area is better than mountain area, the south is better than the north. The light, heat, water, soil condition was not cooperating so well in the northeast area. Cultivated land mainly distributed in the plain area, slope farmland accounted for a little amount. There was a restriction of heat conditions in the north area, the light and temperature potentiality in that area was really low. The water resource in the south area was relatively deficient. Part of the area was disrupted by the frequent natural disasters such as chilling damage, flooding, drought and frost.

Table 5 Area of natural grading land, utilizing grading land and comprehensive grading land(1993) unit：×$10^4$$hm^2$

Graded cultivated land	Natural grading land	Utilizing grading land	Comprehensive grading land
First grade	299.89	106.21	277.44
Second grade	656.40	449.28	623.25
Third grade	811.02	679.99	808.36
Forth grade	587.51	933.39	604.33
Fifth grade	101.17	287.14	142.62
Total	2456.00	2456.00	2456.00

Table 6 Area of natural grading land, utilizing grading land and comprehensive grading land (2003) unit：×10^4hm^2

Graded cultivated land	Natural grading land	Utilizing grading land	Comprehensive grading land
First grade	297.28	109.84	275.51
Second grade	689.80	444.90	633.37
Third grade	870.85	706.46	872.30
Forth grade	668.25	1055.33	680.76
Fifth grade	118.52	328.18	182.76
Total	2644.70	2644.70	2644.70

Division of the high yielding, medium yielding and low yielding cultivated land in northeast area. Based on the different unit area yield, adopting the yield grade division method, the research divided the cultivated land into high yielding, medium yielding, and low yielding land. The procedure takes as follows: based on the average unit area yield of each county in this decade, to divide the cultivated land in northeast area into high yielding land (>5085 kg/hm^2), medium yielding land (2070～5085 kg/hm^2) and low yielding land (<2070 kg/hm^2), by the use of natural breakpoint method of GIS.

Correlation analysis between natural quality, utilization quality and unit yielding. The correlation coefficient between utilization quality and unit yielding in high yielding land is lager than the correlation coefficient between natural quality and unit yielding, the same as medium yielding, but the correlation coefficient between utilization quality and unit yielding in low yielding land is nearly equal to the correlation coefficient between natural quality and unit yielding (according to Table 7, Table 8)

Combined with the spatial distribution of topography and geomorphology, soil, climate; the data of agricultural regionalization and the literature material of agriculture regional development, the study found that: high yielding land mainly distributed in the plain agriculture areas in the middle of Liaoning province, the plain agriculture areas in the middle of Jilin province and the Sangjiang Plain in Heilongjiang province;. Medium yielding land mainly distributed in the coastal agriculture areas, the eastern mountains agriculture areas, the western low mountains agriculture areas in Liaoning province; and the western plain farm and pastoral areas, Changbai Mountains' forest farm areas in Jilin province; and the Songjiang Plain, Zhangguangcai ling and Laoye ling mountains, Nengjiang Plain, Sangjiangdi Plain and Kebai mountains areas in Heilongjiang province. The high and medium yielding land has the relatively stable production, because of the superior natural conditions, flat surface relief, and convenient traffic, advanced water and soil conditions, high soil fertility, and so on. The variation of production on high and medium yielding land mainly depended on the social and economic input. And the high yielding lands mainly are the agricultural production bases which have high agriculture produces benefit; it stimulated the farmer's enthusiasm, so the farmers are willingly to spent more material, scientific input and more times to administrate the high yielding land. However, the low yielding land mainly distributed in the coastal agriculture areas in Liaoning province, eastern half-hill forest farm area and Changbai Mountains' forest farm areas in Jilin province, Songjiang Plain, Sanjiang platform, Xiaoxinganling in Heilongjiang province. The cultivated land' natural quality is relatively low, because of the inferior natural conditions and environment deterioration: low accumulated temperature, severe natural disaster, soil salinization, serious soil and water loss, it not good for crop's growth. And if confront with the disaster situation, the production will decrease dramatically. So the natural quality effects heavily on unit area grain yield. It costs a lot to disaster-resistance, and the quality of low yielding land is difficult to be improved in a short time, so the farmers' enthusiasm is really low.

Table 7 Relationship between cultivated natural grading land and Grain yield per unit area, cultivated utilizing grading land and Grain yield per unit area in 1993

		correlation coefficient	regression equation
High yielding	Natural quality	0.054	Y=0.040X+0.707
	Utilizing quality	0.537	Y=0.401X+0.495
Medium yielding	Natural quality	0.101	Y=0.085X+0.372
	Utilizing quality	0.533	Y=0.304X+0.281
Low yielding	Natural quality	0.211	Y=0.105X-0.013
	Utilizing quality	0.314	Y=0.088X-0.008

Table 8 Relationship between cultivated natural grading land and Grain yield per unit area, cultivated utilizing grading land and Grain yield per unit area in 2003

		correlation coefficient	regression equation
High yielding	Natural quality	0.061	Y=0.044X+0.703
	Utilizing quality	0.540	Y=0.402X+0.494
Medium yielding	Natural quality	0.123	Y=0.106X+0.359
	Utilizing quality	0.538	Y=0.319X+0.272
Low yielding	Natural quality	0.211	Y=0.101X-0.012
	Utilizing quality	0.321	Y=0.089X-0.009

The comparative analysis of 1993 and 2003 shows that, the correlation coefficient between unit area grain yield and natural quality in high and medium yielding land has raised, the correlation coefficient between unit area grain yield and natural quality in low yielding land is nearly no change; the correlation coefficient between unit area grain yield and utilizing quality in high yielding land is not changed, the correlation coefficient between unit area grain yield and utilizing quality in medium and low yielding land has raised. Combined with the agricultural regionalization data, topography and geomorphology data, climate data and some of the relative document materials, a comparative analysis found that the natural quality of high and medium yielding land has improved in this decade due to the long term relatively stable material, capital and sci-tech input. And the low yielding land has been under reclaimed and has been improved these years.

General variation of cultivated area of each comprehensive grading land area overlaid the cultivated land comprehensive grading land area data 1993 and 2003 by GIS, a overlay analysis shows that(according to Table 9): the first grade land has a net decrease of 1.93×104hm^2, which accounted for 1.02％ of the total cultivated land use changes; the area of other grades showing a rising trend, and the forth grade land has the biggest increase among the increasing grades, which reached 76.43×10^{4}hm^2, accounted for 40.50％ of the total cultivated land use changes; then followed by third grade and fifth grade, increased 63.94×10^{4}hm^2 and 40.14×10^{4}hm^2 respectively, accounted for 33.88％ and 21.27％ separately.

Table 9 Change of area and percentage on cultivated comprehensive grading land

unit: ×10^4 hm^2,%

Grading land	comprehensive grading land area in 1993	comprehensive grading land area in 1993	Changes on each comprehensive grading land area	Proportion (%)
First grade	277.44	275.51	-1.93	-1.02
Second grade	623.25	633.37	10.12	5.37
Third grade	808.36	872.30	63.94	33.88
Forth grade	604.33	680.76	76.43	40.50
Fifth grade	142.62	182.76	40.14	21.27
Total	2456.00	2644.70	188.70	100

Combined with the agricultural regionalization data, topography and geomorphology data, an analysis found that: among the decreased cultivated land, the first grade land mainly distributed in the coastal agriculture areas, middle plain agriculture areas of Liaoning province; middle plain agriculture areas of Jilin province. The second grade land mainly distributed in Liaoning, Jilin province, and eastern region of Heilongjiang province. The third grade land dispersed in these three provinces. The decreased forth grade land mainly distributed in west plain agriculture area of Jilin province, Nengjiang Plain, Songjiang Plain, Sanjiang platform and Kebai mountains area of Heilongjiang province. The decreased fifth grade land mainly distributed in Heilongjiang province.

Among the decreased cultivated land, the first grade land mainly distributed in the north part of the coastal agriculture areas and the northeast part of middle plain agriculture areas of Liaoning province; southeast part of the Songjiang Plain of Heilongjiang province. The second grade land mainly distributed in Liaoning province and the other areas in Heilongjiang province except Daxing'an Mountains, and there is still some of the second grade land distributed in Jilin province. The third, forth, fifth grade land mainly distributed in Heilongjiang province.

Using the cropping index of northeast area 1993 and 2003(according to Table 10), combined with the quantitative change of cultivated land in northeast area, the study calculated that the grain sowing area has increased about 162.67×10^{4}hm^2. Among them, the grain sowing area in Liaoning and Jilin province have decreased 24.44×10^{4}hm^2 and 66.36×10^{4}hm^2, however, the grain sowing area in Heilongjiang province has increased 253.47×10^{4}hm^2.

Table10 Change of grain sowing area in northeastern region during 1993-2003

Unit: $\times 10^4 hm^2$

Area	Cultivated land area		Cropping index		Grain sowing area		Variable quantity of grain sowing area
	1993	2003	1993	2003	1993	2003	
Total	2456	2644.7			2444.07	2606.73	162.67
Liaoning	585.4	571.4	105.2	103.5	615.84	591.40	-24.44
Jilin	609.1	589.3	103	95.2	627.37	561.01	-66.36
Heilongjiang	1261.4	1484	95.2	98	1200.85	1454.32	253.47

Overlaid the quantitative change data of cultivated land use and the spatial distribution of each kind of land by GIS, combined with the average unit area grain yields of this decade, the study drew the change information of total grain yields (see Table 11).

The area of the high yielding, medium yielding, and low yielding land has increased $34.44\times 10^4 hm^2$、$12.57\times 10^4 hm^2$ and $141.83\times 10^4 hm^2$ respectively. The total grain yields of each kind of land have increased $305.04\times 10^4 t$、$14.25\times 10^4 t$ and $122.88\times 10^4 t$. It shows that the total grain yields were increased by the improved unit area grain yields in the high yielding land and the expanded utilization area of the low yielding land. Among them, the area of cultivated land and the total grain yields are all decreasing. The area change of the low yielding land in Jilin province is the most significant, which decreased $20.00\times 10^4 hm^2$; however, the total grain yields have increased remarkably, which gained another $136.03\times 10^4 t$. Heilongjiang province has gain the biggest increase in the medium yielding land and the total grain yields, that is $185.02\times 10^4 hm^2$ and $724.88\times 10^4 t$ respectively. the area of high yielding land in this province has the minimum increase, but the increased total grain yields brought by the expanding of the area of high yielding land is larger than the increased total grain yields produced in low yielding land.

Table11 Change of cultivated land area and grain yield during 1993-2003

unit: $\times 10^4 hm^2$， $\times 10^4 t$

	Liaoning province		Jilin province		Heilongjiang province		Total	
	Cultivated land area	Grain yield	Cultivated land area	Grain yield	Cultivated land area	Grain yield	Cultivated land area	Grain yield
High yielding	-23.40	-82.13	19.27	136.03	38.57	251.14	34.44	305.04
Medium yielding area	-172.97	-713.00	0.52	2.37	185.02	724.88	12.57	14.25
Low yielding area	-1.11	-1.52	20.00	1.45	122.94	122.95	141.83	122.88

The increase of the low yielding land mainly concentrated in Heilongjiang province, this is because the Heilongjiang province has greatly developed its dominant agriculture in the 1990s, and the development of animal husbandry industry has promoted the maize production. In addition, by the comprehensive influence of globe warming, ascending cropping benefit and technical progress, state farms utilize their advantages to develop rice production and to reclaim the wasteland, which have made the grain yield in Heilongjiang province increased greatly, and this is the main factor that keeps the grain production in Heilongjiang province stable. For example, the growing population and the increasing input have made a great exploitation on the Sangjiang Plain. Farmland becomes the main landscape type; however, wetland and forest land shrinks a lot.

Consider just the quantitative change that effects the grain production is far from enough, we also have to consider the cultivated land resource quality especially the spatial distribution of cultivated land; the same quantity decrease of cultivated land but different quality type can cause different influence on grain production, and the influence is much greater caused by the decrease of high yielding land. So this study using the related study results of comprehensive quality assessment of cultivated land, to analyse the influence of grain production caused by quantitative change and spatial distribution of cultivated land comprehensively.

Average unit area grain yield fixing in each grading land The average unit area grain yields in each grading land: the first grade is 5225.82 kg/hm^2; the second grade is 4780.23 kg/hm^2; the third grade is 4277.12 kg/hm^2; the forth grade is 3515.46 kg/hm^2; the fifth grade is 2364.08 kg/hm^2. the ratio of unit yield in each grading land is 2.2：2.0：1.8：1.5：1. We can find that the produce ability is high in high yielding and we should strength the effective protection to the high quality cultivated land.

The influence on total grain yield caused by cultivated land use change. The change information of total grain yield in each grading land was acquired by the use of changing quantity and average unit grain yield in each grading cultivated land. The result shows that, the first grade cultivated land in northeast area has decreased in this decade, lead to a 10.08×10^4t decline of the total grain yield in this region. The third and forth grade land account for a comparative big amount of the increased land in the studying area, played an important role in grain production increasing (according to Table 12).

Table12 Change amount of cultivated land quantity and grain yield during 1993-2003

unit: kg/hm^2, $\times10^4$ hm^2, $\times10^4$t

Comprehensive quality grading	Unit yield	2003		1993		Change amount	
		Area	Total yield	Area	Total yield	Area	Total yield
1	5225.82	275.51	1439.75	277.44	1449.83	-1.93	-10.08
2	4780.23	633.37	3027.67	623.25	2979.29	10.12	48.39
3	4277.12	872.30	3730.92	808.36	3457.44	63.94	273.48
4	3515.46	680.76	2393.20	604.33	2124.51	76.43	268.69
5	2364.08	182.76	432.06	142.62	337.17	40.14	94.89
Total		2644.70	11023.6	2456.00	10348.24	188.70	675.37

Provincial difference on total grain yield change. There is obvious regional difference on the total grain yield in northeast area. The net decrease of total grain yield in Liaoning province is 49.64×104t. All of the grading land have a decline trend on total grain yield, except the forth grade land, which has increased 2.23×10^4t of total grain yield. There was a net increased of total grain yield in Jilin province, rose up to 3.85×10^4t, among them, the total grain yield on the first and third grade have decreased 2.44×10^4t and 0.82×10^4t respectively, and the other grades have a ascending trend on total grain yield. However, in Heilongjiang province, all of the grading lands have a rising trend on total grain yield, and the net increase of total grain yield in this province is 721.16×10^4t. Among the grading land, the third grade land has contributed most to the total grain yield increasing, and the first grade has the least contribution.

The research found that since the policy of “total cultivated land dynamic equilibrium” has been proposed in 1997, the cultivated land protection in China has proved to be effective to a certain degree. But we can't ignore that there appeals a series of problems on food production in the northeast areas such as instable comprehensive grain production capacity, declined high quality cultivated land quantities and ecological environment deterioration. A good example is that the supplemented cultivated land mainly distributed in waterlogged lowlands in the Sangjiang Plain, Songneng Plain and the mountain and pastoral areas in the east and west regions in the northeast area. There were heavy soil and water loss, low land suitability, poor production conditions in those areas. Although a lot of field engineering such as irrigation facilities constructions have been made in those areas, the general quality is still low. There were a lot of high quality cultivated land have been encroached for construction, all these lands have flat surface relief, convenient traffic, superior water and soil conditions, high soil qualities, and convenient for intensive management. So the empirical study on the influence of grain productivity caused by cultivated land quantitative change spatial distributing change has provided a new idea to execute the strategic target of total cultivated land dynamic equilibrium correctly. Also we must guarantee the double balance both quantity and quality.

Both the quantity and quality of cultivated land were composed the foundation of stable grain production; meanwhile, they were determined the grain productivity, and related to the fulfillment of the strategic target of total cultivated land dynamic equilibrium. The high yielding land is the important part to make stable grain production in the northeast area, and the grain productivity should be improved by scientific and technological progress, more material and technique input, rational fertilization, cultivated land quality improvement. But the medium yielding land constitutes a large portion in this area, so we should focus on the transformation and development of low and medium yielding land by the modern agricultural technology; involve more material, capital and technique input; solve the limiting factors by local conditions. To reform the low and medium yielding land should to reform the dry and waterlogged land and slope land firstly, fertilize the soil fertility, and improve the cultivated land quality. Practice shows that transformation and development of low and medium yielding land can improve the unit grain yield and grain productivity effectively. It is also an effective way to fulfill the strategic target of total cultivated land dynamic equilibrium, and to guarantee food safety. Its ecological and economic benefit is higher than reclamation of low quality reserved land. In summary, the northeast area should construct basic farmland, highlight high yielding land, ensure medium and low yield farmland rehabilitation, develop and protect the land arable for agriculture designedly, strengthen infrastructure construction, improve the production efficiency of cultivated land, enhance ecological management and restoration, protect land use environment, and take the road of sustainable development to guarantee and improve the comprehensive grain production capacity in this areas.

5 Conclusions and Discussions

(1) The total quantity of cultivated lands in northeast area has increased 188.8×104hm^2, and the general trend is that increase in north but decrease in south. The natural quality of cultivated land in the northeast area is mostly at the middle or high middle level, and the utilizing quality mostly at the middle or low middle level. The unit area grain yield in the high and medium yielding land is greatly influenced by the social and economic input; however, the unit area grain yield in the low and yielding land is greatly influenced by the natural quality of cultivated land. The grain sowing areas have increased 162.67×104hm^2, the unit area grain yield in the high yielding land show a ascending trend, the unit area grain yield in medium yielding land increase steadily, the unit area grain yield in low yielding land somewhere increase and somewhere decrease, but it is most likely to be the former case. The total grain yield in the northeast area are increased by the improved unit area grain yields in the high yielding land and the expanded utilization area of the low yielding land. The ratio of unit yield in each grading land in the northeast area is 2.2：2.0：1.8：1.5：1. The first grade land has a net decrease of 1.93×10^{4}hm^2, which accounted for 1.02％of the total cultivated land use changes; the area of other grades showing a rising trend, and the forth grade land has the biggest increase among the increasing grades, which reached 76.43×10^{4}hm^2, accounted for 40.50％ of the total cultivated land use changes; then followed by third grade and fifth grade, increased 63.94×10^{4}hm^2 and 40.14×10^{4}hm^2 respectively, accounted for 33.88％ and 21.27％ separately. The first grade cultivated land in northeast area has decreased in this decade, lead to a 10.08×10^{4}t decline of the total grain yield in this region. The third and forth grade land account for a comparative big amount of the increased land in the studying area, played an important role in grain production increasing

(2) Due to the heavy workload and limited time, it is hard to acquire more soil sample data. But this research used the acquired soil nutrient data to do the assessment, combined with the soil type figure, geomorphologic map, soil sample nutrient data, and make use of mean value method to modify the soil nutrient data acquired by Kriging method. So in general, it can reflect the spatial distribution of natural quality of cultivated land in the northeast area. The utilizing quality of cultivated land used the social and economic data to reflect the average input on county level. When do the rasterizing, we equal distributed the certain sized grid cell in each administrative area, to define the evaluation index value in each pixel. Make use of the recorded input data of the samples or near the samples to modify the raster data of social and economic by the method of average mean. It generally reflects the average cultivated land input of each county in the northeast area, although it can not represent the input of each land block accurately. How to use the spatial

analyse technology of GIS, assimilate the spatial data characterized by natural resource and the social and economic data based on county level is still an unsolved problem, so it calls for further studies to do the comprehensive assessment on cultivated land use. In the future studies, we should develop the cultivated land assessment in a higher precision level, to provide scientific and technical support on cultivated land use and management in the northeast area.

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A simulation on Spatial Distribution of the Per unit Area Yield of Maize by Statistics

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Abstract: In the past years, integration of physical geographic factors and human factors, accompanying with the development of spatial information technology and its application in geosciences, has become an important research field. The key issue of integration is to spatial simulation of human factors, especially the socio-economic statistics. The important work is to allocate these statistics to each pixel according with the actual situation. Through summing up the existing research, we find that most studies focused on population, GDP, agricultural output value, etc., while few of them paid close attention to agricultural fields. The current agricultural statistics still doesn't reflect the finer-scale reality. So, this paper launched the study of spatial simulation of agricultural statistics, taking Jilin province in northeastern China as study area. We selected the per unit area yield of maize by statistics, considering the important status of maize in agriculture of Jilin province. And the method we used were multiple linear regression model based on regionalization. From the process and result of this study, we can conclude that the study provides reasonable estimates of crop distribution. Also, spatial data of influencing factors provide richer information to design the actual distribution of agricultural statistics data.

Keywords: spatial distribution; per unit area yield of maize; regression model; regionalization

Introduction

Land use-cover change (LUCC) is important research content on world environment change and sustainable development, which is affected by the interaction between nature and human factors at different time and space. As the profound understanding of land use evolution and in the view of current research results, we perceive that human factors have deeply affected global change, climate warming, environmental deterioration, water shortage and land desertification in short-time land use process in the recent years. Accompanying with the development of spatial information technology and its application in geosciences, land use and its relevant research tend to acquire multiple source data about physical geographic elements and human elements, mainly based on means of remote-sensing technique, ground station observation, long-term field observation, laboratory simulation, physical-chemical analysis and socio-economic statistics. Both physical geographic factors and human factors nowadays can be expressed as relevant spatial distribution maps. This expression form contributes to the visualization, overlay analysis and spatial operation in GIS. But with the complication and comprehensive of research on global change, sustainable development, ecologic problem, etc., the current problem we often encountered is that the difficulty of integration of these different format data, namely the physical geographic data and socio-economic data. And integration of these data has become an important research field. Comparing with the more accurate physical geographic data, the key issue of integration becomes the spatial simulation of human factors, especially the socio-economic statistics with low spatial resolution. In order to integrate these different format data, we need to build a basic unified pixel with fine-scale and the same spatial resolution, by transforming the socio-economic statistics based on county-scale or vector format to grid or pixel format with the same spatial resolution of physical geographic data. Spatial simulation of socio-economic statistics also can provide the reference guide and significant value for policy decision-making and interdisciplinary study.

By summing up the existing research, we find most of them focused on population, GDP, agricultural output value, etc. Since the end of the last century, spatial simulation of population has become a hot issue in academic circles with the strong population influence on nature and society. And some representative global programs of population emerged such as GPW(Gridded Population of the World)(1995), UNEP/GRID(the United Nations Environment Programme/Global Resource Information Database)(2000), LandScan(Oak Ridge National Laboratory's Global Population Project, part of a larger global database effort called LandScan)(2001), etc.. GPW didn't use the environmental auxiliary data but only use the population data and administrative boundary data. We can consider that it's the direct data format conversion from vector format to raster format with the spatial resolution of 5km. UNEP/GRID also generated a series of spatial distribution maps with the spatial resolution of 5km, by inputting two major variables of transportation and city center information, and using inland water bodies (lakes, glaciers), protected areas and elevation data to modify the estimation results. LandScan proposed innovative approaches of combining the GIS(geographic information system) and RS(remote sensing) to product and update the unprecedented global population data with the spatial resolution of 1km. LandScan collected the best provincial level census data, and calculated the probability coefficients based on road, slope, land cover, night lights and urban density. Then, the census data were allocated to each pixel combined a variety of input variables and probability coefficients. RS provided not only the land cover and nighttime lights for LandScan model but also some indicative factors such as the built-up areas, residential areas, etc.

The current used methods of spatial simulation of census data can be concluded as follows: ⑴ population information retrieval method from remote sensing interpretation with the help of the data source from aerial or high-definition images (Dobson JE, 2000; Henderson FM, 1997; Langford M, 2001); ⑵ population information retrieval method on the basis of the DMSP-OLS nighttime lights data (Elvidge CD, 1997; Lo CP, 2001; Paul CS, 2001); ⑶spatial simulation of population according to the relationship of population distribution and a variety of land-use data (Wang, 2007; Liao, 2003; Wang, 2004); ⑷ a direct inversion of population from the spectral characteristics of remote sensing (Iisaka J, 1982; Webster CJ, 1996; Harvey JT, 2002; Du, 2007; De, 1998). In addition, considering the disadvantages of expert judgments or simple area-weighting rules, You(2005)described a new, entropy-based approach to the plausible estimates of the spatial distribution of crop areas.

Although domestic research started later, they also achieved certain results. And the methods adopted by many Chinese scholars mainly include the grid generation method (Liu, 2003; Yue, 2003), the regionalization-based modeling methods (Koto, 2002; Yang, 2002; Tian, 2004), multi-factors weighted fusion method (Liao, 2003), the recursive-based population density method (Lu, 2002, 2005), population density study based on DMSP/OLS nighttime light image(Zhuo, 2003) , integrating genetic programming & Genetic Algorithms and GIS(Liao,2007), etc.

Gross domestic product (GDP) is a key composite indicator to measure the economy or region’s economic development level. Some scholars also conducted GDP-oriented research. Yi (2006) created the multiple correlation models by using the land use/cover data with the 1:10 million scale based on LANDSAT TM information and statistics-based GDP data. Then the author generated the grid-based spatial distribution map of GDP by calculating the GDP coefficient of all kinds of land-use types in the GIS environment. Liu (2005) and Kang (2006) also used a similar method to research the spatial distribution of GDP for different regions. Zhang (2007) divided Tibet into two regions, with the integration of geo-statistical methods and spatial analysis function in GIS, and analyzed the relationship among regional land use, topographical factors and agricultural output. On this basis, considering the indicative factor of land use and the topographical factors on the impact of the spatial distribution of agricultural output, using the method of multiplying factors to achieve multi-source data integration, the author established the spatial simulation model of agricultural production in Tibet.

From the current research results, we can find that few parts of them paid close attention to agricultural fields. But the current agricultural statistics doesn’t reflect the finer-scale reality. The necessity of spatial simulation of agricultural statistics manifests various fields as follows:⑴meeting challenges of WTO, integration of global economy, and food safety, ⑵enhancing the competitive ability of agricultural products in the domestic and world market, ⑶improving effectiveness of agricultural management, ⑷supplying the accurate basic data for policy decision, ⑸achieving integrated analysis of physical geographical elements and human factors in agricultural research field, and ⑹supplying the valid parameters for crop monitoring by remote sensing

Funded by Special Social Commonweal Research Programs of MOST, this paper launched the study of spatial simulation of agricultural statistics. Taking Jilin province in northeastern China as study area, we selected the per unit area yield of Maize by statistics to spatial simulation, considering the important status of maize in agriculture of Jilin province. The purpose of this study was to allocate the above statistical data to each pixel in order to match the real situation.

This paper is organized as follows. The section 2 describes the data we need, their acquisition pretreatment. Section 3 introduces the method and procedure of spatial simulation, where we introduce the multiple linear regression model based on regionalization and correlation analysis, the model validation and correction. In section 4, we discuss the results and further work.

Data Acquisition and Pretreatment

This paper utilized mainly the influencing factors of maize yield to construct the regression model. So the data included a series of agricultural statistics, soil nutrients, physical geographical elements in various forms, while we didn’t consider those destabilizing factors such as climate data, peasant household input, etc.

2.1 physical geographical data

All physical geographical data in this research have the scale of 1:250,000.

⑴ Administrative boundary data

Administrative boundary data mainly refers to the spatial distribution map of the provincial-level and county-level individually.

⑵Digital elevation model (DEM) and its derivative data

The longitude and latitude data can be generated in GIS platform with the coordinate calculation command, while slope, aspect and hillshade data were derived from the DEM with the spatial analysis module in GIS.

⑶ 1:1000,000 digital map of soil types

Due to soil nutrient content of different regions influenced by various soil types, we generated a series of spatial distribution maps of soil nutrients by cokriging method with the auxiliary data based on soil samples data and its laboratory analysis results.

⑷Land use map based on remote sensing data in 2003

The land use map of remote sensing data was derived from the interpretation of TM remote sensing data from April to November in 2003, with combination of a 453 (RGB)-based standard pseudo-color bands, and supplemented by 432 (RGB) and 471 (RGB). Interpretation process was as follows: First, the work included in sequence of pre-processing of remote sensing images, geometric correction, image mosaics and clips. Then, the land use classification system for remote sensing data were determined based on field survey and image features. And the image interpretation were constituted by using the linear stretch and enhanced treatment of RGB453 -based false color TM images, with the reference of the current land-use map, and taking into account the TM image acquisition time. Then we used the screen information extraction method of remote sensing and GIS integration, with the help of expert knowledge, field inspection and ETM images in 2003 to conduct man-machine interactive interpretation. The interpretation of accuracy evaluation demonstrated that the overall classification accuracy of 95.6%.

2.2 per unit area yield of Maize by statistics

We made the spatial distribution map of statistics-based per unit area yield maize by joining the tabular statistics data with county-level administrative boundary data.

2.3 soil sampling and pretreatment

⑴ Field sampling and laboratory analysis

We collected and investigated the 144 soil samples in Jilin province. And the emplacement of samples used uniform fabric mesh point mode with the sampling interval of 10km. In the field work, some samples location modified by virtue of characteristics of cultivated land type, soil type, topography, as well as the second soil survey data. In addition, we utilized GPS to locate the spatial orientation of soil samples, adjusted the location of sampling points, or added sampling points considering the real situation(i.e. the complicated environment condition), so that each unit of arable land evaluation have samples.

Then these soil samples were sent to the laboratory to analyze their nutrients with the method of ASI. We obtained the data of pH value, organic matter (OM), available kalium(K), available phosphorus(P) ,available NH_4 and microelements.

⑵ Pretreatment of soil nutrient data

In this paper, we adopted logarithmic transformation, domain method processing (sample mean $\bar{x} \pm 3\sigma$) , Box-Cox transformation and K-S test , calculated skewness, kurtosis and the K-S parameters of samples by means of SPSS14.0 statistical software. And its conduct is subject to normal distribution tests were also conducted.

Then, Using GIS and geo-statistics technique, the paper quantified the spatial variability characteristics of soil pH，soil organic matter, available K, available P and available NH4 in the soil in study area. At the same time , the correlation among these main soil nutrients and other soil properties were analyzed, such as available boron(B) ,available calcium(Ca), available magnesium(Mg), available copper(Cu), available zinc (Zn), etc, and the correlation with the geographical elements was also calculated, such as longitude, latitude, elevation, slope, aspect, plane curvature and profile curvature, etc. Then from the contrast of the results derived from the method of kriging and the cokriging applied to the soil type and microelements, the paper determined the cokriging as spatial interpolation method for the spatial distribution of five types of soil nutrient elements with each grid being 1km by 1km.

Finally, all the above data in this section are unified to the same spatial resolution of 1km.

Method and Procedure of Spatial Simulation

Drawing lessons from the current research achievements, the paper adopted the multiple linear regression model based on regionalization to simulate the real situation of maize distribution. Then on a GIS platform, the multiple linear regression model was developed to simulate the relationship between per unit area yield of maize by statistics and the geographical environmental elements, while the correlation analysis were conducted to validate the result of modeling. Finally, the spatial distribution of maize yield was mapped with a spatial resolution of 1km .

3.1 Regionalization

According to the previous agricultural regionalization results of Jilin Province, the paper constructed a framework of regionalization in order to establish the corresponding regression models within these regions and facilitate comparative analysis among models. Just as the Fig.1 shows, the framework of regionalization was composed of region Ⅰ, region Ⅱ and region Ⅲ. Therein region Ⅰ covers the whole Jilin province area , region Ⅱ mainly represents the (a) agricultural and pastoral areas in west of Jilin province& (b) farm belt in middle part of Jilin province, and region Ⅲ includes (c) agricultural forest zone of half-hill in the east of Jilin province & (d) forest agricultural zone of Changbai Mountain. In a word, Jilin province was divided into two other regions named region Ⅱ and region Ⅲ respectively.

- **region Ⅰ** : Jilin Province
- **region Ⅱ** : (a) agricultural and pastoral areas in west of Jilin province& (b) farm belt in middle part of Jilin province
- **region Ⅲ** : (c) agricultural forest zone of half-hill in the east of Jilin province & (d) forest agricultural zone of Changbai Mountain

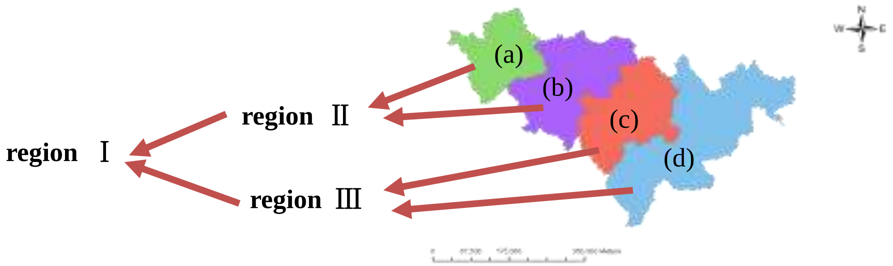

Fig.1 agricultural regionalization in Jilin Province

3.2 Correlation among per unit area yield of Maize and its influencing factors

Considering the different levels of relationship among the per unit area yield of maize and its environmental elements, this paper selected elevation, slope, aspect, hillshade, soil nutrients (pH value, organic matter, available NH_4, available phosphorus and available kalium) as the influencing factors of per unit area yield of maize. The correlations among them were analyzed as the table 1 shows. The results shows that only aspect, pH value and available NH_4 present the high correlation with per unit area yield of maize within region Ⅱ (Table 1.). These results can serve the multiple linear regression analysis and the variables selection.

Table 1 Correlation among per unit area yield of Maize and its influencing factors

	elevation	slope	aspect	hillshade	pH value	organic matter	available kalium	available NH_4	avaible phosphorus
Ⅰ	-0.175	-0.198	0.176	0.311	-0.185	0.226	0.092	0.256	0.099
Ⅱ	0.438	0.402	0.757**	0.454	-0.630**	0.306	0.305	0.657**	0.328
Ⅲ	-0.363	-0.382	-0.148	0.471	-0.036	0.211	0.063	0.185	0.140

Note: **. Correlation is significant at the 0.01 level(2-tailed); *.Correlation is significant at the 0.05 level(2-tailed).

3.3 Multiple linear regression analysis

Multiple linear regression analysis is a widely used and well documented statistical procedure. Regression analysis can identify and deal with influential data cases, and select a series of explanatory variables for building the appropriate regression function.

This paper utilized this method to build the different functions within three regions. First, considering the different spatial expression details among physical geographical factors, soil nutrients and statistics, and in order to match the real situation, we calculated the average value of each influencing factor within every county boundary corresponding to the county-based per unit area yield of maize by statistics. So the regression analysis and the above correlation analysis were based on the average values of county level after standardization of all variables. And the work was performed in the statistical software named SPSS. All influencing factors or some of them were used as the independent variables, while per unit area yield of maize was regarded as the dependent variable. Studies have shown that increase of the number of variables can improve the correlation coefficient obviously.

Table 2 Multiple linear regression results based on regionalization

region	Regression fuction	Multiple correlation coefficientR
Ⅰ	$Y = 34842.375-2.011 X_1 -912.323 X_2 +75.174 X_3 -183.64 X_4$	0.525
	$Y =- 91131.7-10.213 X_1 -237.43 X_2 +83.074 X_3 +464.803 X_4 +952.474 X_5 +661.871 X_6 +170.443 X_8$	0.733
	$Y =-115288-13.268 X_1 -59.176 X_2 +84.666 X_3 +577.086 X_4 +1370.647 X_5 +926.298 X_6 -2.651 X_7 +179.126 X_8 +67.144 X_9$	0.761
Ⅱ	$Y = 26851.984- 2741.435 X_5 – 846.272 X_6 + 31.075 X_7 + 254.153 X_8 – 248.303 X_9$	0.716

region	Regression fuction	Multiple correlation coefficientR
	$Y =- 1989311 + 3.502 X_1 - 2381.037 X_2 + 74.443 X_3 + 11058.194 X_4 - 275.684 X_5 - 324.697 X_6 + 74.088 X_7 + 393.168 X_8 - 500.373 X_9$	0.92
Ⅲ	$Y =- 13828.1 – 0.916 X_1 – 405.406 X_2 + 32.797 X_3 + 102.422 X_4$	0.349
	$Y=-12520.7+1663.084X_5+ 1515.171X_6– 6.541X_7 + 240.559 X_8 + 55.687 X_9$	0.428
	$Y = =- 280190 - 13.999 X_1 + 1038.51 X_2 + 40.828 X_3 + 1455.482 X_4 + 2550.803 X_5 + 1610.968 X_6 - 11.262 X_7 + 187.516 X_8 + 96.935 X_9$	0.808

Note: X_1-elevation，X_2-slope，X_3-aspect，X_4-hillshade，X_5-pH value，X_6-organic matter，X_7-avaible kalium，X_8-avaible NH4，X_9-avaible phosphorus.

According to the results of multiple regression analysis and their multiple correlation coefficients, we can conclude that function with the multiple correlation coefficient of 0.92 in region Ⅱ and the function with multiple correlation coefficient of 0.808 in region Ⅲ were the most appropriate two models(Table 2.).

Afterwards, we utilized the GIS to build the estimated spatial distribution map based on the above two appropriate regression model. This work can be done with the corresponding raster calculator command in the spatial analysis module of GIS platform. Then，the whole estimated map covering the Jilin province was product by means of merged two maps calculated by the above two appropriate regression model. So, the final estimated map of per unit area yield of maize generated with the spatial resolution of 1km.

3.4 Model validation and correction

Because of the limitation of multiple linear regression models and the complication among independent variables and dependent variables, the above estimated result does not adequately reflect the actual information of per unit area yield of maize. And this point also can be observed from the analysis of relative error (Table 2). So correction is absolutely necessary for this research. And we attempted to use per unit area yield of maize by statistics to correct the estimated results. The main process of the amendment can be concluded as follows: ⑴ converting the vector format data of per unit area yield of maize directly by county level statistics to raster format with the spatial resolution of 1km;⑵ calculating the ratio of the above statistics-based spatial distribution map and the estimated distribution map with the GIS spatial analysis module and generating the ratio spatial distribution map; ⑶ the estimated distribution map was multiplied by the ratio spatial distribution map, and then we can obtained the final simulation results after correction(Fig. 3). Table 3 shows that the results by correction have the smaller relative errors than initial estimated results.

Table 3 relative errors of estimated results and

County name	Relative error (%)	
	Estimated results	results by correction
Dehui county	43.75	6.88
Huadian county	8.62	23.15
Qianan county	100.55	0.48

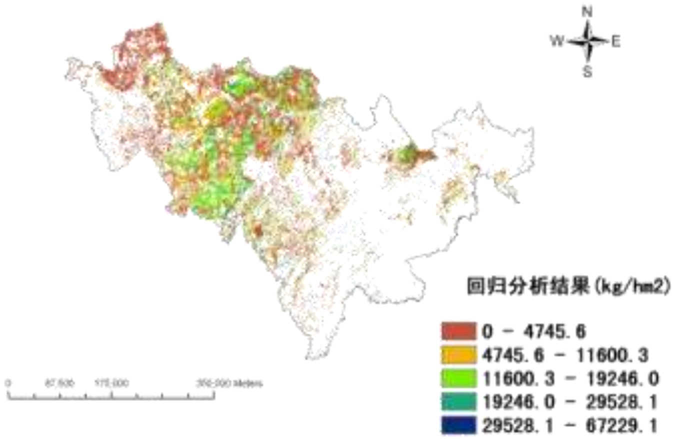

Fig.2 Simulation results of per unit area yield of maize in Jilin Province

Conclusion and Future Research.

We have proposed the multiple linear regression model based on regionalization for simulating the spatial distribution of the statistics-based crop yield. This research utilizes multiple sources information such as satellite data, ground station observation data, field sampling, laboratory, physical-chemical analysis data, socio-economic statistics, as well as previous regionalization results including maps, tables and reports. This rich information can help to estimate and allocate the pixel value of per unit area yield of maize.

From the process and result of this study, it appears that the study provides relative reasonable estimates of crop distributions. In addition, we can see modern technologies (remote sensing, GIS, GPS etc) provides efficient tools for spatial analysis. The technologies can be great policy research tools.

But just as mentioned in introduction section, our work is preliminary. Although we have made some progress, many still remain to be continued. The next work will be the following aspects. First, more peasant households' surveys and better information on farming system including agricultural mechanization, fertilizer application, irrigation condition, etc. are much needed. Also, we need to collect more accurate statistics from local administrative department. In addition, the difficult work is related to distinguishing maize from other crops (e.g., wheat, rice, bean, etc) through filed survey or more accurate interpretation of satellite image. It appears to be urgent to develop an integrated methodology on spatial heterogeneity of agricultural elements. In a word, we can anticipate more research will launch on the global and regional scale.

Acknowledgements

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The Effect of Agricultural Land use on Climate Chage and Food Security

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Abstract: Land use is a manner of utilization of land, including its allocation, development and management. In the Philippines about 32 percent of the economy’s total land areas constitute the agricultural land. Of this, 51% and 44% were arable and permanent croplands respectively. In the past 4-5 years, the Philippine Agriculture sector perform poorly as affected by the occurrence of several natural calamities aggravating the food insecurity of households that live a hand to mouth existence.

In the last decade, the Philippines have been hit severely by natural disasters. In 2005 alone, Central Luzon was hit by both a drought, which sharply curtailed hydroelectric power, and by a typhoon that flooded practically all of low-lying Manila's streets. Still more damaging was the 1990 earthquake that devastated a wide area in Luzon, including Baguio and other northern areas. The city of Cebu and nearby areas were struck by a typhoon that killed more than a hundred people, sank vessels, destroyed part of the sugar crop, and cut off water and electricity for several days. The Philippines is prone to about 18-21 typhoons per year. Of course the 1991 eruption of Mt. Pinatubo also damaged much of Central Luzon, the lahar burying towns and farmland, and the ashes affecting global temperatures.

In the recent years, the Philippines was chosen by the UN as a pilot area for long term and planned climate change response systems due to its unique vulnerability to natural disaster. Current effort of the Government of the Philippines are exerted both to mitigate and to adapt to the changing climate easing up the pressure on food production ensuring national food security. Legislations and policies supportive of control against indiscriminate land use conversion and increased food production were likewise promulgated. National sectoral teams (crops, fisheries and research and development) were formed and tasks to revisit and reformulate action plans to mitigate and adapt to the short and long term effect of climate change.

The problem of inefficiency and improper land utilization is mainly due to lack of a rational land use plan at all levels that would take into account the different needs for land for various sector of the society and designating lands for each use.

Key Words: Climate Change, Food Security, Adaptation, Mitigation, Indiscriminate conversion, Vulnerability

1 Introduction

1.1 Geographic Location

The Philippine Islands is an archipelago of over 7,107 islands lying about 500 mi (805 km) off the southeast coast of Asia with a total land area of 300,000 km^2. The overall land area is comparable to that of Arizona. Only about 7% of the islands are larger than one square mile, and only one-third have names. The largest are Luzon in the north (40,420 sq mi; 104,687 sq km), Mindanao in the south (36,537 sq mi; 94,631 sq km), and Samar (5,124 sq mi; 13,271 sq km) in the Visayas. The islands are of volcanic origin, with the larger ones crossed by mountain ranges. The highest peak is Mount Apo (9,690 ft; 2,954 m) in Mindanao. The total coastline of the economy is approximately 36,289 km. The major natural resources include: timber, petroleum, nickel, cobalt, silver, gold, salt, and copper.

Fig 1 Satellite image of the Philippine Islands

2 Climate

The Philippines has a tropical wet climate dominated by a rainy season and a dry season. The summer monsoon brings heavy rains to most of the archipelago from May to October, whereas the winter monsoon brings cooler and drier air from December to February. Manila and most of the lowland areas are hot and dusty from March to May. Even at this time, however, temperatures rarely rise above 37 ℃. Mean annual sea-level temperatures rarely fall below 27 ℃. Annual rainfall measures as much as 5,000 millimeters in the mountainous east coast section of the economy, but less than 1,000 millimeters in some of the sheltered valleys.

Monsoon rains, although hard and drenching, are not normally associated with high winds and waves. But the Philippines sits astride the typhoon belt, and it suffers an annual onslaught of dangerous storms from July through October. These are especially hazardous for northern and eastern Luzon and the Bicol and Eastern Visayas regions, but Manila gets devastated periodically as well. Corona defined four types of rainfall distribution in the Philippines as described below and is presented in (Fig. 2)

2.1 Climate Classification

Type I. Two pronounced seasons, dry and wet. Maximum rain period is from June to September during the prevalence of southwest monsoon season. The dry season lasts from 3 to 6 months

Type II. No dry season with a very pronounced maximum rain period. The maximum monthly rainfall generally occurs in December and January. There is not a single dry month in the region of this type.

Type III. No very pronounced maximum rain period, with a short dry season lasting from one to three months. This is in between the preceding two types although it resembles the first type more closely since it has a short dry season. Relatively dry from November to April and wet during the rest of the year.

Type IV. Rainfall is more or less evenly distributed throughout the year. This also is in between the first and the second types, but it resembles the second more closely since it has a dry season.

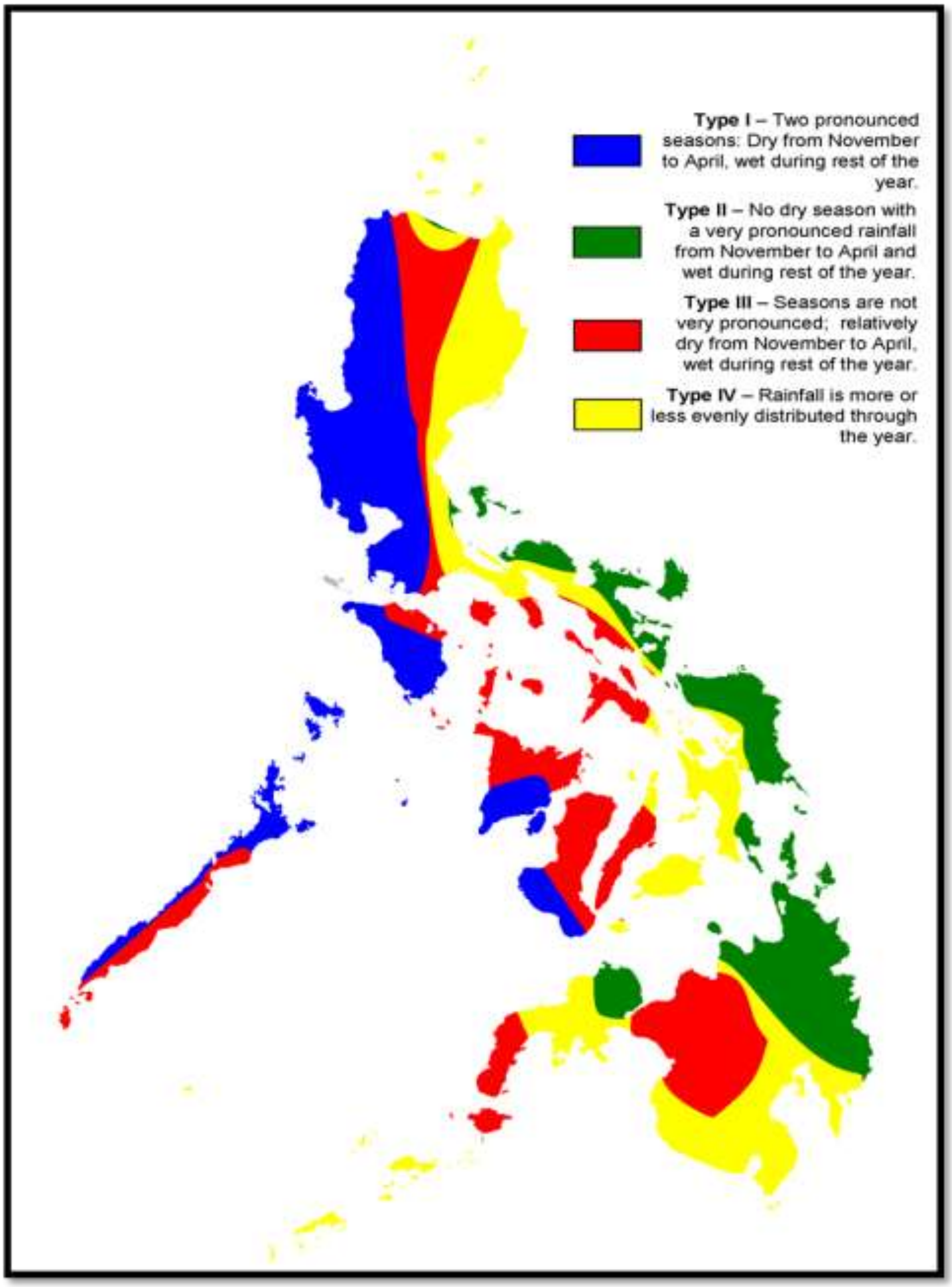


Fig. 2. Map of the Philippines showing the different climatic classifications

3. Land Use

Land use is a manner of utilization of land, including its allocation, development and management. The data below showed that forests and woodland still account for about 46 % of the total area although in the early 1960's forests area accounted for about 60% of the total area of the Phil. A satellite-generated statistics in 1987 of land use classified according to broad categories is shown in table below. About 65 percent of the total land area of the Philippines in 1987 was covered by forest while agricultural land use represents about 33 percent.

Table 1. Existing Land Use, by Broad Category (in thousand hectares), 1987

Island	Agriculture	Forestry	Settlement	Mining & Quarrying	Inland Fisheries		Total
Luzon	4,552.7	8,991.1	95.7	3.9	318.9	7.3	13,9339.6
Visayas	1,892.3	3,665.0	11.5	2.1	72.6	3.7	5,647.2
Mindanao	3,283.8	6,406.5	24.2	2.7	204.2	0.0	9,921.4
Philippines	9,728.8	19,062.6	131.4	8.7	595.7	11.0	29,538.2

As of CY 2002, Agricultural lands totaled to an estimate of 32 percent (9,671 million hectares) of the economy's total land area of which 51 % are arable lands while 44 % are occupied by permanent crops (Fig 3). Compared to the 1987 data for Agriculture (9.728 million hectares) there was a decrease of about .057 million hectares that could be attributed to conversion of agricultural areas to non-agricultural uses.

