ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

Final Report
ARCP2014-09CMY-GOMBOEV

Boreal and Tropical Forest and Forest-steppes in East Asia: A comparative Study on Climate Impacts and Adaptation

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"Boreal and Tropical Forest and Forest-steppes in East Asia: A Comparative Study on Climate Impacts and Adaptation''

Final Report Submitted to the APN

Part One: Overview of Project Work and Outcomes

Non Technical Summary

The project focuses on comparative assessment of the contribution of different forest biomes (boreal, tropical, forest-steppe) to mitigate global climate change, and development of measures (strategies) to reduce emissions and increase carbon sequestration by forests. The research is done in three study locations in three countries: Selenga River basin area in Buryatia, Russia; Selenga River basin area in Mongolia; and Yellow River delta area and tropical forest area in China. The project developed common approaches and methods to assess the carbon budget, costs and benefits of adaptation measures, and recommendations for the effective use of the adaptive capacity of the study areas.

Keywords

Climate impacts, East Asia, carbon budget, ecosystem services, adaptation measures.

Objectives

1. Estimation of the carbon budget in key areas of different forest ecosystems (boreal and tropical forests and forest-steppe) in the study locations in collaborating countries, and comparative analysis of their contribution to the mitigation of global climate change;
2. Development of adaptation strategy of these forest ecosystems to climate change, based on analysis of the carbon budget and estimation of "cost-benefit" from sustainable forest management, as well as recommendations for implementation in a variety of regional programs in collaborating countries.

Amount Received and Number of Years Supported

The grant awarded to this project was:

- US$ 45,000 for Year 1
- US$ 40,000 for Year 2

Activity Undertaken

- Conducted five international workshops in Ulan-Ude (Russia) on 25 – 28 December 2013; Ulan-Baatar (Mongolia) on 17 – 18 April 2014 and 29 – 30 July 2016; and Beijing (China) on 17 June 2014 and 10 November 2015. National workshops and seminars with local specialists and communities were also held in collaborating countries.
- Collected different types of data (municipality to province levels data) in accordance with the goals of the project, including expeditions in key areas (e.g. international expedition to the project area in Yellow River delta on 18 – 19 June 2014), and conducted the carbon budget calculation and analysis of ecosystem services.

- Presented the results of the project in various conferences at national, regional and international level.
- Published scientific papers in scientific journals and conferences' proceedings.
- Disseminated results of the project to the local authorities and communities in the key areas in Russia, Mongolia and China.

Results

- In accordance with the goals of the project it was collected and analysed different types of data in different levels – from municipality to province;
- It is calculated the carbon budget of the studied areas, the calculation shows that in Russia there is the growth of carbon sinks, and in the territory of Mongolia, on the contrary - the reduction. This is due to climate change and economic activity. In the key areas of China's forest ecosystems are also subject to oppression due to climate warming;
- It is determined and calculated ecosystem services on the studied areas, the calculations show the real possibility of significant revenue from the use of forest ecosystems in the study area, and that the value of ecosystem services of forests is comparable to the gross domestic product, produced in the area;
- It is suggested the adaptation measures for the studied areas which include the improvement of forest management to contain global warming and improve the management of the operational part of the forest fund
- The results of the project were presented in different Conferences in Russia, China and Mongolia;
- Main ideas, Methodology, and results of the project were published in Scientific journals, and Conferences Proceedings
- Different parts of the project were presented to the local authorities and communities in the key areas.

Relevance to the APN Goals, Science Agenda and to Policy Processes

- The project is relevant to the **APN goals** of supporting regional cooperation in global change research through investigation forest and forest-steppe ecosystems in East Asia as well as through strengthening appropriate interaction among scientists and policy-makers and providing scientific input to policy decision-making and scientific knowledge to the public.
- The project conforms to the **Scientific Agenda** in all areas of research activities through the assessment of the state of the forests and the carbon budget of the territory as well as through the development of a mechanism of equitable distribution of costs and benefits of measures to mitigate climate change.
- Communication with the **Policy Processes** is implemented through the inclusion of the results and findings of the project in different programs and plans for the balanced development of forestry

Self-evaluation

The project kept good momentum and followed the proposed schedule. Comparative analysis of the responses of different forest ecosystems to global climate change was conducted in the territory of the key areas of the participating countries. The team also successfully examined the institutional differences in the control system, market-based instruments and mechanisms for sustainable forestry in Russia, Mongolia and China. Suggestions on adaptation strategy of these forest ecosystems to climate change and recommendations for their implementation in a variety of regional programs worked out. Overall, research was carried out in accordance with the work plan of the project.

