分类号

密级 UDC

学位论文

基于模型方法的蒙古国森林资源动态研究

(中文题名)

Study on Mongolian Forest Stand Dynamics Using Mathematical Modeling

(英文题名)

Khulan Myagmar

(作者姓名)

指 导 教 师 刘俊昌

申请学位级别 硕士

学科专业名称 林业经济管理

研 究 方 向 林业资源与环境经济

论文提交日期 2017年4月

论文答辩日期 2017年6月

学位授予日期

答辩委员会主席：

评 阅 人：

北京林业大学

Declaration

The author hereby declares that the work presented in this paper has been carried out and composed by herself as part of two-year study programmed at the School of Economics and Management of the Beijing Forestry University, People Republic of China. All views and opinions expressed remain therein the sole responsibility to the author and it has not been presented in any previous application for a degree.

Candidate: ……………………………. Date: ………………………………..

Candidate: ……………. Supervisor: ………………. Date: …………………….

基于模型方法的蒙古国森林资源动态研究

摘要

全球的温室效应、气候变化和人类的不恰当的行为方式都对蒙古国森林资源的面积和质量产生了直接的负面影响（粮农组织，2010）。2015 年蒙古国的森林面积是 1218.82 万公顷，比 2010 年减少了 86.45 万公顷。森林面积减少和森林质量退化的重要原因是火灾、过渡放牧、采矿、不适当的采伐、非法采伐和获取薪材和病虫害等。蒙古国的森林不但面积减少，森林的年龄结构也不合理，2016 年成熟林的比重高达 74%。

关于蒙古国森林资源动态研究的文献几乎没有，本文是首次应用随机过程方法对蒙古国森林资源进行动态研究的实例。本研究依据蒙古国森林资源变动实际情况，首先选择了影响森林资源动态变动的主要因素（气候变化、社会经济因素、环境因素），然后选用了相应的回归模型对影响森林资源变动的主要因素的影响系数进行了估计，并对主要因素的变动的动因进行了数量分析。在此基础上利用马尔科夫链方法对森林龄级结构的未来变动进行了预测。

研究结果表明影响蒙古国森林资源变动的主要因素是森林火灾、商业采伐和再造林。未来火灾将趋于减少，但商业采伐和再造林呈现上升的趋势。模型计算结果显示到 2030 年森林资源将减少 13%，其中幼龄林将增长 27%，中龄林将减少 15%，近熟林将减少 39%，成熟林减少 16%。

关键词：森林资源变动；森林龄级结构；马尔可夫连锁过程

STUDY ON MONGOLIAN FOREST STAND DYNAMICS USING MATHEMATICAL MODELING

Khulan Myagmar, M.Sc
Liu Junchang, Professor

ABSTRACT

A Global warming, climate change and negative human activities are expected to directly and negatively influence Mongolia's forest resource area and quality (FAO, 2010). In 2015, Mongolian forested area was 12,188.2 thousand hectare and in compared with the forested area in 2010, it has decreased by 864.5 thousand hectare. The important causes of deforestation and forest degradation are fire, improper commercial logging, illegal collection of wood for construction and fuel, overgrazing, mining activity, and damage by pests and diseases. Mongolian forest stand is not only decreasing in quantity, but also forest age class has been changing into maturity forest classification in recent years. The maturity forest (more than 200 years) resource has counted for 74 percent of total forest resource is in National Forest Inventory, 2016.

There are few study for Mongolian forest stand dynamics and this work is first research that used stochastic process to predict forest stand dynamics in Mongolian case. This paper considered the main factors such as Climate factors and Socio-Economic factors in predicting forest stand dynamics. The factors are chosen based on real situation of forest resource's changes in Mongolia. The study has estimated coefficients of relationship between forest resource and main factors, as well as main factors and their explanatory variables, using suitable regression model for each estimations. Moreover, Markov chain process has been used to extracted future dynamic of forest stand by age class structure based on imbalanced age structure of total forest resource today.

The result of this paper shows that the most important factors which influenced the future forest stand changes are forest fire, commercial logging and afforestation. The estimated model results shows the forest fire will be decreased (9%), commercial logging will be increased (25%) and reforestation will be increased (30%) by 2030. Specially, this paper presented that forest resource will decrease by 13 percent in future 15 years. Additionally, this decrease is consist of forest age structure changes which is young aged forest would be increased by 27%, middle aged forest would be decreased by 15%, maturing forest would be decreased by 39% and maturity forest would be decreased by 16% in 2030.

Keywords: Forest stand dynamics, Forest age class structure, Transition matrix

目录

Contents

列表

LIST OF TABLES

图表清单

LIST OF FIGURES

ABBRIVIATIONS

DEFE	Department of Environment and Forest Engineering
DLMGC	Division of Land Management, Geodesy and Cartography
GDP	Gross Domestic Production
FAO	Food and Agriculture Organization
MEGD	Ministry of Environment and Green Development
MEGDT	Ministry of Environment, Green Development and Tourism (since2016)
NFE	National Forest Enumeration
NFP	National Forest Policy
NSOM	National Statistical Office of Mongolia
NUM	National University of Mongolia
OLS	Ordinary Least Squares
REDD+	Reducing Emissions Deforestation and Forest Degradation
RDCF	Research and Development Center of Forest
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestations and forest Degradation
SFM	Sustainable Forest Management
UN	United Nation
WWF	World Wide Fund

1 INTRODUCTION

1.1 Background

An understanding of forest stand dynamics (i.e., natural disturbance regimes, natural regeneration, and natural stand development) has long been considered essential underpinnings of scientific silviculture and management (Goldammer, 1996).

Mongolian forest reserve lands comprise 18.3 million hectares, with 12.9 million hectares of the forest-covered area; this includes 10.5 million hectares of coniferous and hardwood forests, which is equivalent to 67 percent of the forest reserve. There is protected area is around 80% and utilization area is 20% Besides, Mongolian forest annual growth rate is 10.5% that is compared to an average of the world's growth rate 5 times less. Mongolian state forest land is 11.09 percent of total country area (MEGDT, 2016). However, Mongolian forests play a very important role in preventing soil erosion and land degradation, in regulating the water regime in mountain areas, maintaining permafrost distribution and in creating habitats for wildlife.

A Statics on deforestation is confusing and often conflicting, it has been estimated (World Bank, 2002 and MEGD, 2015) that Mongolia lost about 1.6 million ha of forest 1950-1980, 660 thousand ha 1990-2002 and a further 32 million ha 2000-2015. The major of causes of forest loss have been unsustainable forest harvesting (both permitted and illegal) for timber and fuelwood, forest fire, insect and disease, mining, uncontrolled grazing and long-term fluctuations (Mongolia Forestry Sector Review, 2004). An unsustainable management has been affected in not only decrease of the forest resource, its effecting in forest age structure that it has been estimated that Mongolian forest consisting of 72% of maturity forest, 12% classed as maturing, 11% classed as middle aged and less than 5% classed as young trees (NFE, 2016). Besides, there is 420 million cubic meters of dead standing trees and deadfall trees in total forest resource in 2015 year's statistic. This statistic shows that Mongolian forest has been used slightly and inappropriate. Main causes are global warming level is 3 times more than world average warming level, and forest management has some weakness such as unregulated use, over- use, and inadequate protection.

During past 2 years, National forest census was implemented by UN programme and Federal Republic of Germany. The outcome of census is including following main results such as 1. Growth rate of forest was slowed and poor, 2. More than 70 percent of forested area is maturity forest, 3. Utilization of forest (including timber, fuel wood and non-timber products) is minor which compared with real opportunity, and 4. Regeneration dominant is high (MEGTD, 2016). The result of National Forest Enumuration-2016 presents that have to manageme sustainable Mongolian forest. Also, lack of knowledge and information of forest is one of the reason to decrease Mongolian forest sector. Only five universities have a program of forest engineering, and graduate this programs totally about 300 students in a year. In the goal of sustainable forest development's document, has written following concepts such as to protect terrestrial ecosystem and to use it consensually, restoration and sustainable use of forest resources and ensure sustainable reduction, combating desertification, land degradation and to stop the extinction of biodiversity in 2020s (MEGDT, 2015). Experts of the forest sector pay attention to share knowledge in social which is significant to develop management in forest sector.

1.2 Problem statement

Recently, a forested area has been decreasing by environment and human factors such as a climate change and desertification, harmful insect, forest fire, and wood consumption year by year. As a Mongolian forest sector has not developed sustainable.

One of the major causes of forest degradation in Mongolia is forest fire. The long-term fire history of the Mongolian forests is poorly known, although the disturbance dynamics is one of the key questions in attempts to develop sustainable forestry practices. There is a need to fully understand the fire ecology of natural forest systems so that silvicultural systems can be adapted to this natural and important disturbance regime. Such an understanding would contribute significantly to better fire management programs and improved, ecologically- based silvicultural prescription (Haynes *et al*., 2002).Wildfire might lead to disastrous consequences such as huge economic and ecological losses in the forest coverage of Mongolia (Ochirsukh, 2011). About 95 percent of steppe and forest fires in Mongolia are caused by human activities (Erdenetuya, 2012). Between 1981 and 1999, approximately 160 fires per year were recorded in Mongolia, each burning an average of 2,933,659 ha (Goldammer, 1999).

Forest losses in Mongolia due to fire and insects are dramatic (Enkhbat *et al*., 1997). Although, ecological and economical damage is increasing affected by pests and disease. Insect and disease infestations are the second most important mechanism for forest renewal in northern forests after fire, particularly in cooler and moister forest zones and in older age classes (The World Bank, 2004). The structural patterns of old growth forest include a wide range of tree sizes and ages, a higher proportion of small trees than large trees, more young trees than old trees, many standing dead trees and snags, abundant large logs on the ground (e.g., Whitney, 1987; Oliver and Larson, 1996; Goodburn and Lorimer, 1998; McGee *et al*., 1999; Ziegler, 2000).

Industrial logging of forest resources in Mongolia has increased since the 1960s. According to government reports, Mongolia produced 1.7 million cubic meter of timber annually. Ministry of Environment and Green Development has given permision 671.0-837.0 thousand cubic meter during last 6 years, which is consist of other wood consumption is 14% and fuel wood is 86 percent. A Permission of harvest is determined too low compared with wood and wooden product's real demand in Mongolia (Batchuluun, 2016). Annual fuel consumption could be reduced by at least 70,000 tonnes of coal and 510,000 m^3 of fuel wood (Project Manager, Improved Household Stoves Project, MNE pers. comm.).

Reforestation activities in Mongolia started in the 1970s. Since 1975, reforestation was carried out on 68,748 ha within the country where most of the areas were replanted by seedlings. The GOM currently invests between USD 400,000 and 600,000 per year in reforestation and afforestation programs (MEGDT, 2015). The budget is controlled by MNE and shared with aimags according to approved plans. Payments are made to contractors for the planting of non-forested areas. Logging contractors are required to replant as part of their permit, although they often get paid (for reasons that are not clear) and continue to be issued with cutting permits even when they do not plant.

Management of forest resources in Mongolia suffers from several weaknesses such as unregulated use, over- use, and inadequate protection (The World Bank, 2008). Besides, there is 80 percent of total forest resource is old aged forest and also there is 420 million cubic meter of dead standing trees and deadfall trees in total forest resource in 2015 year's statistic (MEGDT, 2015). This statistic shows that Mongolian forest has been used slightly and inappropriate.

This study is focused on that to estimate relationship between forest resource and major causes of changing forest resource, and to predict forest stand dynamics by forest age structure.

1.3 Objective of study

The main objective of this study is that to find the quantitative influence of the main factors of forest stand dynamics and to predict future changes in order to provide the information for sustainable management of forest stand in Mongolia.

Moreover, to know factors which are climate and socio-economical factors have been affecting in forest resource changes, as well as to analyze dynamic patterns of these main factors in future. The result of the study will provide information for descision makers to manage harvest permission and silviculture sustainablity in long-term.

1.4 Research questions

- How strong positive or negative relationship has been being between forest resource and main factors?
- How would be changed main factors in the future?
- How would be changed forest stand dynamics explained by main factors and their explanatory variables?
- How would be changed forest age structure according to prediction of forest stand dynamics?

1.6 Limitation of the study

This study focused on that to predict forest stand dynamics explained by main factors such as forest fire, permitted logging and reforestation which have been affecting a large in forest covered area in past years. The study is not considered other factors such as uncotrolled grazing, mining effect and other long-term fluctuations. Therefore, the result of estimations might be represent minor differences between real value and estimated value.

1.7 Organization of Thesis

The thesis is consist of six chapters. Chapter one introduce an overview of the research framework is including problem statement, objective of study, research questions, scope of the study and limitation of the study. Chapter two gives overview of experience of sustainable forest management in Mongolia and at the World. Chapter three indtroduce study area including anallysis of geographical context, socio-economical context and current condition of forest sector. Chapter four shows mathematical models that used to get results. Chapter five presents data collections and data analysis. Chapter six deals with conclusion and recommendation based on this study.

2 LITERATURE REVIEW

2.1 Study on Mongolian forest resource changes

In outlook of history, basic steps of reforestation such as breeding and tree seedling places, nursery places, and semi-mechanized brigade of reforestation were established in 1970. In 1980, there were Independent Ministry of forestry, about 60 wood industries, including approximately 10,000 employees. Forest sector was producing a 15 percent of GDP, and 18-20% of total product was exporting in abroad.

In 1990, Mongolian forestry sector has went down hill due to the transition to a market economy. In this period, forest policies and structure of forest sector were escaped and had stopped all of professional training over the country. At the same time, Under these same time, has been intensifying desertification, furthermore increased forest fire, insects, and illegal logging in during the 2000 years. As a result, Mongolian forest was extremely degraded. Recently, Mongolian forest has damaged by insect affect a lot, forest fire could burtn many hectares area in every year, age structure has been changing in to maturity forest which is more than 60 percent of total forest resource. Economic contribution of forest sector has decreased into around 2 percent of GDP which it compared with early 1990s, contribution od forestry sector was accounting about 16 percent of GDP.
Therefore, in past few years, forest institutions and ministry of environment have been working to develop sustainable forest management in Mongolian forest sector.

In 1997, in order to implemented project “ co-owned forestry” by the United Nations, have started training workshops and seminars about how can be protect and utilize forest products for first 4 co-owned forestry. It was pretty new concept in my country. Since 2012, Government Agency and Forest department have implemented co-owned forest management sector. The basic unit of co-owned forestry is a community partnerships protecting forest area consisting of local residents.

The new Law on Forests is an up-date of the original Law, enacted in 1995 and last amended in 2002. The new Law defines and regulates the protection, ownership, utilization and rehabilitation of Mongolia’s “forest territory”. Mongolia became a partner country of the UN-REDD Programme in 2011. It was significant decision to develop forest management.

An according to new management, government's main point of policy for forest sector in 2015 wrapped up in to refer "forest sustainable management". This means that would be plan forestry planning on purposes to keep or increase forest growing reserves and stability. This decision was important action for development of forest sustainable management based on scientific research works. Recently, Researchers have been focusing on forest ecology, forest fire, harmful insect, forest policy and sustainable management. The published reports and papers contain a review of current forest management practices in Mongolia and analyzes how potential developments and changes in the forest sector. But currently, forest economic is totally new field in Mongolia. Researchers are starting to pay attention about sustainable forest management with ecological balance. In "Asia Pacific Forestry Sector Outlook Study II, Mongolia Forestry Outlook Study" (Hijaba Ykhanbai et al, 2010), expected changes in forest resources dynamics explained by most important variables such as environmental, climatic, human and economic factors for 2007-2021. Forest sector financing flows and economic values in Mongolia, presents the findings of a study on forest sector financing flows and economic values in Mongolia. (UN-REDD, 2013). They have focused on to analyze the economic value of the forest sector and related public financing flows, so as to identify point to potential entry points to mobilize additional financing for sustainable forest management and increase it's effectiveness and impacts.