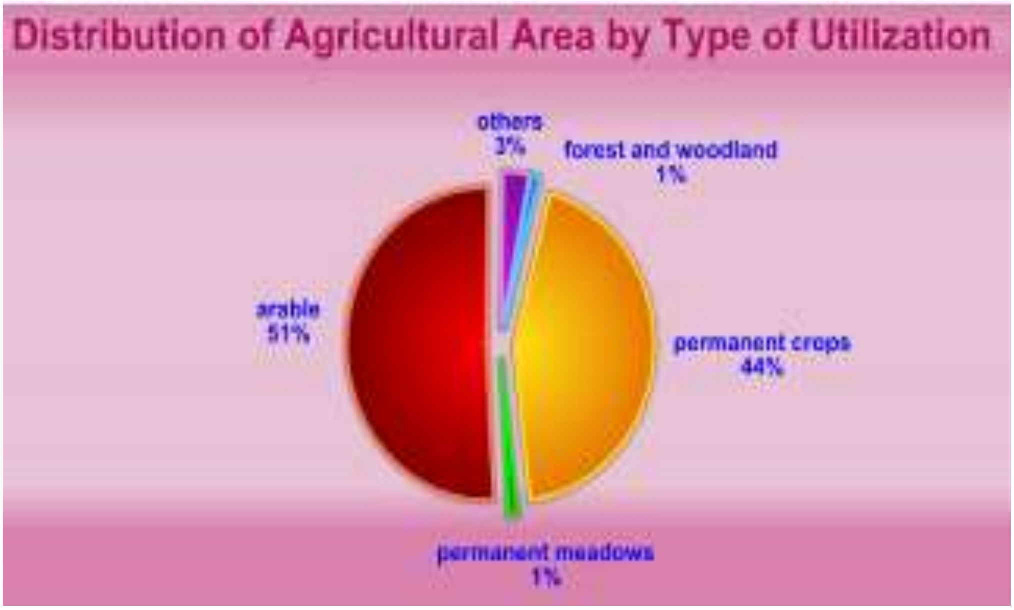


Fig. 3 Area distribution of Agricultural lands by type of utilization

3.1 Land Use Scenarios

There are four land use scenarios that exist in the Philippines today as follow:

Land Use Scenario 1: **Massive Migration of Poor vulnerable communities and urbanization leads to:**

Loss of arable and irrigated lands
River and wetlands pollution
Change of dietary and eating habit

Land Use Scenario 2: **Deforestation and unsuitable agricultural practices (overgrazing, slash and burn farming, subsistence hillside farming)**

Biodiversity depletion through habitat loss and breaking of biological food chain;
Extensive & persistent colonization of invasive, low productivity grass (*Imperata cylindrica*);
Loss of water and water generation capacity of the watersheds.

Land Use Scenario 3: **Environmental disasters and decline of human productivity.**

Massive soil erosion in the sloping areas,
Loss of land productivity (resulting to lower farmers' income and lesser food supplies).
Flooding that isolate poor communities and disrupt economic activities

Land Use Scenario 4: **Undetected emerging agro environmental and climate events that predisposed natural resources of desertification in the Philippines**

Massive, pervasive and creeping process of loss of soil fertility caused by:

(a) Incipient desertification

- ☐ Soil mining (high yielding crops and unsustainable imbalanced fertilizer use)
- ✓ High yielding, high nutrient demanding plant varieties
- ✓ Improper nutrient management and
- ✓ Excessive Imbalance use of nitrogenous fertilizers
- ☐ Depletion of water and water recharge areas
- ✓ Rapid urbanization and unsustainable consumption
- ✓ Deforestation and mining
- ✓ Massive soil erosion and river siltation
- ✓ Expanding incidence of salinization

(b) Seasonal aridity

- ☐ Increasing incidence of El Niño and drought (once in two years)
- ☐ Very high summer temperature
- ☐ Extended dry periods (5-6 months of extremely dry climate where evapo-transpiration exceeded rainfall)

4 Agricultural Developments

As development goes on, the requirement on the use of the natural resources become eminent as the need to provide basic necessities is urgent. Changes in the use of the land be it in arable and in forest lands, becomes a continuing process. Table 2 presents distinct scenarios of events in the natural resources use and agricultural development in the Phil.

Table 2. Significant events on natural resource use and agricultural development in the Philippines (Concepcion, 2004)

Decade of Change	Significant Events in Agriculture and Environment
Pre-1960s	Era of traditional extensive agriculture; healthy watershed; low population density; many intact natural forest trees (high biodiversity)
1961 – 1980	Decade of policy conflict on natural resource management and infrastructure development: ▪ Massive construction of dams for irrigation systems, power and domestic uses (almost all prime irrigable lands provided with irrigation system at the end of the decade) ▪ Massive watershed deforestation (logging) for the generation of cash resources
1981 – 1990	Decade of environmental degradation characterized by: ▪ Massive soil degradation in the lowlands caused by the excessive use of urea resulting into unprecedented soil mining and human-induced micro-nutrient deficiency, and stagnation of yield of food crops ▪ Increase use of marginal lands left behind by logging operations ▪ Increase area of idle grasslands replacing natural forests ▪ Loss in biodiversity caused by destruction of natural habitat

Decade of Change	Significant Events in Agriculture and Environment
1991-1996	Decade of irrational land use conversion to urban development and industrialization: ▪ Deterioration of river systems and aquifers ▪ Rapid deterioration of irrigation systems established in the last decade ▪ Net importation of practically all food products despite the availability of human and natural resources
1997 Onwards	Philippine agriculture and environment in transition development and self review: ▪ Passage of Agriculture and Fishery Modernization Law which advocate for legal establishment of Strategic Development Zones which fully recognized: ▪ Scarcity of land and financial resources as the major constraint to modernizing agriculture and fishery sectors ▪ Switch to planning focus on non-agri-based livelihood option for marginalized communities

5 Historical Analysis of Land Degradation Scenario

About 45% of the arable lands in the Philippines have been moderately to severely eroded triggering the movement of subsistence farmers to marginal lands with the hope of meeting their day-to-day food requirement. Approximately 5.2 M ha are seriously eroded and 8.5 M ha are moderately eroded resulting to 30-50% reduction in soil productivity and water retention capacity. This situation will predispose the degraded lands to drought, other water availability related problems and other form of land degradation.

The Philippines is well endowed with natural resources and is known to host many interesting habitats that are biologically diverse composed of universally unique biological plants and animal life. However, because of complex conditions, ranging from increasing population, isolated small islands and diverse cultures, intricate political condition, stagnation of the rural economy, and a host of other reasons, the decision chain relates to the evolution or emergence of various forms and sources of environmental degradation

5.1 Soil Mining and Decline of Soil Productivity

The long term and continued use of urea “alone” resulted in serious nutrient imbalance and contributed to the actual silent soil degradation widely known as soil mining. The general trend based from soil analysis covering the period 1970 to 1990 indicated very active soil mining where through time there is an increasing number of plant nutrients required to sustain plant growth, as follows:

1960-1990 - Nitrogen (N) fertilizer is generally required

1970-1980 - Nitrogen plus Phosphorous (P) are generally required

1980-1990 - Nitrogen, Phosphorous plus Potassium (K) including micro-nutrients
(Zinc in rice and Magnesium in corn) are generally required

This practice contributed to the stagnation of yields of rice and corn because of excessive use of urea or nitrogen fertilizer beyond the normal ratio of 3N: 1P. Table 2 shows the soil mining and nutrient imbalance between N & P. Most pronounced imbalance was in 1991 where the N/P ratio was three times higher than the normal ratio.

The long-term impact on soil is expressed in terms of depleted soil P, K and induced Zn deficiency. The net impact of soil mining is the increased cost of fertilization and decline in the farmer’s income.

Table 3 Yearly Trend and Ratio of N, P, K Utilization in mt/yr (Concepcion, 2000)

YEAR	N	P	K	RATIO (N/P)
1980	224,866	53,784	55,782	4.18
1981	209,875	51,163	60,620	4.10
1982	232,840	56,139	57,435	4.15
1983	244,179	54,784	64,496	4.46
1984	180,569	45,372	38,617	3.99
1985	205,364	42,822	35,060	4.80
1986	298,323	42,771	46,267	6.97
1987	371,925	63,340	48,661	5.87
1988	372,118	77,471	54,934	4.80
1989	375,940	84,101	77,260	4.47
1990	394,767	46,188	68,512	8.55
1991	292,483	30,397	54,197	9.62
1992	331,537	36,025	61,628	9.20
1993	395,183	42,473	93,331	9.30
1994	396,751	46,920	38,944	8.46
1995	389,295	56,817	59,098	6.85
1996	462,776	65,055	90,346	7.11
1997	541,112	65,253	93,331	8.29
1998	408,778	53,299	81,740	7.67

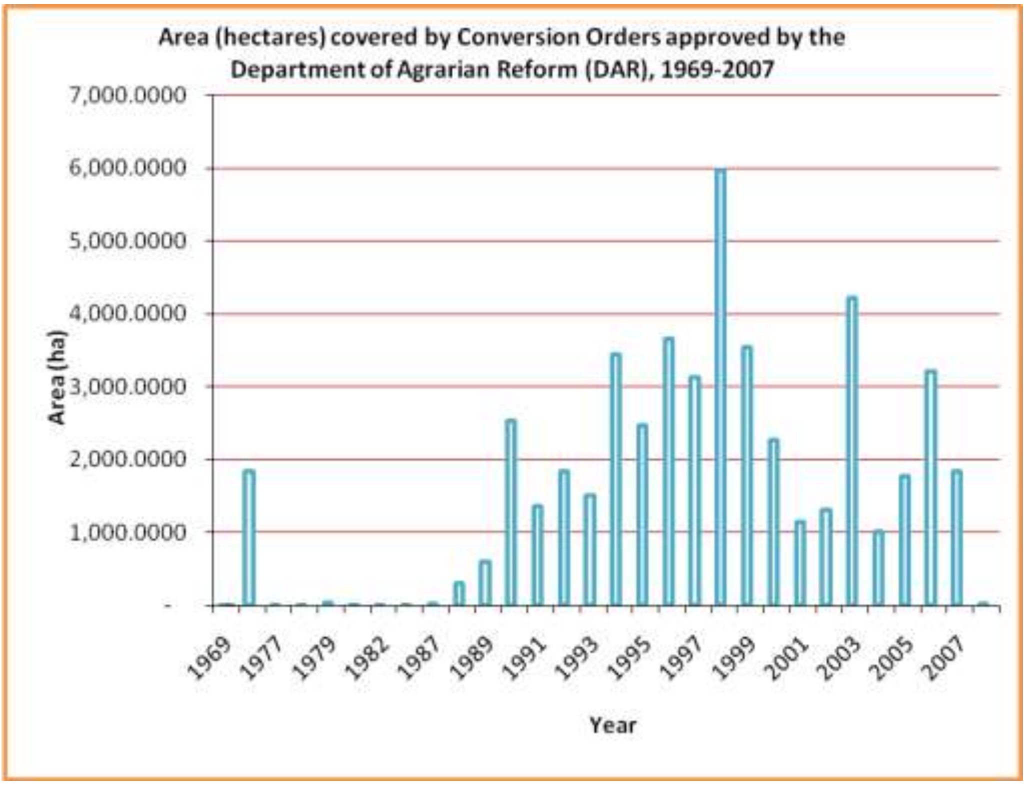
6 Land use Conversion

6.1 Agriculture to Non-Agriculture

Land conversion or change of land use normally undergoes a certain procedure as required by law. Generally, areas applied for conversion passed through a series of processes prior to its approval. The Department of Agriculture **(DA)** serves as the recommending agency after the deliberation and inspection has been undertaken while the Department of Agrarian Reform **(DAR)** promulgates the conversion orders. Massive land use conversion started way back 1970, however, the peak of conversion was during 1998. This was before the RA 8435 (known as AFMA Law) was signed into law which outlines the stricter version of procedures and criteria for conversion of agricultural areas. The law aim to ensure that lands are efficiently and sustainably utilized for food and non-food production and agro-industrialization.

Most of the areas applied for conversion are for housing development, golf courses, industrial and commercial purpose, and memorial parks. Figure 4 presents the rate of land conversion from 1969 – 2008 as approved by the DAR.

Figure 4. Areas covered by conversion orders approved by the DAR, 1969 - 2007



Rapid urbanization has resulted to indiscriminate conversion of agricultural lands to residential, industrial, and commercial uses that may undermine food security. The annual conversion rate of cropland to urban uses was 11,337 hectares or 2,267 hectares each year from 1987 to 1991, and 2,300 hectares in 1993**. *(Velasco, Y. T., Philippines National Communication)*.** This however, is in the process of documentation and validation particularly in the regional areas.

Encroachment of non-agricultural activities into agricultural lands forces the utilization of vulnerable and marginal upland areas for farming activities without sustainable land management practices. These practices aggravate land degradation and soil erosion. The latest in 2000, the extent of areas devoted to Agriculture is 10.18 million ha. (*NSCB, 2003; Velasco, ND*). From 1990 - 2007, the average land conversion is 2,561 ha/year, pointing the highest rate of 5,962 ha/annum in 1998 (**Source of basic data: DAR**).

6.2 Forest Cover and Rate of Regeneration/Reduction

The Philippine forest cover had decreased in terms of area from 1969 to 1990. However, it went up from 1991 to 2003 (Figure 5).

The estimated Philippine forest cover is 7.168 million hectares or 23.89% of the total land area *(NAMRIA, 2003)*. This includes 2.47 million hectares of closed forest, 4.28 million hectares of open forest and 297,160 hectares of forest plantation. Among the identified forest covers, 6.432 million hectares (89.73%) are within forest lands while 0.737 million hectares (10.28%) are within alienable and disposable (A&D) lands. The forest plantations may have significantly contributed to the increase in forest cover; however, they are not seen to provide the appropriate habitat for indigenous species. As of 2008, there are 234 Protected Areas (PAs) under the National Integrated Protected Areas System (NIPAS) covering a total area of about 5,234 million hectares.

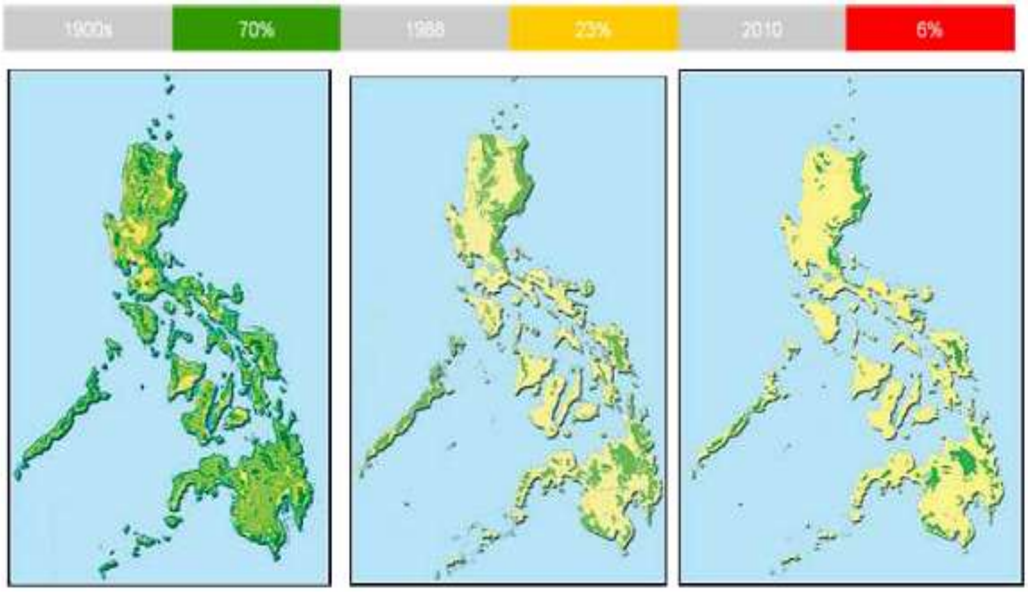


Fig. 5. Percent Forest Cover of the Philippines (ESSC, 1999)

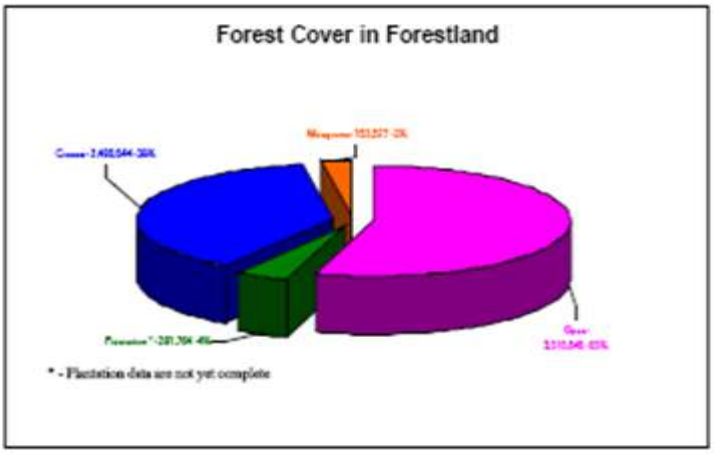


Fig. 6. Forest cover in forestlands (Philippine Forestry Statistics, 2003)

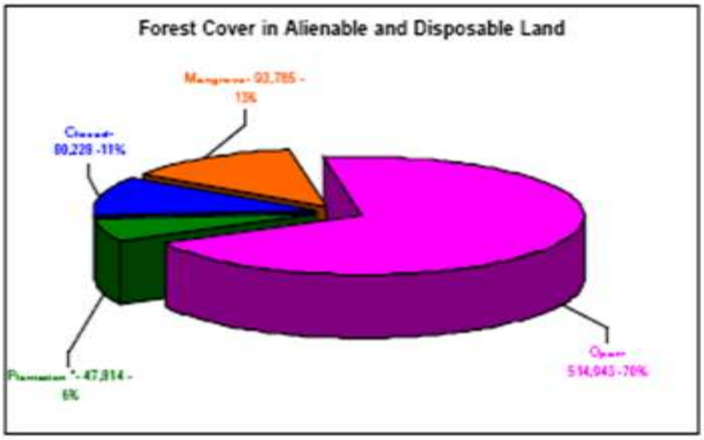


Fig. 7. Forest cover in A&D lands (Philippine Forestry Statistics, 2003)

6.3 Estimated Carbon Stocks

Land use change and forestry make an important contribution in the national carbon emissions and sinks. The carbon stock from the Philippine forest was estimated to be at 1.329 Billion tons *(Lasco, et al., 2003)*

The depletion and recovery of ecosystem carbon stocks due to land use changes are highly asymmetric. While depletion is nearly instantaneous, the recovery may take decades or centuries. Its effects on soil carbon stocks can be detected even after centuries. The six types of land use change that are known to have particular impacts on the change of carbon stock are: conversion of natural ecosystems to slash-and-burn agriculture, conversion of pastures, and conversion of natural forests to tree plantations and managed forests (*Azofeifa, ND*).

The Philippines' greenhouse gases (GHG) contribution in 2004, excluding the changes in land use, represented 0.27% of the world's total (79.1 MtCO2), an increase of its 1990 emissions share of

0.18 percent (CAIT 2008). In 2000, the latest year with data on land use change and forestry, emissions were 0.51% of the world's total, ranking the Philippines in the 36th place.

In 2000, land use change and forestry was responsible for 55.9% of GHG emissions making it a great contributor on the rise of the economy's total GHG emission rate. In contrast to other economies, GHG emissions in the Philippines need to be curbed from the land-use and forestry angle.

Table 4. Philippines' GHG Emissions by Sector 1990, 2000, 2004 (World Resources Institute, 2008)

SECTOR	1990		2000		2004		% Change
	$MtCO_2$	%	$MtCO_2$	%	$MtCO_2$	%	1990-2000
Energy	36	30.4	68.9	40.6	72.6	91.8	91
Electricity and Heat	14.2	11.9	26.8	15.8	28.9	36.5	89
Manufacturing & Construction	8.3	7	9.2	5.4	11.2	14.1	11
Transportation	6.2	5.2	23.5	13.9	25.4	32.1	279
Other Fuel Combustion	7.4	6.2	9.4	5.5	6.8	8.6	27
Fugitive Emissions	0	0	0	0	0.3	0.4	0
Industrial Processes	3.2	2.7	6	3.5	6.5	8.2	88
Land Use Change and Forestry	79.4	66.9	94.9	55.9	na	na	20
TOTAL	**118.6**		**169**		**79.1**		**43**

7 History of Extreme Climate Events

In the last decade, the Philippines have been hit severely by natural disasters. In 2005 alone, Central Luzon was hit by both a drought, which sharply curtailed hydroelectric power, and by a typhoon that flooded practically all of low-lying Manila's streets. The city of Cebu and nearby areas were struck by a typhoon that killed more than a hundred people, sank vessels, destroyed part of the sugar crop, and cut off water and electricity for several days. The Philippines is prone to about 18-21 typhoons per year. Of course, the 1991 Mount Pinatubo eruption also damaged much of Central Luzon, the lahar burying towns and farmland, and the ashes affecting global temperatures.

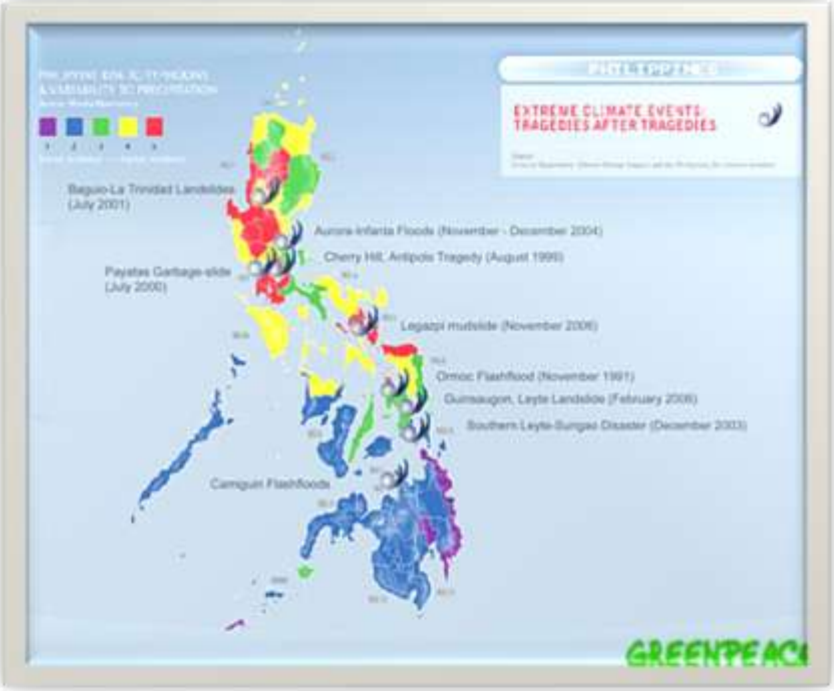


Fig. 8. Extreme Climatic Events in the Philippines (Greenpeace, 2005)

Metro Manila, Sept. 26, 2009
Flooded all over due to Typhoon Ondoy

7.1 Drought

Drought is a natural phenomenon that occurs when precipitation or rainfall is significantly below the recorded normal levels and consequently, affects the surface and subsurface water supply. Simply defined, it is the lack of sufficient water supply to meet the requirements for agricultural, economic, domestic and environmental uses.

7.1.1 Distribution and Extent of Drought Hotspots

The most vulnerable areas to drought are located in the following:

- Rice, corn and other grain-producing and moisture-deficit areas (Figure 9 and Figure10) specifically in:
  - Northern tip of Luzon:
    - Region 1 - Ilocos Sur and Ilocos Norte
    - Region 2 - Cagayan Valley

  - Mindanao
    - Region 9 - Zamboanga del Norte, Zamboanga del Sur
    - Region 10 - Bukidnon, Lanao del Norte, Misamis Oriental
    - Region II - Davao del Sur, Davao Oriental)
    - Region 12 - South Cotabato, General Santos, Sarangani
    - Autonomous Region for Muslim Mindanao (ARMM) - Maguindanao,

- Provinces in the western portions of the economy experiencing Type 1 climate characterized by two pronounced seasons, dry and wet, with maximum rain period from June to September due to prevalence of Southwest monsoon (Figure 6);
- Provinces in the central portions of the economy experiencing Type III climate characterized by no very pronounced wet season and with a short dry season lasting from one to three months. This closely resembles Type I climate (Figure 6).
- Island and small-island provinces/municipalities of the Visayas, northern and southern tip of Luzon and southern tip of Mindanao. These areas have limited freshwater resource given the size and nature of their surface and subsurface water systems.

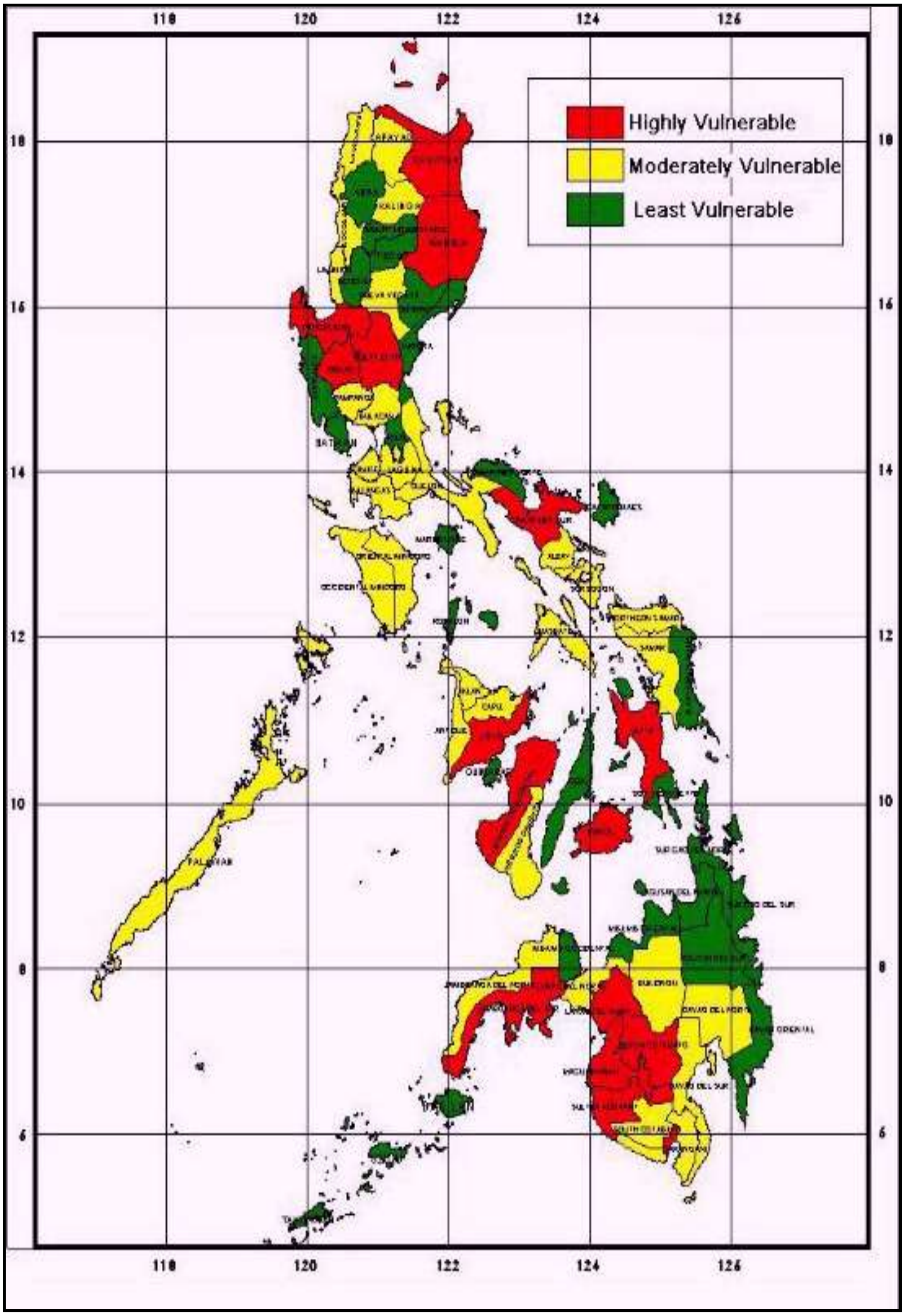


Fig. 9. El Niño Vulnerability Map for Rice (PAGASA, ND)

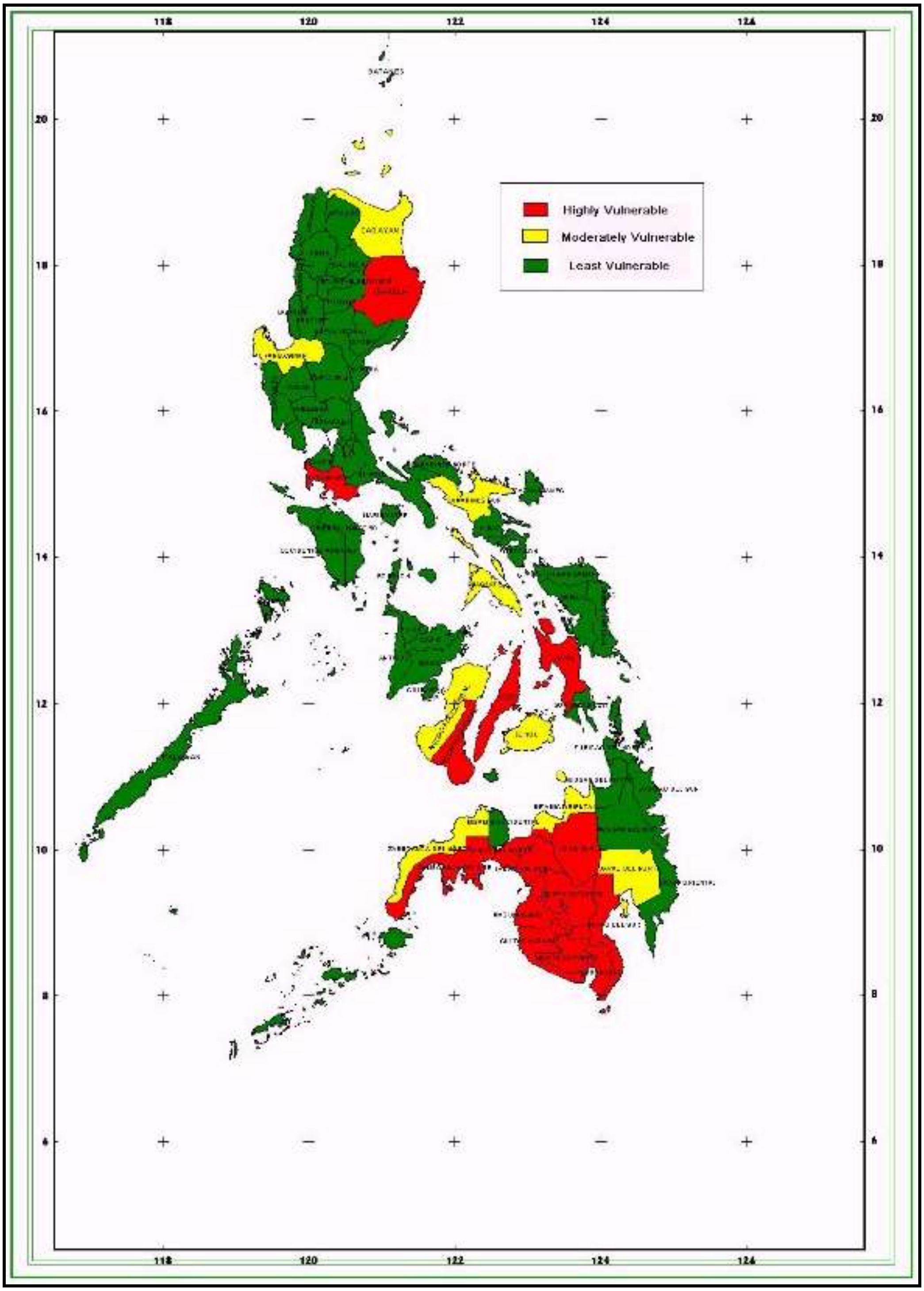


Fig. 10. El Niño Vulnerability Map for Corn (PAGASA, ND)

The mean daily temperatures in these areas ranges from 30 to 35 0C with relative humidity of 70-80%, induce depletion of soil organic matter and significant water loss through evapotranspiration. Thus, in prolonged dry periods, soil and water resources in these areas are not able to support crop production.

Seasonal aridity is exacerbated by the increasing incidence of El Niño Southern Oscillation (ENSO) phenomenon or El Niño, which is now occurring at a two to three year cycle from previous five-year interval (Figure 8). The water stress periods in the seasonally arid areas are extended to four to nine months depending on the intensity of drought or El Niño (six to nine months).

Historical records from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) showed that major drought events are associated with ENSO occurrences (de Guzman, ND; PAWB, 1999). Figure 8 indicates that from 1950 to 1998, there have been fourteen ENSO episodes. The affected areas, degree of severity and the damages of each ENSO episode are presented in Table 6. The worst and most extensive of which in terms of coverage and damages is the 1997-1998 El Nino episode.

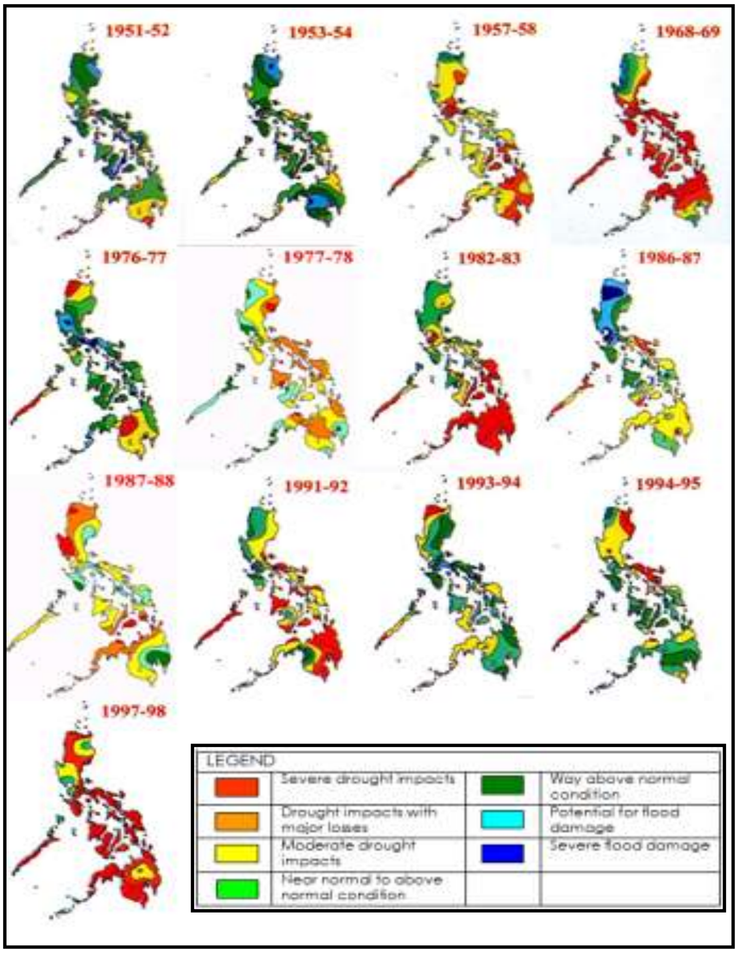


Fig.11. El Niño Episodes in the Philippines (PAGASA, ND)

Table 5. Degree of severity, affected areas and damages of major ENSO-induced drought events in the Philippines (PAGASA, ND; de Guzman, ND, PCARRD, 2001)

Date of Occurrence	Degree of Severity and Areas Affected		Damages
	SEVERE	MODERATE	
Oct. 1968 – Jan. 1970	Bicol Region	Rest of the Philippines except Regions 1 and 2	rice and corn production loss of 5x10^{5} mt
Apr. 1972 – Apr. 1973	Central Luzon	Visayas and Mindanao	rice and corn production loss of 6.3x10^{5} mt
Aug. 1977 – Mar. 1978		Mindanao except Davao	rice and corn production loss of 7.5x10^{5} mt
Oct. 1982 – Mar. 1983	Central Luzon Southern Tagalog Northern Visayas Western Mindanao	Regions 1, 2, 3 and 5	rice and corn production loss of 6.4x10^{5} mt; insurance claims amounted to PhP 38 M; hydropower generation loss of PhP 316 M
Apri. – Sep. 1983	Region 2 and parts of Region 1		
Oct. 1986 – Mar. 1987		Western Luzon Bicol Region	estimated agricultural damages of PhP 47 M
Apr . – Sep. 1987		Most of Luzon Central Visayas Northeastern Mindanao	estimated hydro energy generation loss of PhP 671 M
Oct. 1989 – Mar. 1990	Cagayan Valley Panay Island Guimaras Northern Palawan Western Mindanao		Rice and corn production loss of 5x10^{5} mt; hydropower generation loss of PhP 348 M; 10% cutback in water production in Metro Manila
May 1991- Jul. 1993	Comparable with that of 1982-1983		PhP 4.9 B agricultural losses; 20% shortfall in Metro Manila water supply
Apr. 1994 – Mar. 1995	Regions 1,2, 3, 5, NCR and Palawan	Visayas and Western Mindanao	
May 1997 – Apr. 1998	about 70% of the Philippines experienced severe drought		production loss of 622,106 mt of rice and 1,187,346 mt of corn amounting to about PhP 12.3 B; water shortages; forest fires human health impacts
May 2002 – Mar. 2003	Region VI Western Mindanao	Regions 1, 2, 3 Central Mindanao Bicol Eastern Visayas Southern Tagalog Northern Luzon	

7.1.2 Historical Impacts of Drought and El Niño

Drought can strike at any region at any time with varying degrees of severity, depending on the intensity (degree of moisture deficiency), duration and scope. Increase recurrence of drought and El Niño resulted to loss of land productivity and crop failure, loss of biodiversity and fragile ecosystems; and even loss of human lives and properties. A summary of damages incurred due to the major El Niño-induced drought years are presented in Table 6**.**

a. Agriculture and Fisheries

Prolonged droughts induced by ENSO episodes have caused severe damages and losses to the agriculture sector. For instance, aggregated agricultural production dropped by 6.6 % as a result of the 1997-1998 El Nino episode (*PAWB, 1999; de Guzman, ND*). Recent studies by Lasco et, al., (2008) revealed that, the estimated total damages due to 1990-2003 ENSO events amounted to US $ 370 million.

(i) Rice and Corn

Rice and corn, the two major food grains in the economy have had the highest losses due to El Niño. Results of the study on the impacts of the three major ENSO episodes (1982-1983, 1991-1992 and 1997-1998) that hit the economy which was conducted by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) in 2001 showed that:

- Total production loss for rice and corn amounted to about PhP 18.2 billion resulting to increased importation in order to meet the food requirement of Filipino households and in the case of corn, to supply requirement of feed millers;
- For rice, the estimated production loss was 628,480 tons in 1982-83 and 622,106 tons in 1997-1998. The monetary value of the loss increased to P4, 666 M in 1997-1998 from only P851,955 in1982-1983 (Table 7);
- Corn production loss was higher by 65% compared to losses in rice production in 1997-1998 (Table 7).

Table 6. Production Losses, value of damages and affected area due to El Niño (PCARRD, 2001)

El Niño Years/Crops	Production Loss (tons)	Value (Pesos ‘000)	Area Affected (ha)
1982-1983			
Rice	628,480	851,955	152,660
1991-1992			
Rice	669,220	2,440,380	274,655
Corn	710,038	2,489,193	450,406
1997-1998			
Rice	622,106	4,665,795	314,896
Corn	1,187,346	7,717,749	646,500

Moreover, data on the most recent 2003-2004 El Niño event that hit the economy showed that, palay production in the first quarter of the year slid by 0.8 % compared to the 8.7 % growth recorded in the previous year. The prolonged dry spell damaged major production areas in Central Visayas, Eastern Visayas and SOCSKSARGEN, reducing the harvest area of palay (*NSCB*, *2003*).

(ii) Livestock and Poultry

Results of the PCARRD (*2001*) study also revealed that during the 1997-1998 ENSO episode, the swine and poultry industries had the highest loss with 79 % and 67 % change in population respectively.

Percent change in poultry population is attributed to heat stroke and avian pest while swine and goat population decreased because they are immediately disposed of to generate cash to compensate for the loss in rice and corn farming (Table 8). Farmers have to sell cattle due to lack of water and grasses in grazing areas. Moreover, market price decreased since cattle are thinner due to poor nutrition.

Table 7. Percentage Change in Livestock and Poultry Population in 1997-1008 El Niño event (PCARRD, 2001)

Animal/Ranking of susceptibility	Percent Change in Population between Normal and El Nino year 1997-1998
1. Swine	-79
2. Poultry	-67
3. Goat	-45
4. Cattle	-30
5. Carabao	-28
6. Horse	-24
Average	**-45.5**

(iii) Fisheries

The fisheries sector incurred losses amounting to about PhP 7.2 B during the 1997-1998 El Niño. The prolonged and severe drought led to dried ponds, constricted production cycles, stunted growth and high mortality rates caused by stress, disease and poor water conditions. Regions III and VI were the most severely affected due to their extensive areas for aquaculture and marine fisheries (*PCARRD, 2001*).

Estimated production losses are about fourfold and fivefold of the reported production losses; however they give the best shadow indicator of impact before a more comprehensive data collection strategy is institutionalized (Table 9).

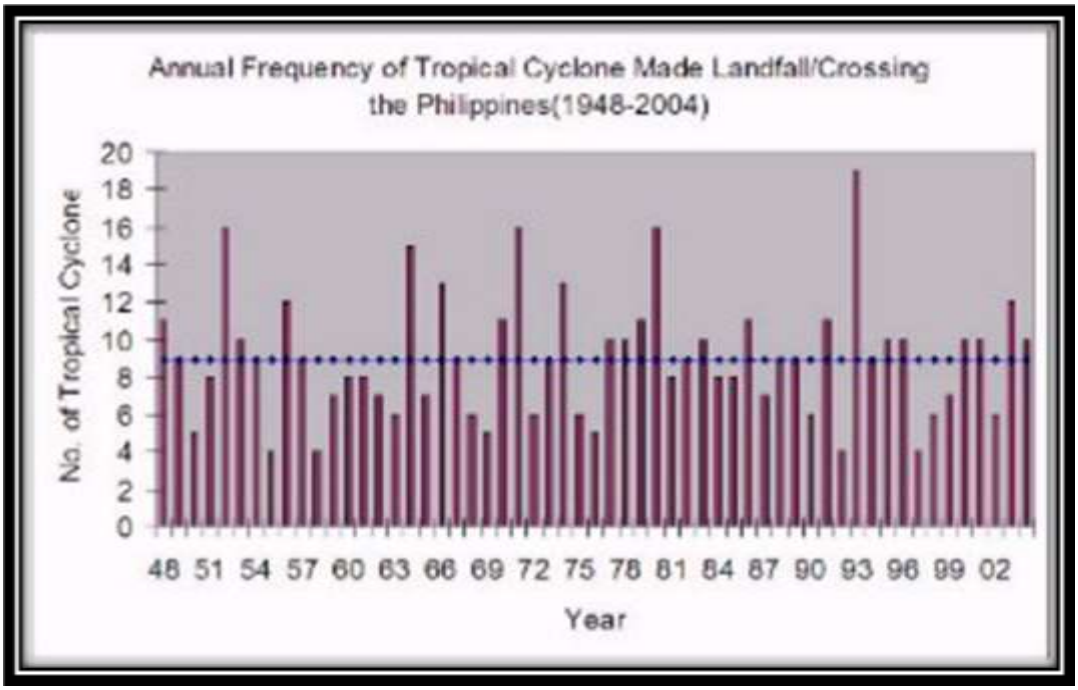
Table 8. Production Losses of the Fisheries Sector due to 1997-1998 El Niño episode (PCARRD, 2001)

Sector	Production Losses (ton)		Economic Losses (PhP '000)	
	Reported	Estimated	Reported	Estimated
Marine Fisheries	7,142	22,293	319.21	1,071.60
Aquaculture	29,687	260,375	1,523.44	6,157.95

7.2 Tropical cyclones

Every year the Philippines are prone to an average of 20 tropical cyclones passing through its Philippine Area of Responsibility (PAR). This is the most commonly occurring natural hazard in the economy. These are low atmospheric pressure areas of tropical origin characterized by strong winds and normally accompanied by rainfall. Depending on their wind speed, tropical cyclones are classified as tropical storm, tropical depression, severe tropical storm and typhoon. No other economy in the Pacific experiences a large number of tropical cyclones comparable to this that causes billions of pesos in damages.

Fig. 12.)



8 Coping Mechanism with Current and Future Climate Change

8.1 Adaptation Strategies

The agriculture sector addresses the current and future effects of climate change through a national adaptation strategy that focuses on the following aspects:

1. Fertilizer and Soil Management that will improve soil water holding capacity and nutrients availability through organic based agriculture fertilization program using the Modified Rapid Composting technology and Community based composting facilities to produce organic fertilizer.

2. Irrigation and Drainage Program that will augment water supply, improve irrigation delivery, increase irrigated area and cropping intensity, and facilitate immediate discharge of flood waters like restoration and rehabilitation of irrigation systems, watershed management and re-use of wastewater for irrigation and other agricultural purposes.

3. Extension, education and training that will provide relevant trainings to farmers on knowledge-based farming technologies such as water management and water saving technologies, organic fertilizer production, Farmer field school and livelihood trainings

4. Loans and agricultural credit that will give the farmers access to all formal credit for livelihood to increase their resilience and coping capacity.

5. Dryers and other post harvest facilities to enable farmers to undertake drying and processing of their produce during unfavorable weather conditions

6. Seeds and other varietal improvement to develop tolerance to the stress of having “too little” or “too much” water due to climate change.

8.2 Mitigation Strategies

the process of limiting the causes of climate change through measures that could slow down the build-up of atmospheric GHG’s concentrations by reducing current and future emissions and by increasing GHG sinks

1. Community-based Watershed Management Approach in Improving Livelihood Opportunities in Selected Areas in the Philippines - to promote livelihood opportunities and improve income while conserving soil and water resources through community-based watershed management.

2. Evaluation and Adoption of Improved Farming Practices on Soil and Water resources – enhance transfer of technologies for sustainable agriculture and soil/water resource management through implementation of and critical evaluation of best management practices at farmer managed demonstration sites.

3. Small Scale Irrigation Projects (SSIP’s) - establishment of new and rehabilitation of existing SSIP facilities such as Small Water Impounding Projects (SWIP’s), Small farm Reservoir (SFR) and irrigation canals including the distribution of shallow tube wells. The ultimate aims are to enhance rainwater harvesting, foster soil and water conservation, flood control mitigation, and provide supplemental irrigation for both crop and inland fishery production.

4. Rain Stimulation Program- to provide rain water in selected areas, critical hotspots for dry spell through cloud seeding operations.

8.3 Legislations

The government promulgated sets of legislation that describes the specific uses for land and water resources. The lists below are some of the Republic Acts, Presidential Decrees and Administrative Orders which are enforced by various sectors in relation to utilization and management of land and water resources.

a. **R.A. No. 6657: Comprehensive Agrarian Reform law** provides that after the lapse five years from it award, when the land ceases to be economically feasible and sound for agricultural purposes, or the locality has become urbanized and the land will have a greater economic value for residential, commercial or industrial purposes, the Department of Agrarian Reform may authorize the reclassification or conversion and deposition of the land.

b. R.A. No. 7160: Local Government Code of 1991 states that a city or municipality may classify agricultural lands provided that there exists an approved zoning ordinance implementing its comprehensive land use plan and provided that it is within the limits prescribed thereof. It is further stated that agricultural lands maybe classified if it cease to be economically feasible and sound agricultural purposes or when the land shall have substantially greater economic values for residential, commercial and industrial purposes. Agricultural lands may be reclassified in excess of the limits for food production, human settlements, ecological considerations, and other relevant factors in the city or municipality.

c. **R.A. 8435: Agricultural Fisheries and Modernization Act of 1997** provides the delineation of Strategic Agriculture and Fisheries Development Zones (SAFDZ) within the Network of Protected Areas for Agriculture and Agro-industrial Development (NPAAAD) to ensure that lands are efficiently and sustainably utilized for food and non-food production and agro-industrialization.

d. **R.A. 8550: The Philippine Fishery Code of 1998** provides for the achievement of food security as the overriding consideration in the utilization, management, development, conservation and protection of fishery resources and ensue the rational and sustainable management and conservation of the fishery and aquatic resources in the Philippine waters including Exclusive Economic Zone (EEZ) and in adjacent high waters.

e. **Executive Order No. 481 – Promotion and Development of Organic Agriculture in the Philippines.** The aim of the program is to promote organic agriculture as an effective and sustainable approach to food security, resource management, income generation and poverty alleviation in the rural areas.

f. **Administrative Order No. 09, Series of 2006** which governs agribusiness venture arrangements (AVAs) in agrarian reforms areas. It stipulates that there shall be approval of the

AVA if its end result will be transfer of ownership, exemption/exclusion for the CARP coverage and/or conversion to non-agricultural use except for those necessary for the operation of the AVA. Further, the landholding subject of AVA shall be used solely for agricultural purposes or to exclusively use and cultivate the land for the purpose of agricultural production.

g. **Administrative Order No. 02, Series of 2008** which governs lease of lands under Agribusiness Venture Agreement (AVA) in agrarian reform areas. It provides the rights and obligations of the lesser-agrarian reform beneficiaries and lessee-investor. As defined, leased agreement is an AVA scheme wherein the agrarian reform beneficiaries bind themselves to give the former landowner or any other investor control over the use and supervision of the land for a specific period of time and for a certain amount.

8.4 International participations

a. United Nation Convention to Combat Desertification and Drought (UNCCD) – a special UN agenda for poverty reduction in the dry, arid, semi-arid, and dry sub-humid areas, particularly the African Continent.

b. United Nation Framework Convention on Climate Change (UNFCC) - DA as member

Conservation of the Northeast Black Soil Area and China’s Food Security

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Abstract: The northeast black soil area is an important strategic food security base in China. The grain yield is about 85 million tons annual, which accounts for about 1/5 of the total China’s grain yield, it can also provide 1/3 commodity grain every year. The grain yield shall increase about 20 million tons by the black soil protection, technological innovation and policy control, which will account for 50% of the total increasing grain yield in China, and it maybe become the greatest potential areas of China’s grain yield increasing in future. However, due to the affect of urbanization, water shortage, and unreasonable tillage, the northeast black soil area faces outstanding problems such as fast non-agriculturalization of cultivated land, intensified degradation of black soil, declining of soil fertility, and serious soil erosion, which maybe has a significant impact on China's food security if it can not be protected and controlled. According to the long-term strategic needs of ecological security and China’s food security, countermeasures and advises were put forward to strengthen the conservation of the northeast black soil area, which are as follows: First, to demarcate the northeast black area as the permanent national food security base, and solid the quantity of cultivated black soil resources; Second, to strengthen the construction of agricultural infrastructure, and accelerate the sustainable use of water and soil resources; Third, to improve the middle-low yielded farmland, and promote the comprehensive grain production ability; Finally, to **c**onstruct 8 to 10 large grain production bases, and improves grain purchase, storage and transportation and circulation system.