Potential for further work

The project has big potential for further work. On the basis of the established network between different institutions in Russia, Mongolia and China, future investigations might include other ecosystems such as agricultural areas, protected areas and others according to structure of land-use. Also, the approaches used within the project for the territory of East Asia can be used on other territories.

Publications [please write the complete citation]

Journal Article:

Gomboev, B. O., Puntsukova, S. D., Andreev, A. B., Vasileva, L. S., Jamsran, T., Tsendsuren, D., & Dong, S. (2016). The impact of climate change on boreal and tropical forests in East Asia. *Scientific Review*, *5*, 50–54. (In Russian.)

Puntsuova, S.D., Forest fires in the Republic of Buryatia in the face of climate change / AK Tulokhonov, SD Puntsukova // Society: politics, economics, law. - 2016. - № 3. - S. 72-78.

Tulokhonov, A. K., Mikheeva, S. A., Puntsukova, S. D., Sanjeev, E. D., Batomunkuyev, V. S., Zamanov, D. D., & Darbaeva. (2016). Ecological and economic approaches to rational nature management in the transboundary Selenga river basin. *Scientific Review*, *5*, 54–57. (In Russian.)

Puntsukova, S. D., & Andreev, A. B. (2015). Механизм рационального лесопользования на основе оценки лесоресурсной ренты. [The mechanism of rational forest management on the basis of the forest resource rent]. *Общество: политика, экономика, право. [Society: politics, economics, law]*, *6*, 38–45. (In Russian.)

Puntsukova, S. D., Gomboev, B. O., Akhmetzyanova, M. ramilievna, Jamsran, T., Dagdan, T., & Dong, S. (2015). Comparative Analysis of Different Forest Ecosystems Response to Global Climate Change and Economic Activity. *Journal of Resources and Ecology*, *6*(2), 106–109. (In Russian.)

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Li, F., Dong, S., Li, F., & Yang, L. (2014). Is there an inverted U-shaped curve? Empirical analysis of the Environmental Kuznets Curve in agrochemicals. *Frontiers of Environmental Science & Engineering*. https://doi.org/10.1007/s11783-014-0700-y

Puntsukova, S. D. (2014). Evaluation of the effectiveness of the methods of regulating forest management and conservation of forest environment. *Vestnik of ESSUTM*, *2*(47), 94–100. (In Russian.)

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Puntsukova, S. D. (2014). Методы экономической оценки лесной экосистемы региона. [Regional forestry eco-system: methods of evaluation (Russia, Ulan-Ude)]. *ПРОБЛЕМЫ СОВРЕМЕННОЙ ЭКОНОМИКИ.[Problems of Modern Economics]*, *3*(51), 314–319. (In Russian.)

Puntsukova, S. D., Akhmetzyanova, M. Ramilievna, Osodoev, P. V., Borisovich, A., Darbalaeva, D. A., & Zhamyanov, D.-T. D. (2014). Лесоэкономическое районирование территории республики Бурятия - основа создания эффективной системы лесных рентных платежей. [Forest economic zoning of the territory of the Republic of Buryatia as a basis for creating an effective system of forest rent payments]. *Научное Мнение [Scientific Opinion]*, *9*(3), 172–179. (In Russian.)

Conference Paper:

Puntsukova, S. D., Gomboev, B. O., Akhmetzyanova, M. R., Jamsran, T., Tsendsuren, D., & Dong, S. (2014). Comparative analysis of different forest ecosystem response on global climate change and economic activity. In *International Conference on Ecology, Environment and Sustainable Development of Silk Road Economic Zone, Beijing, 15 - 16 June 2014* (pp. 119–125).

Puntsukova, S. D. (2014). Economic value of the forest ecosystem of the region. In *International Conference on Ecology, Environment and Sustainable Development of Silk Road Economic Zone, Beijing, 15 - 16 June 2014* (pp. 129–134).