Mongolia is defined forest policy and main goals of forestry on four major documents of the world. For example, in objectives of forest sustainable development of United Nation, is reflected several important concepts such as to stop destroy forest area and rehabilitation of degraded forest. Finally, Ministry of Environment's future 10 years goal is determined such as would be increasing forest resource and at during the same time would be increasing economic contribution of forest sector to utilize forest timber and non-timber product due to develop sustainable forest management.

A researh field of mongolian forest sector divided into major 2 fields such as first, a research about seedling, plantation and genetic etc that field is developing by forest engineers and experts, second field is forest economic. However, forest economic field is developing, in this field researchers focusing on law and legislation on forest sector (Tsogtbaatar.J, Forest Policy Development in Mongolia . 2015) which is telling that How is changing forest policy in Mongolia and How is impacting in this sector. Mongolia s policy priorities are focused primarily on combating forest fires and insect infestations, planting previously harvested or non-forested areas, and encouraging more efficient wood processing.

One of the major causes of forest degradation in Mongolia is forest fire and the long-term fire history of the Mongolian forests is poorly known, although the disturbance dynamics is one of the key questions in attempts to develop sustainable forestry practices. (Oyunsanaa et al., 2011) I was studied on Oyunsanaa's doctoral dissertation. The dissertation was focused on 2 tasks such as forest fire and forest stand dynamics. In generally, forest resources in Mongolia have increasingly degraded over the past few years, due to illegal timber cutting, forest fires, pests and diseases, which cause severe ecological stress in some regions. Although fire plays a natural role in Mongolia's ecology, anthropogenic fires generally result in ecological imbalance and economical damage. His first objective was to study the structure, dynamic pattern of different type of forests and specifically, to examine present tree species composition, regeneration pattern, size distribution, radial growth pattern of trees, composition and structure of downed logs within different type of forests. The results of this study will improve our understanding of the structure, dynamics and succession of old-growth mixed forests in north-west Khentey Mountains, Mongolia. Tree-ring analysis will enable the analysis of the fire history within the different forest stands (Heinselmen, 1973). Also, tree-ring analysis can determine the effect of growth rate (diameter increment) and age structure in relation to the fire history of the site (Baisan, 1990). His research of forest stands dynamic based on tree-ring method. According to tree-ring method, calculated indexes that are diameter structure, tree recruitment, growth pattern of trees and downed logs for five kinds of species in at the west mountain of Mongolia. Then he studied to explore the relationship between radial growth of different tree species and climatic variables such as monthly mean temperature, monthly total precipitation and steamflow impacts. Second, Oyunsanaa worked on that to understand a relationship between forest fire and other factors, also stand dynamics within different types of stands. He has obtained the result for four types species. In generally, his result of forest fire seasonality was fires occurred in the spring of that year and also fires was for the most period, constant and unchanging within each forest type.

A fire impact is huge in forest and steppe area in Mongolia. Researchers and experts working on that to know fire reason, to know a conditions fire distribution and fire risk by geographical area. Besides, researchers are using different methodology such as Modis Hotspot, Spatial analysis and tree-ring analysis. In paper of Hiroshi Hayasaka and Murad Ahmed Farukh, Sapporo, determined a relationship between forest and steppe fire and weather impacts such as temperature, precipitation, air pressure and wind speed for spring, summer, and autumn. In generally, their result was large fire occurrence tendency using hotspots clearly indicate that pasture fire occurred mainly in spring and forest fire occurred under drought condition or low summertime precipitation, and they have showed that wild land fire in Mongolia is mainly caused by humans (Hiroshi Hayasaki et al.,2012). This paper showed that weather impacts for season's how has been affecting for big fires.

Another paper which is analysis of wild fire risk estimated relationship between wild fire and main three group factors such as Environmental, Socio-Economic and Climate factors. There are climate factor consist of air temperature, rainfall, soil moisture and wind speed and direction and social-economic factor consist of number of population and number of Livestock, between 2000 and 2015 years. In additionally, they have estimated linear regression between wildfire and climate data. The dryness of the climate causes somehow ignites wildfires which is precipitation has low, meaning that there is a low amount of water vapor in the air, wildfires are more likely to start (Bylow et al., 2012). The statistic value of the correlation coefficient has 0.75, or 75 percent are dependent on precipitation (Elbegjargal Nasanbat et al., 2016). Finally, have estimated risk of fire in five other regions.

2.2 An International experience using Markov process in forest sector

In this section, I have study on International experience and orientation about application of Markov process in forest sector. Markov chains are useful tools in modeling many practical systems such as busines sector, risk some disease, labour structure in company and dynamics of forest stand and vegetation. Markov chain models have a large history of applications in biology, particularly, in the life cycle analysis (see Caswell, 2001). Markov chain models operating with the tree composition matrices have been used to predict the vegetation dynamics within forest stands (Usher, 1969; Acevedo et al., 1995, 2001; Mladenoff, 2004).

Kent, Brain M Dress and Peter E (1980) developed model that is a single-stage-time dependent Markov chain is incorporated to model stand dynamics over. Samples of distance squared data are taken at different stand ages for all generate stands. There is used Weibull distribution with Markov chain.

Also, a Markov chain model was developed to predict the development of foreststands and landscapes (Ching-Rong Lin, Joseph Buongiorno et al., 1999). In this paper, they have built a transition probabilities between stand states were obtained with a non-linear matrix growth model by Monte-Carlo simulation. A result of this paper shows that Markov chain framework provides a naural way to describe the landscape diversity of disturbed or undisturbed forests, based on the proportional abundance of stands in different states.

According to the paper by Jean F.Leanard, Dominique Gravel and Nikolay S.Strigul, method which is approached Markov chain is useful conservation and silviculture, and for sustainable forest management (Jean F.Leanard et al., 2014). This work presents that prediction of long-term dynamics of the forest stands by computing the equilibrium states of the transition matrices in 2010s, 2020s and 2030s based on distribution in 2000s.

Another researchers developed a Markov chain approach for the modeling of forest stand dynamics that is stage-structured dynamics of forest stands for 3 kinds of species which are boreal broadleaf, boreal coniferous and boreal mixed wood. A result shows that Pollution and climatic changes caused by anthropogenic activities may disturb forested ecosystems at the stand and landscape level by affecting tree growth and nutrient cycles (Nick Strigul, Lonut Florescu, Alicia R.Welden Fabian Michalcze et al., 2012).

2.3 Study on Sustainable Forest Management of the International experience

In this section, I have study on International experience and orientation about Sustainable Forest Management. This section summarizes knowledge and experiences in forest management as a response to climate change, based on a literature review and a survey of forest managers which is implemented by FAO.

In general, climate change will affect the forest conditions (area, health and vitality and biodiversity), allowing increases in growth rates in some areas while endangering the survival of species and forest communities in others. Temperature, availability of water and changes in seasonality may all become limiting factors, depending on geographic area, original climatic conditions, species diversity and human activities. Most commonly, these changes will affect the frequency and intensity of fires and insect pests and diseases, as well as damage done by extreme weather conditions, such as droughts, torrential rains and hurricane winds.

Reviews by Lucier *et al*., (2009) and Fishlin *et al*., (2009) on detected impacts, vulnerability and projected impacts of climate change on forests found that impacts varied across the continents with some forest types being more vulnerable than others. Impacts included increased growth, increased frequency and intensity of fires, pests and diseases and a potential increase in the severity of extreme weather events (e.g. droughts, rainstorms and wind). Human activities, including forest conservation, protection and management practices, interact with climate change and often make it difficult to distinguish between the causes of changes observed and projected. Deforestation and fires in the Amazon region, for example, form a vicious circle with climate change (Aragão *et al*., 2008, Nepstad *et al*., 2008), with the potential to degrade up to 55% of the Amazon rain forests (Nepstad 2008, Nepstad *et al*., 2008).

The climate and weather conditions' changes are effected on forest composition, diversity and processes for the major forest type in different parts of the world. Many of the world's forests and woodlands, especially in the tropics and subtropics, are still not managed sustainably. Some countries lack appropriate forest policies, legislation, institutional frameworks and incentives to promote sustainable forest management, while others may have inadequate funding and lack of technical capacity. Where forest management plans exist, they are sometimes limited to ensuring the sustained production of wood, without paying attention to the many other products and services that forests offer . At the same time, other land uses such as agriculture can seem financially more attractive in the short term than forest management, motivating deforestation and land-use changes.

China has made great strides in increasing its forested area and standing volume over the past two decades, largely attributed to sustainable forest management. Forest management in China has gone through two stages, i.e. timber-oriented forest management that once caused several problems such as depletion of forest resources, soil erosion and desertification before 1990s, and sustainable forest management after the 1990s. The practice of sustainable forest management in China mainly includes continuous efforts through government initiatives to restore degraded landscapes and encourage production orientated plantations through its six key forestry programs, providing policies, encouraging community-based forest management, and individualizing forest management in collective forest regions. The six key programs, lasting ten to 15 years, cover 97 percent of all China's counties and 760 million hectares of trees will be planted under the programs. Their aim was to protect natural forests, wildlife and natural reserves, to prevent soil from eroding and grassland from turning into desert.

China is still faced with challenges, including limited suitable areas for afforestation/reforestation, balancing the demands between economic requirements and ecological needs from forests, improving the quality of forests to improve its protective functions and ecosystem services.

China’s sustainable forest management system has therefore made great contributions to the “dual increase” of both the forest area and forest stock volume.

2.4 Comments

Firstly, I would like to discuss about SFM between Mongolia and other countries. An experince on sustainable forest management of international countries and China has been indicating that they could protect forest and biomass, kept balance of ecology, and moreover they have been earning a lot of money form forest sector due to managing sustainable. These positive changes are affecting into income of households and develop of rural cities.

Mongolia should be manage policy of forest sector sustainablity , we would be decided current problmes such as ecological, economical and social problems. An other hand, SFM is developing Forest economics in country. Forest economics deals with the choices that are How forest are managed and used, How other factors of production such as Labor, Capital are used in wood production, forest utilization and forest conservation and How much products are produced and marketed etc.

Mongolian forest is old aged and used unsustainable. At the same time, the increasing population and rapid economic growth have caused huge demands for timber and given the problems in Mongolia.

Moreover, we can be applied efficient management for forest sector, should be based research and results. Mongolian research field and methodology has been developing too at the same time in forest sector. An institutions and division of MEGD has been working to create database to provide information for researchers. But lack of correspondence between the departments such as forestry and mathematics, hydrology and mathematics is the reason that to maintain slowly and uniform development of departments.

Second, Markov chains are useful tools to predict forest stand dynamics with other mathematical tools and other many kinds of dataset and levels. The papers of applications of Markov chains were written by mathematicians due to this methodology is required mathematic knowledge. Therefore, collaboration between other departments can be developed research area and research field, as well as can be get efficient results for sustainable management forest sector.

3 AN ANALYSIS OF FOREST RESOURCE AND FOREST POLICY IN MONGOLIA

3.1 Geographical current situation of Mongolia

Mongolia is a landlocked country situated in Central Asia, occupying a unique geographic location between 41035' and 52009' North latitudes and 87044' and 119056' East longitudes. Its territory comprises 156.65 million hectares (ha), and it shares borders with Russia and China.

Source: https://www.pinterest.com/pin/378513543652542027/

图3- 1蒙古国地图

Fig.3-1 The Map of Mongolia

Average elevation is1,580m, however, over 80% of the country lies above 1000 m. The lowest point is Khoh Nuur in the eastern Dornod Steppe at 518 m and the highest point is Khuiten Uul in the Mongol Altai at 4,374 m. Mongolia is situated on a major continental watershed that is aligned roughly east-west. North of this line, rivers flow either to the Arctic Ocean (Selenge and Orkhon) or the Pacific Ocean (Onon, Kherlen and Khalkhiin). South of the line all rivers flow to the Central Asian Depression, which has no outlet. Climate is extreme dry continental, with marked variations in both seasonal and diurnal temperatures.

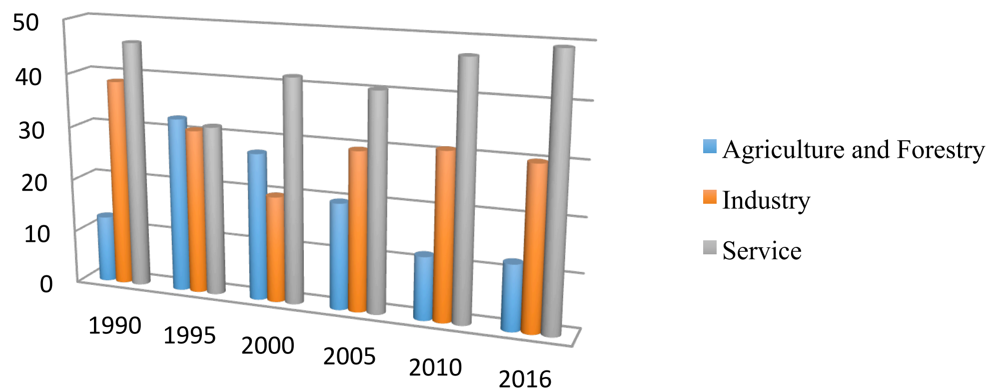
Mongolian total land area spans the major transition zone between the deserts of Central Asia and the Boreal Taiga of Siberia and comprises six broad biogeoclimatic zones, such as desert, desert steppe, steppe, forest steppe, boreal forest and montane.

3.2 Socio-Economical condition of Mongolia

Mongolia has a population of about 3.12 million people. Eighty percent of the population is Kalkh Mongol, however, the government recognizes about 20 ethic groups; mainly Mongol but also including Turkic-speaking Kazakhs, Khotons and Tsaatans in western parts of the country.

The population is very young, almost 70% are under 35 years of age - due to significant government family subsidies in the 1960s and 1970s, when the growth rate was 2.9% (the highest in Asia) and the population almost doubled in twenty-five years. Since the late 1980s, the growth rate has fallen to an estimated 1.4% in 2001, in past years growth rate of population has been increasing to an estimated 20.5% in 2016. The life expectancy is 66 years for man, 77 years for woman and the literacy rate at age 15 is 97%, surely one of the highest in the developing world.

Gross domestic production 1990, 2000, 2016 were apportioned 12%, 27%, 12% to agriculture, 39%, 20%, 30% to industry and 46%, 42%, 49% to services, respectively.



Source: Statistical Yearbook, NSO, 2016

图3-2按生产部门的国内总产值（百分比）

Fig. 3-2 Gross Domestic Production by sector (percent)

Out of a total employed population of 1,151,200 people, 28% worked in agriculture, 18% in industry and 54% in service or other sectors. Semi-nomadic livestock production accounts for over 70% of agricultural returns, with the balance made up of cold-climate crops such as wheat, barley, potatoes and domestic fodder on the small area of available arable land.

Per Capita Income. The economic reforms and privatization process initiated in the early 1990s have significantly affected Mongolia s economy. Over the period 1990 to 2016 the standard of living of the average Mongolian has worsened. GDP per capita declined from USD 1,671 in 1989 to around USD 572 in 2002 and has ben rising back into USD 3,704 in 2016. Almost half of the active labor force is reportedly now involved in agriculture (primarily in the livestock sector), and in formal and informal resource exploitation activities, forest products harvesting, hunting and gold mining due to 1990s transition economic situation. These illegal activities have been continue active till 2000s. With respect to the latter activity, Grayson (pers. comm.) reports significant consumption of woody fuels in northern Aimags to heat water to melt frozen river gravels in order to ensure that at least a minimal level of artisanal alluvial gold extraction can continue through the winter. In past 10 years, Legacy institution has been settled and improving in every sector, its would controlling illegal activities of labor force.