Key words: conservation; food security; countermeasure; the northeast black soil area

1 Introduction

Grain security, which is one of the global issues attracting lots of attention internationally all through these years, it is not only the central issue of agricultural development, but also the basic issue relative to national economy and social development. Being an economy of over billion of population, China’s grain production and grain security attract more and more attention of worldwide. Grain security refers to access by all people at all times to sufficient food for an active, healthy life (Shi et al., 1999), this means that the world must produce enough food to ensure quantitative security to stabilize grain supplement to a maximal extent. Furthermore, it must ensure anybody can buy any healthful food so as to ensure purchase security and nutritional security. As we all know, China is an economy with huge grain consumption, and the grain security condition of which has an important impact on world’s grain security pattern. Under the situations of China’s water-land resources, economic-society conditions, and macroscopically background

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of the world’s grain security, it is still the leading issue to insure quantity safety in China for a long period (Zhang et al., 2004). With rapid non-agriculturization of cultivated land, China’s cultivated lands have been decreasing dramatically in recent years. Additionally, affected by grain production benefits and agricultural structure adjustment, proportion of grain plantation area to crop areas is also in decreasing. Grain plantation area shall decrease 22% in 2030 and 34% in 2050 according to this trend, which shall have great impact on China’s grain security (Cai et al., 2004). On the other hand, China's population will reach about 1.5 billion by 2030, and the food consumption demand will reach 600 million tons, which shall increase 20% than right now. Moreover, China's food security shall face serious challenges due to the effect of various factors change such as the resources and environment, economic, social and technology.

The northeast black soil area in China is one of the largest three belts of black soil areas in the word, the total area of which is about 103 km^2 , including the province of Heilongjiang, Jilin and Liaoning, but exclude the western Liaoning Province (Xiong et al., 1987; Liu et al, 2009). As we all know, the northeast black soil area is one of the most important major grain producing region and commodity grain base in China, it also has important statues in the strategic system of national food security. However, due to the affect of urbanization, water shortage, and unreasonable tillage, the northeast black soil area is facing outstanding problems such as fast non-agriculturalization of cultivated land, intensified degradation of black soil, declining of soil fertility, and serious soil erosion, which maybe has a significant impact on China's food security if it can not be controlled and protection.

2 Status in China’s Food Security

2.1 Important commodity grain base

The grain yield of the northeast black soil area is about 85 million tons annual, which is accounting for about 1/5 of the China’s total grain yield, it can also provide 1/3 commodity grain every year. And the ratio and quantity of commodity grain are the first place in Chain, the same as the per capita quantity of grain yield. And sown area of the major food crops such as the corn, soybeans, and rice is about 25.46%, 37.87% and 5.30% separately of the total sown area of China, but the annual yield of which accounts for 30.03%, 42.08% and 8.0% of the total yield of China.

The grain potential of per unit yield in the northeast black soil area is 1.04×10^4kg/hm^2, but the current per unit grain yield is only 40.4% of the potential grain production, and it has great increasing potential of food yield. In addition, the area of the middle-low yielded farmland is about

$1374.8\times10^4 hm^2$, which covers 2/3 of the total cultivated area of the northeast black soil area. It needs to increase 40 million tons of grain production capacity in the next 15 to 20 years in order to safeguard the national food security. The grain yield of the northeast black soil area shall increase about 20 million tons by the black soil protection, technological innovation and policy control, which will account for 50% of the total increasing grain yield in China, and it maybe become the greatest potential areas of China's grain yield increasing in future.

The center of China's grain production in China has the changing trend from the southern region to the northern region such as the Songliao Plain, and the Huanghuaihai Plain in recent years. Moreover, with the great change of the grain production structure and regional pattern in China, the status of the northeast black soil area shall be further outstanding in the strategic system of national food security.

2.2 Important green agricultural production processing base

The northeast black soil area has the ecological and environmental advantages to develop large green agricultural production and processing. Green food industry has played a very important role in the development of modern agriculture, which also was taking as a pillar industry in agricultural development planning of the northeast provinces. The northeast black soil area has become one of the most important green and ecological industrial base of China and the northeast Asia region by strengthening the safety management of agricultural products and transforming the agricultural recourse and ecological advantage to economic advantage.

The Sanjiang Plain has become one of the largest and high-quality rice producing bases relying on the abundance wetland resource. The central Songnen Plain develops scale grain processing industry of starch and bean production for predominance utilizing its abundance grain resources. The eastern and northern mountain regions develop the forest especial and famous brand production relying on its forest ecological advantage. And the suburban area has constructed nuisance-free food and new especial vegetable base facing to the demand of agricultural production market of the large and middle cities.

2.3 Important exquisite animal husbandry base

The northeast black soil area is a most perfect region to establish national high-quality animal husbandry base for its outstanding combinatorial advantages of animal husbandry resources. The central agricultural region of the Songnen Pain has abundant resources of straw, corn, and soybeans, which are the important guarantee for the development of large-scale animal husbandry, which also accelerate the integrated development of the corn belt-cow belt. The natural conditions of the meadow grassland in the western Songnen Plain is better than anywhere of other region in China, it is the perfect region to develop family ranch and grassland animal husbandry, which accelerate the development of the beef cattle, fine wool sheep and meat goat production base. And the high-quality animal husbandry products processing base has also been established in the Songnen Plain and Sanjiang Plain.

3 Main Problems and Challenges

The northeast black soil area is one of the most intensive regions of human-earth relationship change in China under the conditions of global environmental change and human action. It is facing outstanding problems such as fast non-agriculturalization of cultivated land, intensified degradation of black soil, declining of soil fertility, and serious soil erosion due to the excessive and unreasonable use of black soil, which has impacted the sustainable development of agriculture in northeast black soil area.

3.1 Serious soil erosion

The average loss of topsoil in sloping annual is about 3-8mm in the northeast black soil area. Moreover, some areas where has serious soil erosion only left a very thin black layer, or even formed a “lifelong affliction yellow”. The thickness of the black soil was generally 40-80cm in the early period of reclamation, but clearly reduced to 30-60cm after 40 years of reclamation, and even reduced to 20-40cm after 80 years of reclamation (Liu ea al., 2009).

3.2 Degradation of soil quality

The black soil fertility declined by 1/3 for 20 years of reclamation, and declined by 1/2 for 40 years of reclamation, and decreased by 2/3 for 80 years of reclamation. The black organic matter is still decreasing at a rate of about 5 ‰ in annual. The humus layer thickness of the black soil area remain 20-30cm accounts for 27.74% of the total black soil area, and humus layer thickness of less than 20cm accounts for 11.46%, and the complete loss of humus layer that the subsoil exposed accounts for 2.8% of the total black soil area.

3.3 Degrease of soil quantity

The quantity of the black soil become fewer and fewer due to fast nonagriculturalization of cultivated land and serious soil erosion. The first soil survey data showed that the total cultivated black soil of Heilongjiang and Jilin province is $10\times10^4 km^2$, but 20 years later, the second soil survey data showed that the total area of cultivated black soil of the two provinces is about $5.82\times10^4 km^2$, which has an degrease of $20\times10^4 hm^2$ annual(Lu, 2001).

3.4 Simplify of eco-system structure

The natural vegetation of the black soil area is the transition of forest steppe and meadow steppe, due to human cultivation, there has formed the simple systematical structure and single species. The existing woodland is mainly cultivated farmland shelterbelts, which distribute in the plains of square-shaped; and small piece of natural secondary forest is mainly distributed in the steep slopes of Heilongjiang Province. Perspective from an ecosystem, the stability and self-coordination of simple artificial ecosystems must decline.

3.5 Serious environmental pollution

The environmental pollution of the northeast black soil area is becoming serious, for example, the spraying of pesticides cause soil and groundwater pollution; the urban-industrial sewage and solid waste causes water and soil pollution, which may decline the quality of crops; the ridge coating technology has led to the pollution of agricultural mulch film(Wang et al., 2001).

4 Countermeasures and Advises

4.1 Demarcate the permanent national food security base and solid the quantity of the cultivated black soil

1) Demarcate the black area of Songnen Plain and the Sanjiang Plain as the permanent national food security base.

2) Control the non-agriculturalization of cultivated land strictly, and prohibiting the change of farmland uses so as to safeguard the basic farmland;

3) Take the 0.5 º-5 ºslope land as the key region, and accelerating comprehensive governance works construction of soil erosion in order to solid the quantity of cultivated land resources.

4.2 Strengthen modern agricultural infrastructure construction and ensure the sustainable use of water and soil resources

1) Accelerate the main irrigation projects construction of large irrigation region such as the "two rivers and one lake" area of the Sanjiang Plain, Nierji downstream of the Songnen Plain, Da-an, Hadashan supporting irrigation area, Mopanshan Reservoir downstream and so on.

2) Strengthen the research and promotion of agricultural land and water resources use technology, and developing the high effective utilization models of agricultural land and water resources to ensure the sustainable use of water and soil resources.

3) Increase the facilities investment in agriculture research, and strengthening the technological research of ultra-high-yield breeding such as the corn, rice and soybeans, and improving the construction of the R&D base of grain seed.

4.3 improve the reconstruction of the middle-low yielded farmland and progress the comprehensive grain production ability

There middle-low yielded area is about 65% of the total northeast black soil area, and the middle-low yielded area in Liaoning, Jilin and Heilongjiang provinces is about 63.8%, 60.1%, 67.0% separately of its total cultivated land. The grain production capacity shall have a significant improvement by the combination of flood controlling and soil fertility, agricultural drainage, water retention and high efficient use of water. According to research estimates, the grain yield could increase 20 billion tons through transformation of the middle-low yielded cultivated land in the northeast black soil area. So we shall accelerate the improvement of middle-low yielded farmland of the Songnen Plain, the Sanjiang Plain, and the Liaohe River Plain, and improving the increasing potential of grain yield.

4.4 Construct large grain production bases and improve grain purchase, storage and transportation and circulation system

1) Take the municipality as the basic unit, and construct 8 to 10 larger national commodity grain bases that have the mode of the national investment in the construction and management.

2) Strengthen the construction of the central vertical acquisitions and reserve system, and support the commercial acquisitions and reserves of grain enterprises, and accelerate the formation of diversity channel of circulation and reserves.

3) Build large national food logistics center in such cities as Harbin, Changchun, Jiamusi and others, and speed up the construction of important logistics nodes such as the Dalian, Yingkou and Jinzhou port.

4) Speed up the channel construction of Tongjiang to Dalian and the eastern region, and upgrade the Harbin-Dalian transport Line, and form a high efficient grain transport systems.

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The Protection of Cultivated Land Based on Food Security in the Economic Area of Zhujiang Delta

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Abstract: At the stage of accelerating urbanization and industrialization the transfer of large amount of cultivated land into new industrial and urban built-up area is inevitable, especially in the developed area. As the cultivated land resources are the most basic material of production, the decrease of crop production that induced by the decrease of cultivated land leads to the food insecurity problem. Refer to time-series data on register population, food production and cultivated land area from 1993 to 2007 and other research results, though the predicted results from regression models, this paper attempts to propose the strategy could be adopted to protect the cultivated land based on food security for the developed area as the Economic Area of Zhujiang Delta.

Key words: population growth; cultivated land; food security; the Economic Area of Zhujiang Delta

1 Introduction

The cultivated land resources are the most basic material of production. Changes in quantity and quality are directly related to the stability of food security, the effective supply and food safety standards, thereby affecting the socio-economic security. Cultivated land resources are of great significance for national food security and economic security. Though analyzing the relationship among cultivated land, food security and economic development, refer to previous studies, we attempts to propose the strategy should be adopted to protect the cultivated land for the developed area as zhujiang delta(EAZD for short).

The Economic Area of Zhujiang Delta lies in the southern part of China--- Guangdong province, which is one of the most developed area in China. EAZD includes 9 citie: GuangZhou, ShenZhen, ZhuHai, FoShan, JiangMen, DongGuan, ZhongShan, HuiZhou and ZhaoQing. In 2007, the population of EAZD is 47.25 million, 50% of the total population of Guangdong province. The land area is 41. 698 km^2, Which is 23.36% of Guangdong Province’s. As the leading actor of Guangdong province, the GDP of EAZD came to 2,560 billion yuan, which account for 80% of Guangdong’s. The GDP per capita EAZD is 54,000 yuan, which is 1.65 times of the province's and 3 times of the economy’s. EAZD has been one of three economic areas in China. (Guangdong Province Statistics Bureau. 2008).

EAZD is the important base of many productions such as food, sugarcane and fish. However, in recent decades, with the economic reform and the rapid development of commodity economy, the area of the non-agricultural land use increases constantly and the area of the cultivated land decreases. From 1997 to 2007, the agricultural land had decreased by 154,000 ha while the construction land increased by 219,000 ha. The expansion of construction land is mainly at the expense of the loss of agricultural Land. The cultivated land of EAZD was 771,019 ha in 1997 and decreased to 593,022 ha in 2007, totally reduced by 23%. The annual reduction rate of cultivated land was 2.61%. In 2007 the cultivated land was 0.013 ha per capita in EAZD, which is only 43% of province's, far below the standard 0.053 ha proposed by FAO.

Though the production & demand of food of EAZD from 1993 to 2007 as shown in table 1, the gap between production and demand keeps widening. In 2007, the self-sufficiency rate of EAZD was as low as 27.18%. Though correlation analysis, the coefficient of Correlation between the decrease of cultivated land and the increase of GDP is minus 0.989. A conclusion can be drawn that with economy growth the cultivated land reduction is unavoidable.

Table 1 the production & demand of food of EAZD from 1993 to 2007

10^4ton

Time	Production	Demand	Gap	self-sufficiency
1993	502	1006	505	50.00%
1994	536	934	397	57.00%
1995	567	949	382	60.00%
1996	590	964	373	61.00%
1997	612	981	369	62.00%
1998	612	993	381	62.00%
1999	630	1009	378	63.00%
2000	549	1025	477	53.00%
2001	493	1038	545	48.00%
2002	427	1050	623	41.00%
2003	376	1064	688	35.00%
2004	386	1086	699	36.00%
2006	393	1128	735	34.84%
2007	312	1148	836	27.18%

The latent food crisis forces us to study to what extent can cultivated land guarantee food security under the heavy pressure of population and economic development. Therefore, it is an important practice to predict the minimum demand of cultivated land of EAZD based on the food security in 2020 and this will provide scientific basis to establish the policies of cultivated land protection.

2 To Predict the Population and the Demand of Grain

2.1 To Predict the Population

The population prediction is to analyze the fluctuation and determine the dynamic trend of the population in a certain future period. This paper uses the physical accretion and mechanical accretion methods to predict the population of EAZD.

Table 2 the register population of EAZD from 1993 to 2007

Year	1993	1994	1995	1996	1997	1998	1999
Register population(10^4)	2516.05	2333.78	2372.75	2409.2	2451.68	2483.43	2521.25
Year	2000	2001	2002	2003	2004	2006	2007
Register population(10^4)	2563.6	2595.23	2624.93	2660.48	2714.13	2821.27	2872.47

Using the register population data of zhujiang delta from 1993 to 2007, take population as the dependent variable of time, with spss a linear regression model ($Y = 33.944X + 65308.1$) is acquired. The coefficient of determination (R^2) was adopted to indicate accuracy. The Register population of EAZD predicted in 2020 is 32.58 million, R^2=0.872.

For comparison, a usual formulation is used to predict the population. The growth rate is determined by the natural growth rate and the immigration rate.

R^2=0.981 $P_n = P_0(1+k_1+k_2)^n$

p_0: population on basis year

k_1: natural growth rate

k_2: the immigration rate

According to the population statistics last 14 years, the compound rate is 1.55%. The coefficient of determination 0.981 Shows that the increase of population in EAZD is relatively stable, the equation is Adapted to the Reality. Suppose that there isn't any new population policy put in force, analyzing the factors that affect the growth, take the registered population of late 2007 as the basis, the register population of this region will increase naturally to 34.85 million by year of 2020. Considering the coefficient of determination, the result of the second method is adopted.

2.2 To Determine the Standard of Average Per Capita Nutrition in 2020

The standard of average per capita nutrition is the minimum level of nutrition to guarantee the normal life. It can be represented by the quantity of heat, protein and fat needed everyday. EAZD is one of the richest regions of China and the residents' consumption level is higher than that of others. When determining the standard of nutrition in 2020, we adopted two standards, the moderate well-off standard and the rich standard. The consumption structure is shown in Table 3.

Table 3 The population nutrition level and food structure in 2020 (kg/person .a)

Item	**The moderately well-off standard**	**The rich standard**
Meat	21	24
Fowl	12	16
Milk		15
30		
Egg	12	30
Aquatic	product	21
24		
Bean	13	18
Vegetable	oil	8
10		
Vegetable		135
135		
Fruit		20
25		
Melon	60	70
Processing grain ration	180	165

2. 3 To Predict the Demand of Grain in 2020

According to the different types of the nutrition standards, food structure and the transformation rate of grain, the demand of grain at the different nutrition standards can be figured out. The results are shown in Table 4.

Table4 The total amount of grain to guarantee the basic living of EAZD in 2020

The nutrition standard	The standard of average of demand (kg)	The total amount grain per person(kg)
The moderately well-off standard	480	1.67×10^{10}
The rich standard	520	1.81×10^{10}

3 The Minimum Amount Demanded of Cultivated Land in 2020

3.1 Estimate the Crops Production Potentiality Per Unit Area

To estimate the land production potentiality per area is mainly to get the crop output per area. The crop production potentiality per area in EAZD was estimated by the method of the trend prediction, by which the law and trend of historical change of the crops output is analyzed and the future crops output estimated. Refer to China's Research Project on agricultural production capacity and population carrying capacity, combining with the situation of EADZ, the production is predicted as up to 10,500kg per ha in 2020.

3.2 The minimum demanded amount of cultivated land in 2020

Refer to self-sufficiency rate of grain of EAZD in the past , the demanded amount of the cultivated Land is predict in 3 level of self-sufficiency rate :50%，40%，30% . According to the prediction of demand of grain & the Crops Production Potentiality per Unit Area, the results of minimum demanded amount of cultivated land in 2020 are shown in Table 5.

Table 5 The prediction of the cultivated land demand of EAZD in 2020

Level	self-sufficiency rate of grain (10^4ha)		
	50%	40%	30%
The moderately well-off standard	718,800	575,100	431,300
The rich standard	778,800	623,000	467,300

In 2007 the area of cultivated land is 723,000 ha. Therefore if the amount of cultivated land could be maintain, the demand below 50% self-sufficiency rate standard could be satisfy.

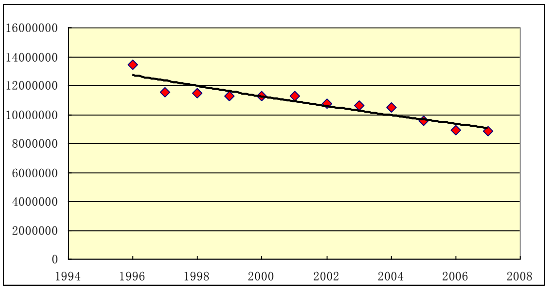
For comparison, the amount of cultivated land in 2020 is predicted with regression model. In order to get a matter-of-fact model, a comparison was made among several models such as linear mode, quadratic polynomial, logarithmic curve, exponent curve where x is sequential natural number of year; Y is dependent variable .A best mode was selected from the models mentioned above according to the value of coefficient of determination.

$$Y = 4.67 \times 10^{32} e^{-0.0308X}$$

X: sequential natural number of year

Y: dependent variable

$R^2 = 0.885$



The amount of cultivated land predicted is 448,480 ha, which could only meet the demand of food for self-sufficiency rate of 30% by moderately well-off standard.

4 Conclution

Though the analysis, it’s no doubt that cultivated land of EAZD can only guarantee a low level of self-sufficiency rate. With the gradually development of agricultural science and technology, the status of cultivated land decreases, but the amount of cultivated land is still an important factor for stability in food production. But on the other hand, as the basis factor of economic development, land is indispensable also. As one of the three economic areas in China, EAZD shoulders the responsibility of the prosperity and stability of the entire economy. In fact, cultivated land is just one of factors which affect grain production. A theoretical framework to analyze the effect of land conversion on food security was constructed, and an empirical study was taken. to study the effect of land conversion on food security. The result showed that if the quantity of annual land conversion increases10% ~50% than the average number of 1997 to 2002, from 2000 to 2030 the loss of grain production caused by land conversion would be about6% of grain demand. It's practical to release some farmland to satisfy the demand of economic development. As a result, considerations should be given to both food security and economic development needs. Recommendation as follow:

4.1 Controlling the Increase Rate of Population and Improving the Qualities

In the relationship between human and land, the demand of grain is an important factor. To reconcile the relationship between human and land, we must firstly control the birthrate of population, reduce the increase rate of population and alleviate the population stress on land, food, etc. Strengthen management on the family planning by means of law, administration and economy, strictly control the increase rate of population and continuously improve the population quality.

4.2 Enhanced farming techniques and new technologies to boost production

Most gains in production will be achieved by increasing yield growth and cropping intensity on existing farmlands rather than by increasing the amount of land brought under agricultural production. FAO's latest projections indicate that Globally, 90 percent of required production increases are projected to come from augmenting yields and cropping intensity, and only 10 percent by expanding arable land. For developing economies, FAO estimates that ratio at 80/20. But in land-scarce economies, almost all growth would need to be achieved by improving yields. This necessitates pushing the agricultural technology frontier outwards, But new technologies should be evaluated carefully to avoid possible negative environmental and human-health impacts.

4.3 Running mechanism for balance of cultivated land's occupation & compensation in different area in Guangdong

Build market for cultivated land's retain target under the control from government by the target divided. The price of cultivated land's retain target is decided by the demand and supply in the market and the guide from government, the system of monitor by government and public and the assessment system should be built to make the balance of cultivated land's occupation and compensation in different area can be achieves and the land resource can be optimal distribution.

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GIS Modeling Land Use/Cover Change and Its Effects on Grain Production in China

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Abstract: On the basis of analysis of land use/cover change and its spatial characteristics and incorporating with GIS modeling, this article discusses the impacts of land use change in arable land on grain production in China, mainly including sown area, production conditions and grain yield.

Key words: GIS Modeling, Land Use/Cover Change, Grain Production, China

1 Introduction

Land use/cover change (LUCC) is closely related with the sustainable development of mankind. One of the key problems brought about by land use/cover change in China is its food security. With the population growth and increasing food demand, grain production and food security have become hot topics at home and aboard. Lester R. Brown, the founder and former president of the Worldwatch Institute wrote a book ***"Who Will Feed China? Wake-Up Call for a Small Planet"*** and predicted that China will face a Great Food Famine in 2030 in this book, which will pose a threat to world food market seriously. Brown's viewpoint has induced enormous responses from the world, since he has pointed a serious problem for China and the world. Frankly speaking, land use/cover change, such as the decline in quantity and quality of arable land, eco-environment deterioration, emphasized by Mr. Brown, will exert profound influence on grain production and food security in China; research on land use change and its impacts on food security at a national level is merely one component of agricultural researches on guaranteeing food security. China has vast territory with diversified natural environment and resources, thus land use change/cover and its effects on grain production differ from region to region. From this perspective, it will be of great significance to investigate the spatial difference of land use/cover change in China with a purpose of providing scientific support for land use planning and regional strategies of grain production.

With spatial GIS modeling, this article presents the recent land use change and its spatial characteristics in China, explores impacts of land use change on grain production and other issues related with food security.

2 Gis Modeling of Land Use Change

The most obvious impact of land use change on grain production is the amount of size change in arable land that affects sown acreage of grain crops. In order to investigate size change in arable land in China, the CLUE_CH model (Conversion of land use and its effects in China) was applied. This model is a dynamic and multi-scaled model on land use change and its spatial distribution, developed jointly by the Wageningen University and Research Center, The Netherlands and the Institute of Natural Resource and Regional Planning, CAAS, China.

2.1Structure of the Model

On the basis of a statistical analysis of land use change and its driving forces at different scales, CLUE_CH can investigate the spatial characteristics of land use change. This model comprises four major modules: Statistical Module, Demand Module, Population Module, and Spatial Allocation Module (Figure 1).

Statistical Module also called Spatial Multi Statistical Module is the basis of the whole CLUE model, which provides necessary parameters and data concerning the relationship and structure. Through this module, the interrelationship among the spatial allocation of arable land and its driving factors like natural ecological, social and economic factors can be obtained and will be considered as inputs for the model.

Demand Module is to analyze and predict the national demand of agricultural products at national level. Considering population and its age structure, change of diet and the food trade situation, this module will analyze the temporal change of demand for agricultural products. Then, by combining with yield or production estimation of grain crops, the acreage change of different land use types can be modeled assuming that the total demand for agricultural products should be met. Results from this module will control the total amount of land use change at the national level by a way of downscaling.

Population change is one of the major driving forces for land use change, which can, on one hand, affects land use change and its spatial allocation through demand change of agricultural products caused by population change; and on the other hand affects directly land use change through different ways, for example, the population growth can increase the demand for residential land and infrastructure land so that cause an increase of non-agricultural land use. This module will mainly apply historical population statistics to predict change tendency of population. Through this module, changes of other factors like social and economic factors can also be analyzed, which is also very important for the land use modeling.

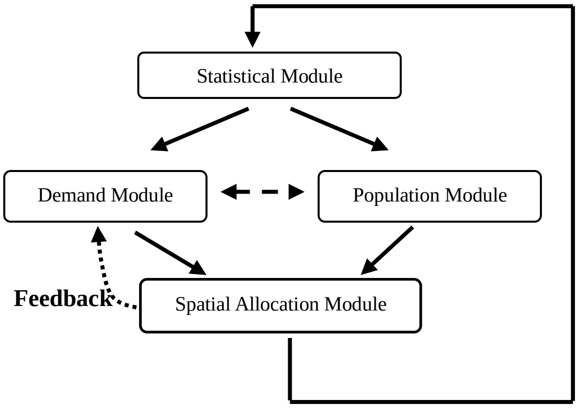

Fig. 1 Structure of the CLUE_CH

Spatial Allocation Module is the key part of CLUE model, which allocates spatially the arable land change at different scales on the basis of results from the other modules.

2.2 Modeled Results

Through this model, quantitative change and its spatial distribution of different land use types can be obtained in the predicted period. The data inputted to the model is from the year of 1991, and the situation of land use/cover situation in 2010 will be modeled.

Figure 2 describes the actual distribution of arable land in 1991, and Figure 3 shows the predicted situation of arable land distribution in 2010. These two figures illustrate a similar spatial characteristics at the first sight, namely, no considerable change can be detected for overall spatial distribution of arable land. The arable land is mainly distributed in the east and middle regions with favorable environment such as flat landscape and humid climate. It is necessary to point out that this situation is come into being over long history on the basis of adapting to the local natural conditions.

Through comparison between Figure 2 and Figure 3, Figure 4 can be obtained. From Fig.4, the arable land change and its spatial characteristics can be observed obviously as follows.

（1） The overall tendency of arable land change in China is the acreage decrease.

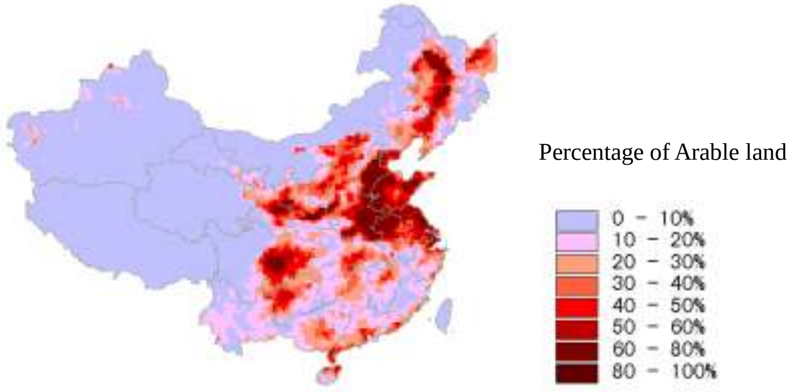

Fig.2 Spatial Distribution of Arable Land in 1991

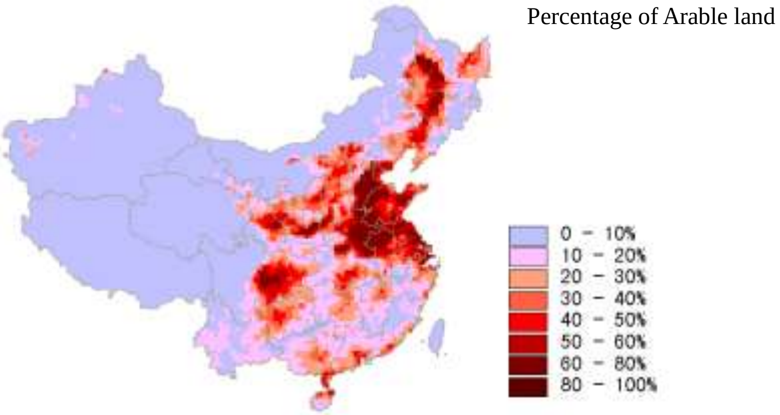

Fig.3 Modeled Distribution of Arable Land in 2010

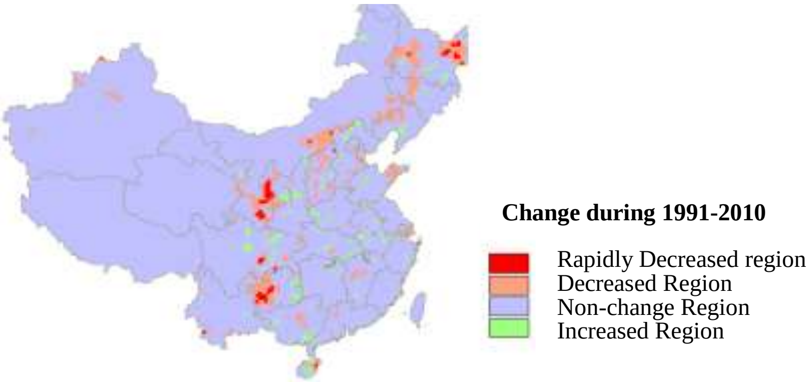

Fig.4 Arable Land Change during 1991 and 2010

（２）Despite an overall decrease of arable land in the predicted future, not all regions will develop toward that direction. During this predicted period, the model finds that there will be some regions developing under a state of increase of arable land. Obviously this simulation is much more reasonable and closer to the reality of land use change and its spatial distribution than those models simply allocating the total deceased amount of arable land to regions.

（3）Future change of arable land will probably concentrate in the middle and northeast areas of china, especially in the stripped area passing Northeast China Plain - Loess Plateau - Southwest China the arable land will decrease severely. This stripped area belongs to the typical ecotones between agricultural region and animal husbandry region or forestry region, where the ecological environment is quite fragile and arable land was developed mainly due to irrational cultivation. So that it is predicted to be the main area for arable land to be converted back to forestland and grassland in the future China. In the eastern agricultural area with high population density, due to the implementation of the strictest possible system for protecting basic farmland and improvement of land use efficiency, the declining speed of arable land will be under control effectively, getting lower and steady, despite of ongoing highly-developed urbanization.

3. Impacts of Land use Change on Grain Production

3.1 Acreage of grain crops

Effects of land use change, especially the change of arable land, on the sown area of cereal crops are reflected in two aspects: the change of sown area caused directly by arable land change; and the indirect affects caused differently on the sown area in different regions due to its different cropping intensity index.

According to the estimation by model, arable land in 2010 will decrease by 12.0313 million ha^2 from that in 1991, and actual arable land will be decreased to 112 million ha^2 or so. In reality this decreased figure may be bigger than other estimates due to the characteristics of arable land decrease. Although in recent years under guidance of the policies like “Total Balance of Arable Land”, while converting some amount of arable land the local government has to develop the same amount of new land for cultivation in return so that in some areas the arable land might be increased. But obviously the quality of the newly increased arable land is surely not as good as the previous land converted. In a view of sustainable development, this newly increased land will be mostly converted back to forest land or grassland in the near future based on the new regional policies for ecological construction, which has been listed as top priority in the developmental scheme by central government. At the same time, according to statistics of the Ministry of Land and Resources, during 1996 and 2000 there was a total decrease of arable land by 3.36 million ha^2, or a yearly decrease by 0.67 million ha^2; the newly-increased arable land was 1.876 million ha^2, so that during this period the net decrease of arable land was 1.488 million ha^2. But in fact the actual decrease of arable land should be much more than this figure. According to some sampling investigations usually the reported figure from local government is usually 47% less than the reality. So together with this un-reported part, the actual decreased amount of arable land should be very similar to the estimate by our model.

Through the model, during the recent 20 years the total decrease of arable land might be 12.93 million ha^2 and increased arable land might be 0.95 million ha^2. Based on the average Cropping Intensity Index-1.55 and the ratio of grain crops in all crops-75%(this ratio was 73% during the latest 5 year, considering the possibility of increase of the Cropping Intensity Index 75% is applied), the sown area of grain crops in 2010 will probably decrease by 13.21 million ha^2, and the total sown area will then be about 130.2 million ha^2. Some researches pointed out that there would be a great increase of the average Cropping Intensity Index in China, but according to our investigation, although theoretically it is possible that the Cropping Intensity Index of China can be promoted to a great extent, in the near future it is impossible to fulfill this because of various objective factors.

Secondly, the regional difference of arable land change will also affect the actual sown area of grain crops. Due to difference of production environment, the Cropping Intensity Index (CII) differs obviously among regions (Figure 5). Under different CII, arable land change will cause different change of sown area of grain crops. Based on the change rate of arable land, China can be grouped into 4 different regions: increased area (**I**), no-changed area (**II**), decreased area（**III**）and rapid decreased area（**IV**）（Figure 4）.In different area, the CII is quite different (Table 1), and the effect of arable land change on sown area will be different due to the different CII. According to table 1, we can recalculate the change of sown area of grain crops caused by the arable land change. To the year of 2010, the total sown area will probably decease by 12.8 million ha^2, compared with the previous figure; there is a difference of more than 0.4 million ha^2.

Table 1　Regional Difference of the Cropping Intensity Index

Regions	Increase of arable land (%)	Area percentage of regions (%)	Cropping intensity index (%)
Increased area (I)	＞+0.2	13.86	158
No changed area (II)	+0.2－-0.2	66.97	156
Decreased area (III)	-0.2－-5.0	16.03	146
Rapidly decreased area (IV)	＜-5.0	3.14	133

3.2 Production environment

Recently the qualitative loss of arable land caused by the acreage change of arable land is astonishing[2]. Firstly most converted arable land is of high quality especially the paddy rice field; secondly most converted arable land is located in the productive area such as in the south China, around the urban area, along the transporting lines, but the newly-developed arable land are mostly located in the mountainous areas and fringe areas; so the loss of grain productivity caused by this conversion should be greater than estimates only by the change of sown area. This fully

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[2] Economyal Office of Agricultural Regional Planning:《Report of Agricultural Resources in China》, China Population Publishing House, 1998.6.

demonstrates that acreage change of arable land will not only affect the sown area of grain crops but also affect the production conditions, thus affect yield and grain output.

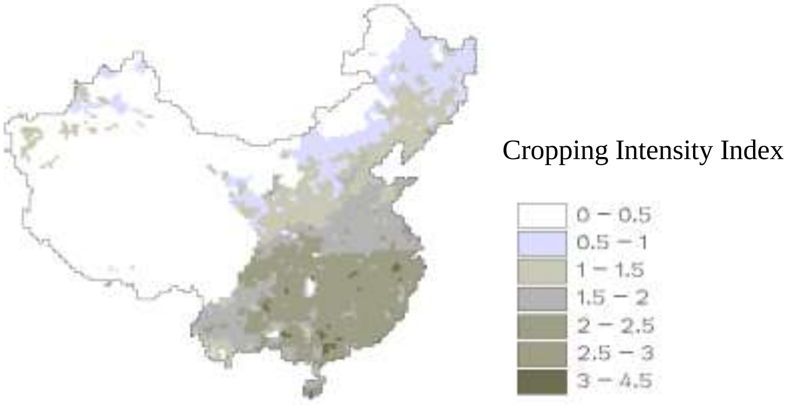

Figure 5 Spatial Distribution of Crop Intensity Index

Table 2 Grain production conditions in different regions in 1996

Factors		Increased area	not-changed area	decreased area	rapidly de-creased area
Management	percentage of machine-cultivated area (%)	42.47	55.43	29.35	47.72
	percentage of irrigated area (%)	51.30	61.10	25.99	26.31
	fertilizer applied (kg/ha)	360.04	274.14	228.95	233.51
Natural environment conditions	percentage of poor soil(%)	24.17	25.78	26.01	21.69
	percentage of fertile soil(%)	59.05	32.99	41.92	52.55
	percentage of sloping area(%)	32.03	30.81	31.21	43.85
	percentage of flat area(%)	51.47	39.33	42.09	45.01
	percentage of well-drained area(%)	28.77	26.76	25.08	26.66
	average temperature(℃)	9.92	3.98	9.14	7.23
	Annual precipitation(mm)	904.69	522.26	833.06	718.52
	percentage of deep soil(%)	76.17	58.83	62.89	68.49
Social-economic conditions	Ratio of illiteracy (%)	26.27	35.60	24.30	28.81
	density of agricultural labor (person/km^2)	56.74	26.43	34.77	49.80
	total population density(p/km2)	190.39	91.91	140.73	179.60
	net income per farmer(yuan)	1539.05	1426.43	1712.71	1590.01
	distance to city(km)	58.27	144.97	41.98	35.27

Conditions for grain production among those four areas vary obviously (see Table 2). Firstly, in terms of management, Area **I** and Area **II** are more advanced than the others, which means that the agricultural production and management are more modernized and advanced; at the same time because the rapid decrease of arable land will happen partly around cities or in urban fringe areas the management level in Area **IV** is a little bit higher than Area **III**. Secondly, in terms of natural environmental conditions, Area **I** is also more favorable than Area **III** and Area **IV**, and because of the same reason existed in urban fringe areas the parameters like Percentage of Fertile Soil, Percentage of Deep Soil, Percentage of Flat Area, and so on are a little bit more favorable in Area **IV** than in Area **III**. Thirdly in terms of social and economic conditions, the most obvious characteristics is that the no-changed area mainly belongs to typical agricultural area with a far distance from urban, isolated, less educated and sparsely populated, and backward economy, low income per capita.

Frankly speaking, there is no direct causal link between condition change of grain production and acreage change of arable land; yet change of spatial characteristics of arable land is certainly a contributor to the changed grain production conditions.

3.3 Grain productivity

In terms of general situation all over China, according to the estimation by model, the average yield of grain crops per unit acreage will be 3643.95 kg/ha^2. And based on this figure, due to the acreage decease of arable land, the total grain output in 2010 will be 474.442 billion kg (without considering the annual yield fluctuation). Assuming in 2010 the total population will reach 1.4 billion (1.394 billion according to some estimates[3]), and per capita grain consumption will be 400 kg, the total demand for grain in 2010 will be 560 billion kg, hence, grain insufficiency will probably reach 85.558 billion kg for China in 2010.

However in fact, on one hand because of the regional difference of CII discussed above, the decrease range of sown area of grain will be 12.8 million ha^2, so that there will be a difference of 0.041 million ha^2 and the total production of grain will be 1.393 billion kg more than the 45.168 billion kg (if without considering this factor), and the actual total production of grain will be 475.835 billion kg. This means the insufficiency of grain will be 1.63% less than that estimate without considering the regional difference of CII.

On the other hand, due to the regional difference of production conditions, a big difference of yield exists among regions. From table 3, it is not difficult to discover this difference among the four areas, where the increased area has a comparatively high yield of grain production. And especially in the decreased area accounting for 83.62% of total decrease of arable land the yield per unit acreage is only 2062.5 kg/ ha^2, less than half of the yield in Area **I**.

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[3] Ma Xiaohe: Agricultural Problems in the economic development during 1996-2010,《Can Chinese People survive by themselves》, Economic Science Publishing House, P50,1996.

Table 3 Grain production situations in different regions Unit: kg/ha^2

Regions	Yield of grain	Yield of rice	Yield of wheat	Yield of corn	Yield of potato	Yield of soybean
increased area (I)	4283.63	6170.25	2785.5	4604.1	3691.43	1833.23
not-changed area (II)	4138.13	5570.78	3339.98	4890.15	3554.7	1923.15
decreased area (III)	2062.5	1515.68	807.68	1764.83	1289.03	669.83
rapidly decreased area (IV)	3822.07	2285.7	2406.3	5742.15	3497.48	1638.08

The combination of the regional difference of grain yield with the spatial difference of acreage change of grain sown area will certainly result in another obviously different situation for the total production of grain in China. As estimated after considering the regional difference of grain yield, the total grain production in 2010 will be 481.015 billion kg, and there will be another 5.18 billion kg more than the figure only considering the CII. Thus, grain insufficiency will decrease to 79 billion kg in 2010, decreasing by 5.85%.

4. Conclusion

Effects of land use change on grain production are various. Based on analysis of land use change spatial characteristics and application of GIS modeling, this article discusses the effects of arable land change particularly quantitative and qualitative changes on grain production. This is of great significance.

Firstly, through GIS modeling we have investigated the possible effects of the arable land change especially its regional difference on grain production in China. Due to the great territory of China, the method is more feasible than the traditional methods, and tested to be more powerful to explain the reality.

Secondly, although the result indicated by model approach is different from normal statistics in some aspects, it is for sure that reliability of the model approach is higher and the results turned out to be very closer to facts and figures. Therefore, the results of this study should be useful references for some researchers.

Understandably, not all results are very precise since this study was carried out on a large-scale level. For example, in the four different areas, detailed analysis can render more detailed figures on grain yields and CII than average calculation; however, this modeling still works well to reveal general spatial distribution of arable land change and its impact on grain production.

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Agricultural Land use in Mexico

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Introduction

Mexico has an area of 1.9 million square kilometers, and It presents a variety of climates, including arid, humid and subhumid, two thirds of the economy is considered arid or semiarid, while the southeast is humid, with average rainfall in excess of 2 000 mm per year in some areas. The economic indicators are: GDP per capita: $ 8,500. Average inflation rate: 4%. For the relief features of Mexico, the economy has a great variety of climates. On vegetation and land in Mexico use, its variety of climates, topography and geological history have been one of the most impressive biological wealth of the world. This is manifested in the great diversity of plant communities that can be found in their territory continental and insular and ranging from their own Alpine areas, those of coastal dunes and wetlands, passing xerófilos bushes, temperate forests, rain, forest mountain mesófilos and natural grasslands. However degradation in the economy's territory is not homogeneous and 88 million ha (45% of the total area) has a level of degradation, of which 32 million ha degraded agricultural. Every entity, degradation, their specific types and levels, have different importance. For example, in Chiapas practically there is no evidence wind; erosion while in Chihuahua, this process has affected to 28.5 per cent of its territory. Both water and wind erosion include processes in which there is movement of soil; material while in chemical and physical degradation processes that cause the internal deterioration of the soil. This article discusses the strategies and actions that the Department of Agriculture has established in order to reduce land degradation in Mexico.

OBJETIVE

Disseminate strategies and actions that the Ministry of Agriculture of Mexico has been established to reduce the degradation of the economy.

METHODOLOGY

Mexico features

Mexico's surface comprises an area of 1.9 million square kilometers. It lies between North America and Central America, bordering the north by the United States of America and south by Guatemala and Belize.

Its population has quadrupled from 1950 to 2005, reaching 103.4 million people, being in 1950, 57.4% rural, while in 2005 the 76.5% urban (Figure 1). While average annual growth rate declined significantly. On average each Mexican family comprises 4 members.

Changes in the structure and composition of the population are part of the demographic transition that the economy increasingly less the proportion of children, and are increasingly being young and older adults.

GDP per capita of Mexico in 2007 was close to $ 8 500 and inflation has been in recent years in values close to 4 per cent, far below what was recorded in the previous decade.

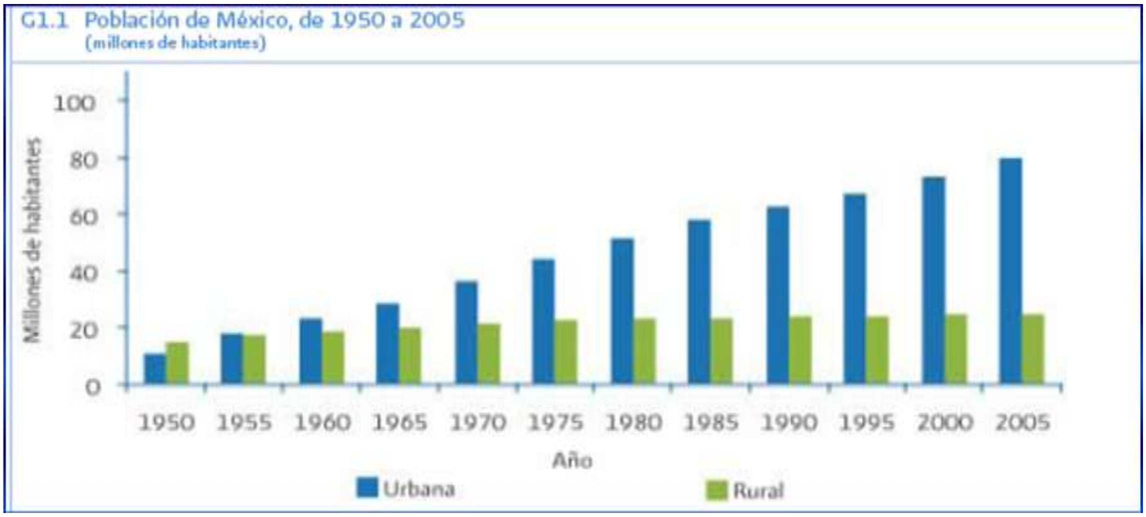
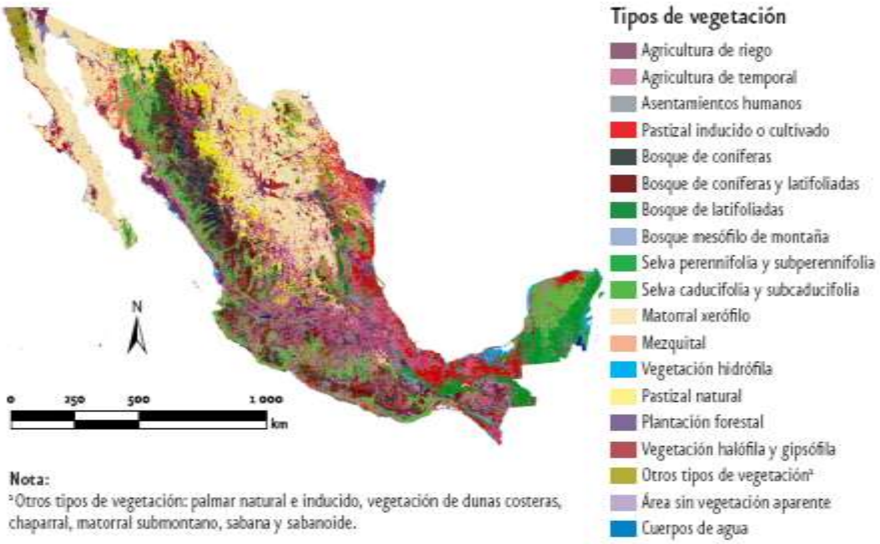


Figure 1. Population of Mexico from 1950 to 2005.

Vegetation and land use in Mexico

The geographical situations of Mexico, its variety of climates, topography and geological history have been one of the most impressive biological wealth of the world. This is manifested in the great diversity of plant communities that can be found in their territory continental and insular and ranging from their own Alpine areas, those of coastal dunes and wetlands, passing xerófilos bushes, temperate forests, rain, forest mountain mesófilos and natural grasslands.

In 2002, 72.6 per cent of the economy was covered by natural communities with different grade conservation; the remaining surface has been converted to farming, urban land and other antrópicas covers. The bushes are predominant plant training in the economy (26.1 per cent of the territory), followed by forests and jungles that together, occupy 33.6 %. (Figures 2 and 3).



Nota:
¹Otros tipos de vegetación: palmar natural e inducido, vegetación de dunas costeras, chaparral, matorral submontano, sabana y sabanoide.

Figure 2. Vegetation types in Mexico.

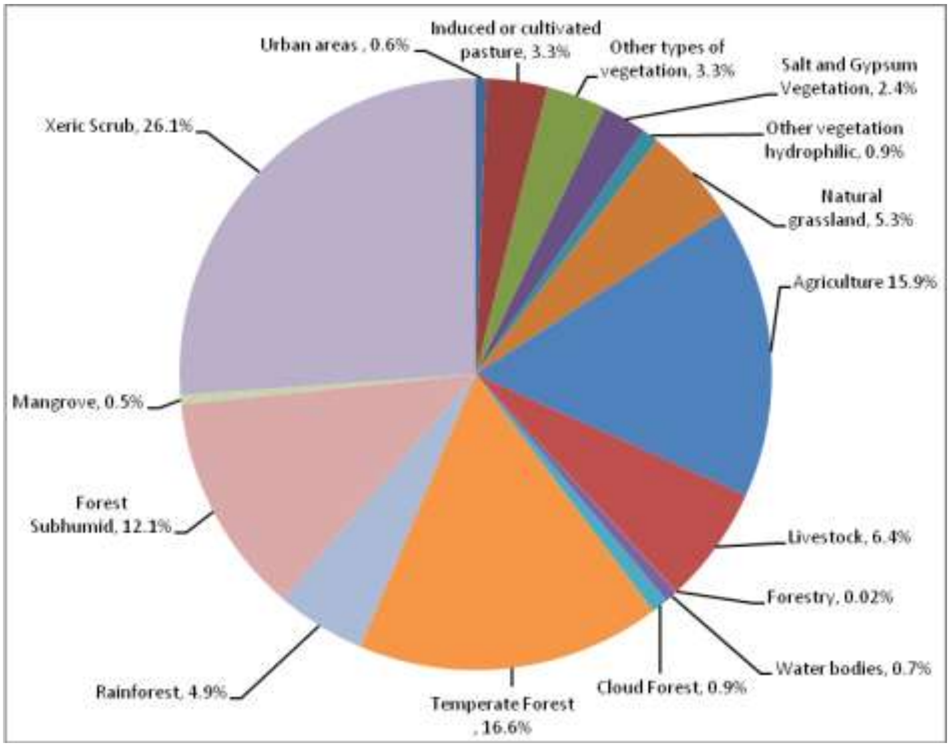


Figure 3. Percentage of Vegetation in Mexico.