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Preface

The project is performed by scientific consortium composed of Baikal Institute of Nature Management of Siberian Branch of the Russian Academy of Sciences (BINM SB RAS), Institute of Geography-Geoecology of Mongolian Academy of Sciences (IGG MAN), the Institute of Geographic Sciences & Natural Resources Research of Chinese Academy of Sciences (IGSNRR CAS) under the contract with the Asia-Pacific Network for Global Change Research. The purpose of the project is to conduct a comparative assessment of the contribution of different forest ecosystems (boreal, tropical, forest-steppe) in East Asia in the territory of Russia (Buryatia), Mongolia (the Selenga river basin), China (Yellow river delta, tropical (monsoonal) forests in the southeast of China) in the mitigation of climate change and the development of strategies to increase this contribution.

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1. Introduction

Project *"Boreal and tropical forest and forest-steppes in East Asia: a comparative study on climate change and adaptation"* is performed by scientific consortium composed of Baikal Institute of Nature Management of Siberian Branch of the Russian Academy of Sciences (BINM SB RAS), Institute of Geography-Geoecology of Mongolian Academy of Sciences (IGG MAN), the Institute of Geographic Sciences & Natural Resources Research of Chinese Academy of Sciences (IGSNRR CAS) under contracts with the Asia-Pacific Network for Global Change Research (Kobe, Japan). Implementation of the project is provided under these contracts for 2 years.

The purpose of the project, in accordance with the approved application of the consortium is to conduct a comparative assessment of the contribution of different forest ecosystems (boreal, tropical, forest-steppe) in East Asia on the territory of Russia (Buryatia), Mongolia (the Selenga river basin.), China (Yellow river delta, tropical (monsoonal) forests in the southeast of China) in the mitigation of climate change and the development of strategies to increase this contribution. In line with this purpose, a set of objectives has been established:

1. To estimate carbon budget in key areas of different forest ecosystems in the countries of APR (boreal and tropical forests and forest-steppe), and perform comparative analysis of their contribution to the mitigation of global climate change;
2. To develop adaptation strategy of these forest ecosystems to climate change, based on analysis of the carbon budget and estimation of "cost-benefit" from sustainable forest management, and develop recommendations for their implementation in a variety of regional programs in collaborating countries.

To do this, the project implemented a number of interrelated tasks:

- Assessment of the status of forest ecosystems (area, species and age composition, wood stocks, etc.);
- Assessment of the carbon budget;
- Studies on good practices on sustainable forest management aimed at reducing emissions from deforestation and degradation, binding and preservation of carbon sinks;
- Development of mechanism to mitigate climate change based on equitable distribution of costs and benefits (including the sale of ecosystem services) among stakeholders in accordance with national institutional capabilities.

In compiling this scientific-informational report took part from

Russia: D.Sc. B.O. Gomboev, chief researcher BINM SB RAS, project manager, D.Sc. S.D. Puntsukova, leading researcher BINM SB RAS, executive in charge of the project, Akhmetzyanova M.R., a leading engineer BINM SB RAS, executor of the project, with participating researchers: PhD, Darbalaeva D.A, researcher, PhD Zhamyanov D.Ts-D, researcher, PhD Osodoev P.V, leading engineer, PhD Andreev A.B., leading engineer, PhD Vasilyeva L.S., leading engineer, D.Sc. Bardakhanova T.B., leading researcher, Eremko Z.S., leading engineer, PhD Ulzetueva I.D., leading engineer, PhD Makarov A.V., senior researcher, PhD Maksanova L.B., senior researcher, Munkueva V.D., leading engineer;

Mongolia: Dr. J. Tsogtbator, director of IG MAN, the project manager from Mongolia, Dr. Tsendsuren D., researcher IG MAN, executor of the project, with participating researchers: B. Udval, D. Khorolgarav, Ts. Dashzeveg, B. Batgodor, N. Tsagaantsoozh, D. Ganbat, Sh. Mandal, D. Zoyo, G. Batsaukhan, G. Nandin-Erdene, B. Dembrel. E. Batdorj, S. Amatyuvshin, Kh. Bilgun;

China: prof. Suocheng Dong, director of the Center for Ecological Economic Research and Planning IGSNRR CAS, project manager from China, Dr. Li Fei, IGSNRR CAS, executor of the project with participating researchers: Vice Prof. Yu Li, Vice Prof. Zehong Li, Dr. Jun Li, Dr. Fei Wang, Dr. Qiliang Mao, Yongbin Huang, Peng Guo, Huilu Yu, Fujia Li, Zhongping Zhao.

2. Methodology

Based on the objectives, there are two main activities planned in this research:

- Estimation of the carbon budget;
- Development of adaptation strategy of forest ecosystems to climate change.