Continued Urban Drift. A process of rapid urbanization began in 1960 and peaked in 1990 at 57 per cent. Economic difficulties experienced in the mid-1990s reversed this trend but by 2011 the urban share of the total population was back at its 1990 peak percentage. The population of Ulaanbaatar in particular continues to grow quickly and in 2011 it accounted for about a third of the country s population. Urban drift is occurring for both economic (i.e. jobs) and social (i.e. health and education) reasons. This shift to an urban population, combined with the cessation of transportation subsidies, places disproportionate demands on those forest areas near urban center to meet fuel wood needs for heating and cooking. Besides, in past 10 years, construction and infrastructure have been developing rapidly, its one of the reason of wood consumption.

High Unit Transport Costs. A significant constraint to economic development and poverty alleviation in rural areas is the high unit transport cost due to the vastness of the country, poor access and the low population density. Affordable access is a factor that will feature prominently in the design of future poverty alleviation strategies, in the viability of rural based commercial activities and in sustainable resource.

3.3 Forest resources in Mongolia

Forest reserve lands comprise 18.3 million hectares, with 12.9 million hectares of forest-covered area; this includes 10.5 million hectares of coniferous and hardwood forests, which is equivalent to 67 percent of the forest reserve.

The forested areas of Mongolia can be divided into two broad types: the northern coniferous forests of the Forest Steppe, Boreal Forest and Montane zones, which form an ecological transition between the Siberian Taiga and the Central Asian Steppes; and Saxaul forests of the southern desert and desert steppe.

In Southern Desert and Desest Steppe zone, almost all saxaul forests are contained in five aimags which are Umnugovi (46%), Govi-Altai (27%), Khovd (12%) and Bayankhongor (8%), and Dornogovi (6%) (NSO & MNE 2014). In the northern Boreal Forest and Forest Steppe zones, over 90% of northern forests are contained in seven aimags which are Khuvsgul (29%), Selenge (16%), Bulgan (14%), Khenti (11%), Tuv (10%), Arkhangai (8.5%), and Zavkhan (5%) (NSO & MNE 2014).

Source: MEGD

圖3-3森林面积和蒙古国的常见树种

Fig.3-3 Forestet areas and common species in Mongolia

表 3-1 10 种最常见树种的生长量表
Tab.3-1 Growing stock of the 10 most common species

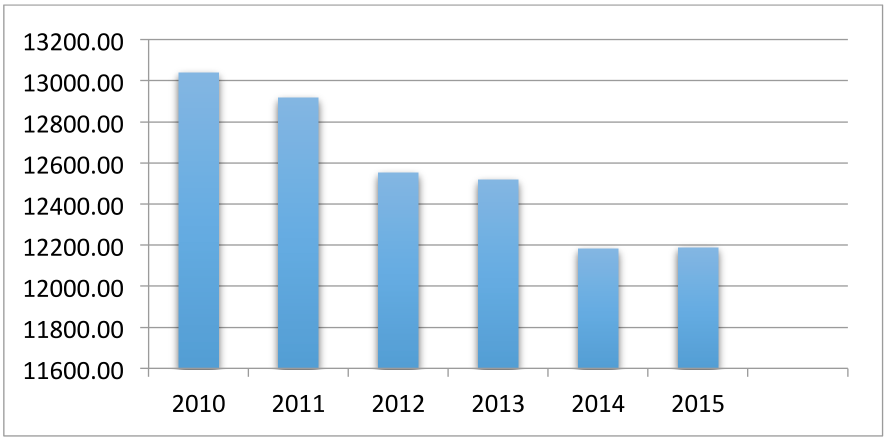
	Species name		Growing stock in forest (million m3)				
Rank	**Scientific name**	**Common name**	**1990**	**2000**	**2005**	**2010**	**2014**
1	*Larix sibirica*	Siberian larch	1 123.7	1 043.0	10 330	1058.5	977.1
2	*Pinus sibirica*	Siberian pine	180.6	167.7	150.5	126.8	116.1
3	*Pinus sylvestris*	Scots pine	99.9	92.8	97	66.7	61.8
4	*Betula platyphylaa*	Birch	90.6	84	89.4	86.5	76.8
5	*Picea obovata*	Siberian spruce	4	3.7	3.7	3.6	2.9
6	*Populus spp*	Poplar	3.8	3.5	3.3	2.4	2.2
7	*Salix berberifolia*	Willow	1	0.9	0.6	1.8	3.4
8	*Abies sibirica*	Siberian fir	0.4	0.4	0.4	0.24	0.24
9	Populus tremula	Aspen	n.a.	n.a.	n.a.	1.3	0.7
10	other	other	n.a.	n.a	n.a.	1.55	1.91
TOTAL			**1 504**	**1 396**	**1 379**	**1349.5**	**1243.2**

Source: FAO, 2014

Mongolian forest resource is consist of about 140 species of trees and shrubs that are divided into 2 groups such as coniferous forest (larch, pine, spruce, fir), and broad-leaved forest (birch, poplar, ulmus, brush). There is about 10 kinds of species of which dominant species is Siberian Larch (Larix Sibirica) that is 78.6 percent of total forest covered area.

The details are shown in Tab. 3-1.

Climatic influences, especially reduced precipitation over the past 20 years, have increased susceptibility to forest fires. Fire risk is high approximately 75 percent of the time, and 80 percent of fires are caused by careless human activities. Approximately 40 percent of Mongolia's forests are already suffering from degradation as a result of detrimental human activities, insect damage and fire.



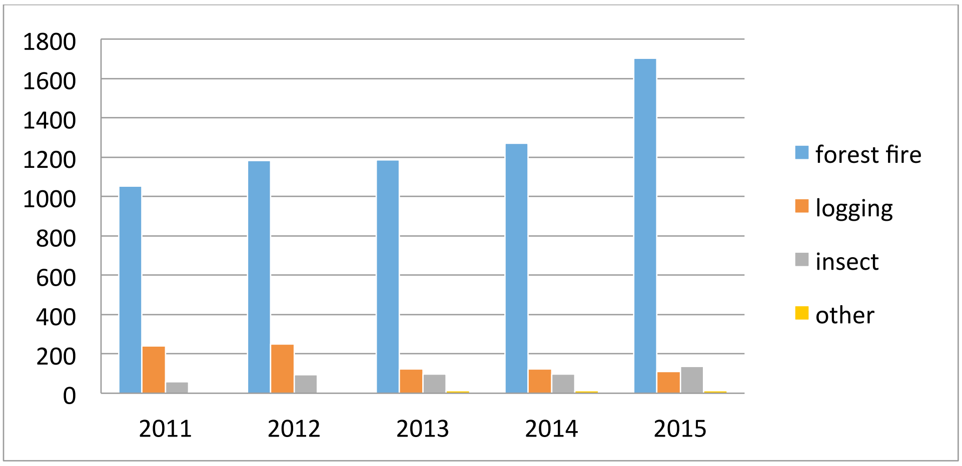
Source: Annual Bulletin by year, NSO

图3-4 林地总面积,（千公顷)

Fig.3-4 Total forested area, (thousand hectare)

Past year's statistic shows Mongolian forest is decreasing and changing into old aged forest classification. There is 74 percent of total forest resource is old aged forest. In 2015 year, Mongolian forested area was 12,188.2 thousand hectare and in compared with 2010 year's statistic, forested area has decreased by 864.5 thousand hectare and non-forested area has increased by 1052.3 thousand hectare respectively.

The important causes of deforestation and forest degradation are fire, overgrazing, mining activity, improper commercial logging, illegal collection of wood for construction and for use as fuel, hay making in forest steppes, complacency in enforcement of forest rules and regulations, and damage by pests and diseases.



Source: Annual Bulletin, NSO

图3-5 森林资源变化图，（按主要因素划分）（千公顷）

Fig.3-5 Forest resource change, by main factors (thousand hectare)

There are some main reasons of forest resource is changing.

Forest fire: An important factor that impacts negatively on forest ecosystems in Mongolia is forest fire. Since 1990, 6.47 million hectares have been damaged by forest fire. The frequent fires damage and destroy newly planted forest areas, have adverse effects on river flows and generate forest soil erosion. Increasing forest degradation is increasing the potential and likelihood of forest fires.

Insects harmful: A combination of factors, led by forest fires and creation of young and new growth forests are increasing vulnerability to infestations by harmful forest insects. Forest insects in Mongolia comprise 7 groups, 56 families, 168 types and 315 species. Insects that eat leaves, needles, stems and bark are causing increasing damage in Mongolian forests.

Timber Harvest and Wood consumption: Forest research centres and forest scientists estimate “allowable cuts” to be harvested from the forest resource each year. These estimates have been based on assessments of Mongolia’s climate and environment to provide water protection and ecological balance, and prevent adverse effects on forest reserves. During the last few years, the allowable cut has been reduced rapidly, because of severe impacts on forest ecology, especially increasing damage by fires, insect diffusion and other factors. Shortages of quality wood to supply domestic households’ and manufacturers’ demands have focused the government’s attention on importing wood and wooden products. Wooden materials have been exempt from import tax since 2005.

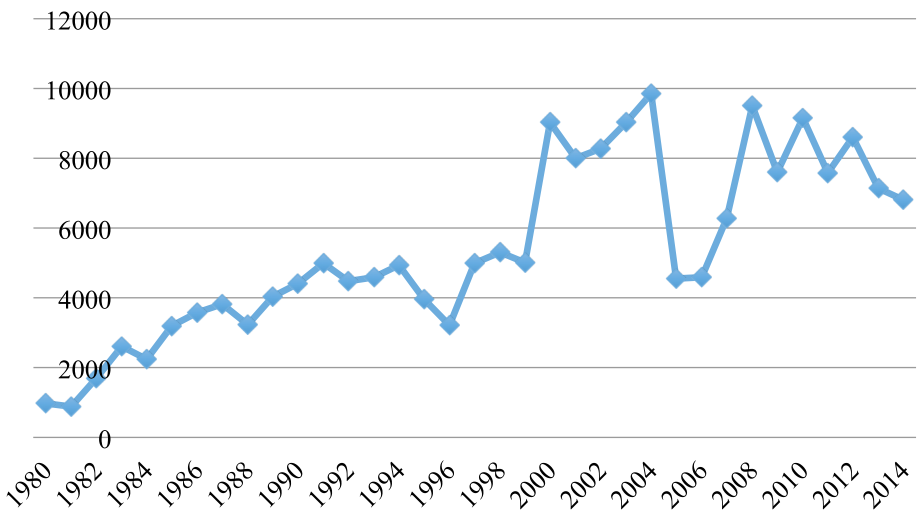
Desertification and drought: Mongolian climate has been changing fastly in over past 60 years. The danger of desertification has been increasing year by year.

Grazing land and forest: Mongolia's basic economic sector is agriculture and this contributes 35 percent of the GNP, and accounts for approximately one-quarter of the country's exports. Agricultural potential is directly related to climatic conditions. Animal grazing in the edges of forest areas often exceeds the ecological carrying capacity and hence, negatively impacts on forest regeneration.

Illegal logging: Currently between 36 percent and 80 percent of Mongolia's total timber harvest is categorized as illegal. That is, the government receives no royalties or taxes on this and it severely distorts domestic prices for both construction wood and fuel wood. Fuel wood currently constitutes between 65 percent and 80 percent of the total wood harvest and is used by many poor rural and urban households for both cooking and residential heating.

Mining Industry: Mining industry incur costs to rehabilitate and revegetate degraded lands and to carry out forest components of environmental management plans, as required by Mongolian law. For example, around 40 hectares ha of forest land is recorded as having been degraded as a result of mining in 2010, and there are currently 759 exploration or mining licences which cover almost 1.5 million ha of boreal forest (MEGD 2013).

Reforestation : Mongolia's reforestation activity was started in 1971. Since 1971, re-afforestation activity has been regulated by the State Central Plan and directive. Reforestation activities totally 197.1000 ha area which is only 30% of total logged area in the country.

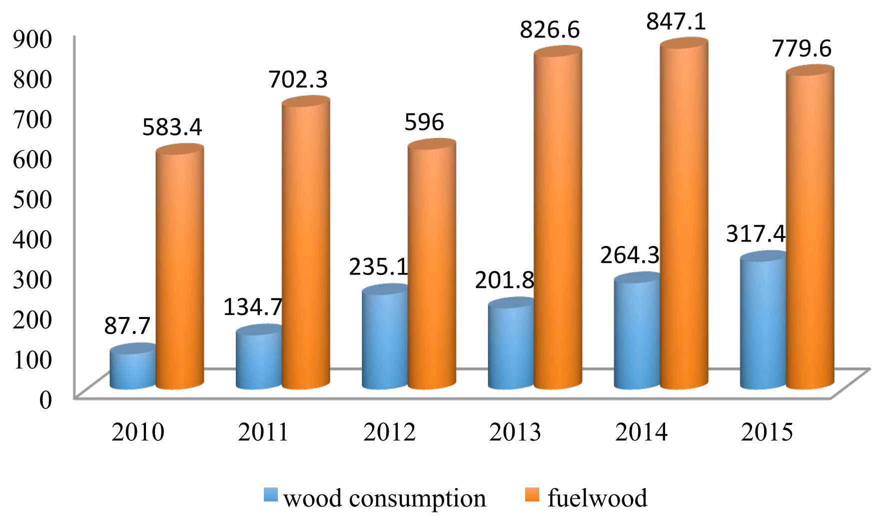


Source: Annual Bulletin, NSO

圖 3-6 过去 35 年中植树造林面积（公顷）

Fig.3-6 Reforestation in past 35 years, (ha)

During past 6 years, ministry of environment and green development has decided quantity of cut tree from forest is about 670,0 thousand cubic meter per year, which of 14% was for construction and other activities, 86% was fuel wood.



Source: Report of Forestry, MEGD, 2015

图 3- 7 按类别的木材消耗量，立方米

Fig. 3-7 Wood consumption by category, (cubic meter)

There is total wood consumption is determined 3,1 million cubic meter of which fuel wood is 66.3 percent and 33.7 percent for others per year based on research.

Contribution of Forest sector to Mongolian economy

The forest industries' share in the GNP has declined during the past 20 years. At present, the forest industry contribution to the GNP is 5-billion tugrug. (1.3 percent of the GNP), and the wood processing sector contributes 4-5 billion tugrug (1.2 percent of the GNP). The total forestry sector contribution to the GNP is 2.6 percent.

表3-2 蒙古国与世界相关森林统计数据比较表

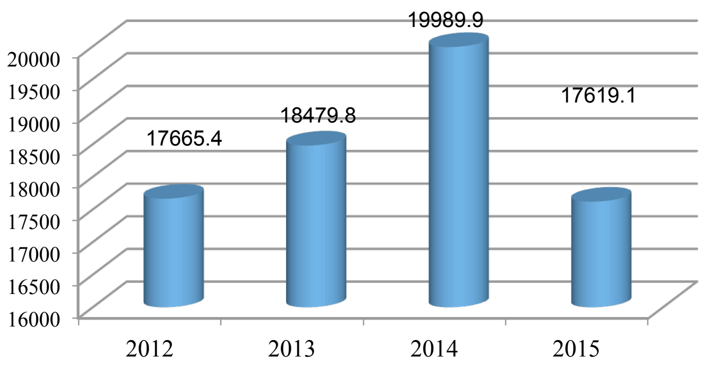
Tab.3-2 Compared statistics of forest between Mongolia and the world

№	Index	Average of the world	Mongolia

1	Forest Abundance, (million hectare)	11.5	18.3
2	Maturity forest under 80-years, (%)	16.5	76-78
3	Percentage of forest land, (%)	46.4	6.5
2	Forest resource, (million cubic meter)	1.8	1.3
5	Forest resource per ha, (cubic meter)	195	140
6	Average wood consumption per year, (million cubic meter)	39.7	1
7	Growth rate of forest, (million cubic meter)	52.1	10.5

Source: Report of MEGDT, 2015

Industry :A totally about 450 enterprises have been working in forest sector with 5000 employers in whole country including 21 aimags and capital city. They supply 2-3% products of total industryof Mongolia. Main activities are logging, sanitation cutting and manufacturing such as timber, strips, furniture, wooden house, musical instrument, wooden toy, suvenier and briquitte.