On the types of soils

Mexico is an economy with a complex product, largely, of intense volcanic activity that occurred during the Cenozoic topography; has a that ranges from zero to 5 000 metres above sea level, presents four of the five main types of climates recognized by the classification of Köppen; altitudinal gradient enormous landscape diversity and types of rocks (igneous, sedimentary and metamorphic).

These factors help to explain the wide diversity of soils in the economy, which also forms part of the national megadiversidad in Mexico there are 26 of 30 soil groups recognized by the system international base reference global resource soil (FAO-ISRIC soil-ISSS, 1998).

The 52.4 per cent of the territory is covered by shallow and underdeveloped soils: Leptosols (54.3 million hectares), Regosols (26.3 million hectares) and Calcisols (20 million of has), which hinders agricultural exploitation and increases their vulnerability. (Figures 4 and 5).

Soils with higher fertility (Phaeozems, Luvisols, and vertisols; 17.3 and 16(5) 22.5 million hectares, respectively) cover together 29.4 per cent of the economy. The rest of the territory (35 million hectares) presents a high diversity of soil, finding the other 20 groups spread across a large number of microrelieves, microclimates and vegetation types.

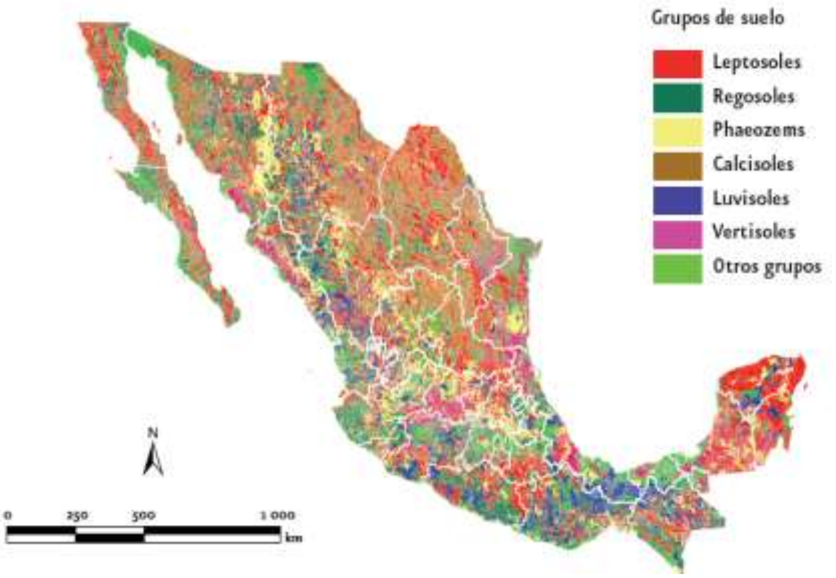


Figure 4. Types of Soils in Mexico.

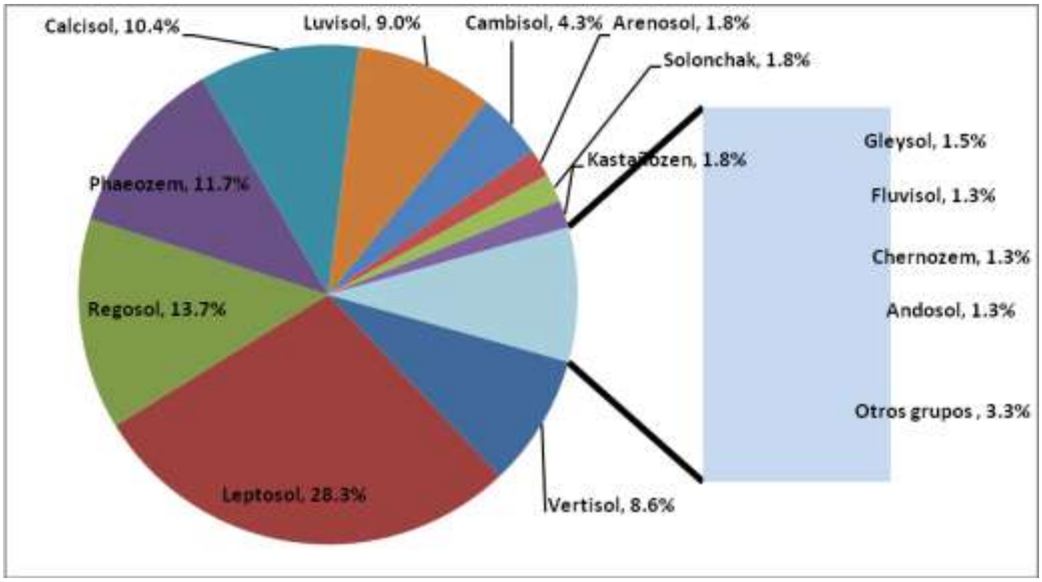


Figure 5. Types of Soils in Mexico.

Soil degradation

Soil degradation refers to processes induced by human activities causing decrease their biological productivity or its biodiversity and for current and/or future capacity to sustain human life. The assessment of soil degradation caused by elaborate man by the Semarnat and the school of postgraduate (2003), is the most recent study on Mexico soil degradation, and which is made with higher level of resolution. Degradation in the national territory is not homogeneous. (Figure 6). Every entity, degradation, their specific types and levels, have different importance. For example, in Chiapas practically there is no evidence wind; erosion while in Chihuahua, this process has affected to 28.5 per cent of its territory.

Type of Degradation	%	🟦
Water erosion	11.4	🟦
Wind erosion	9.4	🟨
Physical degradation	5.9	🟪
Chemical degradation	18.3	🟥
Land not used	23.8	⬜
Flat surfaces	27.3	🟩
Water Bodies	1.2	🟦

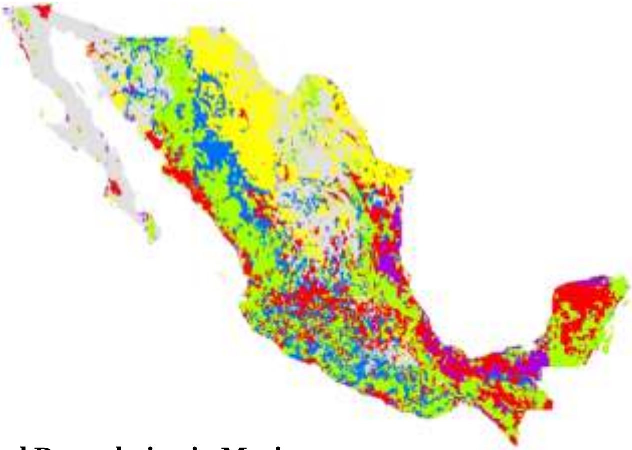


Figure 6. Types of Land Degradation in Mexico

Both water and wind erosion include processes in which there is movement of soil; material while in chemical and physical degradation processes that cause the internal deterioration of the soil. The water erosion is defined as the removal laminar or mass of soil from water currents materials. Action of these you can tweak the ground and cause caverns and gully. In wind erosion, field change agent is the wind. The chemical degradation involves processes that lead to the reduction or elimination of biological productivity soil and is strongly associated with the increase in agriculture. Physical degradation relates to a change in the structure of the soil whose more conspicuous manifestation is the loss or reduction of its ability to absorb and store water.

With regard to the causes of the degraded national surface degradation 35 % is associated with agriculture and livestock (17.5 % each) and 7.5 % loss of vegetation cover. The rest is divided between urbanization, overexploitation of vegetation and industrial activities. (Figure 7).

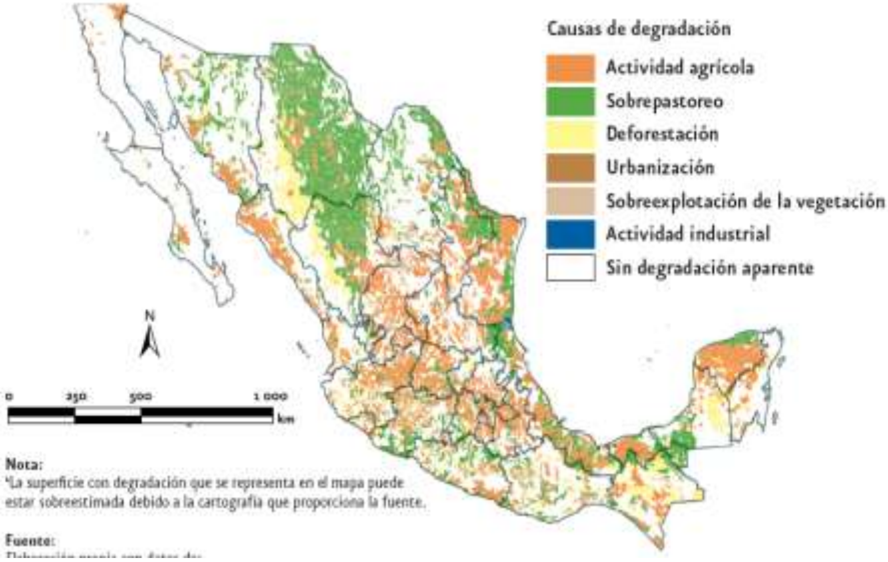


Figure 7. Causes of Land Degradation in Mexico

Impacts of the degradation of soils

- In agricultural gradual loss of productivity and decline in fertility, loss of nutrients, the infiltration of deterioration in carbon stocks and water capacity reduction activities.
- 40 per cent of the livestock surface presents overgrazing. This is the main cause of degradation of the soil in this activity. Impacts include the reduction of forage quality, lower livestock yields, reduction of environmental services and fragmentation of habitats for wildlife species.
- 15 % of the degradation of the soil in the national territory, is due to unsustainable timber extraction and firewood, loss of vegetation cover and forest fires. (Table I.)

Table I. Impacts of Soil Degradation.

Local scale	Regional and global scale
•Loss of income •Decreased infiltration and water retention •Decreased soil quality Increased production costs •Loss of raw materials (food, fiber, fuel) •Decrease in family income •Land abandonment and migration to urban areas	• Reduced aquifer recharge • Loss of biodiversity (flora and fauna) • Increased sediment and siltation in dams, lakes, estuaries, and irrigation canals • Decreased prey life • Increased risk of flooding • Emissions of greenhouse gases • Lower capacity to adapt to climate change Migration, environmental refugees • Increased poverty

Water infrastructure

- The water erosion basin upstream transported azolves (land). The azolvamiento reduces storage capacity and therefore reduces the life of the water infrastructure.
- The drainage also alter the quality of water in the hydraulic, stores and the impact you when there are no suelo-vegetación (runoff without control).

Results

The institutional response to land degradation is varied and includes, among others: regulatory instruments and incentives, utilization rates, duties, establishment of protected areas, inspection and surveillance and support programs for sustainable use, conservation and restoration of soils.

Strategic actions

With the participation of producers, has decided to plan for watersheds, sustainable land use in farming and forestry to promote and support food production and rural development, with the following lines: (Figure 8 and Tables II and III.)

1. Stop the degradation of agricultural and forestry use.

2. Reverse the loss of soil productive capacity.

3. Enhance productive activities according to type and production potential and

rate of degradation.

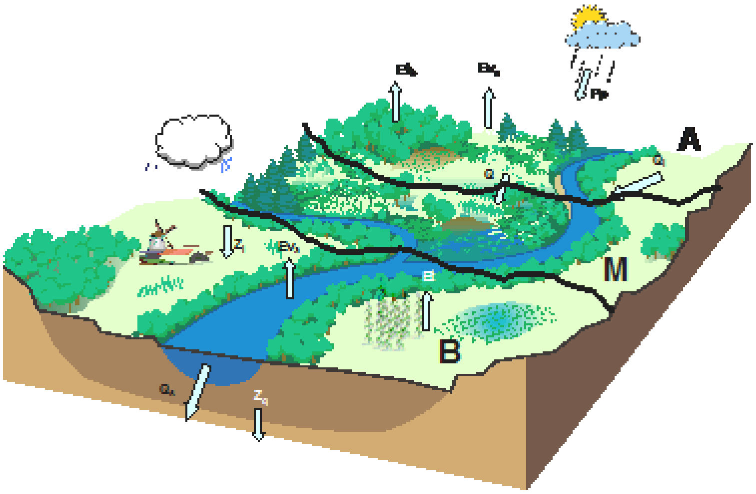


Figure 8. Geographical area, hydrological, economic, social and environmental hydrographically bounded by river runoff.

Specific actions

1. Induction patterns of production with less impact on natural resources.
2. Construction and practices for sustainable use of soil and water.
3. Sustainable livestock production and livestock management.
4. Machinery and equipment for conservation tillage.
5. Research, validation and technology transfer. (Projects that promote sustainable use of natural resources and adaptation to climate change).
6. Training and technical assistance for crop and livestock improvement.
7. Reforestation to reverse the deterioration of vegetation cover.

Agricultural Land Use Changes and Its Implications on Food Security in Northeast China

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Abstract: It is of great significance to study the changing patterns of current regional cultivated land and explore its impact on grain productivity. In this paper, the changes were detected from multi-temporal Landsat TM/ETM+ images of 1993 and 2003 for Northeast China. Then considering the natural and social factors systematically, the comprehensive quality of cultivated land was evaluated. On the basis of field survey data, agricultural statistics data and considering the natural and socio-economic factors, this paper analyzed the impact of cultivated land change on the grain production capacity in terms of cultivated land quantity and quality. Finally, pre-warning on grain production safety in Northeast China was carried on by early warning model, which was developed considering the change of grain yield from two respects of cultivated land quality and quantity.

Introduction

Land use change has being received lots of attention internationally. Understanding of the mechanism of land use change and its effect on grain security, environment is conducive to understanding of population, resources, environment and sustainable economic development on the global, national and regional scales. (Yansui, L., et al., 2004)

Northeast China has always been the major resource of grain and natural resources for the Chinese economy since the founding of the New China in 1949. It plays a vital role in China’s economic development with its fertile land, developed industry and a relatively high degree of urbanization. It is one of the most important bases of commercial food grains (maize, rice) and economic crops (soybean, sugar beets, etc.) in China. The government has always attached special importance to this region. (Gao, J. et al., 2006) As one of the main agricultural regions in China, its yield of corn and soybean accounting for more than 30% of the economy’s total. Northeast China plays an important role in the strategy of ensuring China’s food security. (cheng, Y., et al., 2007) It is also a hot-spot of land use, partly because of its relatively high food production potential, and partly because of its rapid socio-economic change reliant on the land. Studies the change in cultivated land use in Northeast China have become important in the discussion of food supply safety in

China. In past decades, Northeast China has suffered dramatic land use changes as a result of activities of human beings. These changes led to the aggravations of soil and water loss, the decrease of soil fertility in the black soil zone of the central part, the wetland loss in the Sanjiang Plain, and the desertification and grassland degradation in the western part of Northeast China. There were many efforts to analyze climate change, landscape change, and effects of agricultural activities on local environment in Northeast China. Yet quantitative knowledge on the changes in land use and food security at regional level for the whole area is few. (Wang, Z., et al., 2009) Therefore, it is important to study the land use change and its implication on food security.

The purpose of this study is to elucidate the impact of agricultural land use changes in Northeast China in ten years. Specifically, we attempt (1) to reveal the spatial pattern of and regional disparity in agricultural land changes; (2) to explore the temporal dynamics of these changes; and (3) to expound how the observed changes have been caused (4) to evaluate the effect on food security.

Study Area

Northeast China encompasses three provinces of Heilongjiang, Jilin, and Liaoning. It has a total territory of 79.18×10^4 km^2 and a population of about 108 million in 2007 (NBSC 2008) distributed in 151 counties (cities). As one of the main agricultural regions of the economy, the cultivated land of Northeast China accounts for 20% of the economy′s total. In this region, the main crops are spring wheat, spring corn, soybean, rice, beet, etc., grown in the cultivated area which accounts for more than 30% of the whole area of the Northeast China.

Figure 1 Location of the study area

Northeast China is located in the northern part of the natural realm of Eastern Monsoon China. This area has a typical temperate continental monsoon climate with an average annual temperature of 1-7℃. Annual precipitation decreases from southeast (900 mm) to northwest (400 mm) as the distance from the sea increases. Precipitation is generally concentrated on summer and autumn, coinciding with the growing season, yet harvesting is sometimes at risk because of the flood hazard in the low plains. Spring drought is often a problem, and supplementary irrigation is necessary (Zhao 1994).

The main soils are black soil (Luvic Phaeozem, FAO), chernozem (Haplic Chernozem, FAO), meadow soil (Eutric Vertisol, FAO), Solonetz (Solonetz, FAO), Solonchak (Solonchak, FAO) and aeolian soil (Arenosol, FAO). The northern part of this division uses a one-crop per year farming system whereas in southern Liaoning Province, a harvest of three-crops in 2 years is widely practiced.

Methods

In trying to assess the impact of agricultural land conversion on food security, the change of cultivated land in quantity during the decade was detected at first. Then considering the natural and social factors systematically, the comprehensive quality of cultivated land was evaluated. Based on the cultivated land quality and quantity change, impact on grain productivity caused by the cultivated land change was analyzed. Finally, pre-warning on grain production safety in Northeast China was carried on.

Examine the changes of cultivated land in quantity

Land cover changes were indentified from Landsat TM and Enhanced Tm plus (ETM+) satellite images. They were recorded in 1993 and 2003 in a season when the spectral disparity among different land covers was maximized. These images, which had been geometrically rectified in Erdas (Version 8.7), were visually interpreted to produce a land cover map of farmland, woodland, grassland, built-up areas, water, and unused land in the respective year via on-screen digitization. The accuracy of these maps was verified in the field. Changes in land use/cover between two times were mapped through overlaying two land use/cover maps of respective years in ArcGIS (Version 8.3). After intersection with the administrative boundary of the three provinces, these change maps were quantitatively analyzed by province.

Evaluate the quality of cultivated land with conversion data of cultivated land

To evaluate the cultivated land quality, an indirect approach based on an integrated assessment of evaluation factors was developed, which had the advantages in identifying the systematic complexity of land productivity. Cultivated land productivity, usually represented by crop yield per ha, depends on soil productivity, natural environment and agricultural management practices. Therefore, 17 evaluation factors were selected. (Figure 2)

An expert score ranking was use for the evaluation factors. The weight contributions of individual factors to cultivated land quality were determined using the Delphi method and an analytic hierarch process (AHP).

Calculation of the cultivated land quality index

The cultivated land quality index was calculated by Eq. (1), i.e.

$$S = \sum_{i=1}^{n} W_i P_i \tag{1}$$

Where, S is cultivated land quality index; W is the weight of the *i*th layer; P stands for the *i*th standardized evaluation layer.

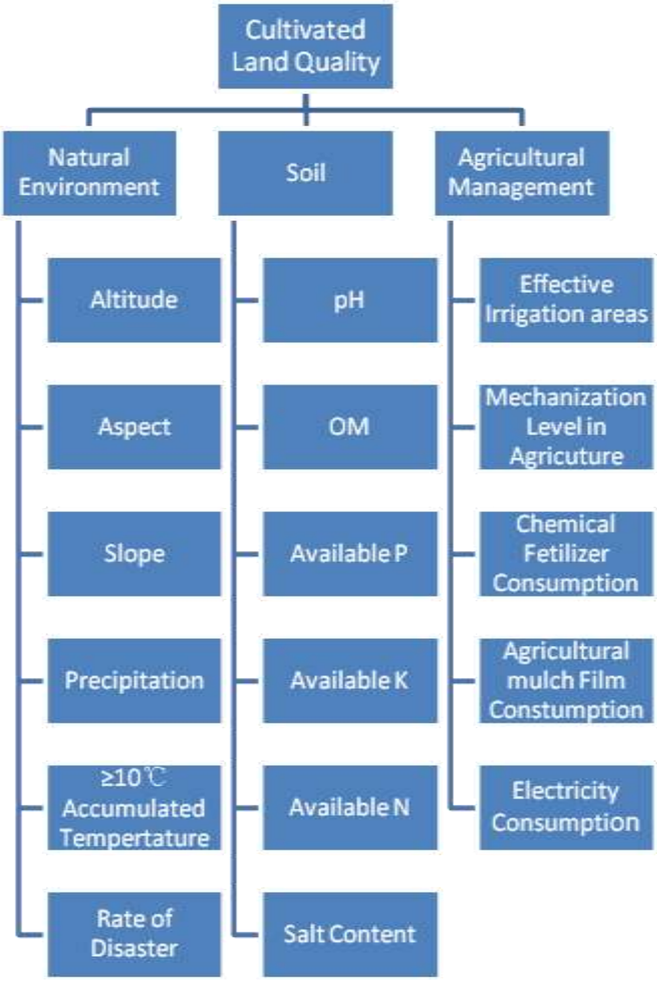


Figure 2 Hierarchical structure for the cultivated land evaluation

Analysis of effect on grain productivity caused by the cultivated land change

The quantity and quality of cultivated land affect grain production. To study the influence of cultivated land conversion on grain production, we should detect the quantity and quality change of arable land, especially the spatial variability of cultivated land quality. After evaluating the quality of arable land, the average grain yield per unit area for every cultivated land grade was calculated by classic statistical analysis of samples which was acquired through household interview. Changes in cultivated land quality were mapped through combining two cultivated land quality maps of respective years in ArcGIS (Version 8.3). Then Grain yield change due to arable land conversion in quantity and quality in Northeast China were analyzed in detail.

Pre-warning on grain production safety in Northeast China

Grain production is very important to national grain security. As the grain production base, the grain production in Northeast China should be monitored by the cultivated land conversion in quantity and quality. Seeing that it is the key of the grain production safety that the cultivated land is safe, the grain production safety model can be comprehensively considered from cultivated land quality and quantity, and be realized through the quality pre-warning and quantity pre-warning of the cultivated land. Taken into account several factors influencing grain production, and integrated the safety of arable land quality and quantity, the early warning model of grain production safety was developed based on the national food security, and then the grain production status of the Northeast China is appraised.

The model of early warning

The early warning model of grain production is the combination of quantity and quality early warning for arable land. Quantity pre-warning model can reflect the pressure on cultivated land originated from the decrease of cultivated land. The formula is as follows:

$$K = \frac{S_{min}}{S_a} \tag{2}$$

Where, K represents early warning index for cultivated land quantity; S_a stands for the actual area of cultivated land per capita.S_{min} is the minimum area of cultivated land per capita that can meet food demand, which can calculated by the Eq.3

$$S_{min} = \beta \frac{G_r}{P} \tag{3}$$

Where, βstands for grain self-sufficient rate; G_r is grain demand per capita; P is grain yield per unit area.

Quality pre-warning model reveals the effect on grain production because of decrease in quality of cultivated land. It is estimated using following equation:

$$R = \frac{\Delta T}{\Delta XN} - 1 \tag{4}$$

Where, R is early warning index for cultivated land quality; ΔX is the change of population; N is the grain yield per capita in 1993; ΔT is the change of grain productivity compared with datum year 1993. ΔT is the function of natural quality of cultivated land (including natural environment and soil), agricultural inputs(including chemical fertilizer consumption, Effective Irrigation areas,…). It was estimated by multiple stepwise regression.

The alert level was divided into 5 grades, which are non-alert, light alert, middle alert, heavy alert and giant alert. The alert level reflected the regional grain production situation in time and space.

Table 1 Threshold of model and alert level for early warning

Grade	R	K	Alert Level
1	$R \geqslant 0$	$K \leqslant 1$	Non Alert
2	$R \geqslant 0$	$K > 1$	Light Alert
3	$-1 \leqslant R < 0$	$K \leqslant 1$	Middle Alert
4	$-1 \leqslant R < 0$	$K > 1$	Heavy Alert
	$R < -1$	$K \leqslant 1$	
5	$R < -1$	$K > 1$	Giant Alert

According Equation 2 and 4, we estimated the R and K. Then the alert level in every county can be obtained by the threshold of different alert level.

Land use Changes and Its Causes

Land use changes in Northeast China

Land use change of Northeast China from 1993 to 2003 is shown in Table 1. In the period, cropland and built-up land increased, but woodland, grassland, water body and unused decrease correspondingly, among which unused land decreased most dramatically.

Table 1 Land use change in Northeast China from 1993 to 2003

	Land use area ($\times10^4$ha)		Change	
	1993	2003	($\times10^4$ha)	(%)
Cropland	2456	2644.7	188.8	7.69
Woodland	3653.8	3586.4	-67.4	-1.84
Grassland	488.4	432.9	-55.5	-11.36
Built-up land	442	475	33	7.47
Water body	263.1	260.5	-2.7	-1.03
Unused land	594.3	498	-96.2	-16.19

From 1993 to 2003, total cropland area increased by 188.8 $\times10^4$ha, with the highest increase rate among all land use type. Build-up land increased by 33 $\times10^4$ha, with an increase rate much smaller than that of farmland. The expansion in built-up areas was caused by urbanization. Unused land decreased from 594.3 $\times10^4$ha in 1993 to 498 $\times10^4$ha in 2003, with a highest decrease rate among all land use types. Area of grassland, woodland and water body decreased by 11.36%, 1.84% and 1.03%, respectively.

Among all detected changes, cropland experienced the most drastic increase, with a general trend of increase in the northern part and decrease in the southern part in view of the spatial distribution. Of this increased cropland, 113.8 $\times10^4$ha were converted from woodland. The other two significant increases to farmland occurred in the form of conversion from grassland at 93.1 $\times10^4$ha and from unused land area at 77.7 $\times10^4$ha. To some extent, the loss in farmland was not compensated for by the conversion of a woodland (29.5 $\times10^4$ha) in the opposite direction. Another significant loss in farmland occurred in the form of conversion to build-up land.

The change from woodland to farmland was distributed in hilly areas around the margin of natural forests. Expansion of grassland was restricted to the border of the agropastoral interlocked west where there was a serious problem of farmland degradation. It is here that fallow land expanded. Considerable reclamation of fallow land (mostly marshes) as farmland took place over the Three Rivers Plain, triggering severe shrinkage in water acreage in the Songnen Plain.

Table 2 Transition Matrix of land use changes during 1993-2003 (unit: $\times10^4$ha)

1993	2003						
	Cropland	Woodland	Grassland	Built-up land	Water body	Unused land	Total
Cropland	2535.6	29.5	8.2	18.1	7	4.6	2603
Woodland	113.8	3507.3	6.4	3.4	1.7	21.2	3653.8
Grassland	93.1	16.3	352.2	1.5	2.6	9.9	475.6
Built-up land	5.3	1.9	0.4	340.9	1.1	0.6	350.2
Water body	10.2	0.7	10.2	2	190.1	8.5	221.7
Unused land	77.7	12.9	40.3	1.5	8.7	452.5	593.6
Total	2835.7	3568.6	417.7	367.4	211.2	497.3	7897.9

Across: original cover type of change (change from) in 1993; down: destination cover type of change (change to) in 2003

Land use Changes in Different Provinces

Due to demographic and socio-economic development varying in different regions, the land use changes have more obvious regional disparity in three provinces in Northeast of China. Trends of land use changes in Liaoning Province, Jilin Province and Heilongjiang Province is shown in Table3.

Table 3 Land use changes in each of provinces in Northeast China during 1993-2003

		Farmland	Woodland	Grassland	Build-up land	Water body	Unused land
Liaoning	1993	585.4	541.7	114.3	140.3	51.2	13.1
	2003	571.4	556.7	105.9	148	51.1	12.8
Change	(×10^4ha)	-14	15	-8.3	7.6	-0.1	-0.2
	(%)	-2.39	2.77	-7.26	5.42	-0.20	-1.53
Jilin	1993	609.1	955.8	86.1	81.7	51.2	141.3
	2003	589.3	978.1	85.6	85.	4 47.8	139
Change	(×10^4ha)	-19.8	22.2	-0.5	3.7	-3.4	-2.3
	(%)	-3.25	2.32	-0.58	4.53	-6.64	-1.63
Heilongjiang	1993	1261.4	2156	288.1	220	160.6	440
	2003	1484	2052	241.3	241.6	161.5	346.2
Change	(×10^4ha)	222.6	-105	-46.7	21.7	0.9	-93.7
	(%)	17.65	-4.86	-16.	2 9.86	0.56	-21.3

In Liaoning Province, farmland, grassland, water body and unused land decreased by 2.39%, 7.26%, -0.2% and 1.53%, respectively. In contrast, woodland increased by 2.77%, and build-up land increased by 5.42%. The same as Liaoning Province, woodland and build-up land increased by 2.32% and 4.53%, respectively in Jilin Province. In contrast, farmland, grassland, water body and unused land decreased by 3.25%, 0.58%, 6.64% and 1.63%. From 1993 to 2003, in Heilongjiang Province, farmland and build-up land increased, but woodland, grassland and unused land decreased. farmland increased by 222.6×10^4ha, account for 17.65% of the farmland area in 1993. and build-up land increased by 21.7×10^4ha, account for 29.86%.

Though the cultivated land increased during 1993-2003 in Northeast China, land use change has regional differentiations in three provinces. The cultivated land area decreased in Jilin Province and Liaoning Province. The cropland area reduced to 571.4×10^4ha in 2003 from 585.4×10^4ha in 1993 by 0.23% average every year in Jilin Province, while cultivated land area decreased from 609.1×10^4ha in 1993 to 589.3×10^4ha in 2003 by 0.32% on average yearly in Liaoning Province. On the contrary, the cultivated land area of Heilongjiang Province newly increased 222.6×10^4ha, account for 17.65% of total farmland area in 1993 .

Causes of land use change

The main reason that the cultivated land increased in Northeast China includes the following several aspects:

a) Because of the agricultural restructuring, some woodland and grassland was converted into farmland. The change from woodland to farmland in Heilongjiang Province during the decade account for 90.9% of the total change, which mainly distributed in Xing'an Mountains (18.4×10^4ha), Three Rivers Plain (25.7×10^4ha), Songnen Plain (34×10^4ha), and et al. For the same time, the change from grassland to farmland happened mainly in Heilongjiang Province, account for 90.7% of the total change.

b) The government policy of "dynamic balance for the total amount of farmland" was introduced, that is to say, farmland lost had to be created through reclamation of other land elsewhere. Rapidly urbanizing provinces/municipalities, unable to conserve arable land, first had to lease land in the Northeast and then had local farmers reclaim it as cropland to make up their quota. Felling of natural forest was strictly prohibited by the central government in the Greater Hinggan Mountains to conserve the natural forests in the early 1990s. Within three years a total of 53,000 loggers were laid off (Heilongjiang Environment Protection, 2000). Without any prospect of finding jobs in nearby cities, most resorted to subsistence farming by reclaiming woodland at the margin of natural forests. Newly arrived migrants from other parts of China were contracted to grow cash crops such as sunflower seeds, for which woodlands and grasslands were reclaimed as dry fields for farming (Liu, Y., et al., 2005).

c) Considerable reclamation of unused land. One is the exploitation of potential land resources suitable for agriculture including swampland and waste grassland. The other is soil improvement referring to the barren land and saline and alkaline land, and land reclamation from build-up land. The exploitation of potential land resources suitable for agriculture mainly took place in Heilongjiang Province, account for 93.6%. Considerable reclamation of fallow land as farmland took place over the Three Rivers Plain, triggering severe shrinkage in water acreage in the Songnen Plain.(Gao, J., et al.,2006)

The reasons for the farmland reduced are as follows:

a) Expansion of build-up land. Rapid development of towns and cities and some high-tech agro-zones occurred along the Shenyang and Harbin transportation corridor. This has led to the expansion of built-up areas. Because of topography, there was little change in land cover in Great and Little Hinggan Mountains and in the east where the land is hilly.

b) Returning farmland to forestland. Change from farmland to woodland took place in the west of the study area where grazing and farming are interlocked. To a large degree, this change was the benign outcome of "returning farmland to forestland". Most of the conversion of grassland into farmland took place in the west and in the Sanjiang Plain.

c) Land abandonment

The western part of the study area is a farming and grazing interlocked region having a semiarid climate. Because of the damage of the wind break system, tilled farmland with a denuded surface is much more vulnerable to soil erosion and land degradation than grassland. After land fertility is reduced to a certain extent, framing is no longer viable, resulting in farmland abandonment.

Abandonment of farmland reclaimed from grassland fuels the advance of sand dunes under the action of predominantly northwesterly wind regime, threatening the productive farmland. (Liu, Y., et al., 2005)

Irrational changes in land use/cover (e.g. reclamation of marginal land as farmland) have also resulted in an increase in salinized land. The majority of the newly salinized land was associated with change of grassland into farmland through land reclamation. Removal of surficial vegetation accelerated evaporation, bring salt from deep down to the surface. Salinaiztion has reduced farmland productivity. In the worst case, it has led to abandonment of the reclaimed farmland. (Yansui, L. et al., 2004)

Cultivated land change in quality

The cultivated land in study area was classified into five grades. Different grades represented the levels of comprehensive grain production ability. The change of cultivated land in quality is shown in table 4. The cultivated land area belonging to Grade I decreased by 1.93×10^4ha, accounting for the 1.02% of the total change area. While area of other grades increased, among which area of grade VI increased most dramatically, account for the 40.5% of the total. Followed Grade VI, area of Grade III and Grade V reduced by 63.94×10^4ha and 40.14×10^4ha, respectively. (zhang, 2004)

Table 4 the change of cultivated land in quality

Grade	Area		Change	
	1993	2003	($\times10^4$ha)	Percent of Total Change Area (%)
I	277.44	275.51	-1.93	-1.02
II	623.25	633.37	10.12	5.37
III	808.36	872.30	63.94	33.88
VI	604.33	680.76	76.43	40.50
V	142.62	182.76	40.14	21.27
SUM	2456.00	2644.70	188.70	100.00

The main causes for the cultivated land quality decreased

a) Soil erosion and degradation has become a serious problem in the region, especially in arid and semi-arid areas. It is caused mainly by intensification of cropping, but also climate change-induced drought and flooding. Soil fertility keeps declining and soil productivity has been seriously affected by the interaction of natural erosion and artificial cultivation since reclamation began (Xin *et al*. 2002; Yan and Shang 2005; Duan xing-wu, 2009), which has greatly threatened the security of grain production and agricultural sustainability (Liu *et al.*, 2003). Especially, Black soil with a thick layer of humus, good physical and chemical properties, biological characteristics, and high fertility suffers from serious degradation. Because of the long-term cultivation, less application of farmyard manure, the black soil SOM content was greatly reduced. Although black soil is a renewable resource, however, human's disturbance on black soil has exceeded the regeneration capacity of black soil.

b) In Northeast China, drying trends have been very significant in the recent decades. The annual precipitation has been decreasing since 1965 (Liu et al. 2005). The semi-arid areas in Northeast China are vulnerable to drought. The water levels of many lakes in northeast China have been falling and some lakes are even disappearing. Moreover, so far, irrigation systems and drought control measures in these areas are relatively weak (Yang, X., et al., 2007).

Grain Security Effects of Cultivated Land Change

Cultivated land conversion in quantity and quality has an impact on the grain production. Based on the area of arable land conversion and average grain yield per unit area for every grade, the change of grain yield for every grade was obtained. The results (Table 6) showed that grain yield reduced by 10.08×10^4t originated from the decrease of the grade I cultivated land. The area increase of grade III and grade VI played a very important role in the increase of grain yield. Though the area of grade I made the only loss of grain yield, but the total grain yield in Northeast China increased by 675.37×10^4t. However, the results show that the largest increase of grain yield owed to the addition of more low quality cultivated land.

Table 6 Grain yield change due to arable land conversion in quantity and quality in Northeast China during 1993-2003(unit: kg/ha, ×10^4ha, ×10^4t)

Cultivated land quality	Average grain yield per unit area (kg/ha)	2003		1993		Change	
		Arable land area	Grain yield	Arable land area	Grain yield	Area	Grain yield
Grade I	5225.82	275.51	1439.75	277.44	1449.83	-1.93	-10.08
Grade II	4780.23	633.37	3027.67	623.25	2979.29	10.12	48.39
Grade III	4277.12	872.30	3730.92	808.36	3457.44	63.94	273.48
Grade VI	3515.46	680.76	2393.20	604.33	2124.51	76.43	268.69
Grade V	2364.08	182.76	432.06	142.62	337.17	40.14	94.89
SUM		2644.70	11023.6	2456.00	10348.24	188.70	675.37

The change of grain yield was different in the three provinces. In Liaoning Province, the net decrease of grain yield reach 49.64×10^4t. The grain yield of cultivated land belonging to grade I, grade II, grade III and grade V decreased, respectively. While the grain yield in grade VI cultivated land increased by 2.23×10^4t. In Jilin Province, the grain yield increased by 3.85×10^4t owing to the grain yield increase of arable land in grade II, grade VI and grade V. The cultivated land in grade I and grade III gain the grain yield loss by 2.44×10^4t and 0.82×10^4t, respectively. Different from Liaoning Province and Jilin Province, in Heilongjiang Province, grain yield of every grade cultivated land increased. It contributed to the grain yield increase by 721.16×10^4t , among which cultivate land in grade III made the largest increase.

Excessive reclamation is a direct response to changes in government policy of “dynamic balance for the total amount of farmland” (Yansui, L., et al., 2004). Under this policy, cultivated land was increased through zealous reclamation of grassland, marginal woodland, and even fallow land (Liu Y S et al., 2005).Most of newly created farmland concentrated in the western mountain area and pastoral area of the study area and in the Sanjiang Plain, etc. (Yansui, L., et al., 2004), where was apt to suffer from waterlogging and soil erosion resulting in low land suitability. Though field engineering (e.g. construction of irrigating facilities) was carried out, the overall quality of supplementary arable land was low. Expanded build-up land resulted in the loss of high quality cultivated land with better cultivated condition and high grain productivity. Nevertheless, the newly reclaimed farmland in Northeast China is no substitute for the fertile land lost in the rapidly industrialized South and East where annual multiple cropping is routinely practiced (Lin & Ho, 2003).

Additionally, with agricultural structure adjustment and policy implementation of converting farmlands to forests and grassland, the enlargement of cultivated lands is limited, so it is not a long-term effective strategy to increase grain yields by increasing sown area. We must promote the grain yield per unit area by improving the agriculture production conditions, enhancing the defenses against natural disasters, constructing agricultural infrastructure, and reconstructing the middle-yield and low-yield farmlands. The final purpose is to improve comprehensive grain productivity and to ensure grain security ability (Cheng, Y., et al., 2007).

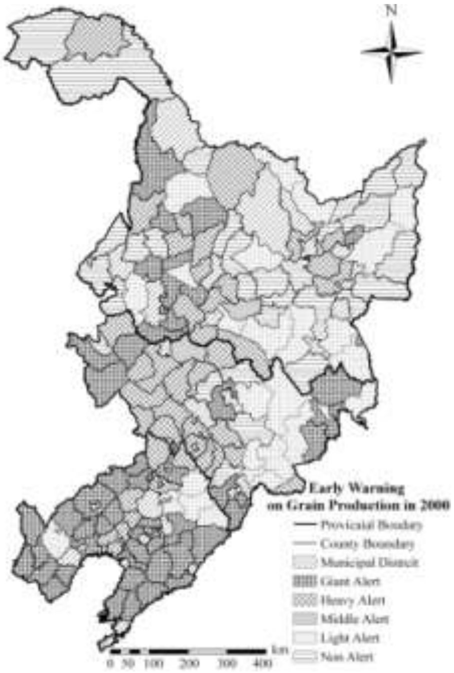
In order to adapt to the warming climate, adjustments of composition and structure of cropping (including the alteration of crop species) in the region have been conducted by governments and farmers. Due to northward movement of the region suitable for cropping, the potential arable land area was greatly enlarged, and total grain production in the region increased rapidly. (Yang, X., et al., 2007)

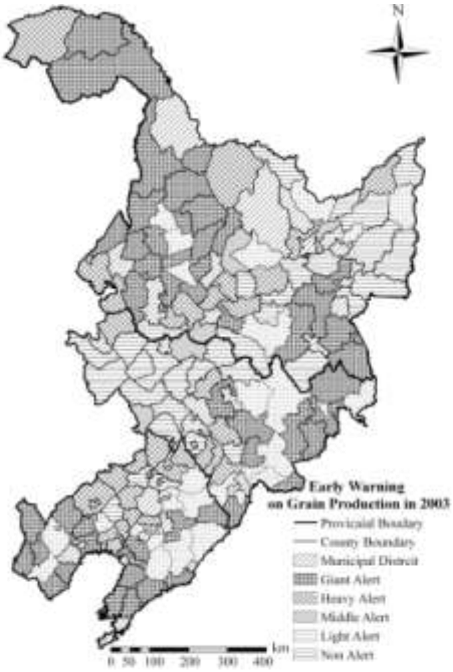
Early Warning on Grain Production in Northeast

On the basis of the above-mentioned early warning models, according to regional practical production, the threshold of each index is confirmed and the early warning degree is fixed, and then the early warning research on the grain-production of three provinces in Northeast China has been carried on, the regional grain-production situation have been received.

Table 2 Number of counties with different alert levels in Northeast China

Province	Year	Giant alert	Heavy alert	Middle alert	Light alert	Non alert
Liaoning	2000	31	8	0	5	0
	2003	19	11	1	10	3
	2010	10	4	4	10	16
Jilin	2000	10	17	1	9	4
	2003	10	5	3	8	15
	2010	8	11	0	7	15
Heilongjiang	2000	11	16	1	13	25
	2003	26	12	3	8	17
	2010	1	12	0	7	46





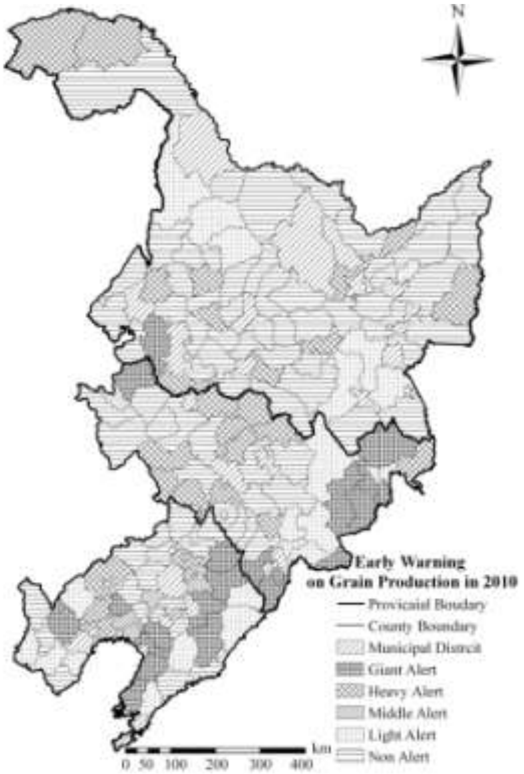


Figure 3 Early warning result of grain production safety in 2000、2003 and 2010

In Heilongjiang Province, there is much more counties with giant alert in 2003 than that in 2000, while the number of county in heavy alert and middle alert is almost the same with that in 2000. In contrary, there was less counties in light alert and non-alert in 2003 than that in 2000. The counties belonging to giant alert and heavy alert in 2003 concentrated in the farming and grazing interlaced zone in Songnen Plain, where is the major grain production area (figure 3), but this area presented non-alert or light alert in 2000. Another main grain producing region located in the farm and pastoral areas of Three-river Plain had the same grain production safety degree in 2000 and 2003. Besides, several counties allocated in agro-forestry zone of Xing'an Mountains were in more severe state in 2003 than that in 2000. Therefore, the grain-production safety degree of 2000 is higher than that in 2003 as a whole. The conclusion could be verified by the grain export in 2000 and 2003(figure 4). There was less grain exported in 2003 than that in 2000 in Heilongjiang Province.

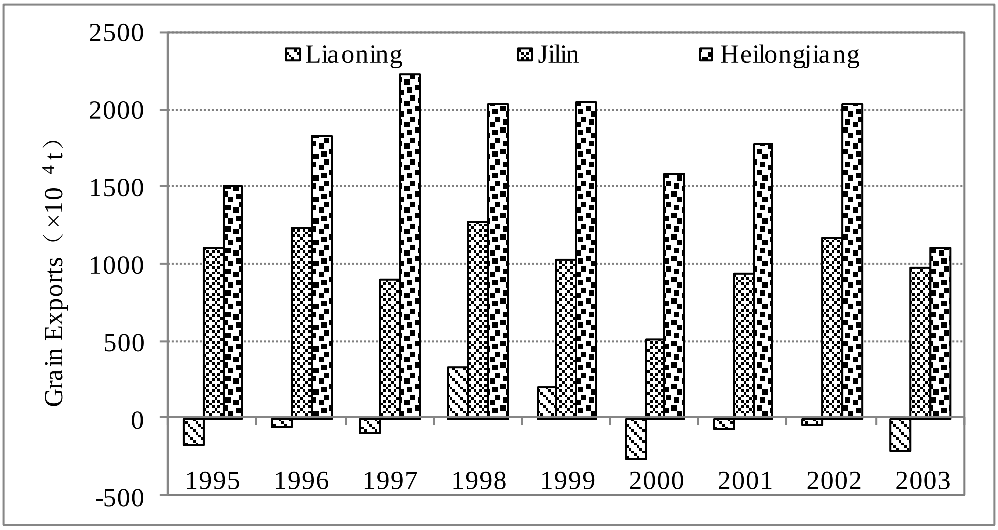


Figure 4 Grain quantity of domestic export from 1995 to 2003 in Northeast China

In Liaoning Province, there was less counties appearing alert in 2003 than that in 2000. The counties with giant alert mainly distributed in the farm and pastoral zone in the west of Jilin Province, and agro-forestry zone of Changbai Mountains in 2000, but it only appeared in the latter in 2003. In addition, much fewer counties stayed in heavy alert in 2003 than that in 2000. And the counties with heavy alert mostly located in the middle plain area, where was the important grain production region in 2000 as contrast with the situation in 2003. The number of counties belonging to middle alert and light alert was nearly equal. Besides, the counties with non-alert merged much more in 2003 than that in 2000. It concluded that the grain-production safety degree of Liaoning Province in 2000 was lower than that in 2003. It could be proved by that Jilin Province exported more grain in 2003 than that in 2000.

Liaoning Province not only had fewer counties with alert but also lower alert degree in 2003 than that in 2000. Except several counties in eastern farming zone of Liaoning with light alert, most counties were in giant alert in 2000. And those counties with heavy alert largely distributed in the middle faming zone of Liaoning Province. On the contrary, in 2003, the counties with giant alert located in the western hilly area and coastal framing zone. The major grain production counties were all appeared light alert, even non-alert. And also the farming zone of the eastern mountain area was in light alert. While other region stay in the same alert degree as in 2000. Therefore, the grain-production safety degree of Liaoning in 2000 was lower than that in 2003. It was also proved by the grain export in 2000 and 2003.

The grain production status was forecast in 2010. The results showed that the rain-production safe coefficient of two provinces Heilongjiang and Liaoning in 2010 is higher than that in 2000 and 2003 while the grain-production safe coefficient of Jilin Province in 2010 is lower than that in 2003, higher than that in 2000. The counties with alert in Liaoning and Heilongjiang Province decreased, and also fewer counties appear heavy alert and giant alert. But the counties with heavy alert increased in Jilin Province. Overall, the grain production safety in 2010 will be better than that in 2003 in Northeast China. To some extent, with the increase of agricultural inputs, especially the implementation of “abolition of agricultural taxes” and “industry nurturing agriculture” policy, the farmers have enthusiasm in growing grain in major grain producing areas. It plays a very important role in the grain production security.

The result shows that: the grain-production safety degree of the two provinces Jilin and Liaoning in 2000 is lower than that in 2003, but the result is opposite in Heilongjiang Province. Therefore, the model can reflect the grain production status really; and also the conclusion can be validated by the grain trade in the area. Finally, we predict the situation in 2010. It is found that the grain-production safety degree of two provinces Heilongjiang and Liaoning in 2010 is higher than that in 2000 and 2003 while the grain-production safety degree of Jilin Province in 2010 is lower than that in 2003, higher than that in 2000.

Conclusions

(1) During 1993-2003, widespread changes in land/use cover took place in Northeast China. Cropland, built-up land expanded by 188.8×10^4 and 33×10^4ha, respectively. By comparison, woodland, grassland, water body and unused land decreased by 67.4×10^4, 55.5×10^4, 2.7×10^4 and 96.2×10^4ha, respectively. Trends of land use changes in three provinces were different because of regional disparity. In Jilin and Liaoning Province, farmland and grassland, water and unused land decreased, while woodland and build-up land expanded. But in Heilongjiang Province, farmland, build-up land and water increased, while woodland, and unused land reduced. Among all detected changes, cropland experienced the most drastic increase, with a general trend of increase in the northern part and decrease in the southern part as a whole. There are three significant increases to farmland in the form of conversion from woodland, grassland and unused land. The detected changes in land use can be attributed to climatic variation, policy adjustment and rapidly urbanizing. Climate warming created the natural environment for grassland and unused land to be changed to farmland. In turn, changes in land use have adversely influenced the local environment by accelerating desertification in the ago-pastoral interlocked west, causing salinization in the Song-Nen Plain, and exasperating flooding in the catchments area of the Nenjiang and Songhua rivers, which resulted in land abandonment and influenced grain production. The “dynamic balance for the total amount of farmland” policy accelerated the reclamation of other land to convert to farmland, while “returning farmland to forestland” policy converted farmland to woodland. Rapid development of towns and cities lead to the expansion of built-up areas, while other land decreased, especially the cultivated land.