Estimation of the Carbon Budget

Regional Assessment of Forest Carbon Budget (ROBUL) technique was used to estimate carbon budget. The technique evaluates forest carbon budget for the balance of flows, i.e. the difference between the absorption with increasing carbon pools in the growing forest plantations and losses violations (logging, fires, and other cases of forest destruction). Payment on the balance sheet flows is one of two basic approaches permitted guidelines of the Intergovernmental Panel on Climate Change (IPCC). The second approach is based on the difference in carbon stocks in subsequent year's counts. This approach was used in particular in Papua New Guinea. Calculations by ROBUL are underway for 4 main forest carbon pools: phytomass, dead wood, litter and soil organic matter in the 0-30 cm layer.

Settlement procedure ROBUL.

1. **Carbon stock estimates by age groups (**young age class I, class II saplings age, middle-aged, ripening, ripe, overripe) and forest tree species in the region of forest carbon pools;
2. **Calculation of carbon sequestration in forest plantations in the growth of all forest carbon pools;**
3. **Calculation of forest carbon losses associated with various disorders** (logging, forest fires, outbreaks of pests and diseases, death of plants from climatic factors);
4. **Calculation of the annual budget for each of the forest carbon pools in the region by the difference of absorption and loss.**

Full description of equations and table settings ROBUL placed on the Internet on the website CEPF RAS.

Development of adaptation strategy of forest ecosystems to climate change

In international practice, different approaches are used for the assessment of ecosystems in order to develop adaptation measures. Therefore, to develop measures to mitigate and adapt to climate change, we need to develop a **unified construction of the logic of research on this topic.**

1. At the beginning**, provide a structured overview of the available information** about the current state of forest resources in the region, carried out by forestry activities, socio-economic status of the key area, forest management, performance and plans forest sector development in terms of climate change.

In our project, a common algorithm was applied for each of the object of analysis (ecosystem services, protected areas, population and forest sector):

a) determination of the current indicators and their possible changes as a result of socio-economic development plans (these plans usually do not take into account climate change);
b) description of the observed and potential impacts of climate change by the types of threats;
c) assessment of vulnerabilities by type of threats and the total potential damage to development;
d) identification of possible adaptation measures and assessment of their value;

Threat posed by climate change (climate change related hazard**)** is referred as the possibility of direct or indirect damage arising as a result of climate change (the definition of the threat is given in accordance with the Strategy of National Security of the Russian Federation until 2020, n. 6).

These threats can be divided into primary and mediated.

Vulnerability is understood as the degree to which a system is exposed to adverse effects of climate change and unable to cope with these changes (IPCC, 2007). However, vulnerability assessment may not always be applied in monetary terms. On making valuation we assume that the vulnerability, on the one hand, depends on the nature, scale and frequency of realization of threats, and on the other, depends on the properties of the system as its sensitivity and internal adaptability. For example, loss of timber from forest fires depend on the frequency of occurrence of fire risk conditions and on the characteristics of the forest, including the percentage of dead and fallen trees (forest combustible materials). Vulnerability can be reduced by external adaptation.

Formula definition of vulnerability (potential damage development):

$$\mathrm{Y} = \mathrm{KU} \times \mathrm{CC} - \mathrm{MA}$$

Where: Y = potential damage to development (vulnerability); KU = the nature, scale and frequency of implementation of the threats posed by climate change; CC = the system properties (sensitivity and interior adaptability); MA = external adaptation

2. **For the development of adaptation measures, it is necessary to assess the impact of climate change on the forest ecosystem and its services.** Approaches in line with Millennium Ecosystem Assessment, 2015 (MEA) and other international projects' approach were adopted to analyse and evaluate forest ecosystem services in this project. According to MEA, the services provided by the ecosystem, are classified by function and are divided into the following categories: provisioning, regulating, cultural and supporting (see Table 1). These categories show in what ways ecosystems contribute to increase in human welfare.

Table 1

Typologies of ecosystem services

Providing	**Regulatory**	**Cultural**
Products coming from the ecosystem:	***Benefits received by regulating the processes in ecosystems:***	***Intangible benefits flowing from ecosystems:***
Food, fresh water, wood, biochemical compounds, genetic materials, and others	climate regulation, water regulation, water purification, pollination, and others.	spiritual and religious, recreation and eco-tourism, aesthetic, educational, and others.
Ancillary		
Services required for the production of all other ecosystem services: soil formation, nutrient cycling, photosynthesis, and others.		