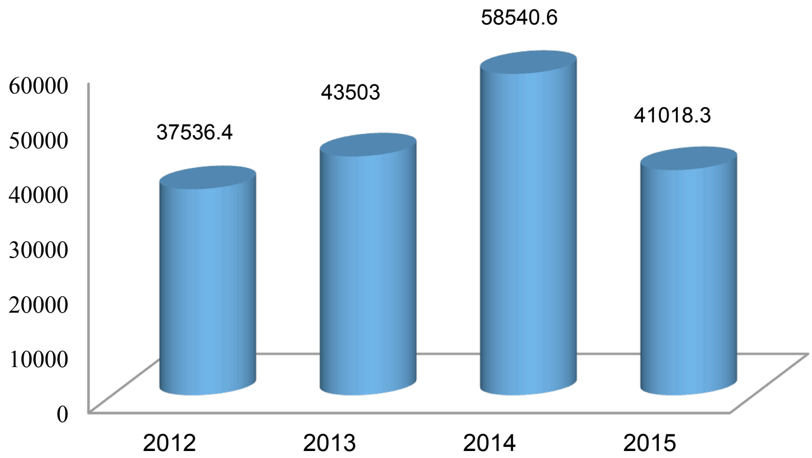


Source: Report of MEGDT, 2015

图 3- 8 生产的木材和木制品（千美元)

Fig.3-8 Produced wood and wooden products (thousand dollars)

Fig.3-7 shows that domestic production and domestic supply of wood and wooden products. According to statistical data, supply of wood and wooden product has increased by 2000 thousand dollars in 2014. The one of reason was government launched morgage loan for apartment and construcrion sector has been working intensive.



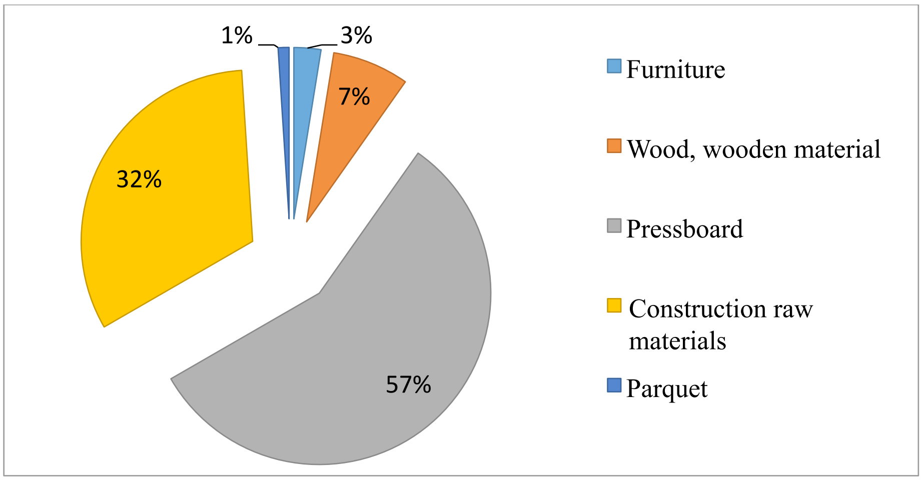
Source: Report of MEGDT, 2015

图 3-9 进口木材和木制品（千美元)

Fig.3-9 Imported wood and wooden products (thousand dollars)

Fig.3-8 presented that imported wood and wooden product at the same years with Fig.3-7. Supply of imported wood and wooden products is 2 times more than domestic production in every year. Wood, wooden product and furniture are consist of 45% from domestic production and 55% from imported products. (except fuel wood)

- In formal stattistic, enterprises of forest sector has produced wood wooden product of 14-18 billion tugrug in during 3 years. But in informal statistic shows they have produced 100-110 billion tugrug's product supplied in last 3 years.
- Domestic enterprises supply domestic demand of furniture such as kitchen furniture and doors more than 50 percent.



Source: Statistical yearbook, NSO, 2014

图 3- 10 木材和木制品的进口结构，2014 年（千美元）

Fig.3-10 Import structure of wood and wooden product, in 2014 (thousand dollars)

Key problems:

- A supply of wooden raw material;
- Should be start construct forest trajectory due to implementing program of "Sanitation cutting";
- To estimate enterprises that to produce boards, briquette to using forest product after sanitation cutting
- To improve technique and technology of logging
- to organize training and workshop for new experts,
- To prepare experts due to organizing training work shop, sharing information and associate with universities
- To establish a market of wood and wooden materials

According to Mongolian Forestry Outlook Study 2010, there is economic contribution of forest sector is calculated US$ 284 million a year based on formal and informal statistics which is shown by some sub-sectors.

- Timber and fuelwood (permitted and illegal) have around US$ 142 million which over half of this value comes from unlicensed operations.
- Non-timber forest products such as fruits and medical plants have a total value US$ 12 million a year. Also, more that 90 percent of this value consist of home consumed products that never enter the market.
- Hunting activity under permit produces value between US$ 65 thousand and

US$ 1.9 million.

- Pasture for livestock from boreal forest has value US$ 24.7 million.
- A tourism based forest makes a direct contribution of 39.73 million. Tourism is including wage earning, sales and capital formation.
- Forest watershed protection services in the Upper Tuul basin alone are US$ 19.6 million a year to urban water users (Ykhanbai et al., 2013).

Non-wood forest product resources

Mongolia has registered more than 600 species of medicinal herbs, more than 1 000 species of nutritional herbs, over 200 species of herbs for food and more than 200 species of technical herbs. Most of these herbs are found in forests (Ykhanbai et al., 2013).

A list of the major non-wood forest products and uses in Mongolia includes:

- Fruits and nuts
- Cones
- Mushrooms
- Medicinal herbs, raw materials
- Herbs for food
- Other herbs, raw materials
- Wild animals
- Bark for various uses
- Saps and pitches (tapped)
- Animal grazing
- Hay making

Ministry of Environment and Green Development records show that, in 2010, just over 300 tonnes of spruce and pine nuts, wild berries and other non-timber forest product were collected under permit in boreal forest aimags. At current market prices these may have a value of between MNT 1.5-2.7 billion (US$ 1-2 million), depending on whether they are home-consumed or sold. It should be noted that this figure is substantially higher than that cited in a 2004 FAO report, which estimates that fruits, nuts, essential oil and resins with a market value of about US$360,000 or MNT 0.5 billion at today's prices were harvested from forests and supplied to domestic markets (Ykhanbai et al., 2009).

Unfortunately, economic contribution of non-timber forest product is close to zero in Mongolia also, have not collecting data about quantity of resource of non-timber forest products.

3.4 Forest Policy and Management in Mongolia

The main objective of forest resource management is to protect and develop the existing forests of Mongolia so that they make maximum contributions to soil and watershed protection, and conservation of existing ecosystems. Also, the forests are expected to produce, on a sustainable basis, increased volumes of industrial wood, fuel wood and minor forest products for the needs of people, and earn foreign currency through the export of wood products.

In history of forest sector, a number of general economic and social trends have emerged over the period of economic transition since the late 1980s, which have significant implications for the protection, conservation and utilization of forest and other natural resource values in Mongolia. Prior to 1974, forestry was a department associated with the Ministry of Agriculture. Between the early 1970s and the mid-1980s, rates of forest exploitation increased dramatically, peaking at between 1.8 and 2.8 million m^3 from the late 1970s to 1988 (Mongolia Forestry Sector Review, 2004).

Since 1994, the Government of Mongolia has expended a considerable amount of effort to develop policy and legislation to guide and regulate its transition towards a market economy. Then A National Forest Policy was prepared in 1998. A NFP focused on forest utilization, forestry resources, conservation and social welfare concerns. Three of the seven objectives of the document dealt with exploitation and utilization of forest resources, illustrating the preoccupation of the government at that time. The forest policy was revised in 2001 as the National Programme on Forestry (NPF). This document represented a shift in government priorities away from utilization towards conservation and protection. Two of the NPF's five objectives, related to improve forest management, two to conservation and only one to utilization. The National Forest Policy priorities are institutional restructuring, fire and pest management, reforestation and efficiency of timber processing. Several of Mongolia's environmental laws have implications for forest management.

The Law on Forests (MLF), enacted in 1995 and amended in 2000, 2002 and 2007 provides the basic framework for the protection, proper use and regeneration of Mongolian forest. Also, Mongolia is signatory to several international treaties with important implications for forest management.

Forest ownership cooperation

Forest ownership legislation framework consist of following two laws such as The Law on Forest (MLF) amended in 2007 and Government supported “The rule of forest ownership” in 2009. Since 2009, public owned forest management has been implementing and forest cooperation and company has been owned forest area by contract.

表 3-3 森林所有权和森林面积

Tab.3-3 Forest ownership and forest area

Index	**2011**	**2012**	**2013**	**2014**
Number of forest cooperation	541	631	1062	1179
Community forest area (ha)	1 342 644	1 854 725	2 310 663	3 074 744

Source: Annual Bulletin, NSO

In concluding, Mongolia’s policy priorities are focused primarily on combating forest fires and insect infestations, replanting previously harvested area or non-forested areas, and encouraging more efficient wood processing. The legislation regulating forest management appears to be reasonably comprehensive. However, it severely constrains the area of forest land available for utilization and limits the type of timber harvesting systems that may be used. The legislation also devolves considerable responsibility to local levels of government that appear to have neither the resources nor the experience necessary for effective implementation.

4 A THEORY OF MODELS FOR FOREST STAND DYNAMICS

4.1 Regression Models

In this chapter,we have dealing with linear and nonlinear regression model in mathematical theory. We estimated some problems such as determined main factors of forest resource's changes, predicted main factor's and forest resource's changes in the future whit using regression linear and nonlinear models.

Considered details of the theory of regression model given by Johnston and Dinardo, Eonometrics, 1997 is as following,

In a simple linear regression model, a single response measurement Y is related to a single predictor (covariate, regressor) X for each observation. The critical assumption of the model is that the conditional mean function is linear: E(Y |X) = α + βX. In most problems, more than one predictor variable will be available. This leads to the following "multiple regression" mean function:

$$E(Y|X) = \alpha + \beta_1 X_1 + \cdots + \beta_p X_{p,}$$

where α is called the intercept and the β_j are called slopes or coefficients.

Going one step further, we can specify how the responses vary around their mean values. This leads to a model of the form

$$Y_i = \alpha + \beta_1 X_{i,1} + \cdots + \beta_p X_{i,p} + \epsilon_i$$

which is equivalent to writing $Y_i = E(Y|X_i) + \epsilon_i$.

We write $X_{i,p,}$ for the j^{th} predictor variable measured for the i^{th}observation.

The main assumptions for the errors ϵ_i is that $E\epsilon_i = 0$ and $var(\epsilon_i) = \sigma^2$(all variances are equal). Also the ϵ_i should be independent of each other.

For small sample sizes, it is also important that the ϵ_i approximately have a normal distribution.

Multiple regression in linear algebra notation

We can pack all response values for all observations into a n-dimensional vector called the response vector:

$$Y = \begin{pmatrix} Y_1 \\ Y_2 \\ \cdots \\ \cdots \\ \cdots \\ Y_n \end{pmatrix}$$

We can pack all predictors into a $n \times p + 1$ matrix called the design matrix:

$$X = \begin{pmatrix} 1 & X_{11} & X_{12} & \cdots & X_{1p} \\ 1 & X_{21} & X_{22} & \cdots & X_{2p} \\ & & \cdots & & \\ & & \cdots & & \\ 1 & X_{n1} & X_{n2} & \cdots & X_{pp} \end{pmatrix}$$

Note the initial column of 1's. The reason for this will become clear shortly.

We can pack the intercepts and slopes into a $p + 1$-dimensional vector called the slope vector, denoted β:

$$\beta = \begin{pmatrix} \alpha \\ \beta_1 \\ \cdots \\ \cdots \\ \cdots \\ \beta_p \end{pmatrix}$$

Finally, we can pack all the errors terms into a n-dimensional vector called the error vector:

$$\varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdots \\ \cdots \\ \cdots \\ \varepsilon_n \end{pmatrix}$$

Using linear algebra notation, the model

$$Y_i = \alpha + \beta_1 X_{i,1} + \cdots + \beta_p X_{i,p} + \epsilon_i$$

can be compactly written:

$$Y = X\beta + \epsilon$$

where $X\beta$ is the matrix-vector product.

In order to estimate β, we take a least squares approach that is analogous to what we did in the simple linear regression case. That is, we want to minimize

$$\sum_i (Y_i - \alpha - \beta_1 X_{i,1} - \cdots - \beta_p X_{i,p})^2$$

over all possible values of the intercept and slopes. It is a fact that this is minimized by setting

$$\hat{\beta} = (X'X)^{-1}X'Y$$

$X'X$ and $(X'X)^{-1}$ are $p+1 \times p+1$ symmetric matrices.

$X'Y$ is a $p+1$ dimensional vector.

The fitted values are

$$\hat{Y} = X\hat{\beta} = X(X'X)^{-1}X'Y,$$

and the residuals are

$$\hat{r} = Y - \hat{Y} = (I - X(X'X)^{-1}X')Y.$$

The error standard deviation is estimated as

$$\hat{\sigma} = \sqrt{\sum_i r_i^2 /(n-p-1)}$$

The variances of $\hat{\alpha}, \hat{\beta}_1, \dots, \hat{\beta}_p$ are the diagonal elements of the standard error matrix.

$$\hat{\sigma}^2 (X'X)^{-1}.$$

We can verify that these formulas agree with the formulas that we worked out for simple linear regression (p = 1). In that case, the design matrix can be written:

$$X = \begin{pmatrix} 1 & X_1 \\ 1 & X_2 \\ \dots & \dots \\ \dots & \dots \\ 1 & X_n \end{pmatrix}$$

So

$$X'X = \begin{pmatrix} n & \sum X_i \\ \sum X_i & \sum X_i^2 \end{pmatrix} \quad (X'X)^{-1} = \frac{1}{n\sum X_i^2 - (\sum X_i)^2} \begin{pmatrix} n & \sum X_i \\ \sum X_i & \sum X_i^2 \end{pmatrix}$$

Equivalently, we can write

$$(X'X)^{-1} = \frac{1/(n-1)}{\text{var}(X)} \begin{pmatrix} \sum X_i^2/n & -\overline{X} \\ -\overline{X} & 1 \end{pmatrix}$$

and

$$X'Y = \begin{pmatrix} \sum Y_i \\ \sum Y_i X_i \end{pmatrix} = \begin{pmatrix} n\overline{Y} \\ (n-1)Cov(X,Y) + n\overline{Y}\,\overline{X} \end{pmatrix}$$

$$(X'X)^{-1}X'Y = \begin{pmatrix} \overline{Y} - \overline{X}Cov(X,Y)/Var(X) \\ Cov(X,Y)/Var(X) \end{pmatrix} = \begin{pmatrix} \overline{Y} - \hat{\beta}\,\overline{X} \\ \hat{\beta} \end{pmatrix}$$

Thus we get the same values for $\hat{\alpha}$ and $\hat{\beta}$.