(2) Apart from the above cultivated land in quantity, the quality changes of cultivated land also evaluated from 1993 to 2003. According to integrated assessment of cultivated land quality, the changes of cultivated land were analyzed. Only the cultivated land belonging to Grade I with highest grain productivity decreased by 1.93×10^4ha, accounting for the 1.02% of the total change area. In contrast, other grades cultivated land expanded. The area of grade III, grade VI and grade V accounted for 95.65% of the total change area, among which grade VI increased most. There are

several explanations for this change. First, many economic development zones and real estate zones were established, consuming a huge amount of high quality farmland. Second, soil fertility keeps declining due to long-term intensive cropping, less application of farmyard manure but more chemical fertilizers. Third, the negative impacts from climate change (e.g. drought) threaten the grain production which challenge to agricultural infrastructure.

(3) Many factor affect grain production directly or indirectly. The paper considered only important and direct driving factors cultivated land quantity and quality. But some uncertain ones were not included, such as severe disasters and popularity and extension of high yield seeds. Additionally, possible effects of global environmental change on food production were also not taken into consideration. The results showed that the total grain yield in Northeast China increased by 675.37×10^4t. The grain yield loss caused by grade I cultivated land decrease about 10.08×10^4t. However, the largest increase of grain yield owed to the addition of more low quality cultivated land. The reasons for the grain yield increase contributed to the positive impact of climate change, agricultural restructuring.

(4) The early warning model of grain production realized quality pre-warning and quantity pre-warning, namely it considered the change of grain yield from two respects of cultivated land quality and quantity. The result shows that: the grain production safety of Jilin and Liaoning province in 2000 was worse than that in 2003, but the result is opposite in Heilongjiang Province, the grain production safety in 2000 is better than that in 2003; it is found that the grain production safety of Heilongjiang and Liaoning Province in 2010 is better than that in 2000 and 2003, while the grain production safety of Jilin Province in 2010 is worse than that in 2003, better than that in 2000. The result was verified by the grain export in every province.

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Session3:

Agricultural land use management and regional planning

From Local to Regional Genius and Future Challenging Program:

Estate Crop Land Use Development for Soil and Water Conservation, C Stock, and Stimulant Economic Recovery

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Abstract: Agricultural land use change should be haven due to every body want to reach a better economic value. Because of that ALUC is always in the position quo vadis. In the confuse condition we purpose local genius which is born in South Halmahera Regency, North Maluku Province Indonesia. This is about developing estate crop to replace idle land. The estate crops have capability to conserve soil and water, to increase carbon absorbs, to become a stimulant economic recovery. In the next future we are going to create and design revitalization estate crop trough dissemination method and keeping technology to increase adoption technology by farmer for coconut and cacao. In this program we are going to introduce liaison officer, rehabilitation, diversification, intensification, and extensification approaches based on soil characteristic and social economic group of farmer in a village. Some training level is included as one method that can not be separated from others approach above. The final goal is to increase quantity and quality of coconut and cacao and to increase farmers' income during three-year activity. Our remarks are: Adoption technology must be increased: *faster, easier, and cheaper; P*articipative approach among researchers, extensionists and farmers, Empowering: farmer, innovation technology, and capacity building, and Communication, collaboration, and consortium.

Global Condition

1. **Challenging or Catastrophe.** There are many comments about agricultural land use changes. Some body says agricultural land use changes is like a catastrophic due to its impact on food security, but for others agricultural land use changes mean a challenge since changes could create other core agricultural business to increase farmers' income. For example in Indonesia, many paddy fields have converted into fishery fields, horticultural fields, estate fields or sugar cane fields. This kind of agricultural land conversion could be found in paddy field area at northern part of Java Island as in Bekasi, Karawang, Indramayu, Brebes etc. The acceleration of agricultural land use conversion is about 30.000 until 50.000 ha per year.

2. **Ratio of Population to Agricultural Area.** In terms of ratio of population who work in agricultural sector to area of agricultural land use, rice ratios for America and Japan are quite low, representing around 0.02 and 0.5 respectively, while rice ratios for China, India, and Madagascar reach the level of 8.2, and 7.2 and 7.5 respectively. For estate crop again, P.R. China has larger area for estate crop such as cinnamon, clove and cacao. The smallest one is Malaysia around 13.4 and Indonesia is around 20.4. Those ration means, the economy with bigger ratio have the function of the land is more heavy to support population food. Beside that in that economy, land cultivation is more intensive and then land degradation will be more rapidly appear. It will be continued by catastrophe such as drought, inundation, and dangerous food crisis, Table 1.

Table 1. Ratio ration between numbers of population who work in agricultural sector

No	Economy	Estate Crop	Estate Area (x1000ha)	Estate Ratio Person/ha	Rice Area (x1000 ha)	Rice Ratio Person/ha
1	P.R. China	Clov, Cinna., Coco.	72.5	6,874.70	20,150.30	8.2
2	India	Clov, Nutm, Coco.	2,070.40	169.6	15,545.20	7.5
3	Indonesia	Cacao, Clov, Cinna, Nutm, Coco	4,279.50	20.4	6,146.00	2.8
4	Viet Nam	Cinna, Coco	146.8	152.6	3,856.70	2.9
5	Thailand	Cacao, Coco	255.7	44.4	3,451.50	1.6
6	Mexico	Cacao, Coco	231.9	34.9	-	-
7	Madagas.	Cacao, Clov, Cinna, Nutm,Coco.	37.8	366.4	386.7	7.2
8	Sri Lanka	Cacao, Clov, Cinna, Nutm, Coco	429.7	20.5	-	-
9	Malaysia	Cacao, Clov, Nutm, Coco	205	13.4	-	-
10	Philippine	-	-	-	1.746,3	3.6
12	Japan	-	-	-	1.171,3	0.5
13	America	-	-	-	967.7	0.02

and land agricultural use

Explanation: Cinna = cinnamon; Clov = clove; Coco = coconut; and Nutm = nutmeg. Sources data is FAO Statistic (2009)

3. **More Crop for Drop.** Due to land degradation and drought more frequently emerge almost 2-3 year 1 time, then FAO in 2008 state that water use efficiency is needed to be implemented in any level water use. The FAO slogan more crop for drop must be adopted by farmer.

4. **Quo Vadis.** Some farmers in Indonesia are confused that the farmers who work in estate crop have better income than the farmers who work in the paddy fields. The farmers' situation are *quo vadis* as they stand in a cross road.

5. **Land Capability.** The calculation an impact of agricultural land use changes in paddy field as below: if 1 person consumes rice 3 times a day is equal around 100-139 kg rice milled per year, then average is around 119.5 kg/person/year. If 119.5 kg rice milled is equal 211.8 kg rice unmilled, and If 1 ha paddy field have two times cropping intensity/year, then we get 9300 kg rice unmilled/year. It means that 1 ha is for 43.9 person/year. If we loss 100.000 ha paddy field, then about 4.400.000 people can not continue eat rice. For solve this problem we need innovation, intensification, extensification, diversification, and capacity building.

National Condition

6. **National Agricultural Land use Changes.** Figure 1 shows land use changes in the last 20 years (1986 – 2006) (CBS, 2007). Lowland rice as the main staple food supplier has little change from about 7.8 million ha in 1986 to 7.9 million ha in 2006. During the period of 1981 to 1999, about one million ha (accounted for almost 30%) of paddy field in Java and about 0.6 million ha (about 17%) near the development centers in the outer islands have been converted to non agricultural uses (Mulyani *et al.*, 2003). This conversion clearly increases the economy's dependence on rice import. With the average yield of 6 t of unhusked rice ha^{-1} year^{-1} (based on assumed average of 1.5 harvests per year) the level of rice production should have been about 9 million tons higher than the current level had this 1.6 million ha not been converted and the development of new rice field occurred at the same pace. The investment that has been spent for infra-structure and unsurpassing high productivity of well irrigated paddy fields in Java compared to that of the outer islands, have been wasted because of the conversion. Much of the environmental services that paddy farming systems are providing have been ignored or otherwise not understood by stakeholders (Agus *et al.*, 2001).

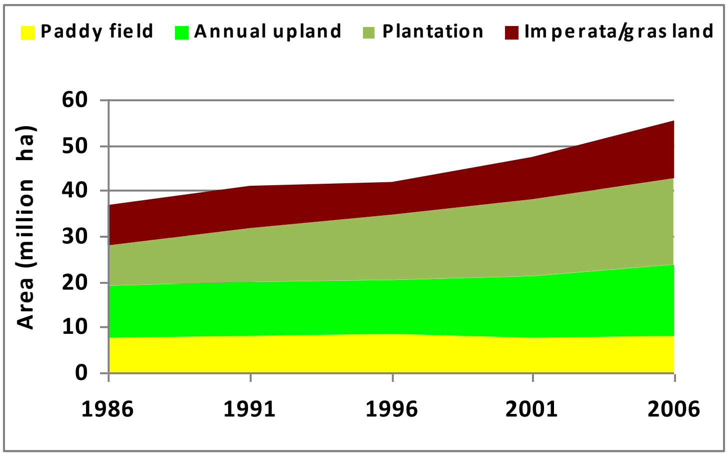


Figure 1. Area used for agriculture and abandoned (wasteland) from 1986 to 2006 from a total of 188 million ha Indonesian land area (Source: CBS, 2006).

7. **The major lift in land use is only observed for estate crops from about 8.8 million ha in 1986 to more than twice in 2006 (Figure 1).** This reflects that investment for estate crops is the most attractive from the economic perspective. The increase in the estate area is almost entirely dominated by oil palm plantation and to some extent rubber plantation. This could be understood since the volume of export of palm oil has increased about five times in the last decade. This rapid expansion could be made possible because of high capital for investment among the government as well as private estate companies.

8. National GDP from Sub Sector. Figure 2 shows that the national GDP in Indonesia obtained from food crop, estate crop and forestry. Food crop produces the largest GDP due to it largely cultivated by farmers. During the period of 2004 to 2008, the contribution of food crop sub-sector to GDP is the largest, even in the year 2008 reached U.S. $ 3,500,000 (Figure 2). Food crop is generally produced from the paddy field and annual upland. The second ranks is estate crop in which GDP is obtained in the year 2008 is still less than U.S. $ 1000,000. Generally, estate crops cultivated are oil palm and rubber and since 1997 oil palm acreage increased (Mulyani et al., 2003). In general, the contribution of estate crop is still low considering some of the plants is not produced yet, but the potential to be improved considerably.

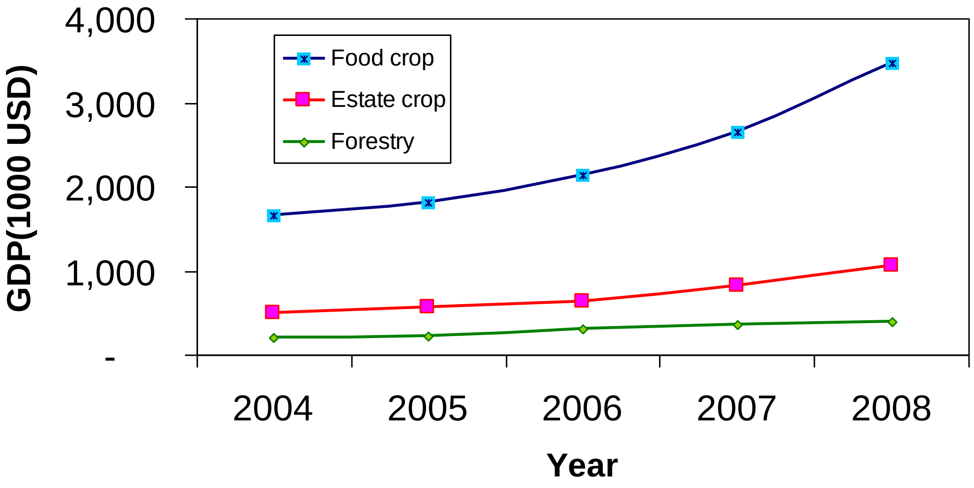


Figure 2. National GDP from sub sector in Indonesia from 2004 to 2006

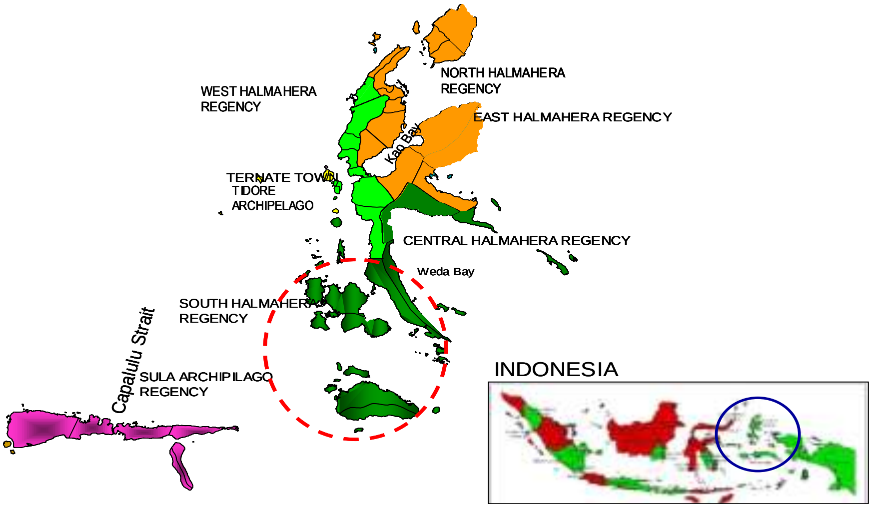


Figure 3. The geographic position of South Halmahera Regency in Indonesia. Entire area of South Halmahera regency is about 40.263,72 km^2, with the number of village is 190

9. **The Estate Crop and Its Production.** The distribution of estate crop land in South Halmahera Regency (SHR) is dominated by coconut and then followed by cacao, nutmeg, and clove respectively (Figure 4). For more than 75% of the coconut trees, their ages are between 20-25 years old. This indicator gives a signal that almost coconut tree there must be changed and replanting again. The coconut tree is like ATM for all farmer in this regency. The fruit coconut is harvested three times a year, where farmers sale their fruit coconut after air dryer (copra) in several days. The price of copra fluctuates between 300 – 600 US$ per ton depend on its quality (Source: CBS, 2006)

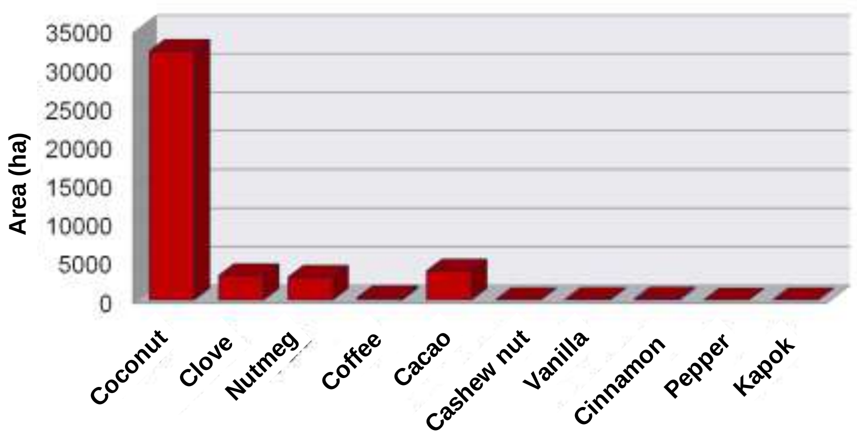


Figure 4 The Area of several estate crop in South Halmahera Regency

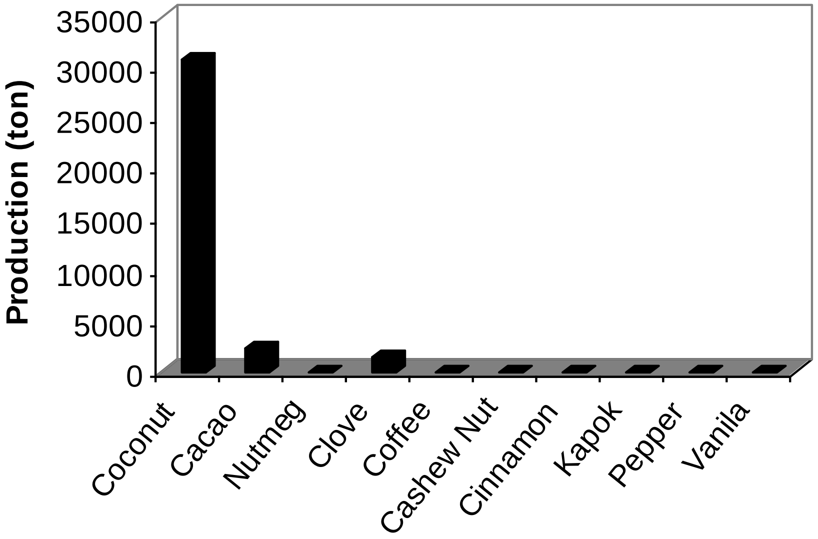


Figure 5. The production of several estate crop in South Halmahera Regency

10. **The Estate Crop as Environment Function**. The estate crop has not only been as social function, it also has been environmental function to conserve soil and water, and absorb carbon. In general, the estate crop is classified in woody tree with large canopy, it have strong, deep and lateral root such as coconut, cacao, nutmeg, clove, coffee, cashew nut, cinnamon, and kapok. When those trees are bigger and canopy are coverage more larger area, then its function for environmental are beginning. Its leaf will shelter rain water and reduce a strengthening water power to broken soil compaction before it reaches soil surface. Due to that, soil dispersion under estate crop canopy is small and water and soil erosion also small. Even thought the estate crops in SHR had been planted about 75% in valley, the water and soil erosion is small. The highest erosion is gully erosion only without any impact to drought or inundation. In the other side, with its structure of root, the estate crop has capability to catches and creates soil aggregation compactly. With this soil structure, water will be infiltrated rapidly into deepest soil layer. Syahbuddin et al. (2006) found that, soil infiltration in secondary forest with the structure forest like mixed cropping in Bukit Barisan mountainous is higher than shrubs area. Sutono et al (2001) found that, water buffering potential mixed cropping in Citarik Watershed decreases from 5.608.000 m^3 in 1969 to 2.434.000 m^3 in 2000. Other prove of estate crop function to guard our environment is also found from their contribution a litter in the surface of soil. Its litter is also can coverage top soil from rain water attack to break up soil aggregation.

11. In correlation with the characteristic of estate crop, especially with their wood, leaf and root, or their biomass, the estate crop have capacity to absorb CO^2 from the air linearly with weight of biomass trough photosensitizes. The IPCC default value state that above ground biomass coconut is around 196 ton/ha and young cinnamon (7 years) is around 68 ton/ha (IPCC, 2006). If carbon organic content in biomass about 50%, then the tree can absorb 98 and 34 ton C/ha respectively.

Afterward from the area of coconut only can absorb around 2.940.000 ton C/ha/year. Two years ago, SHR government planted about 1.000.000 nutmeg tree. After 7 years later, there are about 1.000.000 ton C/ha/year from 10.000 ha will be absorbed by nutmeg. It mean that estate planting is contributed into carbon emission reduction and global climate changes.

12. **The Estate Crop as Stimulant Economic Recovery**. In SHR, the number of family who works in estate crop is about 55.55% higher then the family who works in principal food and fisheries. That work is logic choice because the estate crop is planted only 1 until 3 times in the first years, survive to growth, practice to conserve, and the farmer know about local technology to harvest and post harvest a yield. Usually the farmer will revisit again their land for a long time, and just only for pick up a fruit. The estate crop contributes to GDRP around 42.1% higher then food crop (28.2%) and fisheries (19.2%). Finally in SHR, the total number of village which classified into develop, sufficiency, and developing village is about 55.3% and poor village is rest (CSR, 2006).

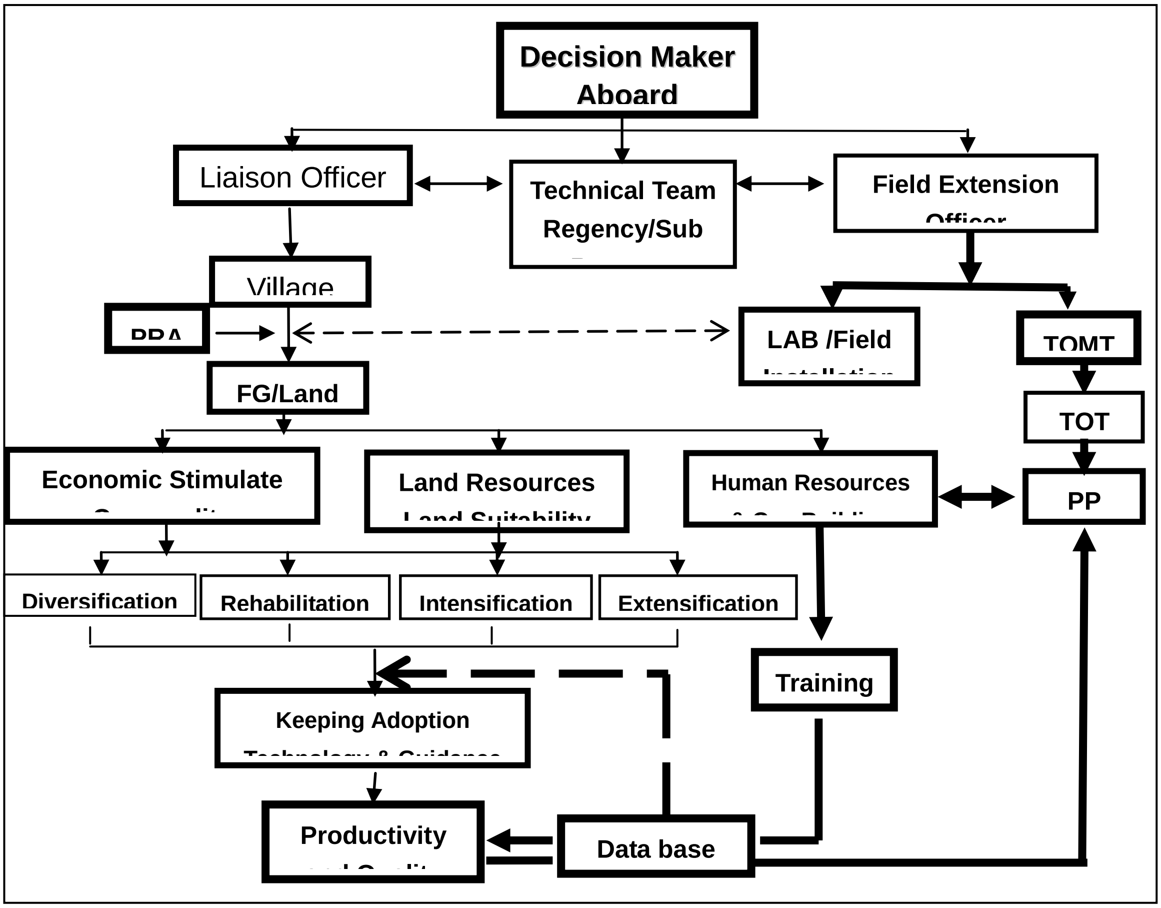
*Challenging Program in the Future:*revitalization of the Estate Crop in South Halmahera Regency

13. The aims of this program are to increase adoption of technology, to develop agribusiness clinic and field school, to increase production and quality, to increase farmer income trough growing and developing agribusiness farming system. This program will be conducted in 3 years with collaboration among BPTP North Maluku, Government Estate Office of SHR, and Agricultural Extension Office of SHR. The method to be used is farmer group participation, dissemination, and keeping technology approach for coconut and cacao. Beside that we are going to use rehabilitation, diversification, intensification and extensification based on soil characteristic and social economic group of farmer. Training method at several levels for farmer group is also executed. Table 2 illustrates the itinerary of revitalization program in SHR.

Table 2. Itinerary program revitalization coconut and cacao

No	Material	Availability	Responsibility
1	Location	10 ha/Village in SHR (190 villages)	BPTP, BP4K and Gov.Estate Office
2	Budget	100.000 US$/Village. Village Budget for Empowering Capacity Building	SHR Government
3	Method	Basic and Implemented. Farmer Participative	BPTP
4	Period	Multi year (3-4 years): 2010-2014	SHR Government
5	Commodity Priority	Cacao and Coconut (1st year, 2010)	BPTP, BP4K and Gov.Estate Office
6	Objective	Farmer income increase 25%	TEAM

14. The pattern of this program is below as the follow chart. The liaison officer consists of BPTP senior staff, Government Agricultural Extension Office senior staff (BP4K), Government and Estate Office senior staff who have capability in technical and communication to disseminate, to improve, and know precision about farmer and location where the technology of estate crops want to implemented. The liaison officer is a bridge between sources of technology and users (farmer or group of farmer). This office located in regency area. TOMT is training which conducted in the level of regency, TOT is training which carried out in the level of sub regency, and PP is a person who done keeping technology in the level of village.



Explanation: PRA: participatory rural appraisal; FG: farmer group; TOMT: training of master trainer; TOT: training of trainer; PP : Agricultural extension in village.

Figure 6. Step by step of revitalization program in South Halmahera Regency

Remark

1) The adoption technology must be increased: *faster, easier, and cheaper*
2) The participative approach among researcher, agricultural extension and farmer must be done.
3) The empowering should be for farmer, innovation technology, and capacity building.
4) The communication, collaboration, and consortium must be develop among APEC member as main pillar for agricultural technology and transfer.

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The Change of Land Resources and the Sustainable Development of Metropolis Modern Agriculture in Beijing

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Abstract: This paper summarized the characteristics of land-use change, the status and problems of agricultural development and its' impact on the development of sustainable metropolis modern agriculture in Beijing. With the economic development, population increase and increase in urban land use, arable land resources decreased continuously in Beijing. With the adjustment of agricultural structure and function, the development of multifunction metropolis modern agriculture become the important guarantee to promote urban-rural integration and economic sustainable development in Beijing.

Key words: Land use; metropolis modern agriculture; sustainable economic development

1 Introduction

Beijing is located in the transition zone of North China Plain to the northwest Loess Plateau and Inner Mongolia Plateau around which is bordered by Hebei Province and Tianjin city. On the west of Beijing is Taihang Mountains and north is Yanshan Mountains. Beijing is about 160 km east to west, 170 km north to south, and the total land area is about 16,422.78 square kilometer (equivalent to 24.63 million mu), which accounted for 0.17% of the whole economy. Beijing has 16 district and 2 counties. Beijing has a diverse landform types including mountains and plains, which accounted for 62% and 38%, respectively. And the mountains locate mainly in north-west, while the plains locate mainly in south-east. With the economic fast-developing, population increasing, people's living conditions improvement, industrial structure adjustment and the process of urbanization speeding up, the urban area expanded gradually, land resources use intensity increased and a large number of arable land changed into various types of construction land. Especially after the eighties of twentieth century, the cultivated land resources rapidly decreased. As an integral part of eco-environmental systems, the land resources exploitation will not only bring enormous material interests but also produce important effect on the ecological environment. Dualistic urban-rural development model become the negative factors for Beijing's sustainable economic development, so with the cultivated land resources decreased, the development of economic benefit taking account of ecological environment benefit metropolis modern agriculture is becoming the main driving force for sustainable economic developing economy and building "Livable City". In this paper, the changes of land resources, agricultural development status and problems, and its impact on metropolis modern agriculture are summarized, and provide references for healthy development of metropolis-modern agriculture and promoting urban-rural integration.

2 Change Characteristics of Beijing Land Resources

2.1. The changes of Beijing land resources

After the liberation, Beijing's land area has experienced five adjustment: firstly, Changxindian, Fengtai, Mentougou, Nanyuan district were combined into the Beijing in 1949, which the land area increased to 1255km^2, and the population increased by 215,000; secondly, the entire Wanping County and parts of Liangxiang in Fangshan district were combined in 1952, which the land area increased to 3216km^2, and the population increased by 131,000; thirdly, the entire Changping County and seven townships in Tong County were combined in 1956 which the land area increased to 4822km^2; fourthly, five county including Tong County, Shunyi, Daxing, Fangshan and Liangxiang and Tongzhou city were combined in March, four county including Huairou, Miyun, Yanqing, and Pinggu were combined in October which the land area increased to 16807.08km^2, and the population increase by 2.179 million; fifthly, the mine of Shougang was combined in 1961, and the population increase by 9,000 people in the year. So far, the amount of land resources was stable in Beijing.

Beijing is a large international metropolis with vast population and limited farmland, economically developed, the demand for land supply is relatively large. All the factors such as the rapid economic growth and the scale expansion, population increasing and the living conditions improvement, policies and regulations changes and the satellite town construction advanced the great changes of land use. More cultivated land has been used for habitat activities, the cultivated land area used for ecology and agricultural production decreased increasingly, leading to increasing environmental pollution, and intensifying the contradictions among population, resources and environment. Since 1953, Beijing urban land use prevails "over pie" phenomenon. urban built-up extended from 90km^2 in 1949 to 340km^2 in 1978, and to more than 1,000 km^2 now. Beijing land-use area showed two large changes in the period after 1984: it has the first large-scale rapid expansion from 1984 to l996. Secondly, affected by Beijing's urban planning and the Beijing Olympics venue construction, the Beijing city come into the fastest-ever expansion stage from 2001 to 2007, which was droved by great events, population and socio-economical factors. It demonstrated the characteristics that the urban land use rapidly expanded leading to arable land area of plain declining and the structures among non-urban land use has been changed markedly during the two periods. In the same time, there existed obvious difference in regional land use/ cover change. And the rural residential area change continually into town land, and the land use/ cover change rate in exurb has already exceeded that in suburb in the 1990s. Furthermore, the emphasis of the high-density urban land moved to the northwest to certain extent during the past decades, showing the trend that the urban land use expanding to the northwest in the same period.Woodland, grassland and water area rapidly increased during the years of 1984-1996, but sharply decreased in 1996-2001 due to turned into urban and rural settlements.Demonstrated that urban expansion achieved by occupying a large number of cultivated land, so the intensity of land use/cover change of peri-urban and suburban areas has been reversed. Due to the most severe farmland protection policy came into existence, the urban expansion rate slowed down during 1990-2000.

2.2. the characteristics of utilization of land resource in Beijing

The urban fringe area is a trinity complex of the urban construction land, rural construction land and rural agricultural land area, so its land-use is restricted by urban geographic spaces conditions and rural construction planning, Also retained the original rural land use pattern to a certain extent, The diversity and complexity of land use types are significantly higher in the regions than in urban built-up areas and rural areas, mainly showing the coexistence of land as follows: industrial enterprises and agriculture, modern buildings and rural housing, facility agricultural and green land, livestock farm and road traffic. the urban fringe area has both urban and rural areas, and the rural area continue to be urbanized. Beijing's new urban land is usually located in marginal peri-urban areas, such as 4 district in urban edge of Chaoyang, Haidian, Fengtai, Shijingshan, suburban plains of Tongzhou, Daxing, Changping and Shunyi, and other suburban district (county) and the surrounding counties and towns. These areas belong to high-yield farmland with irrigation conditions, flat terrain, deep soil, high soil fertility.

Fragmentation of landscape decrease, patch boundary shape tends to smooth with the increase in forest area, and tends to increase with decrease in grass areas. Fragmentation of cultural landscape tends to severeness, and be beneficial to economize the land with the increase in patches of urban and rural settlements. The cropland area decreases, and Fragmentation increases affected by the expansion of urban and rural settlements reforestation policies. OUYANG et al, (2005) showed that totals patches of landscape and land cover in Beijing's suburban areas is 70959, among which patches of farmland landscape types is up to 20376, the highest density of patches is 711,946, it reflected that Beijing urban development has led to fragmentation of the farmland landscape. Agricultural land are separated, split and conversion in urban development.

Beijing's rapid development has led to arable land and pasture area decreased largely, and settlements and land mines increased significantly. The difference in land use is significant. The disorderly urbanization trends makes Scattered large urban and rural construction zone join, combine and expand to the surrounding, leading to declining the habitat quality of living environment.

3 Beijing Agricultural Resources Status

3.1. Changes in cultivated land resources in Beijing

After 1958, the populations of Beijing has continuously increase, especially in the late nineties, the Beijing Municipal population increased significantly, from 12 million in 1999 to 17 million people in 2008, an increase of 41.67% (Fig 1). Increase in population led to an increase in urban land area, and decline in arable land. After 1960, cultivated land area of Beijing decline continuously, with Beijing's rapid development of urbanization, cultivated land area was significantly decreased after 1997, arable land dropped to 0.23 million hm^2 in 2008, compared with 1996, a decrease of 167.3

thousand hm^2, a significant decrease of 41.93% (Fig 2). Suburban districts and counties in Beijing, the per capita arable land dropped from 0.107 hm^2 in 1992, to 0.0104 hm^2 in 2000, then 0.0103hm^2 in 2002, loss of arable land is very grim.

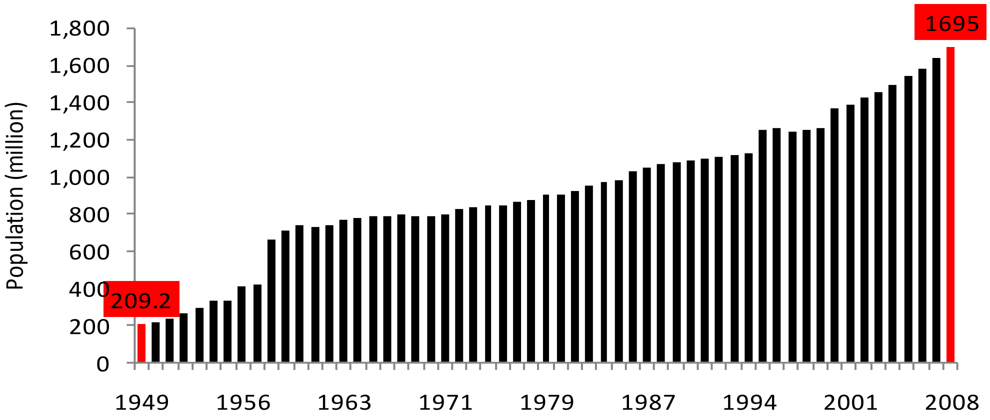

Fig1 1949-2008 , changes of Beijing's population

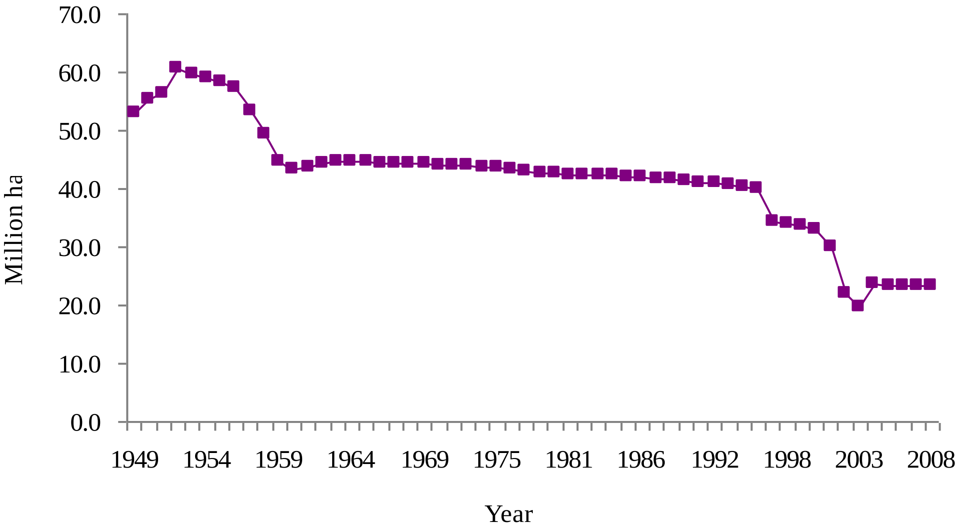

Fig2 1949-2008，Changes of Beijing's cultivated land area

In order to ensure the stability of cultivated land resources, Beijing, "the State Council on the issuance of National Land Use Planning Outline (2006-2020) of the notice" in October 16, 2008, clearly stipulated that The volume of land tenure in Beijing amounted to 3.39 million mu in 2010, and 3.22 million mu, and 2.80 million mu of basic farmland protection size in 2020. "Beijing's overall land use planning(2006-2020)" identified nine basic farmland protection areas of Beijing: Yanqing plain region, Changping eastern region, Shunyi northwest region, Shunyi eastern region, Pinggu Southwest region, Tongzhou eastern region, Tongzhou Southwest region, Daxing southern region, Fangshan southeast region(Fig 2).

3.2 The agriculture industrial structure changing in Beijing

With the developing social economic and raising living standard for people，changing for land use, reducing the area of cultivated field，which made the agriculture industrial structure and product structure change overall importance, the function of agriculture has gradually changed from the " assured for purveyance" changed to "market, benefit, ecotype". Agriculture plant structure happened to change greatly from 1978, the planting area for grain crop has declined, especially at the end of last century 90's, the plating areas decimated than ever before, from 6.15 million mu in 1999 to 2.38 million mu in 2004, during the periods of 5 years that descended 3.8285 million mu, however in recent years the areas for crop planting has increased, raising 2.9625 million mu in 2007. Some priority industry such as fruits and vegetables, greenstuff and so on had grown rapidly, the areas planted for vegetables and fruits kept on a rise, which from 0.845 million mu, 0.135 million mu in 1978 to 1.50 million mu and 1.22 million mu, raising 0.66 million mu and 1.08 million mu, respectively (Fig 3). Some rising economy such as herbage, flower, seedling, fine breed is already beginning to take shape. From the view of agricultural production function, the field in Beijing can only afford apart of grain for people's life, however it mostly afford fruits and vegetables and other subsidiary agricultural products for resident. In 2007, the grain yield in Beijing achieved 1.021 million tons, which account for 0.20% of whole county，but it only can supply 12% for the local residents. Accordingly Beijing's agriculture also has duty of adequate amount of agricultural commodities supply and providing fresh agricultural products.

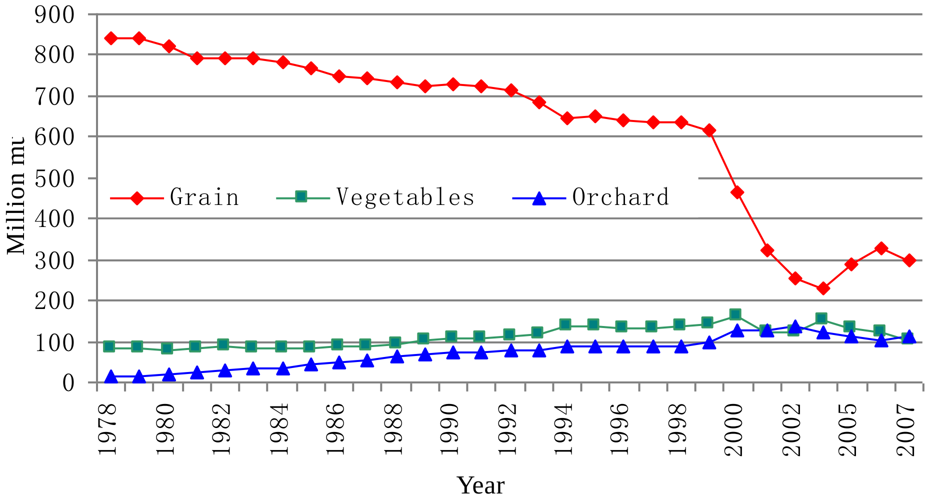

Fig3 1978-2007, changes of Beijing's grain, vegetable and planting area

With developing rapidly economic for Beijing, striving to develop tertiary industry, the proportion of primary industry primary accounted for total output of Beijing declined (Fig.4), in 2007 output value of farming occupied 1.13% during the whole cities' GDP. But it sustained growth, from more than 2 billion yuan in 1978 to more than 27.0 billion yuan in 2007. In despite of natural space in Beijing is limited for agriculture development，“fewness agriculture is not mean fraction one”, the developing agricultural multi-functional agro-ecological service value, aesthetic values and social value etc, made agricultural “ recessive character value domination”. Developing metropolis modern ecological agriculture is the important way to rise Beijing’s agriculture level, eco-agriculture is the important component part of city economic system and food supply system and city eco-environment and landscape. Eco-agriculture is to establish and maintain an ecologically self-sustaining, low input and economically viable small-scale agro-ecosystems, such small-scale agro-ecosystem achieve maximum production, without causing large or a long time in the ethics and morality can not be accepted changes in the environment.

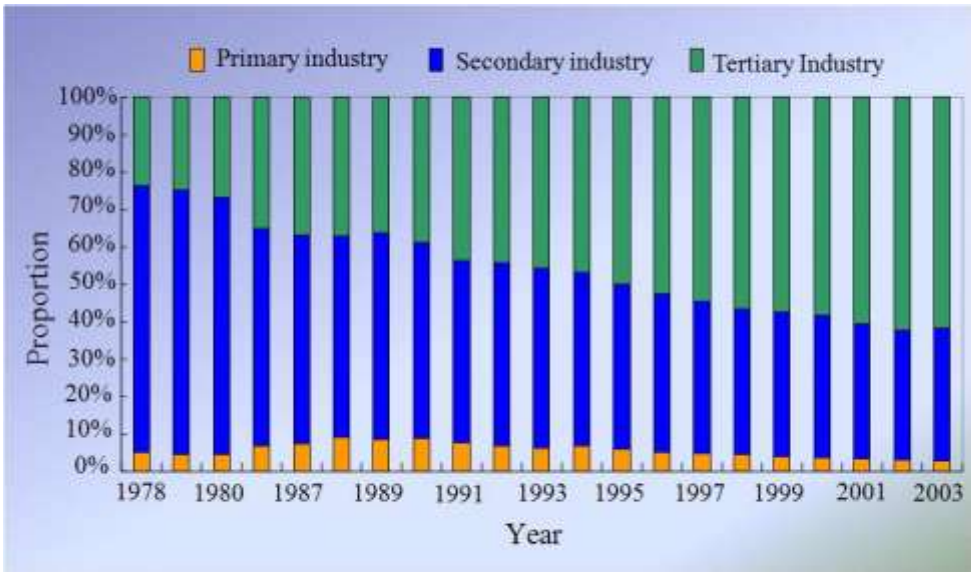

Fig 4 1978-2003, the proportion of each industry in Beijing

3.3 Problems of the land resource in Beijing

3.3.1 The increasingly tense of soil and water resources

Land is the most basic agricultural means of production. In recent years, due to the rapid development of urbanization and industrialization, land resources in the suburb of Beijing is declining. Simultaneously, the proportion of excellent farmland in total cultivated land is reducing and the overall quality of cultivated land is declining. The disorderly development and the damage to the overall landscape of farmland have been the constraints to metropolis modern agriculture. Reduction in arable land resources means the increase in the intensity of cultivated land use. This results in environmental quality issues and the decline problems of agricultural products’ quality. These problems have also been constraints to the metropolis modern agriculture. Although under the basic principle of cultivated land protection which is in terms of “Developing in protection and also protecting in development”, Beijing has started the land reclamation work whose precondition is protecting and improving ecological environment and whose starting point is to improve overall capacity of agricultural production, but the reserve land resources available for agricultural development and utilization in Beijing is inadequate. Now it is 15.3 thousands ha, only 4% of the total area, meantime, the quality is not so high, all this restrict the development and utilization.

The average of available water resource in Beijing per year is 4.76 billion m^3. Now in Beijing, the water resources reserves is 1.827 billion m^3, the entry is 1.915 billion m^3, so the total is 3.742 billion m^3 and the per capita is about 300 m^3 per year, which is only 13.8% of the amount in China. Due to industrial and demographic development, it has begun the phenomenon that groundwater in urban areas was over-exploitation resulting in groundwater level declined year by year since the seventies, 20th centuries. With the city's modernization and forward to the international metropolis, water use in agriculture will become tenser and the water scarcity will become a major constraint to the development of land resources. The intensification degree of eco-type urban agriculture is far higher than other rural areas. At present, the impact on water quality from the excessive application of chemical fertilizers and pesticides and the sewage of livestock and poultry breeding industry has become a prominent environmental problem. The pollution scope in Beijing has enlarged from 72 km^2 in 1982 to the 169km^2 in 2000. The dual pressure of water quality and resources induced water shortage has undoubtedly become an important limiting factor to the development and utilization of land resource.

3.3.2 The Soil quality does not meet the development goal of metropolis modern agriculture in Beijing

Warkentin thought that soil function is the basis of the evaluation to soil quality, Doran et al. generalized the soil function to three aspects: the first is productivity, which is a capacity of soil to improve the biological productivity; the second is environmental quality that is a capacity of soil to reduce environmental pollution and bacteria damage, and the third is animal and plant health, namely, a capacity of soil to impact the health of animal and plant, also including human.

The soil fertility level, especially organic matter, remains to be improved to meet the need of "high-quality, high yield, efficient, ecological, security". According to the long-term location monitoring of farmland fertility and the recent years’data of formula fertilization by soil testing, there are still problems existed in some areas: First, preference for chemical fertilizer rather than organic fertilizer, that leads to the city's soil organic matter content is not high, such as: 92%, 75.9% and 74.5% of Daxing, Shunyi, Miyun’ soil organic matter is less than 1.5% respectively; Secondly, nitrogen and phosphorus overrun and potash shortage in some areas, for example, excessive nitrogen fertilizing leads to the decline of peaches quality in Pinggu district; thirdly, preference for major element such as nitrogen , phosphorus and potash, rather than trace element, that result in an imbalance of soil nutrients, the decline of soil productivity.

These are many soil environmental quality problems. With the socio-economic development as well as a large number of the unreasonable inputs of agricultural means of production, massive organic and inorganic contaminants enter into the soil, when the amount of pollutants exceeds the ability of self-purification, they will lead to the soil pollution. The process of rapid urbanization and industrial development makes the soil pollution worse. The accumulation of toxic and hazardous chemicals in soil is not only a direct impact on terrestrial ecosystems of plants, animals and microbial growth, reproduction and survival, and may damage the ecosystem from pollution sources, and may also bring health risks to human through drinking water, breathing, diet, skin absorption channels. Eighties of the last century, the pollution of heavy metals in soils of arable land happened due to sewage irrigation in south-eastern suburbs of Beijing. In some suburban counties of Beijing the long-term large use of organic manure with higher levels of heavy metals in soils of arable land resulted in the excessive soil heavy metal content, higher value-added agricultural products in the irrational use of pesticides, large use of plastic residues in arable land and so on led to soil pesticide residues. Available information indicates that the cultivated land of heavy metals pollution in Beijing is up to area of 1.20 million mu, in which heavy metal content (lead, chromium, mercury, etc.) were significantly increased. compared to the cultivated land background values in 1985, the presence of mercury, cadmium, lead, arsenic, chromium enrichment phenomenon appears in agricultural soils, heavy metal pollution and potential pollution areas account for about 2%, mainly scattered spots in Tongzhou, Fangshan, Daxing, Haidian and Chaoyang District.

3.3.3. Irrational land use and severe water loss and soil erosion

In order to avoid the negative effect induced by urban development prevailing "over pie" phenomenon, Beijing urban master planning always put emphasis on multi-centred, multifunctional development pattern with “distributed clustered pattern” urban construction policy in 1958 and principle of “one center, ten groups” urban planning pattern in 1992. However, due to the effect of urban center’s fast expansion, green space distributing between center and urban fringes was constantly encroached. Therefore, urban development goes against the objective of “distributed clustered pattern”. Meanwhile, Beijing urban planning was poorly carried out, and 60% of planned urban area were not put into practice, of which, only 30% of actual new construction area conformed to the previous planning, and the remaining implemented due to planning adjustment and beyond the planning limits.

Land use/cover change has taken on the obvious characteristics of conversion from cultivated land in inner suburb to urban land, fast expansion of other land uses, non-urban land structure transformation and fast urbanization. Although balance between occupying and compensation during land occupation, the quality of new cultivated land can not achieve the previous land together with poorer ability of production ability that cultivated land area almost never witnessed reduction while the potential land and its quality reach a low level.

Irrational reclamation of mountainous forestry and sloping cultivated land in the outer suburbs led to large areas of water loss and soil erosion and declining biodiversity. Mountainous areas in Beijing account for 62% of the whole land areas, of which, slope above 25 ° occupied 46% of the overall mountainous areas and thin topsoil layer below 25cm is 64% of the whole mountainous areas. Soil erosion area of Beijing in 2007 reached up to 3524km^2, accounting for 21.47% of the whole area. Although Beijing invest a large number of funds, labor force and material resources for green space and cultivated forest areas gradually increase every year, the phenomenon of consideration of cultivation with poor management and emphasis on quantity with little care for quality results in so low forest survival that forest benefit is difficult to play and ecological and environmental situation is still serious.

3.3.4 Current agricultural infrastructure is not conducive to the rational development and utilization of land in Beijing

Irrigation and drainage facilities urgently need to be upgraded. Among the current agricultural irrigation and water conservancy facilities, much of those were built in 1980s, therefore, some are old motor-pumped wells, damaged channels, and poorly equipped rural power lines. Recently, the start of urban emergency on water source resulted in faster decline in groundwater levels in some areas, leading to inadequate volume from pumping well and poor irrigation. The dispersion of agricultural management resulted in some of the original large-scale irrigation facilities uncoordinated.

Farmland landscape fragmentation has negative effects on the development of farmland ecosystem service. Some residual net and belt are distributed in farmland shelterbelt and field road and need to be repair further. With the fast processes of urbanization, dumping varieties of garbage (living, construction, agricultural waste) is very prevalent, and farmland landscape fragmentation is more common, which lead to visual pollution to some degree and can not satisfy the requirement of leisure and sightseeing. The agriculture and agricultural facilities condition above mentioned no doubt has a bad effect on sustainable and efficient development of land resources in Beijing.

3.4 Measures for improving efficiency of land resources utilization

3.4.1 Scientific and rational distribution, unified planning

To combine the greening planning of three lines of green ecological barriers and the planning of urban agriculture in Beijing, ensure the city layout decentralized group style, and prevent spreading "over pie" phenomenon from center towards margin. To strictly implement the targets that the total amount of cultivated land of Beijing in 2010 is 3.39 million mu while that in 2020 is 3.22 million mu and the basic farmland protection areas reach 2.8 million mu which was defined in Notice of State Council on the issuance of National Land Use Planning Outline (2006-2020) in Oct. 16th, 2008, and the targets of nine large areas of basic farmland protection zones of Beijing determined in Land Use Planning of Beijing (2006-2020), which ensure reasonable and in order use of land resources and the quality and quantity of farmland resources, and promote the optimization of farmland landscape.