This project analysed and evaluated forest ecosystem services, from which the economy and population of the region are most dependent, which include:

- Provision of timber and firewood
- Provision of forest products (berries, mushrooms, nuts, medicinal raw materials, etc.)
- Ensuring of hunting products.
- Carbon sequestration
- Filtration function of wetlands
- Water regulation function of forest ecosystems
- Cultural and recreational services
- Preserving the natural environment for biodiversity

To estimate the services, data collection will be conducted to gather information on: (i) consumption of forest products (timber, wood, berries, mushrooms, nuts, etc.); (ii) preferences on the use of forest services, such as hunting, recreation, etc.; (iii) willingness to pay; (iv) population structure based on the degree of forest ecosystem services (forest products and services) and other activities.

To determine the value of ecosystem services in monetary terms, we applied the most reasonable methods of assessment available, such as study of markets for forest products and forest services and analysis of foreign experience. An important aspect of the evaluation process is to relate the value of forest ecosystem services with the gross national product of the area.

Overview of approaches and methods for assessing forests ecosystem services.

Ecosystem services, whether taken separately, have its value, i.e. the ability to meet people's needs, both material and spiritual needs. However, not all types of ecosystem services have price in the market.

In the past several decades, a variety of methods for assessing ecosystem services have been practiced. The most fully it is written in the works of S. Padzhioly, D. Pearce, A. Freeman, W. Hahnemann, as well as in other publications. Some of them are based on a study of existing markets of ecosystems products and their surrogates (Freeman A. M. 1991, 2003; Hanneman W. M., 1998; Pagiola S., Von Ritter K., Bishop J., 2004), while others are based on the observation of the behaviour of people and public opinion polls on the willingness to pay for the preservation of an ecosystem or its parts (Hanneman W. M., 1991; Pearce D., Turner R., 1990, Shogren J., 1997).

Analysis of the main approaches and methods for assessing the economic value of ecosystem services resulted in the classification as presented in Table. 2. There are two main groups, approaches that use demand curves and approaches that do not use demand curves. The main difference between the two groups is that the first group is composed of methods built on analysing the behaviour of people, while the second group is methods built on the determination of the impact on the environment.

Table 2

Classification of methods on economic valuation of ecosystem services

Methods	Content
	Approaches using demand curves
	Methods Revealed Preference
The method of road transport costs	The value of the specific nature object is determined by the willingness of the population to pay for his visit, including travel and other expenses.

Method of proactive behaviour	The value of natural objects is determined on the basis of public spending undertaken in order to protect against actual or potential environmental degradation
Method of Hedonic price	The dependence of the market of real estate prices on the quality of the environment along with other factors
	Methods of expressed preferences
Conventional valuation method	The value of natural objects (services) is determined based on the analysis of data and population survey to identify the willingness to pay for his existence and preservation
Choice modeling	Estimation based on the selection of a preferred variant of several variants
	Methods without the use of demand curves
Method of production function	Determine the impact of changes in state of the environment to manufactured goods, on the production
The replacement cost	The value of natural ecosystems carried out social and environmental functions is determined through the cost of obtaining the relevant effects of the industrial process
The cost of rebuilding	The value of lost or damaged property (services) is defined by offsetting the potential costs required to replace the resource (services) or in the alternative location
Method of alternative cost	Evaluation of a natural site or service on the basis of lost income and benefits that can be obtained when they are used for other purposes - to select the best options for using natural site or ecosystem services
The dose-response	The cost of changing people's health as a result of contamination is determined through reduced productivity, increased costs of treatment and others.
	Other techniques
Benefits transfer	The results of evaluation services, resulting in one place used to assess service elsewhere (for objects that have similar comparative characteristics)

Mechanism of valuation method build on the principle of functional dependence of the impact and the response to it (the production function, the dose-response, etc.) are based on determination of the quantitative impact on the resource as a result of environmental changes and multiplied by the price or other value unit.

Methods based on the study of human behaviour in terms of social welfare theory are aggregated in the demand function for a resource (service), and reflected as the demand curve. While the offer curve is interpreted as indication of individual's willingness to pay for a certain amount of resources or receive compensation for losses.