Moreover, from the matrix approach the standard deviations of $\hat{\alpha}$ and $\hat{\beta}$are

$$SD(\hat{\alpha}) = \frac{\sigma\sqrt{X_i^2/n}}{\sqrt{n-1}\sigma_X}$$

$$SD(\hat{\beta}) = \frac{\sigma}{\sqrt{n-1}\sigma_X}$$

Sums of squares

Just as with the simple linear model, the residuals and fitted values are uncorrelated:

$$\sum (Y_i - \hat{Y}_i)\,(\hat{Y}_i - \bar{Y}) = 0.$$

Thus we continue to have the "SSTO = SSE + SSR" decomposition

$$\sum (Y_i - \bar{Y})^2 = \sum (Y_i - \hat{Y}_i)^2 + \sum (\hat{Y}_i - \bar{Y})^2$$

Here are the sums of squares with degrees of freedom (DF):

Source	Formula	DF
SSTO	$\sum (Y_i - \overline{Y})^2$	*n-1*
SSE	$\sum (Y_i - \hat{Y}_i)^2$	*n-p-1*

SSR $\sum(\hat{Y}_i - \overline{Y})^2$ p

Each mean square is a sum of squares divided by its degrees of freedom:

$$MSTO = \frac{SSTO}{n-1}\ MSE = \frac{SSE}{n-p-1}\ ,\ MSR = \frac{SSR}{p}$$

The F statistic

$$F = \frac{MSR}{MSE}$$

is used to test the hypothesis "all $\beta_i = 0$" against the alternative "at least one $\beta_i \neq 0$." Larger values of F indicate more evidence for the alternative.

The F-statistic has $p, n-p-1$ degrees of freedom, p -values can be obtained from an F table, or from a computer program.

Interactions

In regression model, each regressor has been merged into the regression function through an additive term $\beta_i X_i$ such a term is called a main effect. For a main affect, a variable increases the average response by β_i for each unit increase in X_i, regardless of the levels of the other variables. An interaction between two variables $X_i$and $X_j$is an additive term of the form $\gamma_{ij}X_iX_j$ in the regression model.

For example, if there are two variables, the main effects and interactions give the following regression function:

$$E(Y|X) = \alpha + \beta_1 X_1 + \beta_2 X_{2,} + \gamma_{12}X_1X_2$$

With an interaction, the slope of X_1depends on the level of X_2, and vice versa. For example, holding X_2fixed, the regression function can be written

$$E(Y|X) = (\alpha + \beta_2 X_2) + (\beta_1 + \gamma_{12}X_2)X_1,$$

so for a given level of $X_2$the response increases by $\beta_1 + \gamma_{12}X_2$for each unit increase in X_1.

Similarly, when holding X_1fixed, the regression function can be written

$$E(Y|X) = (\alpha + \beta_1 X_1) + (\beta_2 + \gamma_{12}X_1)X_2$$

so for a given level of $X_1$the response increases by $\beta_2 + \gamma_{12}X_1$for each unit increase in X_1.

4.2 A Markov chain process

A Markov process is a random process for which the future (the next step) depends only on the present state. Markov chains were introduced in 1906 by Andrei Andreyevich Markov (1856–1922).

Recently, Markov process is useful in some fields such system dynamics are typical of those for queue lengths in call centers, stresses on materials, waiting times in production and service facilities, inventories in supply chains, parallel-processing software, water levels in dams, insurance funds, stock prices, forecasting labour supply and demand, forest dynamic, etc.

We are going to use Markov chain process to extract prediction of forest resource by age classes in future 15 years. In this section, we considered model of theory and basic definitions and theorems, according to the book of Richars Serfozo, Basics of Applied Stochastic Processes, 2009, pp1-84.

What is Markov chain?

A sequence of random variables $X_0, X_1, \ldots$ with values in a countable set S is a Markov chain if at any time n, the future states (or values) $X_{n+1}, X_{n+2}, \ldots$ depend on the history $X_0, \ldots, X_n$only through the present state X_n. Markov chains are fundamental stochastic processes that have many diverse applications. This is because a Markov chain represents any dynamical system whose states satisfy the recursion $X_n = f(X_{n-1}, Y_n), n \geq 1$, where $Y_1, Y_2 \ldots$ are independent and identically distributed (*i.i.d.*) and f is a deterministic function. That is, the new state $X_n$is simply a function of the last state and an auxiliary random variable.

A discrete-time stochastic process $\{X_n : n \geq 0\}$ on a countable set S is a collection of S-valued random variables defined on a probability space (Ω, F, P). The P is a probability measure on a family of events F (a σ-field) in an event-space Ω.The set S is the state space of the process, and the value $X_n \in S$ is the state of the process at time n. The n may represent a parameter other than time such as a length or a job number. The finite-dimensional distributions of the process are

$$P\{X_0 = i_0, \ldots, X_n = i_n\}, i_0, \ldots, i_n \in S, n \geq 0.$$

These probabilities uniquely determine the probabilities of all events of the process. Consequently, two stochastic processes (defined on different probability spaces or the same one) are equal in distribution if their finite-dimensional distributions are equal.

Various types of stochastic processes are defined by specifying the dependency among the variables that determine the finite- dimensional distributions, or by specifying the manner in which the process evolves over time (the system dynamics).

A Markov chain is defined as follows.

Definition 4.1. A stochastic process $X = \{X_n : n \geq 0\}$ on a countable set S is a Markov Chain if, for any $i, j \in S$ and $n \geq 0$,

$$P\{X_{n+1} = j | X_0, \ldots, X_n\} = P\{X_{n+1} = j | X_n\}, \quad (4.1)$$

$$P\{X_{n+1} = j | X_n = i\} = p_{ij}. \quad (4.2)$$

The p_{ij} is the probability that the Markov chain jumps from state i to state j. These transition probabilities satisfy $\sum_{j \in S} p_{ij} = 1, i \in S$, and the matrix $P = (p_{ij})$ is the transition matrix of the chain.

Condition (4.1), called the Markov property, says that, at any time n, the next state $X_{n+1}$is conditionally independent of the past $X_0, \ldots, X_{n-1}$given the present state X_n. In other words, the next state is dependent on the past and present only through the present state. The Markov property is an elementary condition that is satisfied by the state of many stochastic phenomena. Consequently, Markov chains, and related continuous-time Markov processes, are natural models or building blocks for applications.

Condition (4.2) simply says the transition probabilities do not depend on the time parameter n; the Markov chain is therefore “time-homogeneous”. If the transition probabilities were functions of time, the process $X_n$would be a non-time-homogeneous Markov chain. Such chains are like time-homogeneous chains.

Since the state space S is countable, we will sometimes label the states by integers, such as $S = \{0,1,2, \ldots\}$ $(or\, S = \{1, \ldots, m\})$. Under this labeling, the transition matrix has the form

$$P = \begin{bmatrix} p_{00} & \cdots & p_{0n} \\ \vdots & \ddots & \vdots \\ p_{m0} & \cdots & p_{mn} \end{bmatrix}$$

Construction of Markov Chains

Proposition 4.1. Suppose $\{X_n : n \geq 0\}$ is a stochastic process on S of the form

$$X_n = f(X_{n-1}, Y_n), n \geq 1 \quad (4.3)$$

where $f : S \times S' \rightarrow S$ and $Y_1, Y_2, \ldots$ are i.i.d. random variables with values in a general space S' that are independent of X_0. Then X_n is a Markov chain with transition probabilities $p_{ij} = P\{f(i, Y_1) = j\}$.

Theorem 4.1. (Construction of Markov Chains)

Let p_{ij} be Markovian transition probabilities, and let α be a probability measure on S. Label the elements of S such that $S = \{0,1,\ldots\}$. Suppose $U_0, U_1, \ldots$ are *i.i.d.* with a uniform distribution on $[0, 1]$. Assume $X_0 = h(U_0)$, where h is $h(u) = j$ if $u \in I_j$, for some $j \in S$.

Define $X_n = f(X_{n-1}, U_n), n \geq 1$, where, for each i,

$$f(i, u) = j \text{ if } u \in I_{ij}, \text{for some } j \in S, \quad (4.4)$$

and $I_{ij} = (\sum_{k=0}^{j-1} p_{ik}, \sum_{k=0}^{j} p_{ik})$. Then $\{X_n : n \geq 0\}$ is a Markov chain with initial distribution and transition probabilities p_{ij}.

In this chapter, we assumed that models of theory. The specific suitable model of Markov chain for this research is developed in chapter of Empirical result.

5 EMPIRICAL RESULT

5.1 Data Collection

In this research work, we used statistical yearly data which is from 1997 to 2016s that are collected by one year by one year from other sources developed by MEGDT, NSO, ArcGIS program Statistics of FAO, and Statistics of World Bank. I have collected data of Forest abundance, Forest covered area, Forest area by forest type, Burnt Forested Area, Logging quantity, Degraded area by Insect and disease, Forest utilization of Mongolia, Reforested area, and other significant variables such as temperature, precipitation, population, wood consumption, illegal logging and inflation rate. I have to note that data collection was most hard part of this research work due to Mongolian forest sector has been developing during past years and have not collected ordered statistical data of forest resource and others factors in long-term. Since 2010s, have been ordered data and online source available for past 5 years. Other data had collected from other sources.

I have met some experts, researchers, and professors when I was collecting data that I needed to estimate my models and I used some methods such as interview, search in archive, and used some programs that is ArcGIS and used spatial analysis method.

I visited in several institutions such as Research and Development Center of Forestry, MEGDT, Department of Environment and Forest Engineering of NUM, and Division of Land Management, Geodesy and Cartography due to met some experts, researchers that professors.

5.2 An Estimation of Regression Models

Forest resources in Mongolia have increasingly degraded over the past few years, due to illegal timber cutting, forest fires, pests and diseases (Oyunsanaa et al, 2011)

Reforestation activities in Mongolia started in the 1970s. Since 1975, reforestation was carried out on 68,748 ha within the country where most of the areas were replanted by seedlings. Although positive results of restoration were observed, fires, disease infection and grazing by the livestock, have damaged some of these planted forests (MNE of Mongolia, 1998, 2000, 2001; Crisp *et al*., 2004).

In this research work, our model should be expressed by equation (5.1) according to current situation of forest sector in Mongolia which has presented details in Chapter.3. To estimate regression model had used 19 yearly data which from 1997 to 2016.

We assume that following multiply linear regression model to estimate changes of forest resource,

$$Y = \beta_0 + \beta_1 * X_1 + \beta_2 * X_2 + \beta_3 * X_3 + \beta_4 * X_4 \ , \qquad (5.1)$$

Here,

Y – Forested Covered Area, ha

X_1– Burnt forest area, ha

X_2 – Logged wood from forested area, m^3

X_3 – Degraded forest land by Insect and disease, ha

X_4– Reforestation area, ha

There is a correlation matrix that is estimated by equation (5.1). A Correlation matrix shows that variables how strong depend to each other.

表 5-1 森林资源与其主要因素的相关矩阵

Tab.5-1 Correlation matrix between fores resource and main factors

	Forested Area	Forest Fire	Insect and Disease	Logging	Reforestation
Forested Area	1.00				
Forest Fire	0.08	1			
Insect and Disease	0.25	-0.53	1		
Logging	-0.55	0.10	-0.65	1	
Reforestation	0.47	-0.59	0.36	-0.26	1

Source: STATA13.0

Tab.5-1 shows forest fire and insect are affected positive in changes of forest resource. Thus, we assumed developed model without impact of insect. Because forest fire is the one reason of increasing effect of insects in forested area of Mongolia. In other hand, its problem of multicollinearity and shows strong correlation regressors which are forest fire and effect of insect can lead to large standard errors for the OLS estimates. Therefore, we developed regression model that eliminated insect in equation (5.2).

$$Y = \beta_0 + \beta_1 * X_1 + \beta_2 * X_2 + \beta_4 * X_4, \qquad (5.2)$$

where,

Y – Forest Covered Area, (ha)

X_1– Burnt forest area, (ha)

X_2 – Logging, (m^3)

X_4– Reforestation area, (ha)

A correlation matrix is estimated following result,

表 5-2 森林资源与其主要因素之间的相关矩阵（消除 X3）

Tab.5-2 Correlation matrix between fores resource and main factors (eliminated X_3)

	Forest Covered Area	Forest Fire	Logging	Reforestation
Forested Area	1.00			
Forest Fire	-0.18	1		
Logging	-0.58	0.14	1	
Reforestation	0.09	-0.59	-0.06	1

Source: STATA13.0

A forest fire has been affected to forest resource and reforestation negative. A harvesting activity has been affecting to forest resource and reforestation negative, and affect to burn forest fire positive.

The correlations were calculated using the Stata13.0, also methodology of estimation is OLS which is mentioned in Chapter.4.

Tab.5-3 shows that details of solution of regression equation (5.2).

表5-3 回归模型5.2的估计结果

Tab.5-3 An estimation results of regression equation (5.2)

Y	Coef.	P>ItI	R-squared
_cons	21917.27	0	
X_1	-0.09553	0.68	0.4
X_2	-10.2473	0.01	
X_4	5.0014	0.98	

Source:STATA13.0

However, an estimation of regression model shows coefficients β_1 and β_3 are statistical insignificant, these coefficients are practical significant. Therefore, would be estimate prediction of forest resource by equation (5.2) in future 10 years.

Accordingly, have to analyze and predict future value of each factors which are affected in forest resource .

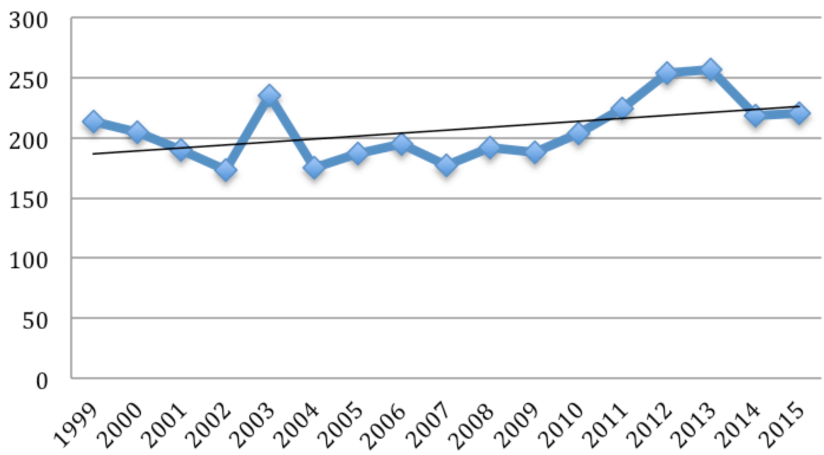
1. **Prediction of factor X_1 which is forest fire.**

There are the factors, such as fire from neighbor countries, illegal logging, private tourisms are the reasons to distribute forest fire in Mongolia (MEGD, 2004, 2009, 2014). Moreover, during the last several years, the fire process has been increasing caused by accumulation of the fire impact to the environment and natural resources.

Besides, the influence of climate changing is the reason to distribute in large area. About 95 percent of steppe and forest fires in Mongolia are caused by human activities (Erdenetuya, 2012).

The impact of global warming is observed in Mongolia more than most of the regions in the world. We have wrtitten Mongolian geographic condition and some changes in Chapter.3 and this section is focused on more details of climate effect.

The annual mean temperature of Mongolia increased by 2.14^{0}C during the last 70 years. However, annual mean temperature decreased in the winter season for the period of 1990-2006.