3.4.2. Right crop for right land and rational utilization

The results of second soil census showed that the total soil area of the whole city is 20,674,400 mu, and the soil resources is divided into 7 classes, 19 sub-categories, 69 genera and 198 species. ① Mountain meadow soil: the total area is 5.26km^2, which accounts for 0.038% of total soil area of the whole city; it is distributed at an altitude of 1800-1900 meters above the top of medium altitude mountain; the fertility is relatively high, the soil layer is medium thick, the herbaceous vegetation is dense, and it is suitable for grazing. ② Mountain brown earth: the total area is 1303km^2, accounting for 9.45% of total soil area of the whole city; it is distributed between 800-1800m high of medium altitude mountain; the soil layer is relatively thick, mostly 30-60cm, it is slightly acidic, the pore condition good, humus thick, fertility relatively high, appropriate for tree growth. ③

Cinnamon: the total area is 8911km^2, which accounts for 64.65% of total soil area of the whole city; it is distributed at an altitude of about 30-800m; according to the leaching degree of calcium carbonate, it can be divided into mountain leaching cinnamon, mountainous regosols Cinnamon, common cinnamon, carbonate cinnamon, cinnamonic soil, moist cinnamon and other sub-categories, among which mountain leaching cinnamon is in the majority. ④ Moisture soil: the total area is 1918km^2, which accounts for 13.82% of total soil area of the whole city, and it is mainly distributed in the alluvial plains, mountain valley plains, first terrace or margin area of alluvial fan; it is mainly distributed in the southeast of the city, and is one of the largest area of soil types of plain soil in Beijing. ⑤ Marshy soil: it is quite small, only 2.14km^2, accounting for 0.013% of total soil area; it is mainly scattered in the soak areas; the surface soil was slightly alkaline, and the organic matter content is mostly 1.2-2.3%; ⑥ Paddy soil: the total area is 52.47km^2, which accounts for 0.38% of total soil area of the whole city; it is formed under moisture soil, salt moisture soil, humid moisture soil or marsh area under rice cultivation. ⑦ Aeolian sandy soil: it is formed by the alluvial and Aeolian roles, mainly distributed in the two sides of Yongding River and Chaobai River.; the organic matter is mostly at 0.2-0.6%, the fertility is very low, only for the growth of drought-resistant or sand-resistant vegetation.

According to the physical, chemical and biological properties and fertility characteristics of various soil types, develop a rational planning of land utilization, to plant trees in case of suitable for forest while to cultivate the land in case of suitable for farming, to develop the soil potential, to increase agricultural productivity, to develop a rational planning of agricultural development, to promote the healthy development of sustainable urban type modern agriculture of Beijing.

3.4.3. Better the soil fertility and improve the soil quality

Through vigorously promoting straw application to field and conservation tillage technique and implementing the fertilization project of soil testing and the “four free” (free soil testing, free formulation, free card and free training) and “two subsidies” (formula fertilizer subsidies, organic fertilizer subsidies) agricultural support policies, soil fertility of farmland in Beijing has been rising continuously. From 1980 to 2000, organic matter content performed a low-to-high accumulation law. The land area with primary and secondary organic matter content increased from zero to accounting for 8.0% and 14.3% of total land area, respectively and the area with tertiary OMC increased from 23% to 37.1%. However, there is a definite gap between the Beijing soil fertility quality and the target of developing urban-based modern agriculture. Thereby, we must continue developing the farmland fertilization project which takes raising quality and reducing fertilizer amounts as the center, strengthening the application of organic fertilizer and promoting straw application to field efficiently, improving the land quality monitoring and management system, raising the technical service level, eliminating soil barriers, improving soil quality, improving soil productivity, to promote the development of the modern urban-type agriculture.

3.4.4. To strengthen pollution control and prevention, improve soil quality of the environment

Soil environmental quality is defined as a certain time and space[11], the soil appropriateness for its sustainable using its own properties as well as other environmental factors, especially for humans or other organisms to survive and reproduce, as well as the social and economic development.

Chen et al. (2004) developed a risk assessment of Beijing's heavy metal contamination of soil and vegetables, which provide an important scientific basis for the status evaluation and risk management of Beijing soil, regional environmental quality improvement, land use planning and agriculture and city development. A further evaluation of soil environmental quality in Beijing and ecological risk assessment of contaminated soil (heavy metal and organic pollution), making measures for source control and prevention need to be carried out to prevent the pollution of cultivated soil and degradation environmental quality. Comprehensive utilization of agricultural production waste need to be enhanced to reduce stress of agricultural non-point source pollution on the soil pollution. phytoremediation and plant-microorganism combined remediation techniques can be used to control the soil contaminated with heavy metals. This will improve soil environmental quality, enhance the level of agricultural production in Beijing, and increase the market competitiveness of agricultural products.

3.5. The land resources use meeting the metropolis modern agriculture

The Beijing metropolis modern agriculture has been experienced the process of practice-cognition-re-practice- recognition, Multi-functional pattern for the Beijing metropolis modern agriculture is taking shape: qualified seed industry, the fresh products distribution industry, agricultural product processing industry, agricultural sightseeing, eco-economic industry, agriculture information industry and agricultural science and technology services constitute the basic framework of the Beijing modern agriculture, forming five functional areas with comparative advantages: Chaoyang-Haidian-Fengtai- Changping modern agricultural exhibition incubator, and Daxing-Tongzhou-Fangshan-Shunyi brand agriculture processing and distribution areas, Pinggu-Miyun-Huaidian-Yanqing eco-agriculture export processing areas, Fangshan-Mentougou-Changping-Yanqing human landscape agriculture sightseeing area, Pinggu-Miyun-Huairou natural landscape agricultural leisure experience areas.

Installment Agriculture is the major form of metropolis modern agriculture in Beijing. By gathering land, capital, technology, labor, and other elements, Beijing has formed a capital-intensive, technology-intensive and labor-intensive as the main features of the intensive and highly efficient industry. From 1996 to 2006, Installation comprising of vegetables, flowers, melons and fruits has actively developed. Installation Agriculture group (zone) that is comprised with modern intelligent greenhouse, solar greenhouse, facilities greenhouse, has extended to 17.8 thousand hectares in area and the annual value of production reached 2.11 billion yuan. Among which vegetables cultivation covers 11.2 thousand hectares and area under crops of 1.30 million mu and output up to 4 billion kilograms, accounting for 40% of the market supply and achieve revenue 1.41 billion yuan; while flowers covers an area of 533.3 hectares, and achieve revenue 240 million yuan; then melons covers an area of 5267 hectares, and achieve 350 million yuan; fruit covers an area of 333.3 hectares, and achieve revenue 60 million yuan. In 2007, the installation agricultural area increased by 2.3 thousand mu in Beijing, and has formed a distribution pattern "two areas". In 2008 an area of 2400 hectares was newly extended, which shows a pattern preliminarily “two areas-two zones-multi-communities”. Beijing municipal government issued a " suggestions about development of facility agriculture", which planned the development of the layout " two areas-two zones-multi-communities" , planning new facility agriculture area of 2700 hectares each year during the period of 2008-2012, and up to 23.3 thousand hectares in 2012.

The facility agriculture has developed well in Beijing, but compared with Europe and the United States and other developed economies, there are still a considerable gap. The mechanized processing is backward existing in the production process include soil tillage, sowing, planting, irrigation, fertilization, pest control, and post-harvest processing technologies. Automated monitor temperature, light, water, fertilizer and gas is in low level. Management technology level and means is extensive. Affected by these adverse factors, the development level of metropolis-modern agriculture is still in being primarily stage, even though the metropolis-modern agriculture based on facility agriculture has greatly improved production capacity, compared with the traditional mode of agricultural production [19,20]. Each function of metropolis-modern agriculture is unbalanced, its social and ecological function doesn’t display well. As an international metropolis, Beijing metropolis modern agricultural development will face more severe problems of shortage of land resources and environmental pollution than in rural areas, as which the population explosion, urbanization and industrialization process accelerated leading to the unreasonable allocation of land resources, reduction of cultivated land, raising the level of agricultural intensification. Particularly during the facility agricultural production process, a large number of agricultural means of production (fertilizers, pesticides, agricultural water) have be unreasonable invest and large-scale farms discharge waste to the ecological environment, as a result of a serious negative impact. It is still more common phenomenon of soil quality barriers in metropolis modern agriculture development in Beijing: soil salinization, nitrate accumulation, soil-borne pests and diseases, nutrient imbalances such as micronutrient deficiencies, plant accumulation of toxic substances. Thus, it is very necessary that strengthen ecological environment construction and upgrade the value of eco-service functions for land-use, and ecosystem services in the process of metropolis-modern agriculture.

4. Prospects for Land use and Development of Beijing Metropolis Modern Agriculture

4.1 The development of resource-saving, eco-friendly metropolitan modern agriculture is the important guarantee for sustainable economic development and the ‘livable city’ construction for Beijing.

Third Plenary Session of the 17 central committee stated clearly that, ‘developing modern agriculture, training new farmers, and leading the masses making them rich, maintaining stability in rural should always be run through the entire activities of rural grassroots party organizations.’ Metropolitan modern agriculture is an important component of the city's economic, social and ecological system, is an important way to urban and rural integration.A strong demand for Beijing developing metropolis modern agriculture depends on the development of production, ecology, life and social in Beijing. At present, Beijing has possessed the basic conditions for developing metropolitan modern agriculture, including eco-leisure agriculture. ‘Without the modernization of rural areas, there is no modernization of the capital,’ and urban-rural social structure is not sustainable. Therefore, The development of metropolis modern agriculture is becoming an important guarantee for Beijing to balance urban and rural development , develop the functions of agro-ecological service agricultural ecosystem service, develop agriculture and rural economy, increase employment opportunities for farmers and improve the overall quality of the farmers, optimize landscape and build Beijing's "livable city" .

4.2 To strengthen the management of land resources is the prerequisite for the healthy development of metropolis modern agriculture

As an international metropolis, with the process of urbanization and urban development, Urban, rural, and other residential areas, and factories, mines, and metropolis modern agriculture infrastructure will undoubtedly take up agricultural land, particularly arable land used for agricultural production, which increased the pressure for metropolitan modern agriculture development with well-coordinated relationship between social economy and ecology & environment, resource-saving and eco-friendly. Therefore, it is the important prerequisite for developing healthily Beijing metropolis modern agriculture, using modern information technology (e.g. 3S technology) to improve information management levels of land resources, and strict implementing the "National Land Use Planning Outline (2006-2020)" and "Beijing's overall land use planning (2006-2020) " to ensure the inventory goals of 3.39 million mu and 3.32 million mu of cultivated land by the end of 2010 and 2020, respectively, and 2.80 million mu of basic farmland protection area.

4.3 To enhance the quality of arable land to promote the development level of Beijing metropolis modern agriculture

Soil fertility and environmental quality are the important factor of the development level for Beijing metropolis modern agriculture. First of all, to strengthen the fertility cultivation of soil with low fertile and the remediation soils with environmental problems soils is the basis of the healthy development of metropolis modern agriculture of Beijing. Secondly, aiming at the issues in the Beijing metropolis modern agriculture development, Research on overall, basic and key technologies concerning increasing agricultural production and benefit and agricultural eco-environment, such as animal and plant breeding, pest control, water-saving agriculture, improvement in soil fertility, healthy breeding supporting technology, soil and water conservation, and vegetation recovery, become an important guarantee to upgrade levels of Beijing metropolis modern agriculture.

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Current Status and Development Orientation Of Agriculture in Viet Nam

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1 Introduction

Viet Nam is an agricultural economy located in Southeast Asia with a population of 86 million people. Agricultural land have nearly 25 million hectares including more than 9.5 million hectares of cultivated, average is 9,200 m2/person;

2 The achievements of Viet Nam Agriculture Production in Recent Years

- Developed for highly speed in the direction of commodity production (reaching 4.5% per year) average value of production/cultivation labor increased from $ 360 in 2001 upto $ 460 in 2008.

- Output, productivity and quality of agricultural products and production efficiency is increasing more and more. Some plants have a breakthrough in productivity, output, include nuts, tea, rubber, maize, cassava, peanuts and etc. Quality of some products is improved such as rice, coffee, and tea.

- National food security is assured. Average food per capita increased from 420kg in 2001 to 500 kg in 2008. Food production for export reached 4.27 million tons annually in the period of 2001 to 2008.

- Some areas of centralized commodity production associated with the processing industry has been formed, giving agricultural products of high economic value such as rice, corn, sugar-cane, fruits, rubber, coffee, cashew, tea, etc;

- Export of agricultural products is increased with an average of 23.6% per year. Some exported products accounting for high position in the world as: pepper, cashew nuts, ranked first in the world; rice, coffee is second in the world; rubber fourth and tea fifth in the world.

3 Restrictions

- Agricultural development is not sustainable, most are dependent on nature; growth of the industry is not stable.

- Production of cultivation remains essentially small scale and decentralized. Some products developed spontaneously, lack of stability, quality without equal.

- Prices of many agricultural products are still high, food safety still poor, lack of competitiveness in the world.

- Period after harvest is not as good, 90% of agricultural products is sold in raw materials and 60% of products is sold at low cost.

- Quality of agricultural labor is still low. Most of farmers implement their production by personal experience; The farmers always lacks information especially information about market.

4 Predictions About the Difficulties for Agricultural Production of Viet Nam in Next Time

- Viet Nam's population continues to increase. There will be at 100 million people in 2020, 110 million people in 2030 and stabilized at 120 million people after 2030. Food demand will increase, to 2015, 2020 and 2030 demand for rice respectively is 32.1 million tons, 35.2 million tons and 37.3 million tons.

- Area of agricultural land continues to decrease, especially of rice cultivated land. According to our forecast in the year of 2020, agricultural land will reduce 550 thousand ha of which 200 thousand hectares of rice.

- Climate change will directly affect to Viet Nam’s agricultural production in the near future. Viet Nam shall be one of five economies most affected. As expected, in next 100 years, about 2.0 to 2.5 million hectares of agricultural land, which is mainly paddy land shall be flooded or salinity and is not cultivated. Climate change also increase natural disasters, floods, droughts, hot, cold, pests increase so as to decease crop yields. This will affect crop production and create more difficulties and challenges for ensuring food security and food for domestic demand and exports in the future.

- Agricultural products of Viet Nam will be subject to competitive market joining WTO.

- The risks of lag in technology over the region and the world if not overcome the gap will increasingly broader.

5 Orientation of Agricultural Development of Viet Nam in the Future

- Ensuring security of food and foodstuffs sustainable long-term in all situations; development centralized towards the commodity production so as to meet the demand for domestic consumption and boost exports.

- Promote to restructure plants and seasonal structure to develop the advantages of each kind of crop for each sub-regional ecology.

- Develop agricultural mounted closely to the industrial processing, formation of the production of goods supplied materials for processing industries.

- Apply strong science and technology; promote the intensive and suitable use of land resources, water resources and labor to improve productivity, quality and efficiency.

- Mobilize all resources to develop agricultural production associated with the implementation of policies on agriculture and set up agriculture ecological sustainability, increase income, stabilize life of farmers to contribute to poverty reduction in Viet Nam.

Disposition land fund agricultural development to 2015 and Vision 2020

In the period from 2008 to 2020, the land use will be reclaimed into arable production about 330 thousand hectares, simultaneous transferred 50 thousand hectares of production forest land to poor agricultural production. Land for agricultural production will be recovered to move into non-agricultural purposes around 550 thousand ha. The land used for agricultural production will be decreased only 170 thousand ha.

- By 2015 the land for agricultural production is 9.25 million ha; land allocated 6.05 million hectares of trees each year, including 3.85 million ha of rice land and perennial land 3.2 million ha;

- By 2020 the land for agricultural production will be 9.25 million ha; land allocated 6.05 million hectares of trees annually, of which: 3.8 million hectares of rice land and perennial land 3.2 million ha;

Land area using for agricultural production is expected to use with the layout as follows:

Categories	2007	2015	2020
Agricultural land	**9.420**	**9.250**	**9.250**
Land for annual crop cultivation	***6.310***	***6.050***	***6.050***
Rice Land	4.106	3.855	3.800
Maize Land	400	400	450
Cassava	544	470	450
Vegetables	307	416	500
Soybean	80	100	100
Peanut	128	140	150
Sugarcanes	271	300	300
Other annual crops	422	148	-
Land used for husbandry	53	220	300
Land used for perennial crops	***3.111***	***3.200***	***3.200***
Tea	130	135	140
Coffee	525	500	500
Rubber	619	800	800
Coconut	135	135	135
Pepper	50	50	50
cashew	405	400	400
Cocoa	7	34	50
Oranges, mandarins	87	105	115
pineapple	40	50	55
Banana	111	135	145
Mango	86	105	110
Longan	98	125	140
litchi	110	135	140
Other fruit trees	258	295	295
Other perennial	451	197	125

6 Main Solutions to Develop Crop Production

In order to implement the proposals to develop crop production, some solutions and policies need to be undertaken and applied as follows:

6.1. Policy group on land and centralized planning for good production

a) Policy group on land

Propose to change some contents mentioned in the 2003 Land Law with the direction to create favorable conditions for accumulation of land, protect agricultural production, especially paddy land.

- Expand the term filled: ensure farmers have favorable conditions for improving scale and self-organization of effective production.

- Terms defined responsibilities and powers of government at all levels in the management of land for agricultural production, especially paddy land as planned.

- Provision the principle purposes of conversion of rice land to other purposes toward savings, no industrial development, urban infrastructure on the rice land, especially land with two rice crops.

- Provision of agricultural land acquisition cost to switch to non-agricultural development with the cost of 1.5 to 2 times higher than market price, especially land acquisition price for rice land.

b) Planning of the concentration of commodity production plants that have advantages in the economic areas.

Based on natural conditions, economic and social development orientation of the economic planning to conduct concentrated commodity production plant has some advantages associated with the development of infrastructure (transportation, irrigation, electricity, and communications), processing, storage and consumption market in seven economic regions.

- Midland and mountainous region of the North: planning of concentrated commodity production for crops such as coffee (Son La), tea, rubber, fruit trees (banana, pineapple, citrus, grapefruit, mango, longan, litchi), rice, corn, vegetables, sugarcane, soybean, peanut, flowering plants, medicinal plants and plant biomass;

- Red River Delta Region: planning of concentrated commodity production for crops such as rice, maize, soybean (winter), peanuts, vegetables, fruit (bananas, pineapples, citrus, pomelo, longan, litchi), ornamental plants.

- North Central Region: centralized planning of production of goods for crops such as rice, sugarcane, peanuts, soybeans, corn, vegetables, fruit (bananas, pineapples, citrus, grapefruit), coconut, tea, coffee, rubber, pepper;

- South Central Coast Region: planning of concentrated commodity production for crops such as rice, corn, vegetables, fruit trees (banana, mango), cocoa, rubber, pepper, cashew and coconut;

- Highlands Region: planning of concentrated commodity production for crops such as rubber, coffee, pepper, cashew, cocoa, tea (Lam Dong), rice, corn, vegetables, flower scene (Da Lat);

- Southeast Region of: centralized planning of production of goods for crops such as rubber, coffee, pepper, cashew nuts, sugarcane, cocoa, rice, vegetables, corn, peanuts, fruit (banana, citrus, mangosteen, pomelo, dragon fruit), ornamental plants;

- Cuu Long River Delta: centralized planning of production of goods for crops like rice, pepper, cashew, coconut, sugarcane, cocoa, fruit trees (oranges, tangerines, grapefruit, Rambutan, mangosteen), ornamental plants.

6.2. Development of science technology and environmental protection

a) On science and technology:

Promotion of applying the biotechnology into plant breeding, production of bio-fertilizers and bio-pesticides with biological materials, so that the contribution of biotechnological cultivation to science and technology for increasing the value of cultivation will be 20 to 30% by 2015 and 50% by 2020.

- Develop agricultural technology for high-value products such as vegetables, flowers and fruits. By the year 2020, high technology agricultural production areas will be created at three key economic regions that equivalent to the level in the region and yield increases of at least 30%, compared with the superior quality of the technology used; products by CNC applications in agriculture create a higher economic efficiency at least 30% compared to that using and competitive technologies in the market.

- Application of technological information to develop information net work about production planting, raising and capacity analysis forecasting supply, market prices, consumption structure of agricultural products, warning evolutions adverse weather and market impact to produce solutions to cope promptly and effectively.

b) Regarding environmental protection

- Completion of the construction standards, standard for managing and controlling the environment for agricultural production in general and agricultural crops in particular. Forced investors to project the industrial, urban, ... have reported impact assessment and environmental protection of the environment. At the same time, encouraging and priorities the invested projects with good solutions for waste disposal, dust environment protection.

- Strengthening of plant protection systems, which focus on pest control activities; model building inspection monitoring and warning on the use of pesticides; building mechanism and process control service plant, using chemical plant protection, to manage and protect the growing manufacturing environment as a whole effectively.

6.3. Investment and development of rural infrastructure to meet the requirements of commodity production focus

- On rural roads: a complete system of internal traffic in the area of commodity production focus, creating favorable conditions for the application of mechanization in manufacturing, especially the stages of irrigation water, as land , plant protection, harvesting;

- Regarding irrigation: irrigation investment and development, supply sufficient water for agricultural production. 2015 to ensure irrigation initiative 9 million hectares of cultivated annual plants (80%) and 1.3 million hectares of perennial plants (reaching 40%). 2020 to ensure irrigation initiative 9.5 million hectares of cultivated annual plants (85%) and 1.5 million hectares of perennial plants (reaching 45-50%) Investment in construction field including how banks, canals clue, interior field. Promote research and widely applied spray irrigation technology, drip irrigation, seepage irrigation to save water.

6.4. Training human resources

- By 2020, vocational training for 70% of eligible farmers switch to non-agricultural sector; technical training of farmers for planting remaining percentage increase farmers were trained to reach 40% by 2020 ;

- Training managers, specialists cultivation, agricultural extension officers, ... on cultivation techniques, terms, test, plant varieties, fertilizers and testing product quality, construction of the mechanism associated with the training strategies employers after training;

- Setting up a new television channel, broadcasting continuous system with full database and information on advanced production techniques, planting progress status and provision of seeds, agricultural materials, disease, harvest results, forecasting and monitoring of crops, market information and willing to provide information quickly, fully and accurately to people if required.

6.5. Mechanization in agricultural production

- For food crops (rice, maize): encourages application of mechanization to the stages of land, planting, care, plant protection, harvesting and processing. Implementation harvesting machine for rice by 50% in 2020, of which the Cuu Long River Delta 80%, mostly using dams associated with harvest of high-tech features; encourage the economic sectors of investment development of dryers, in accordance with the scale and level of production, ensuring from 2015 onwards capacity drying rice on the economy reached 10 million tons per year. Focused investment in advanced drying system, associated with milling facilities, great food reserves; The Plantation 80% of the stockpile, storage and 20% of automation, improve labor productivity and control of technical parameters during storage;

- For coffee, vegetables, tea, pepper, cashew nuts: encourage people to apply machine harvesting coffee for coffee (arabica). For vegetables improved facilities, harvesting equipment to ensure quality of raw materials before harvest; Support people and business investment dryer advanced minimize contamination achrotoxin A for coffee, cashew and pepper; encourage construction of storage systems meet technical standards for temporary storage of coffee, bonded with vegetables; make preservation of fresh vegetables in place towards selling waterproof membrane covering (coating); radiation technology applications, sterilized in hot water with some fresh vegetables for export. Development of preliminary processing system at the vegetable market is invested.

6.6. Development processing, preservation

- Develop processing technology, storage, agricultural production towards innovative, modern and ensure diversity in scale to match the production of concentrated and dispersed; combining a variety of technologies, which obtain in modern technology as a core to create high quality resources and ensure ATVSTP for domestic consumption and export; socialization storage and processing areas, and mobilize various economic sectors to participate in stages: Production - storage - processing - consumption - quality management product, most sectors have a competitive advantage and large market in domestic and export such as rice, coffee, rubber, cashew, pepper, tea, fruits and vegetables.

- Implement support credit loans and support interest, tax-free import of machinery and equipment, provided a production tax for organizations and individuals to apply technology preservation and processing of agricultural products by direction of advanced and modern. By 2020 increase rate of food processing industries, mainly food up to 70%, including rice reached 65%, sugarcane 80%, tea 70%, vegetables 15%, corn 90%.

6.7. International cooperation

Strengthening international cooperation in crop production: building cooperation programs with international research institutions; invited international experts, overseas Viet Namese to work well in cultivation to strengthen the capacity of industry, increase technology transfer, advanced technology. Learning to exchange information, experience organizing production, processing and trade promotion of market development, especially some plants have a competitive advantage for export.

Simulating Annealing for Land-use Planning

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Abstract. Land-use plan is a very complex activity. Generally, it is a multi-objective and nonlinear programming problem with the high dimensionality, determinative mathematical programming tools have difficulty to solve it. Because of its difficulty, planners have to use some qualitative methods, the result is more or less subjective and the resulting land use scheme may be non-optimal. This paper develops a new method called simulated annealing algorithms (SA) for handling such conflict. The simulated annealing algorithm is a robust searching technique, which is quite useful and effective for dealing with many complicated mathematical model. Since it is uneasy to tackle some spatial constraints in the optimisation process, Our SA integrates some spatial constraints into the objective function, including the contiguity and compact form constraints, while the direction constraint is considered into the process of feasible solution searching. The objective of optimisation model is to minimize development costs, maximize the spatial harmony among spatial units and spatial compactness of some types of land use. A special strategy is used to compute the value of spatial harmony. The SA method is successfully applied to Muyun industrial district planning, Hunan province, China. The result shows the method may be a promising one.

1 Introduction

It is a widespread trend that more and more developing economies are developing their new towns (or new communities) in the recent years to satisfy the need of urbanization. Land-use planning becomes an important and often-encountered issue for planners. Generally, in urban planning designers or planners often locate the parcels of various land uses based on the spatial relationships among these parcels. The method is qualitative and the result is more or less subjective. However, generating the best alternative is a more complicated planning problem, a resource allocation problem. In a computational domain, modeling a complex resource allocation problem raises a number of challenging issues, also.

Foremost, there are so many alternatives in urban land-use planning (ULUP). For example, there exist 10^{200} possible land-use plans, a very huge number, for a planned area having 200 land-use zones with 10 possible land uses. Faced with so large solution space, to enumerate all possible solutions, analyze them and then select the best alternative are impossible. Oftentimes planners select a mere handful of candidate plans for analysis and evaluation, usually two to three, and rarely more than ten, and the process of generating land-use scheme has long been viewed as a ‘black box’ inside which planners are subjective and qualitative, and alternatives are explicitly few (Feng and Lin 1999). This is unfortunate, because such plans are usually selected through an ad hoc process, and it is likely that much better plans exist in practice. Obviously, an efficient approach for obtaining the true optimal urban land-use plan becomes very necessary and urgent.

Urban land-use planning is a kind of resource allocation problems, whose solution is often obtained by utilizing mathematical optimization techniques, such as 0-1 integer, linear, and nonlinear programming, and son on. They are often referred to as multi-criteria decision-making (MCDM) techniques. But they run into numerical problems when faced with the high dimensionality encountered in spatial application (Aerts and Heuvelink, 2002). Problem size is a function of the number of spatial units in the data set and the expected number of spatial evaluation units in the study area. Furthermore, many spatial constraints or objectives dilate the problem size and explicitly make it more complex. In practice, using those determinative mathematical programming techniques is very difficult, even unfeasible to get the solution of the problems in question.

Many studies showed that some heuristic solution techniques, such as genetic algorithm, Tabu search, and simulated annealing might be a class of feasible optimisation techniques for analyzing the ULUP associated with GIS (Balling *et al.* 1999, Feng and Lin 1999, Matthews *et al.* 1999, Brookes 2001, Aerts and Heuvelink 2002). The simulated annealing can effectively deal with the nonlinear and local optimum programming models by their powerful parallel search capability. Some studies have concluded that SA is better than current heuristic algorithms in terms of solving efficiency (Miller 1996, Marín and Salmerón 1996, Leão and Matos 1999, Bandyopadhyay *el al.* 1998, Antunes and Peeters 2001, Bornstein and Azlan 1998, Openshow and Schmidt 1996, Aerts and Heuvelink 2002, Wang *et al.* 2001, Wang 2002). This paper is an attempt of using simulated annealing for the ULUP. Its main objective is to test the performance of simulated annealing for urban land-use plans.

The remainder of the article is organized as follows. The next section develops the basic optimisation model of the ULUP. Section 3 discusses some special issues in the ULUP. Section 4 discusses the application of a simulated annealing algorithm to the ULUP, in this part a case study is used for demonstration purposes that illustrate the capabilities of the developed tool. At last, section 5 provides some concluding comments.

2 Basic Optimisation Model

As an example, consider a rectangular area to be allocated with land use. Where k, k' represent the type of land use (e.g. residence, industry, park, etc.) given. i is the number of row. j is the number of column. Eell $i'j'$ means the cells in the Von Neumann Neighborhood of cell ij . $L_{ij,i'j'}$ is a binary variable: 1, if there is a ‘link’ between cell ij of land-use k and cell $i'j'$ of land-use k'. 0, otherwise. $H_{k,k'}$ describes the spatial harmony degree between land-use k of cell ij and land-use k' of cell $i'j'$. X_k is the size of land-use k, given. X_{ijk} is a binary decision variable: 1, if land-use k is located at cell ij. 0, otherwise. $S_{L_{ij,i'j'}}$ is the sum of all ‘link’ between cell ij and cell $i'j'$. Development costs C_{ijk} are involved with each land use type k in cell ij. B_{ij} is the unsuitable zone for allocating the cell ij.

The goal is to minimize development cost and maximize spatial association. Accordingly, the problem may be written as follows:

Objective:

Minimize development costs (Aerts and Heuvelink 2002).

$$\sum_{ijk} C_{ijk} x_{ijk} \qquad (1)$$

Maximize total spatial association.

$$\sum_{ijk,i'j'k'} L_{ij,i'j'} H_{k,k'} \qquad (2)$$

Subject to:

The number of each land-use type must be equal to the pre-determined proportion.

$$\sum_{ij} X_{ijk} = X_k \ ,\forall k \qquad (3)$$

A cell must be allocated one land-use type.

$$\sum_{k} X_{ijk} = 1, \forall ij \qquad (4)$$

One cell must at least be contiguity to another cell. If not so, a smell 'island' would be found.

$$S_{L_{ij,i'j'}} \geq 1, \forall (ij, i'j') \qquad (5)$$

Any two cells from the same land-use type should be contiguity (i.e. the Manhattan distance $m_{i_1 j_1 k, i_2 j_2 k}$ equals to 1).

$$m_{i_1 j_1 k, i_2 j_2 k} = 1 \qquad (6)$$

Two cells from two different land-use types must be located further than *D* spatial units, a distance constraint. $d_{ijk,i'j'k'}$ is the Euclidean distance of two cells from different land-use types.

$$d_{ijk,i'j'k'} > D \qquad (7)$$

A cell is banned to locate at a zone, such as the upper part of other land-use cell, a direction constraint.

$$i' \notin B_{ij}, \text{ and } \ j' \notin B_{ij} \qquad (8)$$

The form of some land-use types must be compactness. a is the area of a parcel in question, and λ is the compact measure (Diamond and Wright 1991).

$$\max_{ij,i^{'}j^{'}} d_{ij,i^{'}j^{'}} \leq (\lambda a)^{1/2} \tag{9}$$

Together with above objectives and constraints, there may be other constraints considered. In the practical models, we can enumerate more other constraints (spatial or aspatial). Such a combinatorial optimization problem with many constrained conditions is not tractable. Thus, often some constraints are combined into objectives. As Aerts and Heuvelink (2002) research, we can define the following objective function for the need of subjecting to the compact form. The land-use type of cell (ij) is x_{ijk}, and b_{ijk} presents a neighbour aggregate variable.

$$b_{ijk} = x_{i-1jk} + x_{i+1jk} + x_{ij-1k} + x_{ij+1k} \tag{10}$$

$$\sum_{ijk} - b_{ijk} x_{ijk} \tag{11}$$

Similarly, the contiguity of cells is also integrated into the objectives, through the way that the spatial harmony index between the same land-use cells is set a higher value, say 2.0.

The overall objective function of the basic model now contains three terms: development costs as in equation (1), and spatial harmony indices as defined in equation (2), and the objective of compact form patches as defined in equation (11). Those three objectives may compete with one another. For instance, if you want to get a lower development cost, you may be at a cost of non-compact patches. It is impossible to develop plans that achieve all objectives. Trade-offs must be based on the relative importance of one objective against another. One may think of these relative importances as weighting factors for the objectives. However, it is very difficult for planners to numerically quantify the relative weight which dependents on the preference of planners or decision-makers. This is the process of MCDM. Multiple objectives are combined into one objective by inhibiting, normalizing, weighting and combining scores for each independent objective into a single score. In order to allow for a preference for either of these two objectives, here, two weighting factors w_1 , w_2 are produced. Thus, we join the three objectives into a single objective function:

Maximize:

$$-\sum_{ijk} C_{ijk} x_{ijk} + w_1 \sum_{ijk,i^{'}j^{'}k^{'}} L_{ij,i^{'}j^{'}} H_{k,k^{'}} + w_2 \sum_{ijk} b_{ijk} x_{ijk} \tag{12}$$

In above formulated model, both objectives and constraints are nonlinear with high dimensionality. Generally, traditional mathematical programming methods have difficulty to solve it or even can’t, so we have to employ other better methods. Simulated annealing is justly a valuable technique.

3 The Discussion About Some Issues

3.1. Spatial units

There are two ways to select spatial evaluation units: one is to use ‘natural’ land parcels, and other is to utilize cells by dividing the planned area with a grid (i.e. 50×50). Provided that land parcels as spatial units, its main advantage is that it may reduce the problem size. However, there are many drawbacks: a) sometimes one land parcel may have more than one land-use type. If we utilized land parcel as spatial unit, then one parcel only represents one land-use type. Thus, in the optimisation processing, it is quite uneasy definitely to maintenance the pre-determined proportion of various land use types. And b) it makes the computing process more difficult when faced with many spatial objectives or constraints, in that in the ULUP there exist many spatial constraints, such as direction, distance, or compact form constraint, and so forth. The ‘natural’ land parcels often have complex irregular figures, it makes the spatial constraints not tractable. Oppositely, the above defects are justly overcome by using the two-dimensional grids because of their regular geometry shapes. However, the later has its fatal problem: as the grid size decreases, the magnitude of the optimisation problem exponentially increases. Generally for a grid (80×80) with 6 land uses, the possible solution number will be 6^{6400}, a very huge solution space. In order to obtain an ideal solution we have to spend more computation time. Furthermore, there are the potential problems associated with translating grid-based solutions into practical land-use scheme.

3.2. Contiguity constraint of spatial units

Contiguity of cells is the defining requirement of land-use parcels. It is a spatial relation between a cell and any of its neighbors, a spatial constraint. It is our hope that land parcels consisting of cells are continuous, not fragmented. Cova and Church (2000a, 2000b), Brookes (1997, 2001) develop some approaches to generate the contiguity of spatial units for locating and configuring the best site. However, the contiguity problem in the ULUP is slightly different from the former. The former is a location problem while the latter an allocation problem.

3.3. Compact constraint of spatial units

There are a number of land-use planning applications where the parcels to be located should be compact or posses preferred shape characteristics. For example, in allocating land for housing development a planning authority may prefer the development to be confined to a single compact parcel rather than dispersed because there will be less impact on surrounding areas.

In the ULUP, the form of one parcel is great concerned. Compact regions can be superior to fragmented regions because of edge-effects. When edge effects are detrimental then patchy spatial pattern is not attractive, and a compact industrial zone will have a minimal disturbance effect on surrounding areas. In most parts of Europe compact city policies have become a popular means of planning for sustainability. Dense compact cities were seen as solutions to reduce continually increasing mobility. They were also seen as a way avoid urbanization of the nationside (Roo 2000). On the other hand, a linear park may maximize accessibility from neighboring residential areas. Shape is complex and multifaceted phenomenon and therefore difficulty to evaluate completely. In computation domain shape is notorious difficult to describe and quantify satisfactorily. Many papers describe this problem (Wentz 2000, Cova and Church 2000, Miller 1996, Roo 2000, Aerts *et al*. 2002).

3.4. Direction constraint of spatial units

As to spatial relationships between cells, the direction is an important factor, too. For instance, a heavy industrial district must be located at the under part of prevailing winds, and the residential zone is at an opposite position. Some special planning objects, such as incinerator, must be located at the under part of prevailing winds in a city, because of their heavy atmospheric pollution.

3.5. Distance constraint of spatial units

Sometimes it is the planning requirement that there exists some distance away among some planning objects, such as gas station or big waste dumpsite to residential area. How to measure the distance of two planning objects with any complex planar figure is a dilemma. In the vector space, there exist some computational strategies (Miller, 1996). Okabe and Miller (1994) formulate exact algorithms for the average, minimum and maximum distances between pairings of the geometric primitives. Voronoi Diagram may be another alternative (Miller 1996, Okabe *et al.* 1992, Wang 2002). In the raster space, we can employ the minimum cumulative resistance (MCR) model suggested by Knaapen *et al*. (1992). MCR is the minimum edge-to-edge distance between two land parcels as measured on a cost, or friction, surface. For any pair of parcels in a raster the MCR is found by first generating a distance layer by spreading from one land parcel and then extracting the minimum value where the second parcel overlays the distance layer. MCR is the minimum length between two land parcels (Brookes 1997).

4 Simulated Annealing for Urban Land-use Planning

4.1. Principles of simulated annealing

In the 1980s new contributions, intelligent heuristic algorithms, to deal with the combinatorial problems emerged, genetic algorithms, neural networks, Tabu search and simulated annealing.

Simulated annealing is motivated by the similarity between the annealing of solids and the global optimization processes. In a physical system with a large number of basic particles, such as atoms, the equilibrium may be characterized as the minimal value for the energy of the system. This is accomplished by a slow cooling of the temperature. Metropolis *et al.* (1953) proposed an algorithm to simulate a system of atoms in equilibrium at a particular temperature.

As Miller (1996) notes, simulated annealing (SA) is essentially a neighborhood search technique. Starting with an arbitrary initial solution, the algorithm explores similar solutions in its neighborhood for one with a lower cost. After finding a new solution, the search continues in the neighborhood around that solution. In contrast to standard search techniques, however, SA not only allows uphill climbs (acceptance of a new solution with a higher cost than the current solution), but permit downhill search (acceptance of a new solution with a lower cost than the current solution at a predetermined probability) also. A temperature parameter in the SA procedure controls the probability of accepting an uphill climb from a current solution. SA in metal annealing, a key implementation question for SA is the rate at which to lower the temperature parameter, that is, lowers the probability of accepting an uphill climb from any current solution.

During early iterations, the SA algorithm maintains a high temperature or a high probability of accepting an uphill climb from a current solution. Thus, the neighborhood search occurs in a more or less random manner. After a set number of iterations, the temperature is lowered and the neighborhood search continues with a lower probability of a hill climb. This continues until the temperature level is low enough so that the neighborhood search behaves like a descent strategy and the algorithm terminates in a local optimum. The cooling schedule for the temperature parameter involves a trade-off between solution quality and computational burden. Slow cooling schedules require high computational burdens while cooling too fast compromises solution quality. Generally, however, the SA algorithm has good convergence properties that have given it respectability beyond most heuristic search techniques, as the same conclusion of this paper later.

The cooling schedule refers to the choice of the three parameters of the SA algorithm. These are the initial temperature t_0, the length of the Markov Chain L_k, and the decrease factor r. According to Aerts and Henvelink (2002), as a general rule, t_0 should be chosen so that initially about 80% of the changes that increase the cost function are accepted. The correct parameter value can be obtained by running the algorithm shortly for a fixed t_0, calculating the corresponding acceptance rate, and adjusting t_0 until an acceptance rate of about 80 % positive changes is achieved. Typical values for the decrease factor r are about 0.80 and 0.98, although it is difficult to make exactly valid statements. The total number of iterations L_k per each temperature stage is chosen by keeping the temperature constant until the cost function has reached a constant value, or until it is oscillating around this constant value. In practical application, it may be in the conflict when setting the parameters of the cooling schedule. For instance, if you make the decrease factor of freezing parameter a bit smaller, then the SA algorithm may be quicker, but there is the danger that the solution is worse. If not, it results in high computational burdens and costs a long time to accomplish the SA algorithm. As such, trade-offs must be made based on a lot of experiment, its objectives is to obtain a satisfactory solution (we can't guarantee an optimal solution) at the cost of least time and least hardware resources as possible.

If t_k represents the temperature at *k*th iteration (Other notations as previous), then, in pseudo Pascal language, the SA algorithm may be outlined as follows (Kang *et al.* 1998):

```
procedure SIMULATED-ANNEALING;
begin
INITIALIZE ($i_0$, $t_0$, $L_0$);
k: =0;
i: = $i_0$;
repeat
for    l: =1    to    $L_k$ do
           begin
              GENERATE (j    from    $S_i$ )
```

```
          if    f(j) <= f(i) (if maximal problem， then    f(j) >= f(i))    then    i:=j
          else
          if    exp((f(i)－f(j))/t_k) > random(0,1)    then    i:=j
       end;
    k: =k+1;
    CALCULATE-LENGTH( L_k );
    CALCULATE-CONTROL( t_k );
 until stopcriterion
     end;
```

4.2. SA test

This test illustrates the application of SA to hypothetical urban land-use planning with a few spatial constraints. Supposed that the planned area is divided to a grid with ten rows and ten columns. Let there be six different land use types, named as *Lu*1, *Lu*2, *Lu*3, *Lu*4, *Lu*5, *and Lu6*. And their pre-determined proportions in over area are respectively 15%, 20%, 10%, 20%, 25%, 10%. As an example, we only consider two objectives, best spatial harmony among all land-use cells and compactness of some land-use types (*Lu*2, *Lu*3, *Lu*4, *Lu*6).

We first assume a matrix that represents the spatial association degree between cells, as shown in Table 1. This is a symmetry matrix, in which the left-down elements are equal to the top-right ones. In Table 1, the more of the number presents the more important spatial relation. For example, the number is 2.0, which is the biggest, means that those cells from the same land-use type must be located near each other, in the other words, keeping spatial contiguity, thus spatial contiguity constraints are embedded into the objective function. The spatial harmony index between *Lu*2 and *Lu*4 is 0.1, it means the two different land-use cells shouldn't be located near each other. How to define the spatial association index is a difficult and complex problem, it involve in the expert knowledge and practical experience.

The objective of spatial association is the sum of harmony degree values in all 'link'. If a cell is in the Von Neumann Neighborhood of reference cell, then it indicates there is a 'link' as shown in Figure 1, which has its associated harmony value. The process of calculating objective function value is illustrated in Figure 1. According to the order from top to down and from left to right, the sum of harmony value of every cell is calculated. After the calculation of a cell' harmony degree is finished, the identifier of this cell is valued a new identifier, 0. Until identifiers of all cells are 0, computing process stops. The cumulation of harmony degree value of all cells is total objective function value.

Aerts *et al*. (2002) have used a neighbourhood of four cells (top, down, left, right), a Von Neumann Neighborhood to define the compactness of cells. In this study, through our experiment, consider that eight-neighbour cells, also named as the Moore Neighborhood, might be more suitable.

Each parameter in the cooling schedule is set respectively as: a) $t_0 = 5000$ (the initial temperature);

b) r = 0.85 (the temperature reduction factor); c) t_f = 4 (number of final function used to decide upon termination); d) L_k = 10000 (the length of the Markov Chain). The new solution is obtained by the way of swapping the land use of two randomly chosen cells. Figure 2. shows the corresponding results.

Table 1 Assumed parameters of harmony degree between two types of land use

	Lu1	**Lu2**	**Lu3**	**Lu4**	**Lu5**	**Lu6**
Lu1	2.0	0.8	0.2	1.0	1.5	1.0
Lu2		2.0	0.3	0.0	1.5	0.1
Lu3			2.0	0.8	0.7	1.0
Lu4				2.0	0.5	1.1
Lu5					2.0	0.2
Lu6						2.0

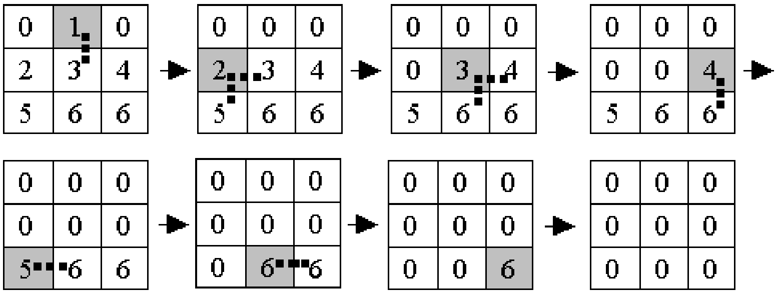

Figure 1. The cumulative process of spatial harmony values

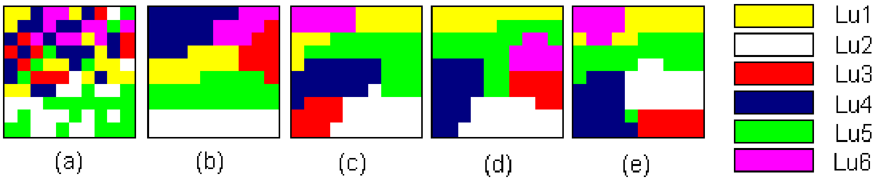

Figure 2. Different pattern of land use allocation:

(a) initial situation with a random assignment of land use;

(b) an optimal solution considered the spatial harmony objective, contiguity constraint and direction constraint (compared with the position of *Lu*4, *Lu*2 must be located at the under part of the northwestern wind);

(c) an optimal land-use plan while adding a compact constraint (*Lu*2, *Lu*3, *Lu*4, *Lu*6 should be compact forms) other than the objective and constraints in (b) (w_1=1, w_2=1);

(d) an optimal land-use plan while adding a compact constraint (*Lu*2, *Lu*3, *Lu*4, *Lu*6 should be compact forms) other than the objective and constraints in (b) (w_1=1, w_2=2);

(e) an optimal land-use plan while adding a compact constraint (*Lu*2, *Lu*3, *Lu*4, *Lu*6 should be compact forms) other than the objective and constraints in (b) (w_1=1, w_2=3).

With the change of w_1 and w_2, generating the land-use layouts is slightly different, as shown in Figure 2. (c), (d), (e). If you emphasize the importance of compactness, then you make the more $w_{2,}$ and the form of every parcel looks more compact, as shown in Figure 1. For the purpose of demonstration, this application doesn't consider the development cost, and so we only need to consider one of two weights w_1, w_2, often set the value w_1=1. Using different values for the weight w_1, w_2 and visual inspection of the corresponding solution, a value w_1=1, w_2=2 appeared to an attractive compromise between the two objectives. From visual inspection of the corresponding solution, set w_2=2 is more suitable.

4.3. Case study

In order to further illustrate the performance of simulated annealing applied to urban land use planning, we give another application of SA.

Figure 3 shows an official planning scheme of Muyan industrial district, Hunan province, the central of China. Its area is about 800 hectares. There are some plants that have environment impact, especially atmospheric and noise pollution, and so this scheme has its drawbacks. For example, residential land shouldn't be located at the under part of the prevailing northwestern wind, and industrial land not at the upper part.

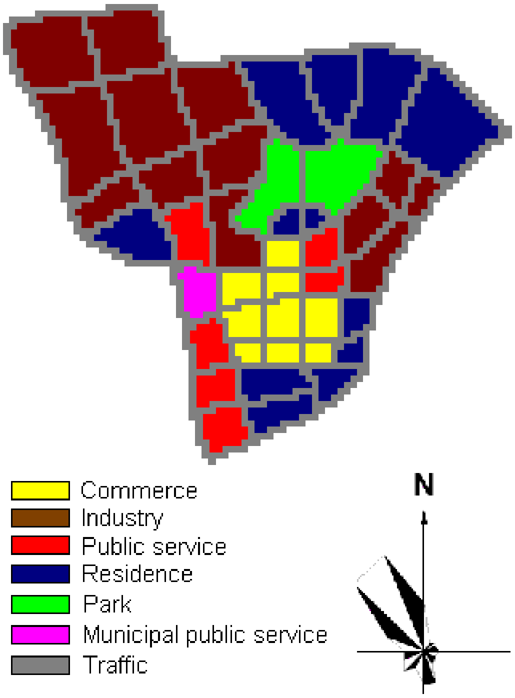

Figure 3. The official land-use plan of Muyun industrial district, Hunan province, the central of China

A grid (80×80) is used to cover the planned area (or employing the functionality module—Grid within the ARC/INFO GIS). The part outside the planned area isn't shown. There are seven types of land use: Commerce (*C*), Industry (*I*), Public service (*S*), Residence (*R*), Park or Green land(*P*), Municipal public facility (*F*) and Traffic (*T*), whose pre-determined proportion are respectively 6.03%, 29.94%, 6.16%, 20.44%, 5.30%, 1.16%, 30.97%, about 182 cells, 904 cells, 186 cells, 617 cells, 160 cells, 35 cells and 935 cells in total 6400 cells. 3381 cells are located at the outside of the planned area. We consider the traffic network has been designed, so the cells of traffic land don't take part in the processing of allocating. The value of the cells outside the planned area, which no object will be assigned, 0, are set for the convenience of computer programming. All 2084 cells of land-use object belonging to six land use types are assigned to the planned area.

For the demonstration purpose, we narrowed the main problem down by considering the less objectives and constraints. In this application we don't consider the development cost, but only involve in the better spatial relationship, spatial contiguity, spatial compactness and spatial direction constraints. As we know, one of the main purposes of the ULUP is to harmonize the spatial relationship among all land parcels by the way of their reasonable location. The spatial harmony indices between two land use types are listed at Table 2. Table 2 is also a symmetry matrix, in which the left-down elements are equal to the top-right ones. For each spatial unit, its contiguity is the requirement of the ULUP, and so the harmony index is high, the value is set 2.0. Because of the atmospheric and noise pollution of industrial parcels, industrial district must be at the under part of the prevailing northwestern wind, and it is better that the park is located at the middle of residential land and industrial land. This direction constraint is combined into the process of feasible solution searching. At the same time there keeps some distance away between the residential cells and industrial cells, which are also implemented by setting the less value of spatial harmony index between both, say 0.1.