Methods of expressed preferences, or else referred to as the conventional method of valuation, are typically used when environmental degradation is not reflected in the behavioural reactions of people. By using these methods, we study the preferences of people for the purpose of constructing compensated demand function (Hicksian demand function) for changes in the environment or its element. The main tool for evaluation methods is questionnaires on people's willingness to pay (WTP), readiness or willingness to accept compensation for certain benefits/ services for their loss. Techniques that use this principle have recently been widely applied in many researches (Pearce & Turner, 1990; Hanemann, 1991; Shogren & Hayes, 1997).

In other cases, the adverse effects of environmental factors derived directly from human behavioural response to changing environmental conditions, regardless of whether it affects them or not. If people attach a certain significance of environmental benefits, there must be some demand for this good, even if there is no market for the good. For example, there is no market of clean air and water, but people spend money on something to reduce exposure to air pollution or water on health (e.g. buy various air filters or water filters, bottled drinking water, acquire a house in a "clean" areas). This score is determined through the revealed preference methods (such as methods of traffic costs, hedonic pricing, etc.), which are designated as a subjective evaluation method. This method analyses human behaviour on the markets of goods related to the study of natural goods and identifies consumer preferences and on this basis, built uncompensated demand function for resource (Marshallian demand function). In general, the term "pay" in many widely understood. Starting with the fact that they are willing to pay a portion of their income to the protection of nature (i.e., pay directly). For example, NGOs collect donations in favour of the development of environmentally significant areas or wildlife conservation. It ended up being ready to apply stricter requirements for polluters, limiting their ability to dispose of pollutants into the environment.

The method is known as the transfer benefits. In fact, the methodology is not as such, but rather using the estimates obtained by the method in any one location, for measuring values elsewhere. This method is the subject of serious discussion in the economic literature since it is not applicable in all cases. It can only take place under certain conditions, i.e. when the measured product or service is the same, having similar characteristics.

Despite the apparent simplicity of these calculations, there are many obstacles to widespread use of these techniques. Chief among them are the lack of information, fragmentation and low quality, the uncertainty of the links between environmental problems and their consequences, which ultimately negatively affect the results of the evaluation and their interpretation.

The concept of total economic value (TEV)

The concept of total economic value (TEV) is considered to be the most promising from the perspective of an integrated approach to ecosystem assessment. The basis of this concept is mainly on assessment of the value of biodiversity and protected areas. The concept of total economic value is selected as the reference method for the assessment of goods and services originating from the ecosystems by the World Bank (2004).

The value of the total economic value of natural resources (*the TEV)* is the sum of the two aggregates: value in use (use value, UV) and the cost of non-use value (NUV) (Dixon, Scura, Carpenter, & Sherman, 1994) :

$$TEV = UV + NUV$$

In turn, the cost of using is the sum of three terms:

$$UV = DUV + IUV + OV$$

where *the DUV* - direct cost of using (direct use value); *IUV* - indirect costs of using (indirect use value); *the OV* - cost alternative to a delayed (option value).

Often the non-use value is determined by the value of existence value. Sometimes non-use value also includes the bequest value. These figures reflect, above all, the importance of the social aspects of the nature for society.

The category of "value in use" includes the subcategory "direct use values" – it is goods and the ecosystem services that are used directly by people. It includes consumption value (collection of food, wood, medicinal plants, hunting, etc.) and the value does not use (recreation, etc.). Evaluation of the direct use does not pose any particular difficulties, as there are market prices for these products, and they can be assessed by any means, including the rental method of valuation. It is also easy to calculate the recreational benefits, since it is possible to directly observe the number of visits of tourists. It is more complicated to evaluate the benefits that come for visitors, but there are methods that use tourist surveys that reveal the actual road travel costs or willingness to pay for visits to recreational facilities.

Subcategory "indirect use value" consists of environmental services that provide benefits outside of the ecosystem itself. In assessing the indirect use there are some difficulties with determining of prices for these services (many of the services are not present on the market).

Subcategory "value of deferred alternative" is at the intersection of two values: the use and disuse, because it is understood as the value of goods and services, which are deposited on the future consumption (direct and indirect), or as a result of their own decisions (the value of deferred alternative) or as solutions of someone (the value of the will).

The category of "non-use value" - the most difficult type of value services in terms of cost measurement, because there is no market, evaluating the ethical, aesthetic value of nature, the duty of preservation of nature for future generations, etc. It is difficult to identify in people's behaviour is the pleasure that people derive from the existence of a resource, service; even if they do not involve personally use them. This kind of value is called the value of existence. In contrast with the value of deferred alternatives, it is not determined by future income from the use of natural wealth, but by the very fact of the existence of a clean, diverse, and productive environment, which is used by all of humanity. This approach reflects the recognition of the right to inhabit the land of the living creatures and other objects of nature to an independent existence.