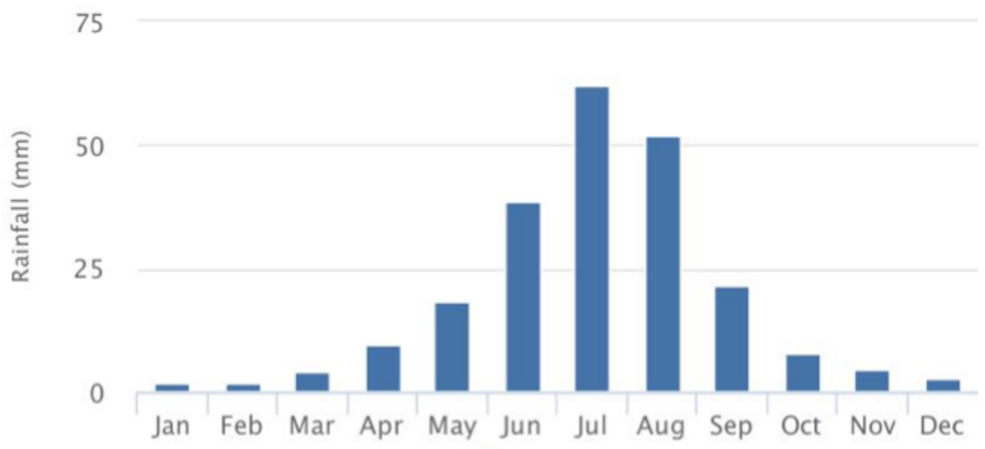
Source: Yearly Report, NSO

图 5- 1 平均温度变动 （1999- 2015）

Fig. 5-1 Average Temperature Trend, for the Period 1999-2015

According to the trend of global warming, average emperature is increased by 0.44^{0}C/year in period 1999-2015.

Mongolian climatic speciality is dry climate. The Average yearly precipitation of Mongolia is 241 (mm per year) with a global rank of 157.



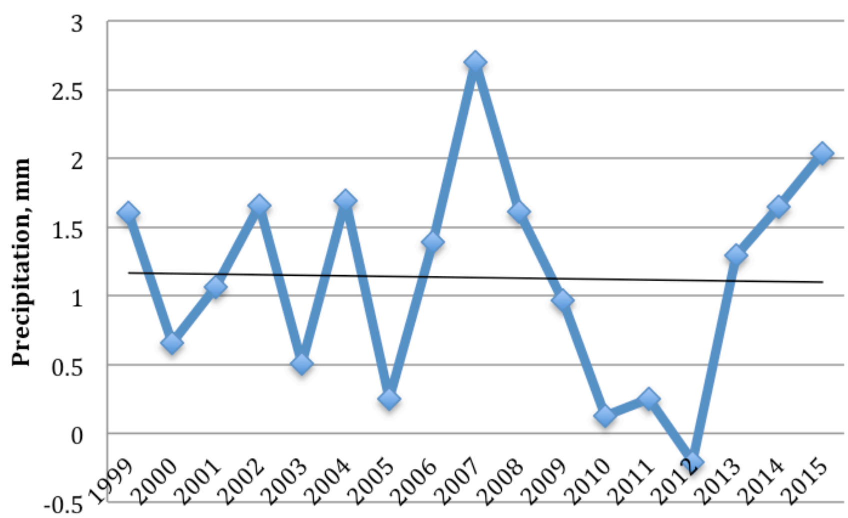
Source: The World Bank

圖 5-2 逐年平均月降雨量, 1999-2015

Fig. 5-2 Average Yearly Rainfall by Month, for the Period 1999-2015

The chart above shows mean historical monthly rainfall for Mongolia during the time period 1901-2015 and mostly in autumn its raining in Mongolia. The spring is most dry season and most of perecnt of forest fire was burnt in spring season.

Linear trend analysis has been used to analyze the trends of the observed yearly mean data of precipitation for the period 1999- 2015.



Source: Yearly Report, NSO

图 5- 3 逐年冰雹变动图， 1999- 2015

Fig.5-3 Average Precipitation Trend, for the Period 1999-2015

In Mongolia, average precipitation has been decreasing by 0.01mm/ year. A high temperature and dry air are keeping up the condition of to burn fire fast distribute in large area.

Therefore, Forest fire has explained equation (3),

$$X_1 = \alpha_0 + \alpha_1 w_1 + \alpha_2 w_2 + \alpha_3 w_3, \quad (5.3)$$

where,

X_1 – Burnt forest area, (ha)

w_1–Average temperature, (3,4 and 5th months)

w_2–Average precipitation, (3,4 and 5th months)

w_3– Illegal logging, (ha)

In equation (3), collected average temperature and precipitation of March, April and May of yearly data from 1999 to 2016. There is a dry season in Mongolia and most of the forest fire burnt during these three months. Also, illegal logging express that human effect to burn fire, because illegal logging has been doing by illegal people who did not pay any tax and without any responsible and control.

表5-4 回归模型5.3的估计结果

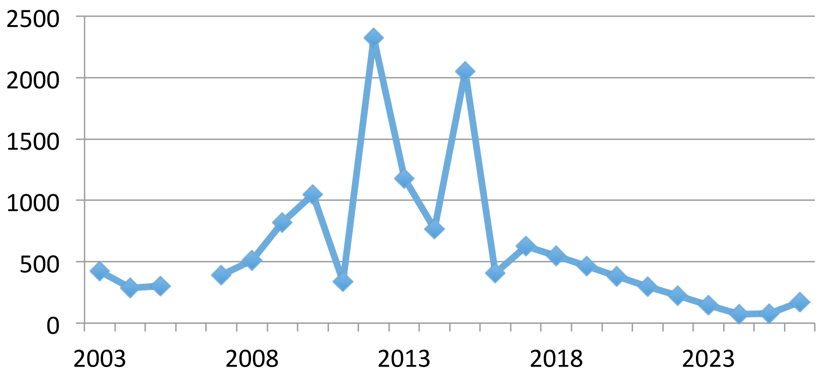
Tab.5-4 An estimation results of regression equation (5.3)

X_1	Coef.	P>ItI	R-squared
_cons	-8614.54	0.04	0.83
w_1	515.26	0.03	
w_2	-458.7	0.02	
w_3	1.86	0.06	

Source:STATA13.0

Tab.5-4 shows that forest fire will be increased when temperature and impact of illegal logging increased, and forest fire will be decreased if precipitation increased.

There is Fig.5-4 shows that prediction of forest fire, which is estimated by equation (5.3). A graph shows that forest fire will be going decrease in future 10 years. The reasons of forest fire is from abroad 23.3%, thunder 13.3% and others by human 65% were written in report of MEGD (2008).



Source: Microsoft Excel

图5- 4森林火灾的预测，公顷

Fig.5-4 A prediction of Forest fire, ha

In past several years, government focusing on illegal logging and government started to own forest for local people and houses who is working in forest sector. These activity has been continued successfully, and in result of these activity illegal logging has been decreasing. Also, local government started to order data such as numbers of illegal logging and quantity of harvest, it was helpful to control. It is the one reason to decrease forest fire in future years by forest protection and government activities.

2. Prediction of factor X_2 which is Commercial Logging

A quantity of harvest from forest is determined by wood consumption, population growth and quantity of import wood in Mongolia. In statistical data, Mongolian population has been increasing constantly and wood consumption also has been increasing in past years. Some general conclusions about the impacts of economic development and population growth on supply and demand for wood can be drawn:

- Wood consumption for housing and fences will increase as the proportion of population in urban areas grows.
- Wood consumption will increase as a result of growth in the construction sector. (Mongolian forestry outlook study, 2010)

Therefore, in this paper we supposed that logging would be change by time affect due to population and wood consumption is increasing over the time.

There is logging expressed in nonlinear regression equation (5.4).

$$X_2 = \gamma_0 + \gamma_1 * \ln(t), \qquad (5.4)$$

where,

X_2 – Logged area, (ha)

t– Time factor in including population and wood consumption effect, (yearly)

In equation (5.4), quantity of logging expressed by time's factor that factor of time would be including affect of population and consumption. Besides, there is used a logarithm function. In Mongolia, a quantity of logging can not be increase linear, because 86 percent of total forest resource is protection forest area.

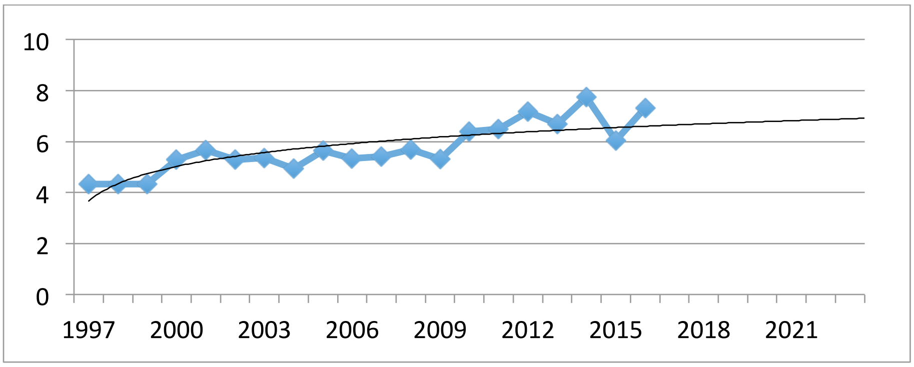
表5-5 回归模型5.4的估计结果

Tab.5-5 An estimation results of regression equation (5.4)

X_2	Coef.	P>ItI	R-squared
_cons	-236763	0	0.76
t	31217	0	

Source:STATA13.0

A graph shows future dynamic of commercial logging.



Source: Microsoft Excel

图 5- 5 采伐量的预测（木材消费和薪柴），公顷

Fig.5-5 A prediction of harvest (both wood consumption and fuelwood), ha

A quantity of harvesting is increasing in Fig.5-5 that is required by wood and wooden products, fuel wood consumptions.

3. Prediction of factor X_3 which is Reforestation

Mongolia's reforestation activity was started in 1971. So far, an area of about 84,000 ha has been planted. The quality of the forest plantations is generally poor, mainly due to lack of adequate maintenance and care, and partly due to the influence of the harsh climate.

Since 1971, reforestation activity has been regulated by the State Central Plan and directive. Reforestation activities implemented totally in 100.3 thousand ha area, its only 30% of all the logged area in the country.

In next regression model, quantity of reforestation was determined by government cost for forestry and reforestation. Because, there is reforestation has not increasing following by increasing financial budget for forestry. Its depends on several reasons such as seedling price has increased, seedling quality has changing and others.

表 5-6 再造林与其影响因素之间的相关矩阵

Tab.5-6 Correlation matrix between reforestation and explanatory variables

	Reforestation	Budget	Inflation
Reforestation	1.00		
Budget	0.24	1.00	
Inflation	-0.15	0.17	1.00

Source:STATA13.0

Tab.5-6 shows that there is postitive relationship between reforestation and government budget for forestry. Also, there is negative relationship between reforestation and inflation rate. Therefore, we have built regression model (5.5) to predict reforestation.

$$X_4 = \theta_0 + \theta_1\phi_1 + \theta_2\phi_2 + \theta_3\phi_1\phi_2, \ (5.5)$$

X_4 – Reforestated area, (ha)

ϕ_1– Budget for reforestation, (tugrug)

ϕ_2– Average inflation rate, (yearly)

$\phi_1\phi_2$– Interaction variable

A coefficients has estimated by Stata13.0 program which is shown in Tab.5-7.

表5-7 回归模型5.5的估计结果

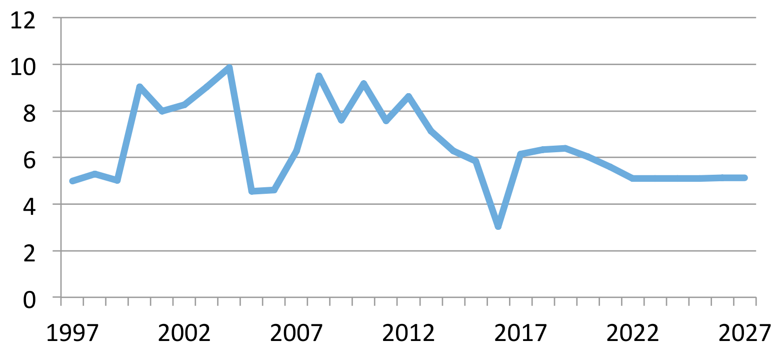
Tab.5-7 An estimation results of regression equation (5.5)

X_4	Coef.	P>ItI	R-squared
_cons	7200.65	0	0.43
ϕ_1	0.13	0.05	
ϕ_2	52.85	0.03	
$\phi_1\phi_2$	-6.09E-06	0.05	

Source:STATA13.0

An estimation of regression equation (3) shows budget of government and inflation rate are affecting in reforestation. Note: government has been planting 40-50 percent of total reforestation in past years, others of total reforestation was planted by local ownership and others. Here, we assumed that government budget for plantation by regressor ϕ_1.

However, a relationship between reforestation and inflation was estimated positive relation, their negative impact was affected in interaction value is $\phi_1\phi_2$.



Source: Microsoft Excel

图5- 6再造林（木材消费和薪柴）的预测，(公顷)

Fig.5-6 A prediction of reforestation, (ha)

Fig.5-6 shows that dynamics of reforestation is including historical data and prediction value. If supppose that will not happen any shocks in future years, reforestation is keeping up constantly around 4000-6000 hectare per year. Note: if can be know statistics of local government's participation for reforestation, equation (5.5) should be estimated better.

There is used equation (5.1) to estimate forest resource's future dynamic by main three regressors which are forest fire, logging and reforestation. The result of prediction of forest resource shows that forest resource will be decreased by these factors, if no development in forest management in future years. Tab.5-4 shows that predicted value of forest resource and main three factors.

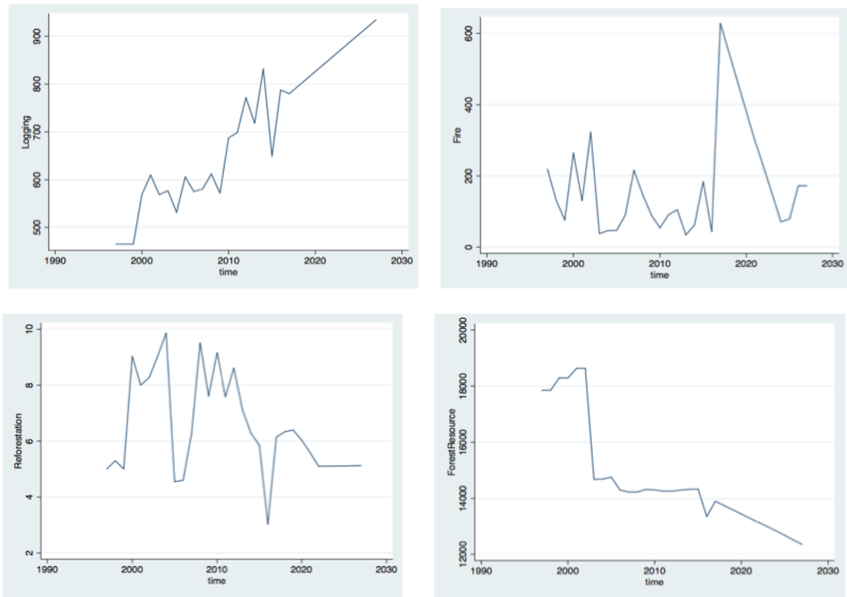
表 5-8 历史数据与 2030 年预测值

Tab.5-8 Numerical value of historical data and prediction for 2030

	1997	2007	2016	2030*
Forest resource	17852	14226.5	13354	11658.1
Forest fire	400	512	407	370
Logging	4.32	5.39	7.32	9.12
Reforestation	5	9.52	3.03	5.13

Source: Microsoft Excel

Next graph shows that dynamics of logging, forest fire, reforestation and forest resource, respectively. The graphs are including statistical value of past years and predicted value of future years.



Source: STATA13.0

图5- 7森林资源预测，(千公顷)

Fig.5-7 A prediction of Forest resource and main factors, (thousand ha)

A Result of prediction of forest stand dynamics determined by climate factors, human effects, socio-economic factors is showing that forest resource will be decreased in future 15 years. In our case, logging impact (legal and illegal) plays role highly in forest stand dynamics.

5.3 An Estimation of Markov chain

Here, used Markov chain process that considered mathematical theory in Chapter.4. We have extracted prediction of forest resource by age class using Markov chain. Our main goal is to know that "How would be changed forest age class structure in 2030" in this section.