Table 2. The parameters of harmony degree between two land use types

	C	I	S	R	P	F
C	2.0	0.1	1.3	0.8	1.5	1.0
I		2.0	0.1	0.0	1.8	0.1
S			2.0	1.0	1.2	1.0
R				2.0	1.2	1.1
P					2.0	0.9
F						2.0

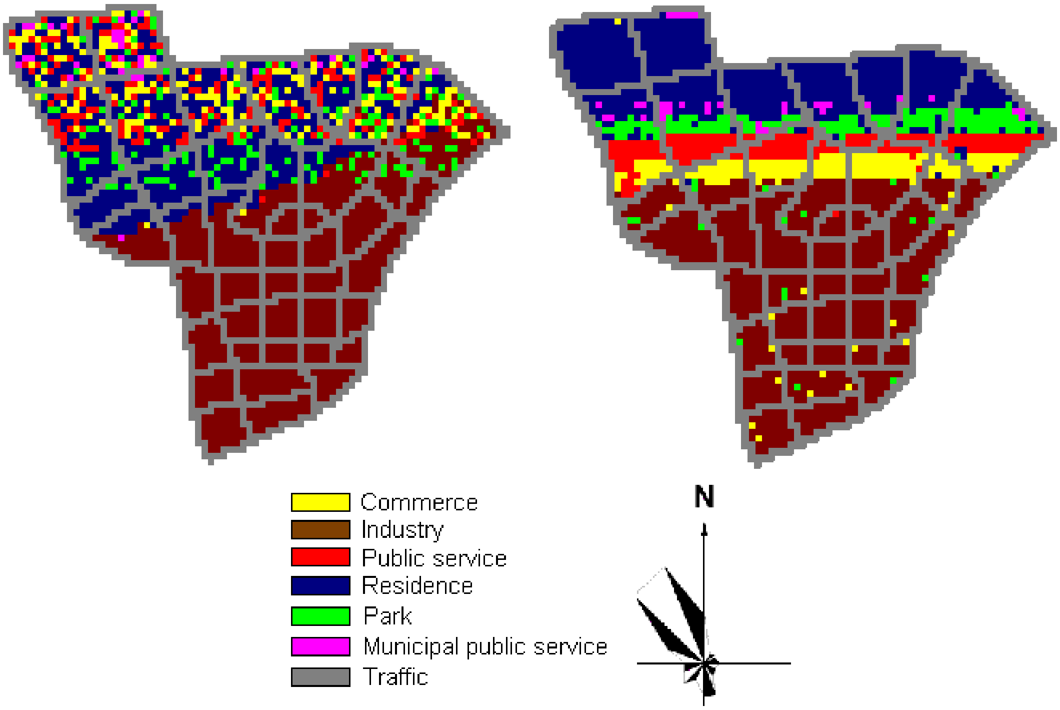

Figure 4. The picture depicts an initial situation (*left*) and an optimized allocation plan (*right*) using six land use types within an area of 80×80 cells (no shown the part outside the planned area).

Each parameter in the cooling schedule is set respectively as: a) t_0 = 5000, b) r = 0.85, c) t_f = 4, d) L_k = 640000. In general, the higher the initial temperature or the temperature reduction factor or the longer the length of the Markov Chain, the better the solution obtained, but the cost of computing time and computing resource is more expensive. Because of the control of road network, we don't give the compact constraint. Figure 4 (right) shows an optimization result, which basically is the desire of planners.

5 Conclusions

Allocating land uses on a planned area is generally a tough task. This study therefore develops a SA method to generate planning sketch maps. Although we only consider an objective and a few constraints for demonstration purpose, the SA tool is tested by a hypothetical numerical example and a practical case, and it is considered to feasible and may be a good resort for urban land use planning.

Using SA for generating the land-use plans has much superiority. First, SA can find the scheme approximating to the optimum of model, whereas the conventional method can hardly reach the optimum. Second, SA method is a visibly systematical approach, which can generalize many constraint conditions, while often-used conventional method is generally viewed as a 'black box', not involved in those spatial constraints, and the result is more or less subjective. Third, if we can gather the input data from the public and integrated with more factors, then the optimization result can reflect the preference of the multitude rather than planners' attitude, and the resulting scheme would be an optimal one. Finally, generating the sketch layouts is an exhaustive job, and SA method can efficiently reduce the work burden of planners with the aid of computer technology.

The SA is one of non-numerical stochastic optimization methods, not a determinative mathematical algorithm, and so it is not guaranteed to obtain an optimal solution for the problem in question. Faced with a huge solution space, in order to get an ideal solution, we have to set the longer Markov chain and the less decrease temperature factor and the high initial temperature, but this is at the cost of the longer computing time. If the problem size unavoidably increases, the computing time increases exponentially. In this study case, we use a grid (80×80) to cover the planned area. Even so, a few hour PC time on average must be spend in order to find a satisfying solution.

The further research will further improve the performance of the SA, and make it quicker and more efficient when faced with the large-size problem. More spatial objectives and constraints would be integrated into the practical model, and the optimisation result would be the requirement of urban planning. Of course, it is expected that it is merely a matter of time. Third, we are going to develop software for urban land-use allocation, integrated GIS, MCDM and intelligent heuristic algorithms (SA and GA) with a friendly simple interface.

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Agricultural Land Use Policy and Management in Chinese Taipei

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Abstract: In facing the serious problems of aged farmers, small-scale farms and fragmented farmland, it has attempted to improve these situations through promoting the farmland reform programs in Chinese Taipei. From 1949 to 2008, we have implemented two stages of farmland reforms. The first-stage farmland reform program included farmland rent reduction, the land-to-the-tiller program and public farmlands from leasing to sale. The second-stage farmland reform program mainly focused to enlargement of the farm scale. The government accordingly offered a number of supporting measures, such as financial loans for purchasing land, encouraging joint, entrusted and cooperative farming and land consolidation and farm mechanization. However, these measures had failed to increase the farmland scale.

In recent years, the climate change and global warming has caused the food security crisis. On the other hand, our agricultural structure is still afflicted with numerous problems. Thus, the third-stage farmland reform program was planned by the government in 2008. The program was named “Small Landlord and Big Tenant”. The purpose of the program is to encourage the elderly farmers to lease their lands for the agricultural managers. In so doing, the agricultural managers can consolidate those released farmlands for industrialized operations management to be applied. The agricultural structure is expected to be adjusted and the agricultural competitiveness be raised.

In addition to a more efficient use of farmland, land resources conservation has also been the tendency globally. How to protect precious resources whilst maintaining a superior agricultural environment is an important mission. Our farmland regulations include employment of land use controlling, restraining of farmland to agricultural use, the farmland’s owner cultivates the land and exempt of land tax. Anyone who violates the regulations will be punished. Through strict regulations upon farmland, we are hoping agriculture to play a multi-functional role in food security, rural village development and ecosystem conservation.

In the future, we intend to set up a more rational mechanism to protect the scarce farmland resources. Not only will we continue the programs of planning the farmland resources in counties and towns, but we will also classify our farmland into different zones and adopt different management standards. We hope that each parcel of land will be used efficiently and the government budget can be expended in the prime agricultural regions and create a sustainable agricultural operation environment.

Introduction

In order to improve farmers' living conditions and reduce poverty gap, in 1949 Chinese Taipei implemented a series of measures for farmland reforms. The first-stage farmland reform program included farmland rent reduction, the land-to-the-tiller program and public farmlands from leasing to sale. Although these measures had reached the goal of increasing the tenant's income and avoiding the concentration of land ownership on a group, the situation of small-scale farm and fragmented farmland had become even more severe. To solve these problems, the government proposed the second farmland reform in 1983. The purpose of that reform was to enlarge the farm-scale by purchasing lands and the government offered the preferential loan interest. Unfortunately, the reform still failed to increase the farmland scale. According to the statistics of the agricultural annual report, the average farmland size is 0.72 hectares.

Such an agricultural structure lacks scale economy in production, and farmers can not decrease the cost of production so as to achieve the maximum profit. On top of this, fragmented farmland is unable to be used efficiently, and that has weakened agricultural competitiveness. These problems have not only existed for a long time, but also have led to enormous adverse effects on our agricultural development. Table 1 shows the macro- agricultural situation for the last 10 years. Agricultural value is gradually descending among the value of total production. It is only 1.45% in 2007. Farm employees only make up 5.4% of employment as a whole. Furthermore, the average age of farm employees is high at 61.2 years old. A further 43.6% are over 65 years old (Table 2). According to estimates, in 2015, the average age of farm owners will increase to 67 and 60% of them will be 65 years or older. The number of farmers 45 years or younger will continue falling. At the same time, the percentage of farmers under 45 years old is expected to be less than 3%, and we will be surprised at the shortage of young successors in agricultural labor. Besides, the lower level of education, part-time agriculture and the lack of agricultural industrialized operations management puts agricultural development into a dilemma. The relatively low income of farmers also deters people from choosing farming as a career.

Table1：Agricultural development tendency for the last 10 years

year item	1997	2001	2002	2003	2004	2005	2006	2007
Agriculture value (Billion dollars)(%)	3,790 (2.42)	3,527 (1.85)	3,505 (1.74)	3,579 (1.66)	3,865 (1.64)	3,824 (1.66)	3,770 (1.62)	3,883 (1.45)
Food self-sufficiency rate (calculated on calorie)	79.7 (37.2)	81.9 (34.8)	81.5 (34.8)	78.0 (34.3)	75.7 (32.2)	74.2 (30.5)	74.4 (32.0)	72.5 (30.6)
Agricultural Employment (1,000 persons)	878 (9.6)	708 (7.5)	709 (7.5)	696 (7.3)	642 (6.6)	591 (5.9)	555 (5.5)	543 (5.4)
Agriculture labor Production per caput (million dollars)	43.2	50.0	49.4	51.4	60.2	64.5	67.9	71.5

source：The agricultural annual report from 1997 to 2007.

Table 2: Tendency of the agricultural labor structure for the last 30 years

year item	1980	1985	1990	1995	2000	2005
Farm owners Average age	48.2	51.0	52.4	55.8	58.6	61.2
Farm owners 65 years or older (%)	9.4	14.3	17.1	24.4	35.1	43.6
Farm owners 45 years or younger (%)	38.9	26.7	28.4	20.1	14.6	9.81
average farmland size per house (ha/house)	0.79	0.80	0.77	0.83	0.79	0.72

source：The agricultural annual report and regional farmhouses sampling investigation report.

Therefore, the third-stage farmland reform program was planned in 2008. The program was named “Small Landlord and Big Tenant”. The purpose of the program is to encourage the elderly farmers to lease their lands to the agricultural managers. In doing so, the agricultural managers can consolidate those released farmlands for industrialized operations management to be applied. In addition to a more efficient use of farmland, land resources conservation has also been the tendency globally. How to protect precious resources whilst maintaining a superior agricultural environment is an important mission. Our farmland regulations include employment of land use controlling, restraining of farmland to agricultural use, ensuring the farmland’s owner cultivates the land and exempt of land tax. Anyone who violates the regulations will be punished. Through strict regulations upon farmland, we are hoping agriculture will play a multi-functional role in food security, rural village development and ecosystem conservation. Both agricultural land utility policy and agricultural land use control are our measure to promote sustainable utilization of agricultural land.

The “Small Landlord and Big Tenant” Program

Because of having limited land which is densely populated, our agriculture is characterized by small and family-owned farms. When faced with globalization and liberalization, agriculture in particular loses its competitive edge, which was aggravated by the agriculture surplus that was on our doorstep. We also felt the effects of the global crises of energy and food supply shortages, as well as running high prices of raw materials. However the farmers’ aging problem, the difficulty in finding successors for farming, the small average farm size, the fragmentation and scattering of farms and the resulting inefficiency in farming together lead to the determination of the government to actively improve the agricultural structure, primarily through the policy of “Small Landlord and Big Tenant”. It is hoped that the new policy could conducive to solving problems of small farm economy, aging farmers, set-aside farmland and weak competitiveness in agriculture, among others. This policy intends to help farmers to enlarge their farming scale, reduce production cost and raise overall competitiveness and entrepreneurial spirit.

The “Small Landlord and Big Tenant” policy aims to help aged farmers or farmers who are uninterested in farming to lease their land on a long term basis to those who are interested in enlarging their farming scale so as to make farming labor younger as well as ensuring aged farmers enjoy their retirement away from agriculture. Those interested in enlarging their farming scale(including professional farmers, production and marketing teams, farmers' associations, cooperatives and agricultural companies) can receive assistance in leased land for long term cultivation. They can also receive professional training on integrating production and marketing, Assistance also includes helping big tenants improve their industrialized operations management and reduce production costs, so as to raise their efficiency and competitiveness. To reach the policy goal, the government establishes a mechanism of retirement for aged farmers, offers set-aside land incentives of rent and subsidy, providing long term lessees with zero interest loans. Also offered is the preferential 1% interest on operation capital loan, the training to implement industrialized operations management and subsidy as well as other initiatives such as services of the farmland brokerage system. These are hoped to increase the liquidity of farmland, to revitalize farmland, to solve problems such as aged agricultural labor and small operational scale so that agriculture can be transformed and upgraded.

To explore the feasibility of this policy, the government had, during the period of researching on inductive mechanisms, organized a task force to implement it. In addition, it also asked county governments to nominate candidates for the project and approached them to know their willingness. In the process, 10 pilot projects were determined and launched in September 2008, which involved selected production and marketing teams, farmers' associations, cooperatives, etc. We hope to spearhead the projects to examine the viability of the "Small Landlord and Big Tenant" policy and to establish various execution models as reference for comprehensive implementation in the future. Presently the policy is in full swing and is targeted to implement 10,000 hectares of farmland in 2012.

The Measures of Protecting Prime Agricultural Land

Agricultural land is the foundation of agricultural production. It cannot reproduce itself and is characterized by its locale and immobility. Following the economic development and social changes, agriculture has expanded from a purely economic function of food-production to multiple functions of ecological resources protection and preservation of traditional rural culture. Agricultural land price has always been significantly lower than urban land price. In consequence, agricultural land is prone to conversion to non-agricultural use. In order to cope with the ever-rising demand of farmland for non-agricultural use and the impact of entering WTO (World Trade Organization), we announced a policy of agricultural land release in 1995 to facilitate a proper converting of farmland. However, related regulations could not meet the need of executing that policy. As a result, industrial development is spreading farmland as it used to and the agricultural environment has been seriously damaged as well. Obviously, this policy has encountered vast difficulties and should be urgently reviewed and adjusted accordingly.

Alongside the gradual rise of environmental awareness and the enhancement of citizen participation, how to protect agricultural land efficiently and keep exploitation and conservation on balance are crucial. We have long adopted the strict zoning and planning permission to set up an agricultural land converting system. The system is criticized for the lack of control flexibility and for failure of keeping land development in order. For the sake of improving the farmland converting system, the overall mechanism has to be overhauled, including inspecting criteria, implementing agents, citizen participation, etc. The primary method is redefinition of agricultural zones, within which farmland will be sub-classified. Use of farmland will be limited according to its sub-class. Agricultural specialization zones are set up in accordance to their suitability of farmland thus to exploit its effectiveness. Besides, environment impact assessment is required during the conversion of farmland of whatever size. Citizen participation will also help in the implementation of policy. The jury system is also favorable to the evaluation of small scaled farmland conversion.

In the future, we intend to set up a more rational mechanism to protect the scarce farmland resources. There is a lot of work to do including establishing land use databases, using GIS technology to monitor land status, ensuring the agricultural development policy and formulating laws to manage land use, etc. Meanwhile, relevant departments should cooperate with one another; for example, departments of land affairs, environmental affairs and economic affairs. Thus, not only will we continue the programs of planning the farmland resources in counties and towns, but we will also classify our farmland into different zones with different management standards. We will assist various county and city governments in carrying out comprehensive farmland utilization planning, to help farmers make the best use of their land, and to establish supporting measures for the production and marketing teams. All these measures will help to formulate a favorable environment for the production and marketing of agricultural products. We hope that every parcel of land will be used efficiently and the government budget can be expended in the prime agricultural regions and create a sustainable agricultural operation environment.

Conclusion

In recent years, agriculture development has suffered from small farm economy, aged and part-time farmers, a low food self-sufficiency rate and the globalization and trend of free trade. The concept of a multi-functional agriculture has deeply influenced the land use and will change the styles of land use too. We need to take these issues seriously and pursue the sustainable utilization of land resources.

The subject of land resources is relevant to issues such as social economic development and population growth. Land resources management has a very important role to play on agricultural development. Especially, what many problems we are presently facing are caused by the inefficiencies of the current land planning and management system. How to ensure the sustainable developments of agriculture, how to address agricultural globalization and liberalization, and how to promote reasonable utilization of farmlands？ How to adjust the structures of agricultural enterprises and to stabilize the sale of agricultural produce, along with advancing the income and welfare of farmers and to promote the living standards of farmers, are all desirable goals of the agricultural sector. Therefore, we must adopt more effective measures to solve the agricultural land problems for agricultural development.

At present, we are convinced that there are two possible solutions to the agricultural land use problems. The first measure is to continuing promotion of the “small landlord and big tenant” program to enlarge the size of agricultural land, and to maintain an efficient management scale. With the support from the government, the big tenants are able to implement industrialized operations management, to reduce production costs and thus raise their agricultural income. It is enthusiastically expected to improve the agricultural labor structure to promote agricultural competitiveness via the execution of this program. The other measure is to set up a rational system to allocate land use in an efficient way. We hope to protect the scarce prime farmland through necessary constrains, and at the same time, to compensate owners for losses resulting from restrictions placed upon their use of land.

Besides, for any measure to be implemented smoothly and successfully, a wide participation of citizens is inevitably needed. That is the spirit of public participation. In a modern society, public opinions must receive due respect. The making of a policy or measure will invite comments and feedback from individuals for their preference to be revealed. There is no doubt that our present public participation is far from satisfactory. How to establish a fair and efficient participation mechanism will definitely be an important agenda in the future.

Urban-rural Fringe Land-use Problems And Countermeasures of Beijing

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Abstract: The urban-rural fringe is the forefront of urbanization, where land-use type is complex. As the national capital, the speed of urbanization of Beijing is relatively fast, hosting the Olympic game has accelerated the pace of building, but there still remain some land-use issues. This article analyzes the basic characteristics of land use of the urban-rural fringe, the cause of the problems and put forward corresponding countermeasures. Hope to contribute to the harmonious land use of urban-rural fringe.

Key words: Beijing urban-rural fringe land-use

Urban-rural fringe, with the development of the urbanization process in urban and rural areas is the transition belt between the urban and rural area. In this zone, Land-use types are complex, the fastest pace of change, conflicts are most acute and most debated. From the reform and opening up, China has been the rapid development of the national economy, urban construction changed greatly at the same time. The rural industry has rapid development followed city pace. Reasonable-building problem between urban and rural areas have become increasingly prominent, especially in the harmony of land use has become the hot issue. As the economic, cultural, and political Center, Beijing is one of China's fastest-growing paces of urbanization. The rational use of land is particularly important. The phenomenon of urban-rural fringe is most typical, worthy for more attention.

1 Basic Characteristics of Land Use

1.1 Ribbon

Urban-rural fringe geographically located between urban and rural areas , but here it refers to the edge of urban development areas and rural areas close to the city, not the unclear division of administrative units. At Urban-rural fringe, land use under the dual impact of urban and rural, where land prices relatively inexpensive compare to the highly urbanized cities, while he has good traffic conditions, rural economic development has been seriously affected the city. With The distance increases, the influence of urban development become gradually reducing, the economic benefits of gradually decline .Therefore, the urban-rural fringe is always around the development of the city's development. Of course, cities are always surrounded by nationside; the urban-rural fringe should also outside the citywide, surrounding the city. Because the development of the city is affected by the policy, economic, cultural, and natural and other aspects, the shape of the development of concentric circles is not always present, and then the urban-rural fringe is also with the development of the city to change the direction, formed by a number of bands around the city. For Beijing, the city in the continuous process of development for a long time showing concentric circles type of development, but on Beijing's east, north, vast mountainous as the city important ecological protection areas will focus on protection. With the commissioning of the Beijing South Railway Station, the city's development will pay more attention to the southwest direction, making the urban-rural fringe in the southwest will be the formation of the wider area. Urban-rural fringe of the spatial distribution of land use may also be broken this out significant features of the spheres, there is not partial regularity.

In discussing the spatial distribution of urban-rural fringe should be to break the division of administrative units. When a village or downtown with better geographical location, transport facilities, relatively abundant resources, it may follow the process from the village or town to the city', to become part of the urban-rural fringe.

1.2 Dynamic

Urban-rural fringe as a continuation of urban development is bound to the development as the development of the city, with the city's continued expansion gradually extended to more peripheral areas. In Zhang Wenbo's article, he has definite the scope of urban-rural fringe in 1984 and 1996 by TM images, you can clearly see that both in the urban-rural fringe of the inner boundary or outer boundary has changed greatly to illustrate the dynamic changes in the speed and magnitude are very Fast . Meanwhile, Chen Youqi calculate the urban-rural fringe of Beijing in 1996, largely outside the Third Ring Road and Fourth Ring and almost same to Zhang Wenbo's result.

Urban-rural fringe covers the Chaoyang, Shunyi, Tongzhou, Daxing, Fengtai.Shijingshan, Haidian district, etc. With economic development, urbanization process, the Fifth Ring Road, the Sixth Ring Road construction and the construction of Olympic venues and other factors, urban scale of constantly increasing, the scope of urban-rural fringe will gradually extrapolation.

For example, Chaoyang district, the total cultivated land resources decreased 22.9% fiom2002 to 2006; agriculture in economic output after entering the new century, are gradually declining. Fengtail district has declined 53.7% during the same period.

Reduction of arable land, construction land increased the decrease of agricultural output, industrial and the third Industrial output is increased, it shows that the original urban-rural fringe is ongoing process of the city, urban and rural areas are gradually losing the significance of the past, and the village is also gradually becoming urban-rural fringe to make it move forward.

1.3 Transitional

Urban-rural fringe zone is located between the urban and rural areas. With the impact of these two aspects, urban-rural fringe can be seen as as the acceleration from rural to urban areas. The transition of the role of urban-rural fringe is mainly reflected in the follow ways:

(1) Transitional of land-use type

Urban-rural fringe is the urbanization of the frontier, is the transition from urban to rural areas, cities, highways, state road, through here, mining and storage purposes, economic development zone; urban-rural fringe in the a certain extent, still retains the typical rural land-use types, particularly arable land still exists in the outer marginal zone, but there is no formation of larger plaques. The urban-rural fringe of the transitional nature of its cities and villages with typical land-use types, such as flower cultivation land, seedlings cultivated land, aquaculture sites, and livestock feeding sites, agricultural Garden on land and so on.

(2) Transitional of the economic benefits

Urban-rural fringe zone is located in the city fringe areas, where land prices much cheaper compared to cities, a number of factories will be located here. With the increase of population, floating population growth, more and more people who work in urban areas have also come here to buy housing, but they will choose the better areas, such as the inner edge of urban-rural fringe with good traffic. Driven by interests, village in accordance with the distance from the city will transform farmland into other land use patterns in order to increasing revenue. Gradually form a fringe, where the interest will decrease with the increase with distance, until the real ending of cultivated land use.

(3) Transitional of the population

Urban-rural fringe of the population is much smaller than in the number of cities, a large number of families which are not rich enough would live here. But many people with good economic conditions will buy high-end residential for very good for the beautiful environment, fresh air in here. Many floating population live here, making the population here is larger than the rural areas. Transitional of the population showed not only by the number of population but also by population density, the population's educational level, type of occupation, lifestyle, ideas, etc.

(4) Transitional of material and energy

As a bridge between urban and rural areas, Urban-rural fringe where the material at all times during the exchange of energy. Power, goods, or in technology, information, knowledge, etc. are in constant exchange, like a bridge connected to two "islands." a slowdown from the city to rural areas, they can be seen

1.4 Diversity

The diversity of urban-rural fringe is reflected in the diversity of land-use types, land-use structure diversity. Urban-rural fringe is the combination of urban and rural areas, where you can find almost kinds of land-use types, as described above high-yield vegetable, aquaculture sites, livestock feeding sites, agricultural sightseeing garden land, etc, making land-use type diversity and complex structure.

2 Problems of Urban-rural Fringe Land-use

2.1 Contradiction of Land Supply and Demand

(1)Industrial Construction Occupation of land

Beijing's construction guideline has changed from the metropolis of the production to the harmony livable cities, based on a large number of large-scale industries moved to the urban-rural fringe. In a large number of industrial relocation outside the city core area produced a huge impact on land use of urban-rural fringe. The result of industrial building Leading role and the long-term effects lead to this problem which land use of the urban-rural fringe supply and demand is becoming increasingly acute. With industrial land and associated gradual construction land increased, agricultural land gradually being eroded.

(2) Non-agriculturalization phenomenon seriously of farm land

Urban-rural fringe as an urban agricultural supply base, agricultural land has always played an important role. Agricultural land-use type also has a very high percentage, but as urban development, it is the area of cultivated land or agricultural Output downward trend emerging, urban-rural fringe of the agricultural land is being converted to non-agricultural land. The type of non-agricultural land including: industrial land, industrial and mining land for warehousing, transportation land use, urban residential land and so on.

2.2 Land-use Issues Highlighted

(1) Serious Waste

Serious waste of land use in urban-rural fringe has existence for a long time. A large number of land levies but not used. The size of building land is expansion year by year, according to statistics, land acquisition in 1994 increased 2-3 times Compared to 1990, but completed in the amount of construction land increased only 20%. If completed 8 million m^2 per year, the land can be maintained for 10 years for using. Protection of arable land, cherish and rational use of every inch of arable land is China's basic national policy, but in the urban-rural fringe, the arable land is not protected quite well. Many people who have left from the farmland choose to work in the city or choose to other non-farm business activities for higher revenue. They abandoned agricultural land or employment of others to plow and plant, making use of cultivated land is not sufficient and even resulting in a lot of waste.

(2) Serious Pollution

Land contamination problem accelerate gradually with the urban-rural fringe of economic development. Land quality of urban-rural fringe seriously affected the population life that around the city’s rural. Pollution mainly comes from: the township industrial which have lower pollution control; heavy use of pesticides and fertilizers; the industrial enterprises moved from the city; urban-industrial waste and garbage pollution. At the same time, we must note that with urban-rural fringe behind the technological level and management system, the pollution of urban-rural fringe has become increasingly serious or even over the city.

(3) Layout Confusion

Person's business practices are always in order to make the maximize benefits for carrying out the process of investment, finding ways to reduce into cost and increase revenue. Cities in the development process will always be outward expansion, but also always try to avoid the rural settlements and the selected agricultural land, choose the areas with better traffic conditions, which lead to form "encircling the cities from rural areas, urban city surrounded by rural "chaos in the urban-rural fringe . In pursuit of higher economic interests, urban relocation of industries and a large number of township enterprises along the road split the agricultural landscape into fragment pieces. Agricultural land and urban construction land and other non-agricultural land staggered, reducing the scale of agricultural production, affecting the quality of the land, and even a direct result of pollution.

2.3 Lost of Land Revenue

As mentioned above, land use shortage of the urban-rural fringe, coupled with the idea "Great importance to industrial neglect of agriculture ", making Land use efficiency is very low and impact on the land revenue seriously. At the same time, due to China's land administration system has been resulting in management responsibility unclearly, causing enormous economic losses.

2. 4 Threatened ecological barrier

Beijing's ecological security is divided into two parts:

(1) The separation zone along the urban transportation system and internal gardens. Beijing’s ecological isolation are mainly distributed in between the four ring to six ring road of city, which is also the regional distribution of places frequented by the city park, and then coupled with within the agricultural land in urban-rural fringe has become important to improve the urban ecological environment.

(2) Beijing's northwestern mountains are important ecological barriers. Urban-rural fringe of the agricultural land not only contribute to the need for fresh food, but also as a greenbelt zone. Beijing has made tremendous contributions to improving the urban environment, but driven by economic interests, agricultural land declined steadily in urban-rural fringe area. Green isolation belt has been squeezed, and seriously hampering the sustainable development of Beijing.

3 Land Use Optimal Strategies

3.1 Perfect Laws and Regulations, Establish a Full-time Administration

Running state affairs according to law is China's basic national policy, laws and regulations are related to the state in all aspects. China, now, has a "Land Management Law" and other relevant laws, but not has any laws and regulations made from the perspective of land use. In the existing laws and regulations, they have not clearly for the property ownership, classification standards and requirements in respect of management functions in the urban-rural fringe. According to China's current development and the trend of the future development, our law should be in line with the age.

Our Land-use management present laws are followed, laws must be observed and strictly enforced situation.

In improving the laws and regulations, we also should be targeted at urban-rural fringe management which is a particular cross-zone. So, we should set up special regulatory agencies, so that urban and rural land management on the right track. In the urban-rural fringe land-use regional management agencies, we can play a positive and proactive administrative or technical function to manage the land. First of all, we can the organization of specialized technical personnel to monitor the rural and urban fringe. With the rapid development in science and technology today, we can use a large number of remote sensing images and a small number of people to save manpower and resources. Second, we can carry out scientific management of land, In the GIS, RS, GPS and other technical support to achieve the land information management, to improve management efficiency. While in the process of land management, land use should exercise strict supervision, seriously follow the "treasure, Reasonable use of land and effective protection of arable land "the basic national policy.

3.2 Coordinating and Implementing Planning, Strengthen Macro-control

China's "Land Management Law", "City Planning Law" and "Urban Real Estate Management Law" are clearly defined Land use of urban and rural construction should strengthen the overall land use planning and urban planning, emphasis on coordination between the two programs. However, the long -period of years, urban planning has always occupied the leading position. In fact, the land-use planning should coordinate Construction land, agricultural land, water and other land-use types during the planning process , should be the basic planning; urban planning focus solely on the in the urban development and construction needs. Development in the planning process, the two plans should be coordinated with each other will make the planning more scientific and feasibility.

The plan formulation should be based on rational, scientific, forward-looking, harmonious goal. But during the implementing of the plan, it often deviates from the plan direction because of human factors and interests. Therefore, the strengthening of macro-control is more significant, thus becoming important safeguard as "a regulation can be according”.

3.3 Develop Regional Advantages, Improve the Level of Intensive

Urban-rural fringe is located in the city's edge, where you can reach the cities of advanced science and technology, management experience, fund. In particular, urban-rural fringe of Beijing city is under the influence of a large number of research institutes and well-known colleges and universities, supported by relevant national policies. At the same time, there is tens of millions of consumer markets, convenient traffic conditions and cheap labor. In order to have a "resonance effect" to improve the intensive levels, we should play huge geographical advantages of urban-rural fringe from technical, industry, market, function in all aspects,

3.4 Adjusting the Layout and Structure, Regulate the Land Market

Land-use spatial layout and structure of urban-rural fringe should walk on the road of virtuous circle, under the reasonable planning. The adjusting can effectively prevent the intensified of "city surrounded by rural areas, rural areas surrounding the city" phenomena. Space layout should be based on the specific circumstances of various districts and counties, combined with its own characteristics, under the harmonious development. Spatial development should be prevented "sharing of large Pie "model of effectively, followed the" decentralized group-style "development. In the land use structure, pay attention to protect agricultural land of urban-rural fringe; strengthen the construction of green isolation belt, develop land for construction rationally. In the land market, we must improve the land price formation system and insist on developing land-use fee system which is a national collective interests do get a reasonable protection.

3.5 Strengthening Protection, Improve the Ecological Environment

During the regulation and governance work in the urban-rural fringe, the pollution problem should be given sufficient attention. For the internal contamination has caused in the urban-rural fringe, we should increase the intensity of governance, introduce advanced management experience and technology, cut pollution ways to prevent pollution from expansion.

Under construction projects must strictly control environmental quality to decline the contamination which is easy to control at the first time. Ecological environment construction should also be strengthening to walk with "two legs". The urban-rural fringe of Beijing city can become a beautiful and harmonious place to achieve sustainable development with our wok hand in hand.

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GIS-based Multicriteria Analysis for Agricultural Land Use Planning in the Western Region of Quang Tri Province, Viet Nam

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Abstract: The main purpose of this research was to develop an agricultural land use plan for the production of rice, maize, cassava, rubber, and coffee in the hilly and mountainous part of the Quang Tri province. To this aim, a GIS-based multicriteria procedure has been developed consisting of the (1) design of crop-specific criteria, (2) standardization of criteria, (3) assignment of criteria weights, and (4) additive or multiplicative combination procedures. The overall score values were classified into the corresponding suitability classes based on the land characteristics-yield relationship reported in the province. Next, a set of priority rules were developed in order to determine the optimal land use plan, taking into account agro-ecological, as well as environmental and socio-economical requirements. The procedure proved successful to determine a preliminary land use plan for the province, indicating options for the expansion of the agricultural land. It also identified some limitations of the dataset as well as options for the improvement of the methodology.

Key words: Land evaluation; GIS; Land use planning; Multicriteria; Quang Tri

1 Introduction

Quang Tri is a coastal province located in Central Viet Nam with, besides its important political history during the Viet Namese war, also very diverse environmental conditions due to its particular geographical location. It is limited by the geographical coordinates 16 ° 18' to 17 ° 10' N and 106 ° 24' to 107 ° 24' E, with the inland area extending over 474,500 ha. Quang Tri is located in the tropical monsoon climate area. Its geomorphology and soils are very diverse. Quang Tri is also a poor province because of the consequences of war, climate, as well as natural disasters such as drought, flood, and soil erosion. In recent years, together with the national economic development, Quang Tri has been achieving good economic growth and the quality of life of its civilians has been enhanced. To meet national policies and requirements, a socio-economic development planning strategy for the province has been carried out, especially since the Ho Chi Minh road, prolonged from North to South of Viet Nam along the western region, has been finished. On September, 13th 2007 the committee of Quang Tri province adopted the resolution on socio-economic development planning in the western area, with specific measures to be taken by 2010, as well as forecasts up to 2015. The agricultural land use planning (ALUP) is one of five aspects of economic planning proposed in this decision. It was decided to increase the agricultural area measured in 2005 with 9,898 ha by 2010. In addition, the resolution also included an orientation towards the development of strategic crops such as rice, maize, cassava, rubber, and coffee. Therefore, the clear and accurate determination of those areas which are suitable for growing these crops is a necessary and very important challenge for the ALUP in the western part of Quang Tri.

ALUP can be implemented by techniques such as land evaluation (Anonymous, 1983) or farming systems analysis (Beets, 1990), or the combination of these two techniques (Fresco *et al.*, 1992). These techniques can be carried out following different methods or tools, depending on purpose, scale, as well as data availability. Land evaluation has been developed and implemented at various scales, from global to local applications, while the farming systems analysis is only effective at farm level, i.e. at a more detailed level dealing with the farms and their production conditions within specific locations in a sub-regional setting (Stoorvogel *et al.*, 1995). The difference with land evaluation is that the farming systems analysis provides feasible development scenarios based on different land use scenarios.

In recent years, development of information technology in general and GIS in particular have been bringing big changes in human society. The functionalities of GIS can be fully promoted in ALUP based on multicriteria analysis (MCA). MCA is a methodology by which the relative merits of different options can be compared by using a range of quantitative and qualitative criteria (Centre for International Forestry Research, 1997). Therefore, GIS-based multicriteria analysis (GIS-MCA) consists of different step-wise procedures for the analysis of an objective or many objectives, influenced by different factors (criteria), by using GIS. Bell *et al.* (2000) concluded that MCA is used to resolve conflicts of site suitability, and balance the trade-offs and risks. Because of its high data requirements, applying GIS-MCA for the ALUP is more effective when the natural resources database is already available, saving time and costs.

The main purpose of this research is to develop a GIS-based multicriteria procedure to identify the most suitable zones for the production of rice, maize, cassava, rubber, and coffee, promoted in the ALUP, in the western, hilly and mountainous part of the Quang Tri province.

2 Database and Methods

2.1. Quang Tri's database

The land resources information system of the Quang Tri province was built up from 2001 to 2003 and updated in the period 2004-2006 using statistical data and thematic reports of projects. Datasets that are being updated include road data from the topographic maps published in 2005 and yield data from statistical reports published in 2007. It comprises different GIS databases including basic data, natural condition and resources data, socio-economic data, and a separate dataset of the sea and island data. The inland databases have been developed at a scale of 1:50,000 and have been stored in a UTM projection. In addition, some secondary data were calculated and interpolated from the above primary data such as slope gradient, internal drainage class, infiltration rate, flooding risk, annual soil erosion rate, and proximity to roads and water bodies.

2.2. Methods

2.2.1. Overview of the GIS-based multicriteria analysis for agricultural land use planning

The approach to perform an agricultural land use planning analysis using GIS-MCA can be subdivided into different stages: (1) Crop selection; (2) Design of the evaluation criteria; (3) Standardization of the criteria; (4) Combination of the criteria; (5) Combination of the crop suitability classes.

Crop selection was based on the socio-economic development plans designed for the province in 2007 and focusing on some industrial and food crops: rubber, coffee, cassava, paddy rice, maize, and upland rice. With respect to the annual crops, cassava cultivated as annual crop is grown from November to September in the study area, whereas paddy rice, maize, and upland rice are in the field from June to September.

2.2.2. Selection and design of the evaluation criteria and constraints

The evaluation criteria for each crop included three different groups: agro-ecological, environmental, and socio-economic criteria. The agro-ecological group consisted of climatic, topographic, wetness, physical soil fertility, and chemical soil fertility criteria. The environmental group was composed of soil erosion and proximity to water bodies criteria and the accessibility considered as a socio-economic criterion had been evaluated based on the distance to roads. Each criterion was evaluated using 4 classes being very suitable (S_1), moderately suitable (S_2), marginally suitable (S_3), and unsuitable (N).

2.2.2.1. Agro-ecological criteria

In the agro-ecological criteria, climatic, topographic, wetness criteria, and criteria related to physical soil fertility were basically selected based on the crop specific requirements published by Sys *et al.* (1991, 1993) and adapted relying on available database, Viet Namese guidelines for specific crops, and actual extent of cultivation.

Evaluation of the chemical soil fertility highlights the capacity to supply and retain nutrients, as well as the risks of toxicity. According to Amberger (2006), availability of nitrogen, exchangeable calcium and magnesium, and aluminum toxicity were the most important yield limiting factors in the humid tropics. In addition, organic carbon contents and the CEC express the nutrient potential of soils. Therefore, these 6 chemical soil characteristics were considered as criteria to evaluate the chemical soil fertility in the study area. However, the Al saturation characteristic was only defined for maize, whereas rubber, Arabica coffee, cassava, and upland rice were considered tolerant to high amounts of exchangeable aluminum (> 60%) (Sanchez, 1976; Landon, 1991; Fageria and Baligar, 2001). Although also paddy rice is sensitive to exchangeable aluminum, the aluminum tolerance of paddy rice is higher than that of maize (Nursyamsi *et al*., 2002) and paddy rice is mainly grown in the floodplain with Al saturation below 20%. As such, no problems related to Al toxicity for the production of paddy rice are to be expected.

The soil depth selected to compute the weighted average value of these fertility criteria (characteristics) is the top 25 cm of mineral soil, since most nutrients, organic matter and micro-organism activities are concentrated in this layer, and plant roots commonly concentrate there to take up nutrients.

The approach to design the crop-specific nutrient criteria in the study area, requiring the identification of optimal, marginal, and unsuitable nutritional value ranges, has been shown in Fig.

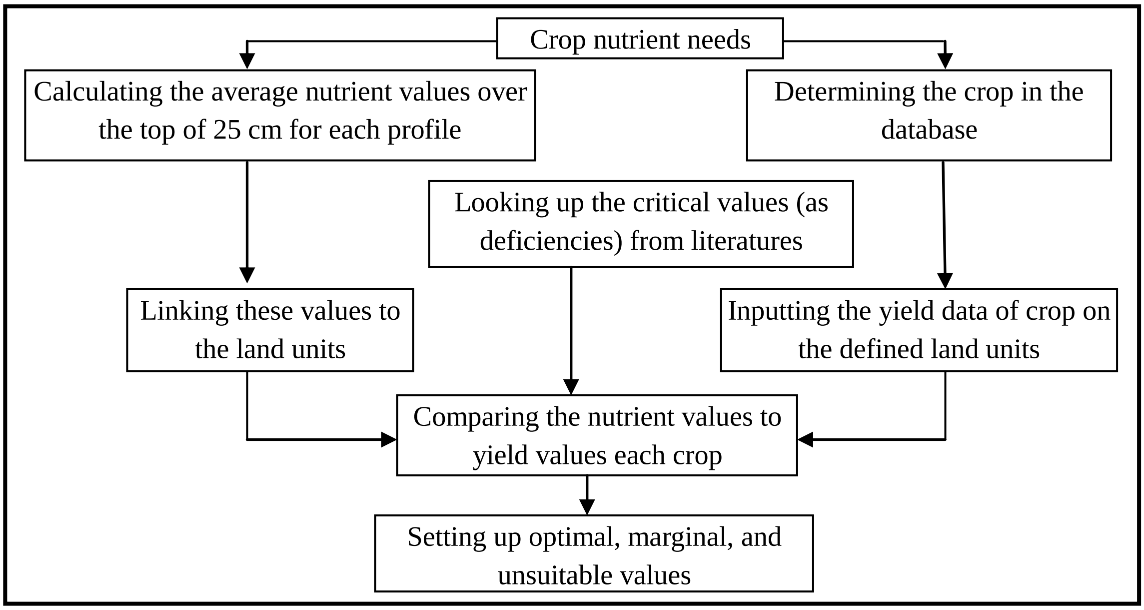

Fig. 1: Steps for designing the crop-specific suitability assessment of chemical soil fertility

Based on the above developed crop-specific nutrient requirements, the chemical soil fertility criteria for these crops were formulated. The ranges were converted to suitability classes (S_1, S_2, S_3, and N). The optimal range was defined as the very suitable class. The marginal range was considered as the marginal suitable class and the unsuitable range was the unsuitable class. The transition range was defined as the moderately suitable class.

2.2.2.2. Environmental and socio-economic criteria

The environmental criteria were designed based on real environmental problems such as soil erosion which is particularly important as cultivating Arabica coffee, rubber, cassava, maize and upland rice. Water pollution on the other hand is an environmental problem often caused by paddy rice cropping. Hence, the proximity to water bodies reflects the risks for water pollution. Consequently, the soil erosion and the proximity to water bodies were considered as the environmental criteria in the study area.

The suitability classes (S_1, S_2, S_3, and N) for soil erosion criteria were designed on the basis of the soil loss tolerance (T-value) determined for the different soil types in the study area. The T-value was determined using the equation (Eq. 1) published by Baja *et al.* (2001) as a function of soil depth. Soils that are deeper than 1.5 m have a T-value of 10 Mg ha^{-1} per year, while those being less than 0.5 m deep receive a T-value of 1 Mg ha^{-1} per year. Between those ranges (i.e., 0.5 m < D <

1.5 m), the following equation is employed:

T-value = 9 D – 3.5 (D in meter is the solum depth) (Eq. 1)

Criteria of the proximity to water bodies and roads were selected and adapted based on those published by Vo *et al*. (2003), Baja *et al*., (2007), Moreno (2007), Thapa and Murayama (2008). The proximity to roads was considered as a single criterion to evaluate the accessibility of the fields. It partly reflected the socio-economic status of the study area.

2.2.2.3. Constraints

Altitude and land cover were used as constraints. The crops can not grow beyond certain thresholds for temperature and wetness. In uplands, these conditions strongly correlate with the altitude. Land cover was selected as a constraint because of conservation purposes. As natural and plantation forests need to be protected, land units with natural and plantation forests were not considered for agricultural production. The constraints were defined as criteria with 2 values: 1 and 0. A value of 1 means very suitable and 0 means unsuitable.

2.2.3. Standardization of the criteria and development of scoring functions

Criteria are standardized by the following model (Fig. 2).

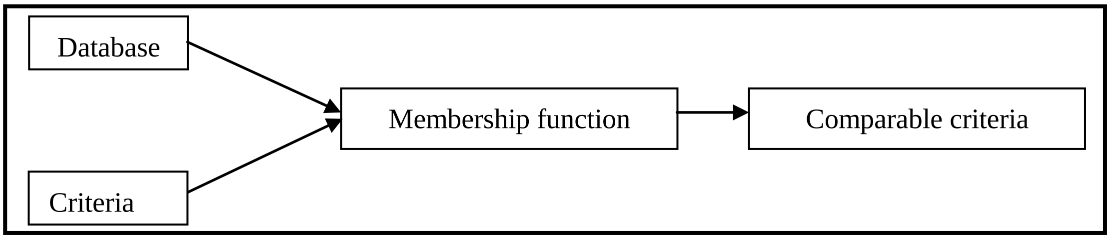

Fig. 2: The model to standardize the criteria in the study area

2.2.3.1. Membership functions

The membership functions (MF) were selected to standardize criteria based on the specific trend of the criteria under consideration as well as of the MF characteristics. More specifically, we considered symmetric, asymmetric or linguistic MFs and/or whether there existed values corresponding to the unsuitable class or not. The following is the selected MFs.

Trapezoidal membership function

The trapezoidal MF is expressed in the following formula:

$$MF_x = \begin{cases} 0 & x \leq a \\ (x-a)/(b-a) & a < x < b \\ 1 & b \leq x \leq c \\ 1 - (x-c)/(d-c) & c < x < d \\ 0 & x \geq d \end{cases} \qquad \text{(Eq. 2)}$$

Where a, b, c, and d are threshold values defining suitability levels.

This continuous and symmetric trapezoidal MF, with values ranging between 0 and 1, is especially relevant for criteria having a non-linear but symmetric relationship with crop yield and can be applied when the threshold values defining the marginal and unsuitable classes can be estimated. A value of 1 means very suitable and 0 means unsuitable. This function was mainly applied for the climatic criteria in the study.

(1) *Kandel extension membership function*

The Kandel extension membership function is also used for criteria with continuous and symmetric values, but without having threshold values defining marginal suitability and/or unsuitable class. It is also applied for asymmetric criteria by adapting the equation. The function was often suitable for chemical fertility criteria. This function is expressed using the following formula:

$$MF_x = \begin{cases} \dfrac{1}{\left[1+\left(\dfrac{x-b_1}{d}\right)^2\right]} & x < b_1 \\ 1 & b_1 \le x \le b_2 \\ \dfrac{1}{\left[1+\left(\dfrac{x-b_2}{d}\right)^2\right]} & x > b_2 \end{cases} \qquad \text{(Eq. 3)}$$

Where: b_1 and b_2 are threshold values determining the optimal class; d is the difference between b_1 or b_2 and the value at the cross point (0.5).

(2) *S-membership function*

The S-membership function has the following formula:

$$MF_x = \begin{cases} 0 & x \in (\gamma, +\infty) \\ 2\left[\dfrac{(x-\gamma)}{\gamma-\alpha}\right]^2 & x \in [\beta,\gamma] \\ 1-2\left[\dfrac{(x-\alpha)}{\gamma-\alpha}\right]^2 & x \in [\alpha,\beta) \\ 1 & x \in (-\infty,\alpha) \end{cases} \qquad \text{(Eq. 4)}$$

where $\beta = (\alpha + \gamma) / 2$ (just applying in cases of no β)

The S- membership function is applied for criteria with continuous and asymmetric values and if the values determining the marginal suitability and unsuitable class are available since the function is continuous, asymmetric and γ, α must be given. It has been applied for slope, environmental, and accessibility criteria.

(3) *The membership function of classes*

The criteria given in classes or linguistic variables such as texture, drainage, flooding were standardized by assigning raw scores and calculating membership values using the linear scale transformation (Eq. 5).

$$x'_{ij} = \frac{x_{ij}}{x_j^{\max}} \qquad \text{(Eq. 5)}$$

where: x'_{ij} is the standardized score for the *i*th object (alternative) and the *j*th attribute (criterion), x_{ij} is the raw score, and $x_j^{\max}$ is the maximum score for the *j*th attribute.

A larger raw score represents a better performance.

2.2.3.2. Standardization of agro-ecological, environmental, and accessibility criteria

Using the above MF, the criteria have been standardized and mapped. The resulting vector maps were converted into raster data with the same cell size (30x30 m) and projection (UTM).