3. **Possible ways and measures to adapt to climate change.** Adaptation to climate change - a dynamic process, extended in time. Similarly with the development process, it should be focused on the continuous improvement of adaptive capacity (natural or anthropogenic) system and its purpose is to reduce the vulnerability to climate change.

   A new adaptive approach called "ecosystems-based adaptation" has been increasing used recently. This approach focuses on the improvement of ecosystem management for the provision of public services. Ecosystem services provide the basis of livelihood for the society, supplying people with food, water and energy, social, economic, cultural services, including disaster risk reduction, carbon sequestration, and, thus, are fundamental tools for climate change adaptation. This approach is defined as the use of ecosystem services as a part of general adaptation strategy to help people adapt to negative climate change impacts (Secretariat of the Convention on Biological Diversity. 2009; World Bank, 2010).

   The approach is aimed at improving the stability and reducing the vulnerability of ecosystems and people by maintaining, protecting and strengthening of ecosystem services. The concept of using ecosystems as a basis of adaptation to climate change is today the most important technology in the set adaptation measures. This approach has been adopted as a basic approach to adaptability of the forest sector to climate change.

   In the area of adaptation, activities focus on national adaptation plans of action (NAPA). Now these plans are carried out in developing countries (web page of the UNFCCC NAPA). Examples of the NAPA show that the greatest attention should be paid to the need of adaptation of negative impacts associated with climate change, since it is in this direction it requires the intervention of governments and international organizations.

   Table 3is constructed based on the materials from NAPA, which shows the adaptation goals, indicators and a set of activities (adaptation strategies) NAPA most approximate to the subject of the project. The actions will be different for each country and region because of peculiarities of their development.

Table 3

Adaptation goals, indicators and a set of activities (adaptation strategies) NAPA

The purpose of adaptation	Indicators of vulnerability	NAPA adaptation strategy
Preservation and improvement of ecosystems and their structural components functioning for sustainability of ecosystem services and products	- Desertification - Deforestation - The degradation of pastures - The replacement of native species, invasion alien species - Loss of biodiversity and ecosystem services in connection with the development of erosion processes and regulation of water flow, economic development of the territory - Loss of forest land (Desertification due to drought) - Reduction of forest productivity - The growing number of extreme weather events	- Fire Prevention - Reforestation and care for plantations - Integrated basin management - Restoration of pasture vegetation - Establishment of forest and grass plantation in ravine and on the slopes - Revegetation on natural pastures - Support the use of not traditional food resources - Creating communication systems for early warning - Including options of climate change into national programmes of education - Training programs of climate change for local communities

It is necessary to determine the indicators for themselves, potentially the most important for each region. The choice of the adaptation measures it is necessary to produce depending on existing real negative impacts of climate change or projections are talking about a serious threat, as well as the results of the analysis of "cost-benefit".

Analysis of "cost-benefit". In order to make the right adaptation measures in the field of climate it is important the correct accounting of value streams of benefits and losses, which are able to provide the ecosystem. Such a systematic approach to ecosystem assessment is as shown in Fig 1.

				Types of resources, ecological services			
			Ecosystem profits	B_1	B_2	…	Bi
			Ecosystem profits without adaptation	B_{1a}	B_{2a}	…	Bia
		Cost	Ecosystem profits with adaptation	$B_{1б}$	$B_{2б}$	…	Bib
Production loss	Damage	Cost	Analysis of "cost-benefit"	Increasing benefit"			
				Δ_1	Δ_2	…	Δi

Fig. 1. A systematic approach to the assessment of forest ecosystem (Puntsukova, 2013).

The first approach to the assessment - general assessment of the benefits flow coming from the ecosystem (the first line). It gives an idea of the scale of the ecosystem's contribution to economic activity, human well-being.

The second approach to the assessment - assessment of changes in the flow of benefits and losses coming from the ecosystem (the second and third row). It shows how climate change affects the flow of benefits and loss of ecosystems.

The valuation mechanism of changes in benefits and losses flow is by comparing these estimates under two conditions:

a) without adaptation measures;

b) with adaptation measures.