We assume that following model to predict age structure of Mongolian forest resource in future.

Suppose that forest resource has divided by such qualification in group ***k.*** For example, forest resource has divided into groups $E_1, E_2, \ldots, E_k$ and let be quantity of forest resource is determined by $Y(t) = (Y_1(t), Y_2(t), \ldots, Y_k(t))$ in *t* time.

In our case we assumed that $E_1, E_2, \ldots, E_k$, $k = 5$. In other hand, we have divided into 5 groups forested area such that 4 kinds of age classes and other 1 group is light forested area is including forest burnt area, logged area etc.

There is Mongolian forest resource divided into 4 age structure such as Young aged forest is including replanted trees(0-40 years), midde aged forest (40-70 years), maturing forest (70-120 years) and maturity forest (under 120 years).
We have several important assumptions about forest dynamic is written below.

- Some percentage of forest has been die from any age groups by some reasons such that forest fire, harvest, and others.
- Growth rate of forest is 10.1% per year. In other hand, after one year 10.1% of trees transfer into another age class.
- Old aged forest never transit into other age group.
- Reforestation depends on damaged forest area in that year. They has been planed about 34% of damaged area based on last 20 years statistic.
- The time unit is one year

Let's note *b(t), y(t), m(t)* and *o(t)* is young, middle, maturing and maturity forest in t^{th} year, respectively. We should wirte vector of age probability by *Y(t)*.

$$\mathrm{Y(t)}=\begin{pmatrix} b(t) \\ y(t) \\ m(t) \\ o(t) \\ l(t) \end{pmatrix}$$

where, *Y(t)* – total forest resource in t^{th} year.

We have calculated probablities that are to destroy trees influenced by harvest, forest fire, and other factor's impact, to transit into other age class and to continue in actual age class according to shown in Chapter.4. Noted, *d*- the probality of destroy, *a*- the probability of transit, and *1-d-a* – the probability of continue.

表 5-9 森林林分动态变动概率

Tab.5-9 Probability of Forest stand dynamics

		b(k)	*y(k)*	*m(k)*	*o(k)*
Probability	*d*	0.00071	0.01650	0.01775	0.11319
	a	0.1	0.1	0.1	0
	1- d-a	0.89928	0.88349	0.88224	0.8868

Source: Microsoft Excel

The transition matrix is written below with using probability of age class's dynamic.

$$P=\begin{pmatrix} (1-0.66*d_b-a_b) & a_b & 0 & 0 & o.66*d_b \\ 0.34*d_y & (1-d_y-a_y) & a_y & 0 & 0.66*d_y \\ 0.34*d_m & 0 & (1-d_m-a_m) & a_m & 0.66*d_m \\ 0.34*d_o & 0 & 0 & (1-d_o) & 0.66*d_o \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

There is sum of an elements in a row should be equal to 1.

In our case, probability transition matrix is determined by matrix *P*.

$$P=\begin{pmatrix} 0.89953 & 0.1 & 0 & 0 & 0.00047 \\ 0.00561 & 0.88349 & 0.1 & 0 & 0.01089 \\ 0.00603 & 0 & 0.88224 & 0.1 & 0.01171 \\ 0.03848 & 0 & 0 & 0.88680 & 0.07471 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

Here, forest dynamic is going by written in each age classes.

$$b(t+1)=(1-0.66*d_b-a_b)*b(t)+0.34[d_y*y(t)+d_m*m(t)+d_o*o(t)]$$
$$y(t+1)=\left(1-d_y-a_y\right)*y(t)+a_b*b(t),$$
$$m(t+1)=(1-d_m-a_m)*m(t)+a_y*y(t)\ ,$$
$$o(t+1)=(1-d_o)*o(t)+a_m*m(t)\ ,$$
$$l(t+1)=\left(0.66(d_b+d_y+d_m+d_o\right)*l(t).$$

A Markov chain process can be written by process (5.6) .

$$Y(t+1)=Y(t)*P(t)\ ,\ (5.6)$$

where,

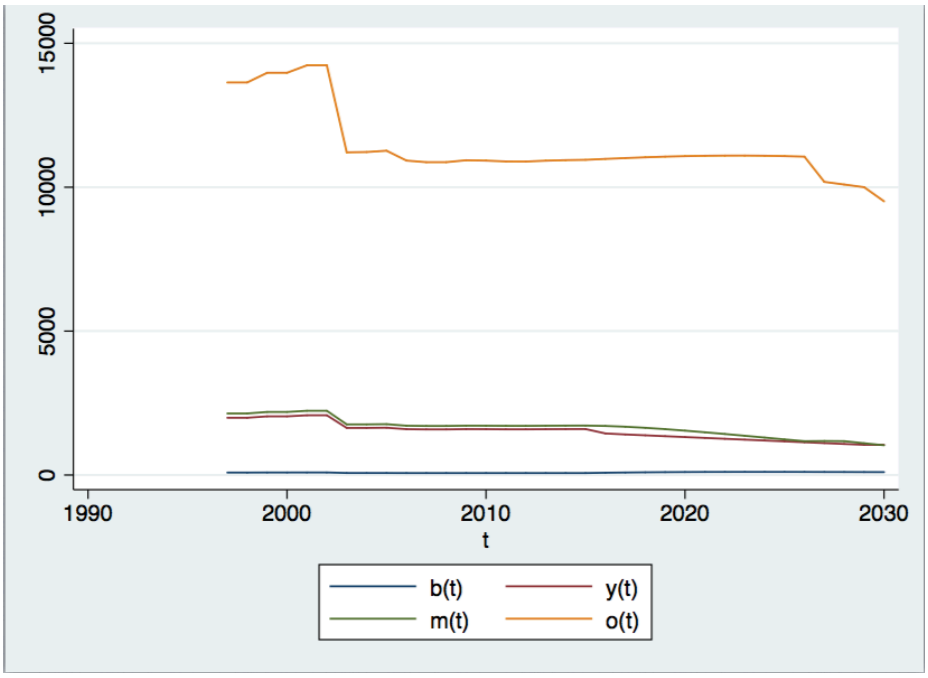
$P(t)$- transition probability matrix of t year,

Y(t)-a vector of forest age structure of t year,

A process (5.6) in algebra notation:

$$Y(t+1) = \begin{pmatrix} b(t) \\ y(t) \\ m(t) \\ o(t) \\ l(t) \end{pmatrix} \times \begin{pmatrix} 0.8995 & 0.1 & 0 & 0 & 0.0005 \\ 0.0056 & 0.8835 & 0.1 & 0 & 0.0109 \\ 0.0061 & 0 & 0.8825 & 0.1 & 0.0117 \\ 0.0385 & 0 & 0 & 0.8868 & 0.0747 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

According to result of a process (5.6), young aged forest will be increasing slowly, middle, maturng and maturity aged forests will going to decreasing in next 15 years. The Prediction of forest age structre is drawn in Fig.5-7.



Source: Microsoft Excel

图5- 8森林年龄结构的预测,(千公顷)

Fig.5-8 A prediction of Forest age structure, (thousand ha)

Fig.5-7 shows that forest resaource will decreasing in totally, because of many reasons we calculated in previuos section. Markov process is showing that in the future, old aged resource will ve decreasing radiply, middle and maturing aged forest will be decrease slowly and youg aged forest forest will be increase if reforestation will increase.

5.4 Result and Discussion

We have obtained following results from estimations. Estimation is consist of 2 sections such as to know main factors of forest resource changes and to predict future value using econometric model and to develop Markov chain of forest resource's age class dynamic.

In first section, estimated relationship between forest resource and 3 kinds of factors which are forest fire, logging and reforestation and developed 4 models for forest resource and each regressor factors. First, we estimated forest fire future changes by average temperature of spring for 1999-2015, average precipitation of spring for 1999-2015 and illegal logging. However, used another methodoly to estimate correlation between forest fire and climate impact that positive correlation between forest fire and average temperature and negative correlation between forest fire and precipitation in Mongolia suggest that same result with other papers about fire risk in Mongolia. The one of the main reason of fire is human negative activity. (MEGD, 2012) In our case, this fact was true according to has been kept positive relationship between fire and illegal logging,. A Result of relationship between logging and time factor shows that logging will be increasing due to increasing population and wood consumption. We estimated reforestation dynamic by budget of government to replant per year. However, a positive correlation between reforestation and budget, reforestation was constantly in pastt years when budget is increasing. Therefore, we estimated inflation impact for reforestation. This result shows that negative correlation between reforestation and inflation rate. Generally, forest resource will be decreasing by these main factors if continue this situation in future.

In second section, we developed Markov chain model to extract forest stand dynamics by age class. Result of Markov chain shows that young aged forest will be increasing including replant, middle and maturing aged forest will decreasing by forest fire, logging and others. Large amounts of dead and decaying wood have usually been related to old-growth forest ecosystems (Wells, 1998). This was also true in our estimation. In generally, mongolian forest resource will be decreasing and its including 7% young aged forest, 13% of middle aged forest, 10% of maturing forest and 70% old aged forest.

6 CONCLUSION AND RECCOMENDATION

6.1 Conclusion

This research work aimed that to know forest resource dynamic and factors of environmental and socio-economic which is affected changes of forest resource and forested area based on statistical data and dynamics of the previous years. Within the scope of the thesis, we have developed some mathematical models which regression models and Marcov chain model. Further, we estimated coefficients of four kinds of regression models. First regression model expressed that relationship between forest stand and main factors which forest fire, commercial logging and reforestation. Second one shows that relationship between forest fire and climatic factors which are temperature and precipitation, and socio-economic factor which is illegal logging. Third model presented that relationship between commercial logging and socio-economic factors which are population and wood consumption. The last regression model expressed that relationship between reforestation and socio-economic factors which are government budget for replant trees and inflation rate. At the end, we have predicted forest stand dynamics has influenced by result of these four regression models. Finally, we have estimated probability transition matrix for transit groups into each other. As well as, we predicted future dynamics of forest age class structure using prediction value which is estimated by regression models and probability transition matrix.

The result of this research shows that relationship between forest stand dynamic and and main three factors.

- There is negative and weak relationship between forest stand and forest fire.
- There is negative and strong relationship between forest stand and logged area.
- There is positive and weak relationship between forest stand and reforested area.

The result which is mentioned above is shown that direct relationship between forest stand and main three factors of forest sector. The result of estimation of regression models also has presented relationship between forest stand and other climatic factors and socio-economic factors.

- Climate factors which is average temperature has been affecting positive for fire, and negative for forest stand.

- An average precipitation (rainfall) was one factor of climate factor in this thesis. Effect of precipitation is negative for forest fire and positive for forest stand.
- Illegal logging has been causing damage of forest resource during past years. Illegal logging affected positive for fire and negative for forest stand in empirical.
- The time factor is including effects of population and wood consumption in the future. A coefficient of the time factor has shown that there are relationship between logging and time factor is positive, and relationship between forest stand and time factor is negative.
- The budget of government for replant forest has been affecting positive for to be reforested area and total forest stand.
- An inflation rate was influenced for reforestation activity negative.

In concluding, logged area was affected more than burnt area in forest stand dynamics of Mongolia. Further, an effect of reforestation is weak in forest stand accordingly surviving rate is weak for replanted trees. Mongolian forest stand would be decreased 13% in 2030 compared with current forest covered area as a our result of estimation.

Second model was Marcov chain model which is used to extract by age class structure. In this section, we have divided total forest stand into four kinds of age classes and one group of open stand area. In order to established probability transition matrix, we have used all of effects of all of factors such as logging, fire, pest, reforestation, quantity of volunteer and dead stands. Then Markov process shows that young aged trees increasing by 27%, middle aged forest decreasing by 15%, maturing forest decreaseing 39% and maturity forest will decrease 16% in 2030.

6.2 Recommendation

We are suggested 2 conceptions based on our result of estimations.

1. Decision makers should be managed commercial logging activity more effective, such that in order to give the permission of logging, based on real consumption and current resource. They can be stopped maturing forest will be decreased fast due to using maturity forest under control. Only this process should be managed many problems which is decreasing illegal logging, to keep balance of age structure, households and forest ownership's income will be increased and forest sanitation cutting would be started working. Additionally, it was found that the 80% of wood from the total harvest is being used as fuel wood. This consumption of fuel wood is

mainly for heating and cooking. Therefore, it should be decreased by introducing various alternatives energy sources and technologies for cooking and heating purpose by developing the related infrastructures by the government.

Besides, in order to logging activity under control, the government could be managed balance of age structure of total forest stand.

2. Also, Decision makers should to manage reforestation activity correspond closely to commercial logging at the same time. If could be managed sustainable both of reforestation activity and logging activity, would be kept balance of forest stand dynamics.

REFERENCES

[1] A Report on Legal and Illegal Timber Trade of Mongolia [R]. World Bank/WWF Alliance Project, 2002.

[2] Ahlback A J, Forestry in Mongolia [J]. International Forestry Review Volume.1(1),(1999).

[3] Batsukh, Mongolian Forest Ecosystem [Z]. Ulaanbaatar, 2002

[4] Bayartaa, Fire environment, fire regimes, ecological role of fire common to country (or vegetation and fire characteristics of the region in which the country is located) [J]. Proceedings of I International Northeast Asia Forest Fire Conference and III International Meeting of the Northeast Asia Wildland Fire Network (28 to 30 September 2006, Khabarovsk, Russia), pp.105-110, 2002

[5] Ching-Rong Lin, Joseph Buongiorno, Managing Forests for Tree and Landscape Diversity Part I: Predictions with Markov-chain Models [J]. Multiple Use of Forests and Other Natural Resources, Volume 61 of the series Forestry sciences pp.137-157, 1999.

[6] Chuluunbaatar.Ts, Forest fire danger of Northern Mongolia [Z]. Ulaanbaatar, 1998, 25 pp.

[7] Chuluunbaatar. Ts, Forest Fires in Northern Mongolian Mountains [J]. International Forest Fire News No. 27, 92-97. 2002

[8] Chuluunbaatar, Ts. 2001. Forest fire danger and its reduction methods. Ulaanbaatar, 125 pp

[9] Chuluunbaatar.Ts.; Zoyoo.D, The forest fire influence on the forest phytocenoses of the Eastern Khuysugul [J]. In: Diversity of the plant cover within the Baikal Region. Ulan-Ude, pp.85, 1999.

[10] Dieterich, J.H. Fire Losses and Fire Control Programs [J]. International Forest Fire News No. 5 , 4- 5. 1991.

[11] Dorjsuren Ch, Dugarjav Ch, Chuluunbaatar Ch, The comprisal of forestry. Ulaanbaatar, 2010.

[12] Elbegjargal Nasanbat, Ochirhuyag Lhamjav, Wild Fire Risk Map in The Eastern Steppe of Mongolia Using Spatial Multi-Criteria Analysis **[J].** The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLI-B1, 2016 XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic

[13] Erdenesaikhan, N. Mongolia Fire Update. International Forest Fire News [J]. Freiburg, No. 15, 35- 36. 1996.

[14] Erdenesaikhan, N.; Erdenetuya, M. Forest and Steppe Fire Monitoring in Mongolia Using Satellite Remote Sensing [J]. International Forest Fire News No. 21, 71-74. 1999.

[15] Faculty of Forestry, Adaptation of Asia-Pacific Forests to Climate Change [EB/OL].

[16] FAO, Management and Climate Change: A Literaure Review [R]. 00153 Rome, Italy, 2012

[17] Forest Policy Statement. Resolution of the Government of Mongolia [Z]. No.248. 2001

[18] Goldammer, J.G. Fire Situation in Mongolia [J]. International Forest Fire News No. 26, 75-83.

[19] Government of Mongolia, Amendments to the Law on Forests, Ulaanbaatar, 27 Jan 2002.