2.2.4. Combination of criteria

2.2.4.1. Distinction between limiting and non-limiting criteria

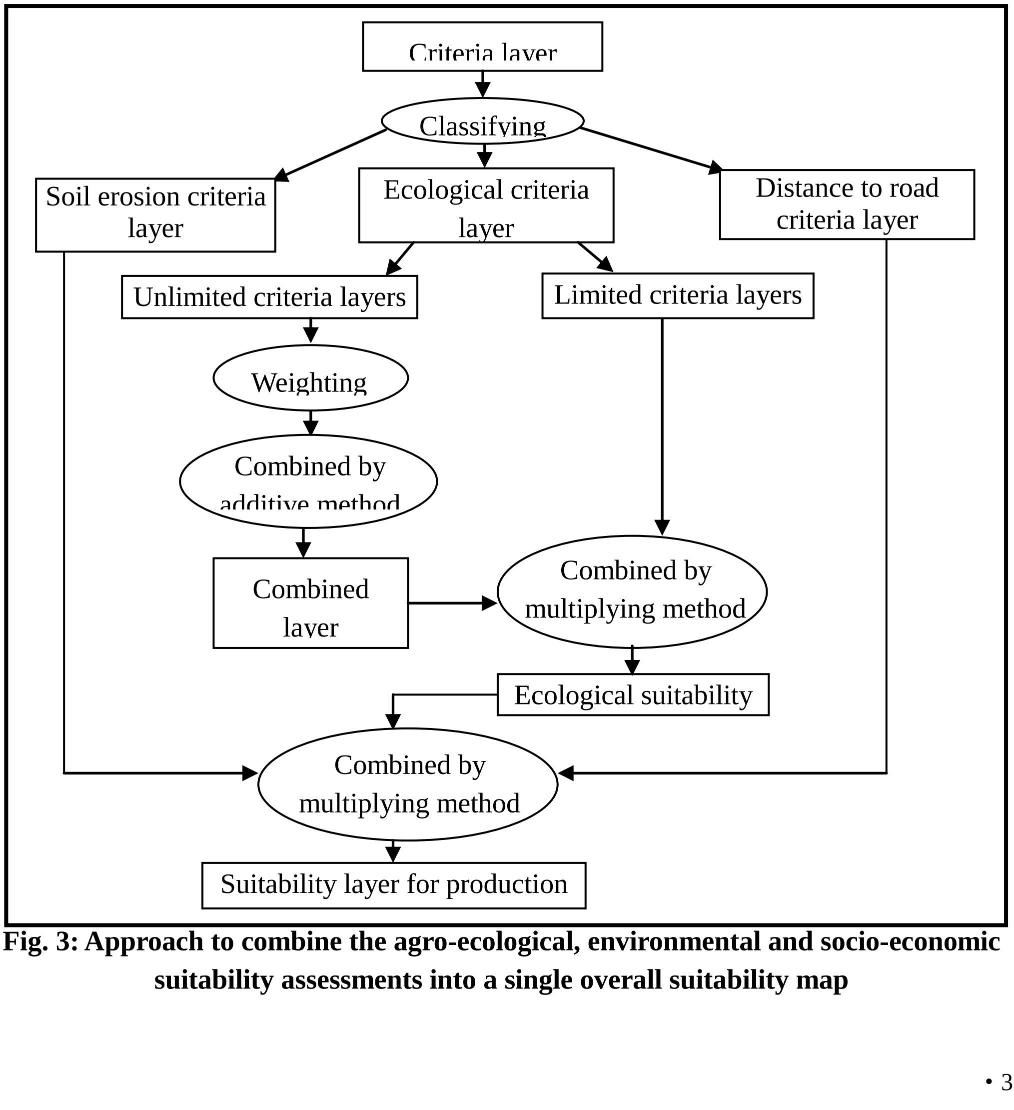

Fig. 3: Approach to combine the agro-ecological, environmental and socio-economic suitability assessments into a single overall suitability map

The approach adopted to combine the criteria has been summarized in Fig. 3. In this figure, a distinction is made between limiting and non-limiting criteria related to the ecological suitability for cultivation of the selected crops. Limiting criteria for cultivating a crop are criteria whose unsuitable values can not be improved by man, such as flooding, soil texture, soil depth, and climate. On the other hand, the non-limiting criteria are criteria whose actually unsuitable values can be improved or compensated by man, through the use of chemical fertilizers for instance. Soil erosion and distance to road were also considered as limiting criteria at this stage to highlight their importance for production purpose and impact on the sustainability of the purposed land use although they can be improved.

2.2.4.2. Weighting

Estimating the weights to be assigned to the different criteria is still a difficult issue in land evaluation. A number of criteria are more than 9 criteria therefore the ranking method was applied. The method is based on the relative importance of the criteria. The straight ranking procedure has been used, i.e. the most important criteria received a rank of 1, the second important is 2, etc. The weights were calculated by using the rank reciprocal approach, and the following formula (Eq. 6) was applied (Malczewski, 1999).

$$\mathrm{w_j} = \frac{1/r_j}{\sum(1/r_k)} \qquad \text{(Eq. 6)}$$

where $\mathrm{w_j}$: the normalized weight for the $\mathrm{j^{th}}$ criterion; k = 1, 2, …, n;

n: the number of the criteria under consideration; $\mathrm{r_j}$: the rank position of the criterion

In order to quantify the relative importance of criteria, the ability of improving the criteria, the number of suitable classes, and area percentage of these classes were considered. Based on these, the ranking of criteria was done.

2.2.4.3. Combination

Additive and multiplicative combination methods have been applied to combine the criteria. Additive combination allows the non-limiting criteria to compensate each other, while the latter method allows us to determine unsuitable areas from the limiting criteria. The additive method uses formula (Eq. 7) to integrate non-limiting criteria layers.

$$y_i = \sum_{j=1}^{n} w_j \times x_{ij}$$

(Eq. 7)

y_i: the overall score for i^{th} crop (i^{th} alternative); w_j: the weight of j^{th} criterion, $\sum w_j = 1$

x_{ij}: the score of j^{th} criterion for i^{th} crop

The multiplicative method employs formula (Eq. 8) to combine the overall score layer of the non-limiting criteria with the limiting criteria layers.

S_i = A x B x C x D x … (Eq. 8); where S_i: the overall score for i^{th} crop (i^{th} alternative);

A: the score of criterion A; B: the score of criterion B; …

2.2.4.4. Setting up threshold values defining suitability classes

The critical values defining the suitability classes have been determined based on the relationship between the overall score and yield data of each crop on one hand, and based on the relationship between the suitability classes and maximum attainable yields (FAO, 1993) on the other hand. Details are given in Table 1. The maximum attainable yield of each crop has been estimated by the maximum crop yields observed in the study area.

Table 1: Relationship between land suitability classes and maximum attainable yields

Suitability class	Maximum attainable yield
Very suitable	≥ 80%
Moderately suitable	< 80% to ≥ 60%
Marginally suitable	< 60 to ≥ 20%
Unsuitable	< 20%

2.2.5. Approach to the agricultural land use planning

The ALUP map in the study area was produced by combining the suitability layers for cultivation of the selected crops. Before developing a land use plan, priority rules need to be assigned. During this procedure, a distinction was made between the very and moderately suitable classes (S_1 and S_2) versus the marginally suitable classes (S_3) for the selected crops, taking into account that cultivation on marginally suitable land units poses the highest risks. In addition, a distinction was made between industrial crops and food crops. As such, among the very and moderately suitable land units for the production of the industrial crops rubber, coffee and cassava, rubber and coffee will require a deeper soil depth. According to Pereira *et al.* (1998), the maximum root depth of rubber, coffee, and cassava is 100 – 150 cm, 90 – 150 cm, and less than 100 cm, respectively. Hence rubber and coffee were considered as the first priority crops. With respect to the land units being very suitable and suitable to the production of the food crops, paddy rice was preferred, followed by maize and upland rice because the crop management factor (C) of maize (0.12) is less than that of upland rice (0.26) i.e. maize causes less soil loss than upland rice. For land units being marginally suitable, priority was given to food crops with short crop cycles since this minimizes risks for production losses. The priority rules are shown in Table 2.

Table 2: Priority ranking of selected crops in the study area

Economic orientation	Crop	Priority ranking	
		S_1 and S_2	S_3
Industrial crops	Rubber	1	4
	Coffee	1	4
	Cassava	2	3
Food crops	Paddy rice	3	1
	Maize	4	2
	Upland rice	4	2

2.2.6. Approach to validation of the methodology

To validate the land suitability assessment for the selected crops in Quang Tri, a comparison was made between the predicted suitability and the current distribution of Arabica coffee and rubber in the province, based on the land cover data. This assumes, however, that this latter map is correct. Validation has been done for these two crops only as they have been cultivated intensively in Quang Tri, whereas the other crops can be grown as intercrops or in a crop rotation or they have been cultivated under irrigated conditions.

3 Results and Discussion

3.1. Land evaluation for crop cultivation

As the crop-specific land evaluation procedure is similar to each crop, this paper is restricted to an outline of the results and discussion for Arabica coffee cultivation only.

3.1.1. Non-standardized evaluation criteria expressed in suitability classes

Table 3 indicates the set of criteria for Arabica coffee cultivation that were selected, adapted, and designed in the study area.

3.1.1.1. Nitrogen criterion (Agro-ecological criteria)

Table 4 indicates that Arabica coffee has been cultivated on Rhodic Ferralsols with very low nitrogen content (less than 0.1%) with a good yield (Sys *et al.*, 1993). Landon (1991) considered the N content of 0.1% as very low N. Therefore, this value has been chosen as the threshold value for optimum conditions for Arabica cultivation. Consequently, the N content reported in the province was considered as being very or moderately suitable for coffee cultivation.

Table 3: Agro-ecological, environmental and socio-economic criteria for Arabica coffee cultivation in Quang Tri

Criteria	Suitability class			
	S_1	S_2	S_3	N
Climate				
Annual precipitation (mm)	1,500-1,800 1,500-1,200	1,800-2,000 1,200-1,000	> 2,000 1,000-800	< 800
Mean annual max. temp. (^oC)	25-28 25-22	28-30 22-20	30-32 20-18	> 32 < 18
Mean annual min. temp. (^oC)	15-19 15-10	19-21 10-7	21-23 7-4	> 23 < 4
Mean annual temp. (^oC)	19-16 19-22	16-15 22-24	15-14 24-26	< 14 > 26
Mean rel. humidity of driest month (%)	55-70 55-40	70-80 40-30	80-90 30-20	> 90 < 20
n/N of 5 driest months	> 0.5	0.5-0	-	-

Criteria	Suitability class			
	S_1	S_2	S_3	N
		Topography and wetness		
Slope (%)	0 - 8	8 - 16	16 - 30	> 30
Flooding	F_0	-	-	F_x
Drainage	good	moderate	imperfect	poor
		Physical soil fertility		
Texture	C, SC	SCL	SL	LS, S

Table 3: Agro-ecological, environmental and socio-economic criteria for Arabica coffee cultivation in Quang Tri (continued)

Criteria	Suitability class			
	S_1	S_2	S_3	N
Soil depth (cm)	> 100	100-70	70-50	< 50
		Chemical soil fertility		
Ca^{2+} (cmol(+)/kg soil)	≥ 3.4	3.4 – 0.6	< 0.6	-
Mg^{2+} (cmol(+)/kg soil)	≥ 0.9	0.9 – 0.2	< 0.2	-
CEC (cmol(+)/kg soil)	≥ 8.0	8.0 – 6.0	< 6.0	-
N (%)	≥ 0.1	0.1 - 0	-	-
Organic carbon (%)	≥ 1.0	1.0 - 0	-	-
		Environment		
Annual soil erosion (ton.ha^{-1}.$year^{-1}$)	(a) 0-1	1-2.8	2.8-5.5	> 5.5
	(b) 0-2.8	2.8-5.5	5.5-10	> 10
	(c) 0-5.5	5.5-10	10-12.5	> 12.5
	(d) 0-10	10-17.5	17.5 - 25	> 25
		Accessibility		
Distance to road (m)	< 500	500-1,000	1,000-2,000	2,000-5,000

F_0: no floods; F_x: a land is very often flooded for a period of more than 2 months

C: clay; SC: sandy clay; SCL: sandy clay loam; SL: sandy loam; LS: loamy sand; S: sand

(a) soil depth < 0.5 m; (b) soil depth 0.5-0.7 m; (c) soil depth 0.7-1 m; (d) soil depth > 1 m

Table 4: The soil fertility characteristics and crop yields of the representative land units of Quang Tri

Land unit	OC	N	Ca^{2+}	Mg^{2+}	CEC	AS	Coffee (a)
	%		cmol(+)/kg			%	kg/ha
Ferralic Acrisols, SCL (1), (II) on metamorphic rocks	2.03	0.18	1.46	0.17	10.65	4.8	1,883
Ferralic Acrisols, SL, (2), (II) on violet clay rocks	1.38	0.17	2.72	0.68	10.23	7.5	548
Ferralic Acrisols, SCL, (1), (II), on violet clay rocks	1.73	0.18	4.25	2.55	12.59	1.5	740
Ferralic Acrisols, SL, (1), (II), on old alluviums	0.79	0.09	0.68	0.2	4.71	15.4	748
Haplic Acrisols, SL, (1), (II), on sandy rocks	1.12	0.15	0.70	0.17	6.51	15.2	293
Rhodic Ferralsols, C, (1), (II), on basaltic rocks	1.70	0.17	2.17	0.74	8.39	2.5	1,859
Rhodic Ferralsols, SC, (1), (III), on basaltic rocks	1.89	0.16	3.40	1.86	13.15	1.6	1,913

SCL: Sandy clay loam; SL: Sandy loam; C: Clay; SC: Sandy clay; (II): slope of 3-8^{o}; (III): slope of 8-15^{o}; (1): soil depth of above 100 cm; (2): soil depth of 70 - 100 cm; (a): yields in term of clean green hulled beans; AS: Aluminum saturation.

3.1.1.2. Environmental criteria

The soil erosion criteria for Arabica coffee have been summarized in Table 3. The selection of the various threshold values for the different suitability classes is based on the following reasoning, illustrated for soil depths between 0 and 50 cm. S$_1$ means that the annual soil erosion is less than or equal to the T-value for a soil depth below 0.5 m. S$_2$ means that the annual soil erosion is within the range of the T-value for a soil depth of 0.5 – 0.7 m. It also means a soil depth below 0.5 m is suitable for a crop, but not suitable in the future since the annual soil loss is higher than the T-value for the soil depth below 0.5 m. Hence, conservation measures are needed to reduce the soil and nutrient losses. S$_3$ means that the annual soil erosion is within the range of the T-value for a soil depth of 0.7 – 1 m. N means the annual soil erosion is within the range of the T-value for a soil depth of 1 – 1.5 m. The reason why the T-values for soil depths considered as threshold values is because when soils are eroded, their soil depth will be reduced and there is a new T-value for their soils. For soils are deep 0.7 - 1 m and above 1 m, the upper threshold values of unsuitable conditions for their soils are 12.5 and 25 ton.ha^{-1}.year^{-1}, respectively. These values are the maximum soil loss tolerance according to USDA-NRCS (1999) and the maximum soil loss tolerance for tropical regions reported by Ringo (1999). For soils that are deeper than 1 m, a soil loss of 17.5 ton.ha^{-1}.year^{-1} was considered as the upper boundary of the marginal suitability class. This value also corresponded to the cross-point value (0.5) of the S-membership function applying to standardize the annual soil erosion criterion.

3.1.1.3. Constraints

According to FAO (2000), altitude for Arabica coffee cultivation is less than 2,800 m. With respect to land cover, residential areas, water bodies, natural and plantation forests, specialized land areas (military land), and industrial zones have not been considered for expansion of agricultural land uses and hence received a score of 0. All other land uses have been rated as 1 and as such were taken into consideration for the evaluation.

3.1.2. Standardized evaluation criteria using scoring functions

The approach using membership functions to standardize criteria has been illustrated by standardization of the mean annual minimum temperature criterion as an example in case of Arabica coffee cultivation. To standardize this criterion, Eq. 9. based on the trapezoidal MF has been utilized. Fig. 4 shows the standardized mean annual minimum temperature criterion for Arabica coffee cultivation in the province. The figure indicates that value 0 distributes in the Quang Tri's eastern and the standardized values ascend from east to west of the province.

$$MF_x = \begin{cases} 0 & x \leq 4 \\ (x-4)/(10-4) & 4 < x < 10 \\ 1 & 10 \leq x \leq 19 \\ 1 - (x-19)/(23-19) & 19 < x < 23 \\ 0 & x \geq 23 \end{cases} \qquad \text{(Eq. 9)}$$

Similarly, the mean annual maximum temperature, mean annual temperature, mean relative humidity of driest month criteria for Arabica coffee cultivation in Quang Tri have been standardized based on the trapezoidal MF.

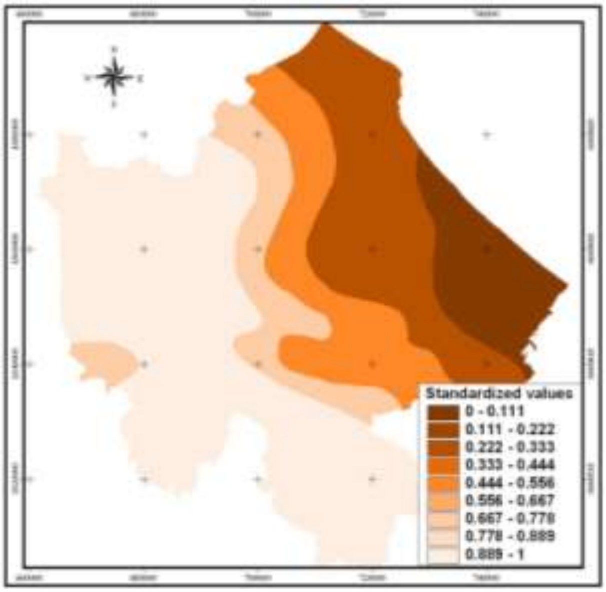

Fig. 4: Standardized score for the mean annual minimum temperature criterion for Arabica coffee cultivation in Quang Tri

The slope, annual soil erosion and proximity to road criteria have been standardized on the basis of the S-membership function, and the soil depth, flooding, drainage, and soil texture criteria were standardized by using the membership function of classes. Meanwhile, the Kandel extension MF was applied to standardize the exchangeable Ca, the exchangeable Mg, CEC, nitrogen, organic carbon, annual precipitation, n/N of 5 driest months criterion.

3.1.3. Weights assigned to each of the non-limiting criteria

The weights of the 12 non-limiting criteria for Arabica coffee have been summarized in Table 5. This table indicates that the slope gradient is the most important non-limiting criterion. Meanwhile, the n/N ratio of the 5 driest months has been considered as the least important criterion as the whole province experiences suitable values for Arabica coffee with the standardized values approximating 1.

Table 5: Non-limiting criteria weights for Arabica coffee cultivation in Quang Tri

Criteria	ranking	$1/r_j$	weight
Annual precipitation (mm)	3	0.333	0.106
Mean annual max. temp. (^oC)	10	0.100	0.032
Mean annual temp. (^oC)	5	0.200	0.064
Mean rel. humidity of driest month (%)	8	0.125	0.040
n/N of 5 driest months	11	0.091	0.029
Slope (%)	1	1.000	0.319
Drainage	6	0.167	0.053
Ca^{2+} (meq/100g soil)	7	0.143	0.046
Mg^{2+} (meq/100g soil)	2	0.500	0.160
CEC (meq/100g soil)	4	0.250	0.080
N (%)	9	0.111	0.035
Organic carbon (%)	9	0.111	0.035
Sum		3.131	1.000

3.1.4. Suitability classification for Arabica coffee

Fig. 5 illustrates the scatter plot, linear regression, correlation coefficient and corresponding regression equation between the yield data of Arabica coffee and the overall scores. The maximum yields of Arabica coffee (1,913 kg/ha) collected and shown in Fig. 5 have been defined as the maximum attainable yields for it in this area.

The records with respect to Arabica coffee (Fig. 5) cluster into 2 groups: one group with yields between 1,500 and 2,000 kg/ha; and one with yields between 250 and 1,000 kg/ha, approximately corresponding to the score ranges for the very suitable and marginal suitability classes (Table 6).

Fig. 6 shows the land suitability map for the production of Arabica coffee in Quang Tri. In the figure, the suitability classes for Arabica coffee and non-agricultural land are shown. The non-agricultural land includes residential areas, water bodies, natural and plantation forests, specialized land areas (military land), and industrial zones. The area (green and yellow color) that is very suitable and moderately suitable for this crop amounts to 2,660 ha (7% of all suitable land for Arabica coffee cultivation). It comprises mainly well drained, deep (>100 cm), clay to sandy clayey Rhodic Ferralsols in relatively flat areas near Ho Chi Minh road and road 9 in the western part of Truong Son range, in the Huong Hoa district. The annual soil loss will be less than or equal to the soil loss tolerance threshold.

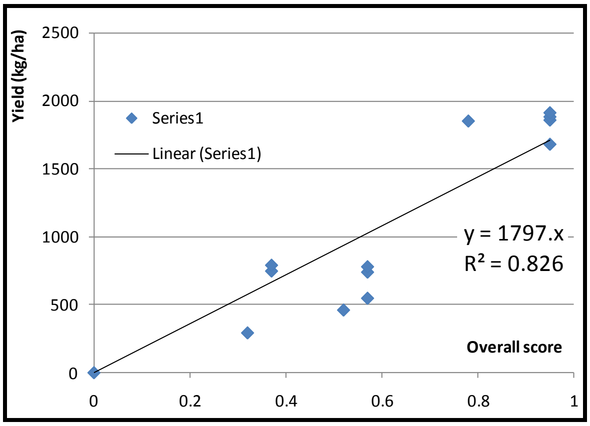

Fig. 5: Linear regression between the overall scores of the land units and corresponding Arabica yields in the study area

Table 6: Threshold values classifying suitability of the Arabica coffee

Suitability class	Overall score
Very suitable	≥ 0.85
Moderately suitable	< 0.85 to ≥ 0.64
Marginal suitable	< 0.64 to ≥ 0.21
Unsuitable	< 0.21

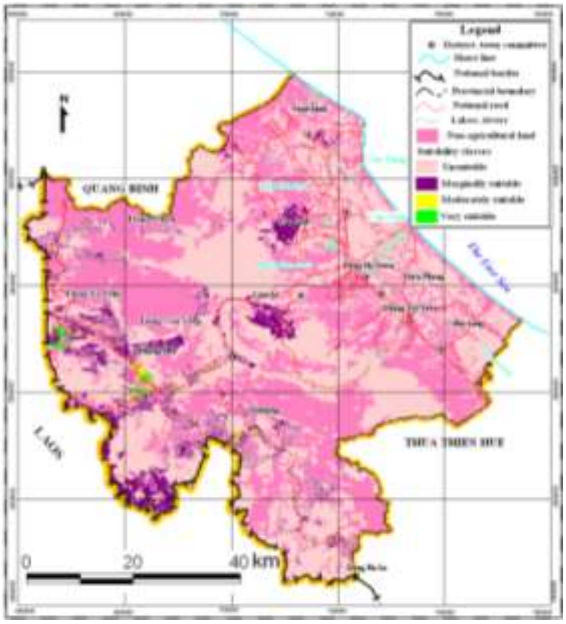

Fig. 6: Suitability map for the production of Arabica coffee in Quang Tri

3.1.5. General discussion for suitability classification for the crops in Quang Tri

Baja *et al*. (2001) used the T-value as a filter after finishing the land suitability classification, i.e. they used Boolean logic based on crisp sets (1/0) to select land units having an annual soil loss being less than the soil loss tolerance. As such, these authors did not consider the ability of applying soil loss reduction and control methods. The design used in this paper, soil erosion loss has been considered as one of the criteria, and classified into different suitability levels. In the hilly and mountainous region, for moderately suitable class, applying erosion control practices to protect that land is necessary, while soil erosion control practices are mandatory for the agricultural use of land that was classified as marginally suitable. Theoretically, when the overall scores are created, in order to classify them, yields recorded on representative land units (including the best and worst production units), need to be collected. Based on this information and the overall scores obtained by the land evaluation, a linear regression between the yield and overall score is built up. Subsequently, the ranges of overall scores are classified into suitable classes (Sys *et al.*, 1991; Van Ranst and Verdoodt, 2005). This method seems to be appropriate at large scale. In practice, survey and collection of the yield data of a crop in a large region are not always easy.

The approach applied for this paper to classify the overall scores seems to fit at regional and national scale since at these scales, using the statistical yield data based on administrative units can be reduce costs and time for surveying and collecting these data.

There are other approaches to classify the overall scores such as usage of equally spaced ranges (Tang *et al*., 1997); using the graph of cumulative percentage of pixels to take the ranges of overall scores based on inflection points (Sicat *et al*., 2005); and applying distance between pixels to reference point whereby the ranges of overall scores are defined on the basis of closeness (Baja *et al*., 2007). Depending on different purposes, one of the above approaches can be used.

There is a big difference in land suitability classification for coffee and rubber between this paper and the results published by Phan (2006) (Table 7).

Table 7: Area (in ha) of suitable classes for Arabica coffee and rubber

Suitability class	Arabica coffee		Rubber	
	Phan (2006)	This paper	Phan (2006)	This paper
S3	167,989.8	35,397.9	239,871.5	30,950.4
S2	239,181.9	1,719.8	107,009.4	4,446.4
S1	15,644.6	939.9	35,426.4	13,266.9

As the available database did not comprise the resulting land suitability maps published by author, only the aerial extent of the various land suitability classes can be compared. The reason leading to the difference can be due to Phan (2006) did not consider the altitude and land cover as constraints as well as she only used the additive approach to combine criteria. Additionally, she did not take into account the environmental and socio-economic criteria as well as the yield data when classifying the suitability classes.

3.1.6. Validation of the results

The validation results are shown in Fig. 7. Based on the land evaluation, 8,013 ha are suitable for rubber production which largely (79.8%) coincide with the 10,043 ha of actual rubber plantations in Quang Tri. The total area of growing Arabica coffee in Quang Tri is 3,840 ha. The coincident area based on the land evaluation is 2,108 ha, corresponding to 54.9%. The results partially reflect the accuracy of method as well as evaluated results.

Fig. 7 also indicates that some of the land units that actually have been used to grow coffee and rubber have been classified as unsuitable. These errors can be caused by various sources of uncertainty, related to the quality of the input data used to run the evaluation and to validate the approach, or related to the representativity and accuracy (reliability) of the modeling approach itself.

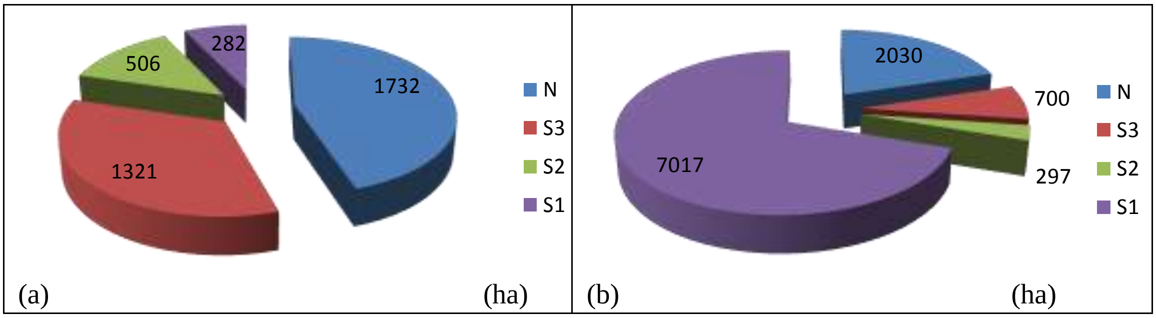

Fig. 7: Distribution of suitable and unsuitable land area actually cultivated by Arabica coffee (a) and rubber (b)

3.2. Agricultural land use proposed for the western region in Quang Tri

3.2.1. Proposed agricultural land use planning

Fig. 8 shows the proposed agricultural planning map of Quang Tri's western region based on the maps at scale 1:50.000. The map indicates that the areas without planning (pink color) are the non-agricultural lands. With respect to the industrial crops, rubber should be cultivated on Xanthic Ferralsols and Rhodic Ferralsols (purple color) in the Cam Lo and Gio Linh district. In fact, rubber already has been cultivated on almost all of these areas. Arabica coffee should be grown on Xanthic Ferralsols and Rhodic Ferralsols (dark blue and brownish colour) in Huong Hoa, especially where Ho Chi Minh road finishes because these areas are near this road. Cassava should be cropped on Xanthic Ferralsols, Rhodic Ferralsols, and Ferralic Acrisols (dark green color) in the south of Huong Hoa district and the west of Dakrong district. In the case of Arabica coffee, Fig. 8 shows the difference between the planning and existing land covers in that area (the Khe Sanh area, Huong Hoa district - the oval with black line). The planning map suggests that cassava should be cultivated in the north of Khe Sanh area and coffee should be grown south of this area. This land use planning is well feasible as cassava processing factories have been built and expanded in the Huong Hoa district.

With respect to the food crops, paddy rice should be grown in the eastern edge of the study area (yellow color) in the Vinh Linh, Gio Linh, Cam Lo, Trieu Phong, Hai Lang districts. Irrigation systems need to be constructed for growing paddy rice under irrigated conditions because the rainfall during the paddy rice's growing cycle is not sufficient for optimal paddy rice cultivation under natural floods. Maize and upland rice should be cultivated to provide food for the local people in land units widely distributed in the Huong Hoa and Dakrong districts (olive, blue color for maize; dark brown, violet color for upland rice).

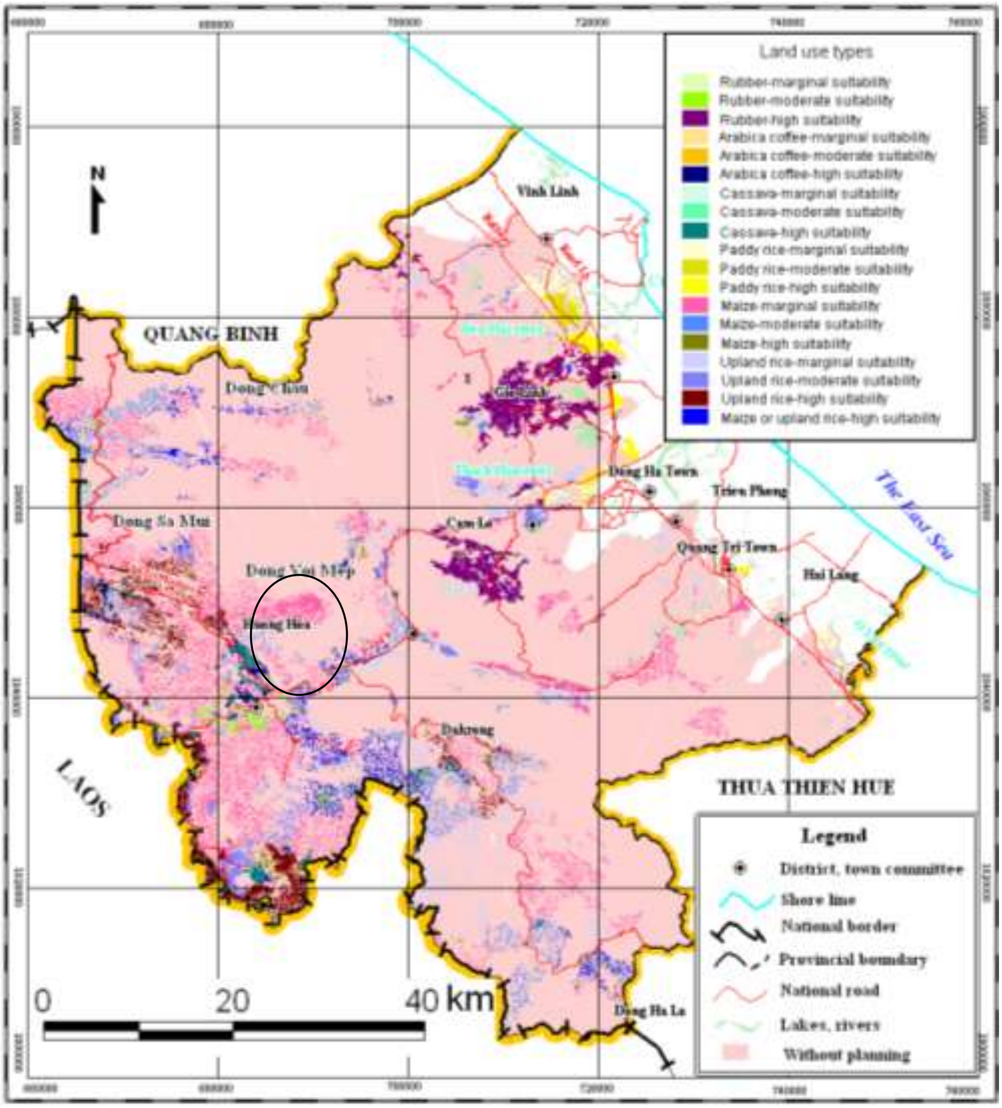

Fig. 8: Agricultural land use planning map for the western region of Quang Tri

More details on the aerial extent of the land units for each of these crops and their suitability have been summarized in Table 8. In this table, the total area of food and industrial crops with high suitability is 12,702 and 11,570 ha, respectively.

Table 8: Land surface of high, moderate and marginal suitability classes for different crops according to the proposed land use planning

Crop and suitability class	Area (ha)	% of total suitable area
Rubber-marginal suitability	1,910	2.5
Rubber-moderate suitability	1,375	1.8
Rubber-high suitability	8,987	11.6
Coffee-marginal suitability	2,285	3.0
Coffee-moderate suitability	644	0.8
Coffee-high suitability	940	1.2
Cassava-marginal suitability	115	0.1
Cassava-moderate suitability	115	0.1
Cassava-high suitability	1,643	2.1
Paddy rice-marginal suitability	4,699	6.1
Paddy rice-moderate suitability	1,025	1.3
Paddy rice-high suitability	1,500	1.9
Maize-marginal suitability	23,116	30.0
Maize-moderate suitability	4,725	6.1
Maize-high suitability	777	1.0
Upland rice-marginal suitability	7,276	9.4
Upland rice-moderate suitability	5,606	7.3
Upland rice-high suitability	5,567	7.2
Upland rice or maize-high suitability	4,858	6.3
Sum	77,163	100.0

3.2.2. Comparison of proposed agricultural land use planning with the actual agricultural use

According to the land cover data published in 2000, Quang Tri has 6 farming systems: (1) Maize, sweet potato, and vegetable; (2) Bean, cassava, maize and vegetable; (3) Upland rice, cassava and maize; (4) Paddy rice; (5) Rubber; (6) Arabica coffee.

In order to provide a preliminary assessment of the ability to expand the agricultural land, we made the following assumptions: First, paddy rice was not included in the comparison because the land cover map included paddy rice fields under both irrigation and natural floods, whereas in our analysis only paddy rice fields fed by natural floods were considered. Secondly, the separate data on maize, cassava and upland rice were not available. This implies that a direct comparison of the extent of maize, cassava and upland rice as proposed in the land use plan is impossible. It was decided to group these 3 crops in a class referred to as "annual crops". Similarly, the first 3 farming system classes of the land cover map were also combined into "annual crops", although they comprise also sweet potatoes, beans and vegetables. Yet, because maize, cassava and upland rice are the main annual crops in the western region of Quang Tri, their planned aerial extent can be safely compared to the aerial extent of the "annual crops" class in the land cover data.

Table 9 expresses the actual aerial extent of rubber, Arabica coffee, and annual crops (maize, cassava, upland rice, bean, sweet potato and vegetable) in 2000 and the planned aerial extent of rubber, Arabica coffee, and annual crops (cassava, maize, upland rice).

Table 9: Actual and planned area for rubber, Arabica coffee, and annual crops cultivation in the western region of Quang Tri

Crop	Aerial extent (ha)	
	Actual	Planned
Annual crops	37,894	53,799
Arabica coffee	3,844	3,869
Rubber	8,724	12,272
Sum	50,462	69,940

Based on this table, the expansion of the agricultural area by 9,898 ha (focusing on rubber, coffee, cassava, maize, and upland rice) from 2007 to 2010 adopted by the committee of Quang Tri province is possible.

4 Conclusion

According to the resulting agricultural planning map, maize is the crop with the largest extension of suitable land in the province, amounting to 28,617 ha, and widely distributed in the western part of Quang Tri. Yet, of this, only 777 ha are very suitable, whereas 4,725 ha are moderately suitable for the production of this crop. About 18,449 ha have been reserved for upland rice cultivation. The very and moderate suitability classes occupy 5,567 and 5,606 ha, respectively. Additionally, an area of 4,858 ha has been characterized as being very suitable for maize or upland rice cultivation. This implies that, depending on the development demands, these land units can be used to cultivate maize or upland rice or both crops. With respect to the cash crops, rubber is characterized by the largest expansion of the very suitable class, amounting to 8,987 ha of a total suitable area of 12,272 ha. Moderately suitable land units reserved for rubber cultivation occupy 1,375 ha, and the marginal ones 1,910 ha. About 3,869 ha of the study area are suitable for growing Arabica coffee, of which 1,584 ha is very to moderately suitable. Rubber should be grown in the eastern part, whereas Arabica coffee should be cultivated in the western part of the study area. The total planned area for cassava cultivation amounts to 1,874 ha, of which 1,643 and 115 ha are very and moderately suitable, respectively, whereas the remaining 116 ha are marginally suitable. Finally, 7,224 ha of land concentrated in the eastern edge of the study area, are suitable for paddy rice cultivation under natural floods. Based on this analysis, the proposed expansion of the agricultural area in the hilly and mountainous part of the province with 9,898 ha is feasible.

Furthermore, the adopted GIS-based multicriteria analysis method is very visual and also useful to the development of the ALUP. In addition to the crop-specific agro-ecological requirements, the method also evaluated the environmental and socio-economic sustainability of the proposed land use. Although the evaluation of the socio-economic aspects was at a preliminary stage, it has been an important step forward to take into account socio-economic feasibility. Selection and design of relevant criteria using literature sources combined with an analysis of the local environment and yields were found to be necessary for highlighting locally important characteristics. The strength of the weight determining ranking procedure is its ability to consider a large number of criteria. Its inability to evaluate the accuracy of the estimated weights, on the other hand, proves to be an important weakness of the approach. This might be improved in future by combining the ranking method with expert knowledge.

The distinction of limiting and non-limiting criteria proved necessary to reflect the impact on the overall score and subsequent suitability classification of criteria that significantly restrict the land suitability as they cannot be solved by land improvements or compensated by other outstanding criteria. The distinction made is, however, only meaningful when a combination of additive and multiplicative procedures is used to determine the overall score. Crop selection in the agricultural land use plan involved designing a set of priority rules based on criteria such as soil depth, and risks for soil erosion versus possibilities for soil protection as well as crop cycle length. This latter aspect was considered to assess the risks associated with the failure of crops having long crop cycle lengths. However, in future assessments, when the necessary data become available, the priority rules should also consider a cost and benefit analysis and take into account the regional development strategies. Since both strongly depend on the market, their inclusion in land evaluation procedures is of high relevance.

The applicability of the proposed GIS-based multicriteria analysis developed within this research for agricultural development planning will increase if the remaining weaknesses are resolved. As such, the following additional research topics are proposed. A cost-benefit analysis of the selected cropping systems is required in order to be able to interpret the relationship between the overall scores of the land units and their estimated suitability, and to – eventually – adopt the agro-ecological, environmental and socio-economic criteria and weights, increasing the accuracy of the results.

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Session4:

Public Participation and Education

Flexible Farming System Strategies for Economic and Environmental Sustainability: Reflections on experiences in several developing economies

Eilers R.G., MSc. PAg.

Presentation to Workshop on Agricultural Land Use and its Effect in APEC Member Economies, Oct. 2009

ABSTRACT: This presentation will briefly describe some examples of how the Agricultural Institute of Canada (a non-government organization of professional agricultural experts) through its International Agricultural Development Program is working with professional agriculturalists and local famers in several developing economies to extend new knowledge and skills which will facilitate the adoption of more flexible, beneficial land and crop management practices to improve food production, nutrition and household incomes.

Introduction

Land best suited for Agriculture is rapidly disappearing under general public apathy and the insatiable drive for development. Unfortunately this seems to be happening in all economies. Recently the UN declared that more than 1 billion people (~ 17% of the world's population) now are malnourished and go hungry to the point of starvation on a daily basis. According to the World Food and Agriculture Organization, world food reserves are at a 50 year low, with only enough food to last for one month, if food production suddenly stopped. Food production is becoming more and more costly as input costs rise due to, among other things, the declining quantity and deteriorating quality of the agricultural land base. Alleviating hunger and poverty especially in developing economies will depend on more intensive, flexible and sustainable agricultural land use practices. Developing and implementing low cost beneficial management practices at the local farm level can help to address some of these issues, but what is needed in the long run is more attention to land use polices that protect the land base and promote sustainable agricultural practices.

Agricultural Land Use – current issues

In nearly all the current competing and conflicting priorities for the use of high quality agricultural land, **- AGRICULTURE LOSES**! Some examples include:

Urbanization and infrastructure

Industrial development and resource extraction

Recreation and

Wildlife Habitat

The inherent decline in quality of agricultural land due to inefficient management practices.

Impact – a direct loss of resource capacity as development encroaches on agricultural lands, and agriculture encroaches on more marginal or sensitive and often less productive lands, it results in increasing risks of declining and failing productivity

Effects on national economies – It can be expected that the loss of agricultural resource capacity will result in:

Increasing costs of production – thus resulting in

Input subsidies, lower yields, poor markets

Increasing Hunger and Poverty – adding to

Strain on national support programs

Increasing imbalance of food exports and imports – leads to

Fiscal imbalance

Increasing susceptibility to natural disasters – increasing costs for

Shelter and infrastructure

Farmers in all economies are facing these global concerns on a daily basis. They are striving to adopt more flexible, intensive and diversified farming system practices as well as new knowledge and technologies within the means available to them.

The following presentation provides a few examples of how twinning partnerships between agricultural professional in Canada and several Host economies are helping to extend new knowledge and skills to local farmers to improve their capacity to produce food and increase their incomes, health and living standards and at the same time become more environmentally sustainable.

Background

The Agricultural Institute of Canada (AIC) – a non-government organization (NGO) of agricultural professionals is working in partnerships with counterpart organizations in several developing economies with objectives of:

Sharing expertise – to facilitate the integration of indigenous knowledge with new agricultural technologies, to improve agricultural productivity, rural income, food security and to lower the risk of poverty, and

Empowering and actively involving women and youth in agricultural activities and improving their education, employment skills and opportunities.

This is being done through 3 specific program strategies:

Strengthening partner organizations

Promoting agricultural innovation

Expanding access to information

Program Resources include:

Technical and professional expertise and knowledge
Wide range of understanding from agriculture and agri-business disciplines.
Organizational knowledge and expertise – governance, democratic procedures and operations.
Knowledge base and successful, replicable experiences.
International contacts to identify appropriate resources.
In-kind support from dedicated professionals in Canada and overseas.
Links with an international network of professional organizations.

Program Goals:

To extend global connections between professional agricultural organizations, and
To increase their capacity and impact nationally and internationally through professional exchanges and strategic activities that:
increase domestic food security,
promote gender equality and
help to alleviate poverty.
Primary focus of the AIC twinning partnership program addresses - 3 of the 8 Millennium Development Goals adopted by the UN:
Eradicate extreme poverty and hunger *
Achieve universal primary education
Promote gender equality and empower women.*
Reduce child mortality
Improve maternal health
Combat HIV/AIDS, malaria and other diseases.
Ensure environmental sustainability*
Develop a global partnership for development.
Currently we have 6 Twinning Partnerships in 5 economies
Viet Nam, Sri Lanka, Ghana, Tanzania and Ethiopia.
Project activity areas include:
Agricultural land use
soil characterization, management, and conservation,
Crop diversification,
Intensive vegetable production,
Post-harvest storage and handling systems,
Animal husbandry,
Training, & participatory farmer research,
Professional development, education, and extension
Project Implementation occurs through local community organizations including farmers, women and youth groups, teacher associations, university student chapters of professional organizations and other local non-government organizations.

Current Status of Projects by Economy

Viet Nam – Project Name: **VIETCANSOL II**
Title: **Community-Based Land Management for Poverty Alleviation in Viet Nam**
Example activities:
Demonstration of intensive spring rice cultivation - (eg. adequate and timely nutrient applications)
Sweet potato demonstration in Con-Thu Cuc-Tan Son-Phu Tho - (eg. Applying new sweet potato cultivation technologies increased yield by 64%)
Vegetable intensive demonstrations using composting farmyard manure in Thu Cuc-Tan Son-Phu Tho and Tan Thinh-Chiem Hoa-Tuyen Quang - (eg. Applying composted farmyard manure for winter vegetable increased vegetable yield by 25-40%).

Sri Lanka – Project Name: **SRICANSOL II**
Title: **Sustainable Soil and Crop management**
Example activities:
Identification of soil fertility constraints and unwise practices which lead to soil and water pollution in major farming/ cropping systems.
Rice Fertility demonstration – (based on crop nutrient requirements)
Household Composting – (recycling organic residues for soil amendments)
Introduction of new techniques and structures for promoting vegetable production under traditional forest gardens – targeting landless households.

Ghana – Project Name: **Horticulture and Social Development**
Title: **Dry Season Vegetable Production**
Example activities:
Water Management Technology - Bucket Kit Irrigation Technology improved water use efficiency and weed growth reduction
Introduction of new crops - "Goat's Head" peppers
Introduction of post harvest processing - dried vegetables (eg. okra, kenaf flowers, leafy vegetables) used for food security during the dry season.

Ghana – Project Name: **Animal Production**
Title: **Integrated Crop and Livestock Production**
Example activities:
Integration of sheanuts and pasture improvement for livestock to increase household income
Establishment of new connections with national and international organizations and associations.
Micro-credit and agri-business training - In Partnership with Bridges of Hope Ministries (Lethbridge AB)

Tanzania – Project Name: **Tanzania Society of Agriculture, Education and Extension**
Title**:** **Youth Agricultural Training Project**
Example activities:

Agricultural Training for Youth and Women
Introduction of new crops and new management skills for women and youth
Mentoring and site visits for group members.
Demonstrations of Sustainable Energy - Solar drying of fruits and vegetables
Establishing small scale village businesses to generate increased income**;**
Deliver on-farm demonstrations to address environmental concerns – eg.
Reducing soil erosion by overgrazing
Training for proper usage of agricultural chemicals
Training for water harvesting, storage, and small traditional irrigation practices

Ethiopia – Project Name**:** **ETCANSOL**
Title: **Transfer of Soil Science Technologies for Enhancing Food Security, Rural Development and Environmental Quality in Ethiopia**
Example activities
Collation of soil management information for technology transfer. Workshops to develop information data base. Introduction of new varieties of vegetables to improve diets, Improving methods of tillage and soil management practices

South-South Collaboration

Annual exchange visits are conducted for project team members between economies with similar agricultural resource and production systems and constraints. This helps to build and strengthen professional capacity and develop new contacts for future follow up for information sharing and exchange. Another important mechanism for sustaining technology transfer is frequent exchange visits among farmers within an economy to various research and on-farm demonstration sites.

Summary

Collectively these projects have developed and implemented modern technologies with existing local knowledge to improve agricultural production, employment opportunities and local incomes, in a more environmentally sustainable fashion. A brief list of these beneficial management practices includes:
Composting -
recycling household organic residues and agri-waste products
Crop Diversification –
Increasing diversity of food and fiber crops – reducing risk of lost income.
Innovative practices –
vertical structures for landless people to improve vegetable production
Urban agriculture – household gardens,
Integrated agri-industry and agri-urban Land Use for food and fiber production
Tillage options
Zero – minimum tillage, or reduced tilling

Deep tillage to mitigation compaction in paddy soils
Hedge rows and contour planting to reduce water erosion
Water – surface and groundwater management
surface water harvesting, quality, quantity and transport
well design, maintenance, and pumping
household and irrigation water requirements -
Indigenous knowledge –
Science integration has lead to innovation for recycling residues – eg. Charcoal from burning paddy husks.
Land quality and capability assessment,
Soil characterization, mapping and reporting
Soil suitability monitoring and quality assessment for resettlement.
Post harvest - management practices
Soil fertility - monitoring and assessment
Soil limitation - evaluation and monitoring
Farmer training - skills dissemination
Technology transfer mechanisms – field days, workshops, pamphlets, etc.
Gender considerations –
land tenure, land management, land use
Micro credit - initiatives for women
Youth training – employment opportunities
Targeting agricultural assistance and development programs
Implementation methods –
Stakeholder/farmer associations/groups

New emphasis for Land use planning – Involve all stakeholders!
Land base (bottom) up vs top down
Climate Change vs agriculture – implications for future being considered
Agro-ecological system sustainability vs commercial/subsistence agriculture

Professional Partnerships – have been highly successful in all of the current projects.
Communications at all levels has been a Key factor!!

Professional Associations in each of the economies have been significantly strengthened, memberships have increased and members have acquired many new skills in project proposal development, monitoring and reporting and publishing scientific papers. These associations have been sought after for their expertise and have undertaken many and varied activities at the request of the various Ministries of Government – Agriculture, Natural Resources, Health, and Universities. In some projects, special working groups or local task forces have been established to develop information packages for government agencies.

Position papers – Agricultural Land Use

ALU status reviews – Developing LU policies for prime lands.
Multi-agency, interdisciplinary partnerships
Agricultural infrastructure development
Advantages of Involvement of beneficiaries in design, implementation and delivery of programs
New and emerging markets development –
local, regional, national and international

Program Successes

- *Organization level*

Strengthens partner organizations by raising their profile, diversifying their professional capacities and services; increasing and diversifying their membership; and increasing their sources of revenue.

Community level

- Development of technologies that enhance agricultural productivity, generate increased revenue and promote agriculture that is environmentally sustainable;
- Positive results in employment for youth in agriculture or related businesses;
- Increased participation of women in project planning and activities. (Increased awareness of gender equity issues and gender equality's impact on the sustainability of results)

- *Economy level*
  - Professional partner organizations are in a position to influence policy on food security, and on environmentally and economically sustainable agricultural practices;
  - Increased and improved national and international networks and connections among agricultural professionals and associations.

Program Outcomes:

In all projects, membership has increased, knowledge and skills for managing projects have been strengthened, and a new awareness of youth and gender equity issues has been developed. Innovative technologies have been developed and extended to other regions and nation-wide through exchange visits, workshops, and training of trainers.

Program IMPACT:

Improved livelihoods, well being and equity through economic, environmental and social sustainability of rural communities.

Conclusions

Agricultural Land Use will have an Effect on APEC Member Economies. Ignoring the challenges and competition for agricultural land will be devastating for the agricultural sector of the economy I have provided some information and a few examples of how some projects are effectively addressing some of the pressing issues of agricultural land use. To quote Valerie Raymond ***"To***

secure the well being of the land is to secure the well being of the people”

Recommendations:

Requirements for more effective ALU:
Detailed land-resource data bases for:
LU planning- Agriculture, Urban, Infrastructure, and Industrial Development.
Policies, programs and tools that:
Improve the awareness of ALU requirements
Protect the high quality agricultural lands for food and fibre production
Provide monitoring protocols to track ALU changes (positive of negative)

LESSONS LEARNED!!

Communications is key to determine needs:
Consult with other professionals
Consult with local rural communities
Design and deliver appropriate training
Training the trainers
Work with farmers - “Do as I do” - vs - “Do as I say”
to demonstrate beneficial management practices and
to monitor resultant changes in soil and water quality, productivity and household income
The Implementation of any change to affect more sustainable ALU must involve the farmers, no matter how big or how small, no matter which economy they live in.

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