[20] HijabaYkhanbai, A Report on Legal and Illegal Timber Trade of Mongolia [R]. Economics of Environment and Sustainable Development, WWF Mongolia, 2000.

[21] Hijaba Ykhanbai, Mongolia Forestry Outlook Study [J]. Asia Pacific Forestry Sector Outlook Study II, FAO, 2010, APFSOS II/ WP/ 2009/ 21.

[22] International Journal of Knowledge, Innovation and Entrepreneurship [J]. Volume 2 No. 2, 2014, pp. 39—49

[23] Jaroslaw Oczki Nicolaus, Copernicus University, Forecasting Internal Labour Supply with a Use of Markov Chain Analysis [J]. Approved 31 July 2014, Poland, 2014.

[24] Jeffrey M.Wooldridge, Introductory Econometrics A Modern Approach, Fifth edition [Z]. Copyright©2013 Cengage Learning Asia Pte Ltd.
[25] Joseph Buongiorno, J Keith Gilles, Decision Methods for Forest Resource Management, An Imprint of Elsevier Science, copyright 2013, USA.
[26] Kent, Brain M Dress and Peter E, On the Convergence of Forest Stand Spatial Pattern Over Time: The Cases of Regular and Aggregated Initial Spatial Patterns [J]. Forest Science, Volume 26, Number 1, March 1989, pp. 10-22(12)
[27] Mathew T Jones, Estimating Markov Transition Matrices Using Proportions Data: An Application to Credit Risk [J]. International Monetary Fund, WP/05/219, November 2015.
[28] MEGD, Assessment report on Climate Change [R]. Ulaanbaatar, 2009
[29] MEGD, The report of Mongolian Environment and Conditions [R]. Ulaanbaatar, 2014.
[30] MEGD, Review of Mongolian Forest Sector [R], Ulaanbaatar, 2000
[31] MEGD, Report of Mongolian Natural Environment - 2006-2008s [R].Ulaanbaatar, 2008
[32] MEGDT, Law and Legislation of Forestry [EB/OL] . http : / / w w w . e I c . m n / forestresource / legalinfo .php.
[33] Ministry of Environment, Green development, Report of Mongolian Natural Environment - 2003 [R]. Ulaanbaatar, 2004.
[34] Ministry of Environment and Green Development, Forest sector financing flows and economic values in Mongolia [R]. UN-REDD program, 2013.
[35] Ministry of Environment, Green development, Report of Mongolian Natural Environment - 2008-2010s [R].Ulaanbaatar, 2011
[36] Ministry of Environment, Green development and Tourism, Report of Mongolian Natural Environment - 2013-2014 [R].Ulaanbaatar, 2015.
[37] National Statistical Office of Mongolia, Statistical Yearbook [R]. Ulaanbaatar, 1999-2016, Nineteen-volume book.
[38] Nicolas Crisp, John Dick, Micheal Mullins, Mongolian Forestry sector Review [R], The World Bank, 2004.
[39] Peter Tarp, Matrix Modelling in Uneven-aged forest Management Planning [J]. Proceedings of the Biennial Meeting of the Scandinavian Society of Forest Economics Vantaa, Finland, May 2004.
[40] Review of Mongolian Forest Sector, MNE, Ulaanbaatar, 2000.
[41] Rodney J Kennan, Climate change umpacts and adaptation in forest management [J], Annals of Forest Science, Springer Verlag/EDP Sciences, 2015, 72 (2), pp.145-167.
[42] The World Bank, Mongolia Environmental Monitor [R]. The World Bank Office, Ulaanbaatar, 2002.
[43] Tsogtbaatar J, Forest Policy Development in Mongolia [J].Ulaanbaatar, 2004.
[44] University of British Columbiahttp. ://asiapacific.forestry.ubc.ca.
[45] Yale University, Basics of Applied Sotchastic Process [EB/OL]. http://www.stat.yale.edu/~jtc5/251/readings/Basics%20of%20Applied%20Stochastic%20Processes_Serfozo.pdf

APPENDIX

```
. correlate Forestedareathousandha forestfire Insectanddesease loggingm3 Reforestationthousandha
(obs=13)

             | Forest~a forest~e Insect~e loggin~3 Refore~a
-------------+---------------------------------------------
Forestedar~a |   1.0000
  forestfire |  -0.5372   1.0000
Insectandd~e |   0.2120   0.3358   1.0000
   loggingm3 |  -0.4342  -0.1364  -0.6561   1.0000
Reforestat~a |   0.0240  -0.1881   0.3342  -0.0476   1.0000
```

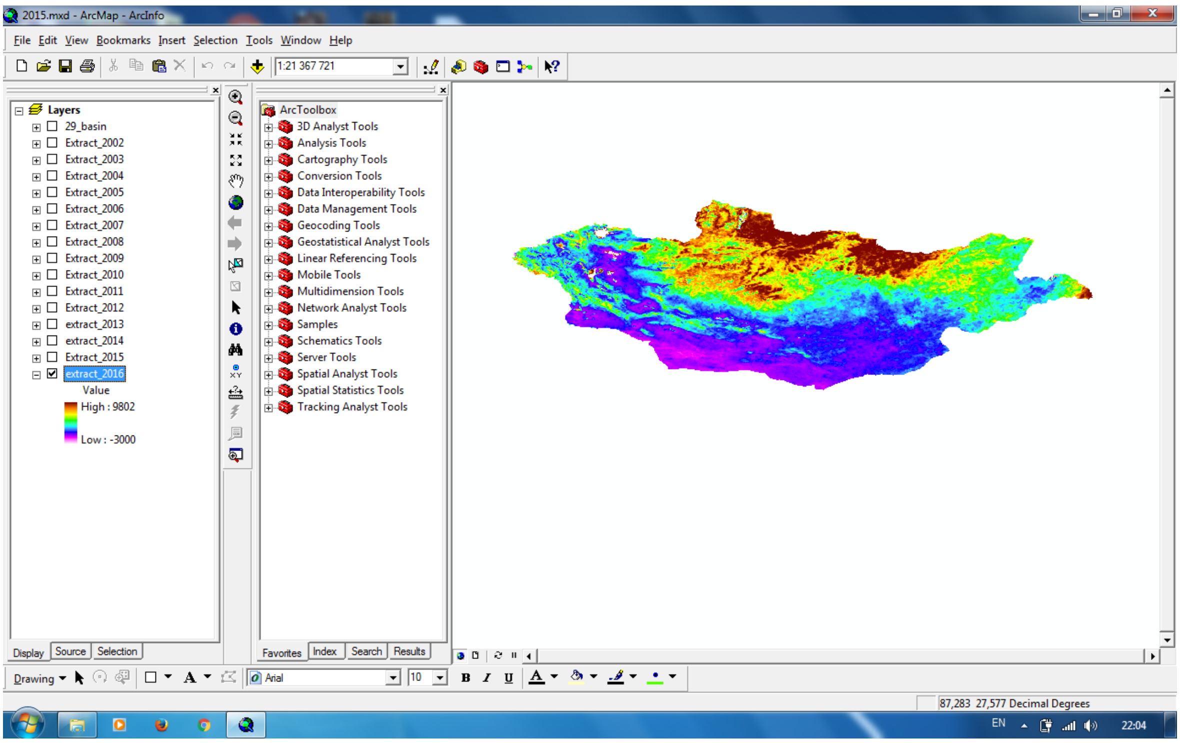
```
. correlate Forestedareathousandha burntforestareathousandha loggingm3 Reforestationthousandha
(obs=17)

             | Forest~a burntf~a loggin~3 Refore~a
-------------+------------------------------------
Forestedar~a |   1.0000
burntfores~a |  -0.2661   1.0000
   loggingm3 |  -0.4705   0.0455   1.0000
Reforestat~a |   0.0564   0.0931   0.0550   1.0000
```

```
. regress  Forestedareathousandha  forestfire loggingm3 Reforestationthousandha

      Source |       SS       df       MS              Number of obs =      19
-------------+------------------------------           F(  3,    15) =    2.64
       Model |  21346451.6     3  7115483.86           Prob > F      =  0.0873
    Residual |  40402097.6    15  2693473.17           R-squared     =  0.3457
-------------+------------------------------           Adj R-squared =  0.2148
       Total |  61748549.2    18  3430474.95           Root MSE      =  1641.2

------------------------------------------------------------------------------------------
 Forestedareathousandha |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------------+-----------------------------------------------------------------
             forestfire |  -.0955316   .2338428    -0.41   0.689    -.5939556    .4028925
              loggingm3 |  -10.24738   3.843342    -2.67   0.018    -18.43927   -2.055491
Reforestationthousandha |    5.00142   233.2646     0.02   0.983    -492.1903    502.1931
                  _cons |   21917.27   3032.547     7.23   0.000     15453.55    28380.99
------------------------------------------------------------------------------------------
```

```
. regress  loggingm3 t

      Source |       SS       df       MS              Number of obs =      20
-------------+------------------------------           F(  1,    18) =   57.99
       Model |  160993.407     1  160993.407           Prob > F      =  0.0000
    Residual |  49970.2894    18  2776.12719           R-squared     =  0.7631
-------------+------------------------------           Adj R-squared =  0.7500
       Total |  210963.697    19  11103.3525           Root MSE      =  52.689

------------------------------------------------------------------------------
   loggingm3 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           t |   15.55941    2.04319     7.62   0.000     11.26683      19.852
       _cons |  -30603.09   4099.679    -7.46   0.000     -39216.2   -21989.99
------------------------------------------------------------------------------
```

```
. regress fire  temperature precipitation ill_logg

      Source |       SS       df       MS              Number of obs =       5
-------------+------------------------------           F(  3,     1) =    1.64
       Model |  1817631.81     3  605877.268           Prob > F      =  0.5084
    Residual |  369797.198     1  369797.198           R-squared     =  0.8309
-------------+------------------------------           Adj R-squared =  0.3238
       Total |     2187429     4  546857.251           Root MSE      =  608.11

------------------------------------------------------------------------------
         fire |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
  temperature |   515.2612   323.5881     1.59   0.035    -3596.315    4626.838
precipitation |  -458.6982   213.1274    -2.15   0.027    -3166.739    2249.342
     ill_logg |   1.857991   2.815546     0.66   0.062    -33.91691    37.63289
        _cons |  -8614.539   8261.923    -1.04   0.048    -113592.2    96363.14
------------------------------------------------------------------------------
```

```
. regress  reforestation cost inflation interaction

      Source |       SS           df       MS      Number of obs   =        16
-------------+----------------------------------   F(   3,      12)   =      0.63
       Model |  5575114.21         3  1858371.4   Prob > F        =    0.6090
    Residual |  35346462.4        12  2945538.53   R-squared       =    0.4362
-------------+----------------------------------   Adj R-squared   =    0.4097
       Total |  40921576.6        15  2728105.11   Root MSE        =    1716.3

------------------------------------------------------------------------------
reforestat~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        cost |   .1343555   .2233976     0.60   0.055     -.352386    .6210971
   inflation |   52.84572   82.82853     0.64   0.053    -127.6221    233.3136
 interaction |  -6.09e-06   7.92e-06    -0.77   0.045    -.0000234    .0000112
       _cons |   6902.367     1000.9     6.90   0.000     4721.593    9083.141
------------------------------------------------------------------------------
```



PROFILE-2017

Name: Khulan Myagmar
Date of Birth: 15 May 1986
Country: Mongolia

Khulan Myagmar, Female, was born 15 May of 1986 in Ulaanbaatar, Mongolia. Current position is lecturer in School of Engineering and Applied Sciences, National University of Mongolia, since 2012. Graduated bachelor in Mathematic Science in School of Mathematic and Computer Sciences of National University of Mongolia in Mongolia (2004-2008). Finished Master program of School of Mathematic and Computer Sciences, National University of Mongolia, from 2008 to 2010. During from 2010 to 2012, worked at School of Mathematic and Computer Sciences of NUM in position of contract teacher. Research field is Economic models, Mathematical Modeling, Stochastic process and currently working on models of environment sector such as forest dynamics and valuation of water resource.

Achievements:

1. Khulan Myagmar, Altangerel Lhamsuren, "Estimation of Risk Portfolio Using Copula function", Journal of Application of Mathematic Science, Science and Technology University of Mongolia, Mongolia, 2015, pp-36-42
2. Ch.Dugarjav, M.Khulan, D.Bayanjargal, "A Cost Benefit Analyses on Reforestation of River Bank Protection in Mongolia", Approved in Journal of Special Issue of National University of Mongolia, 2017
3. M.Khulan, Liu Junchang, " Study on Mongolian Forest Stand Dynamics Using Mathematical Modeling", Approved in Journal of Special Issue of National University of Mongolia, 2017

SUPERVISOR PROFILE

刘俊昌，男，1957 年生，河北省献县人。1982 年 7 月毕业于北京林业大学林业经济专业，获农学学士学位；1990 年在加拿大 Lakehead 大学林学院获林学硕士学位（林业经济）；2002 年在北京林业大学获林业经济管理博士学位。北京林业大学经济管理学院教授、博士生导师，北京市教学名师，国务院政府特殊津贴获得者。兼任全国林业经济学会常务理事、全国林业统计学会副主任、全国林业系统工程学会副主任、北京林学会理事、北京市统计学会常务理事、瑞典林业经济（SCI）编委、“北京林业大学学报”编委、“绿色中国”编委、“林业经济问题”编委等学术职务。

长期从事林业经济管理的教学与科研工作，主持编写了《计量经济学》、《统计学原理》、国家“十一五”规划教材《林业经济学》和全国林业高等院校统编教材《林业统计学》，主持翻译出版了《林业经济学》教学参考书。主持完成了国家林业局重点课题“典型国有林场森林资源经营管理模式与技术”、国家质检总局行业公益项目“森林食品质量安全管理制度与标准框架研究”，教育部博士点基金课题“天然林保护地区自然生态环境与社会经济协调发展模式研究”、原林业部“建立比较发达的林业产业体系的基本框架研究”子课题：基本途径、政策和措施，国际合作课题“美国向中国出口林产品的市场竞争力研究”、WWF（世界野生动物基金）的“陕西秦岭大熊猫保护区景观尺度社会经济调查项目”、科技部国家“十五”攻关课题 “设施园艺科技创新与发展战略研究”等 30 多项课题。出版了《林业产值计量、分析和应用》、《现代林业生态工程管理模式研究》、《现代国有林场森林经营理论与实践》和《中国国有林场森林资源管理研究》等十多部学术著作，发表学术论文八十多篇。荣获原林业部科技进步三等奖、宝钢优秀教师奖和梁希科学技术二等奖。

多次被中德合作造林项目、联合国粮农组织资助的林业项目、联合国开发计划署资助的林业和扶贫项目、澳大利亚国际发展署资助的林业项目聘为林业经济咨询专家。

ACKNOWLEDGEMENT

I would like to thank all those people who extended their help and cooperation for this research.

Firstly, I wish to express APFNet for giving me the chance to study in Beijing. Without this support would not been finished this program.

My special thanks to my honest supervisor Prof. Dr. Liu Junchang, for teaching me that lot of things about this field. Without his intellectual guidance this thesis would not have been completed.

Also, I would like to thank all professors and lecturers who has teach me all subjects during past 2 years study in Beijing Forestry University.

I am thankful to my colleagues of National University of Mongolia, specially thank to lecturer Jamiyansharav, lecturer Munkhtsetseg.Z, Prof.Dr. Batchuluun, Dean of Department of Environmnet and Forestry Prof.Dr. Oyunsanaa, Prof. Dr. Bayanjargal for their support during the work in Mongolia.

I am grateful for my all classmates and friends, who helped me my study in many different ways; Yang Chao, Bhoj Rhaj Patak, Maralgoo Ganbat and Ekanayka Buddhika.

I am pretty thankful to my family for supporting, understanding and loving me study in Beijing. I dedicated this study to my parents, in particular to the memory of my Dad.