In the case of "without adaptation measures", the total value of the resources and services of the ecosystem is reduced due to the negative impact of climate change on the ability of ecosystems to provide goods and services. The difference between the value of the total flow of benefits that gives ecosystem (ΣBi) and the value when there is a degradation (ΣBia) (between the first and second line) is the consequences of ecosystem degradation (D):

$$D = \Sigma Bi - \Sigma Bia$$

In the case of "with adaptation measures", the total value of resources and services of the ecosystem may increase. The difference between the value of the total flow of benefits during the adaptation (ΣBib) and the value of the total flow of benefits without them (ΣBia) (between the second and third rows) shows an increase of benefits from an ecosystem that provides adaptation measures (Δi):

$$\Delta i = \Sigma Bib - \Sigma Bia$$

Events always have their costs and benefits. The benefits include the preservation of resources and services provided by ecosystems (Δi). The costs are regarded as a set of costs and damages (direct loss of production, loss of profits in the form of various kinds of unearned income due to reduced use of the resource (the fourth line). Therefore, we must make sure that the expected benefits outweigh the costs.

This approach, called the analysis of "cost-benefit" (CBA), is to compare the costs and benefits in order to determine whether the benefits from this measure, policy, project, justify related costs. Pearce & Turner (2003) and Pearce (1983) were referred to for the analysis of the environmental benefits and costs..

The work emphasizes that the general rule for effective economic solution option is the excess of the potential benefits (B) on the costs (C). The condition for the effectiveness of the project (if separately allocated a factor of the economic value of nature, or damage caused by it (E)) is the following expression:

$$B - C \pm E > 0$$

Depending on the focus of the project, the benefit may be increased by the amount of ecological and economic effect (Be), or reduced by the amount of environmental and economic damage (Cu). In this case, the expression (3) will be as follows:

$$(B + Be) - (C + Cu) > 0$$

Otherwise:

Be- positive external effects (externalities), including environmental

Cu - negative external effects (externalities), including environmental.

Externalities occur when the production or consumption of goods and services generates uncompensated costs for any third part. Externalities can be negative and positive. Negative externalities arise when the activity is on the one hand the costs of other parties, the decrease in their welfare. Positive - when activity on the one hand brings other benefits, increases their profit. Usually external effects are not fully reflected in market prices.

Environmental projects often have less benefit then the costs. This situation can be expressed as follows:

$$(B + Be) < (C + Cu)$$

This is due not only to the imperfection of the accounting value of the natural component. Here, an important role is played by underestimation of global benefits.

In order to match global and local environmental benefits from the projects and programs, changes is needed for the previous expression:

$$(Bo + Be) > (Co + Cu)$$

$$Bo = Br + Bl$$

$$Co = Cl + Cd$$

In which, Br, Bl - respectively, the overall benefits, consisting of global and local benefits; Co, Cd, Sd - respectively, the total costs, consisting of local costs for the maintenance of ecosystems in good condition and additional costs due to the need to maintain the environmental conditions.

When viewed from this perspective, the favourable condition for the global community of nature protection and conservation of biodiversity in the region is the ratio (6). It shows the excess of the overall benefits, consisting of global (Br) and local (Bl) of the total costs (Co). One of the positive global benefits is a reduction of emissions of CO_2 and other greenhouse gases into the atmosphere. This condition allows a more realistic assessment of environmental projects and programs. In this case, some measures removed obstacle to the implementation of environmental projects due to the fact that they are unfavourable to a particular region, but vitally important at the global level.

Thus, the cost-benefit analysis method can show the effectiveness of the adaptation measures by comparing the above indicators in their conduct without them.

A set of adaptation measures can significantly vary in different countries depending on their individual peculiarities, the degree of threatened forest ecosystems, socio-economic facilities. Therefore, **when choosing one or another adaptation measures it is important to follow a uniform logic.**

Criteria for the selection of adaptation measures. The main priorities in the selection of priority adaptation measures:

- Level of the existing and the proposed vulnerability, threat level;
- Effective options (win-win options), beneficial for all stakeholders;
- Technical and institutional feasibility;
- The potential for reproduction;
- Sustainability;
- Expenses;
- Cost-effectiveness;

The following methods will be used for determining the priorities:

- Cost-benefit analysis (CBA);
- Cost-effectiveness analysis (CEA);
- Expert Evaluation.

It is desirable that selected measures can **reduce the vulnerability of several facilities and services, i.e. have co-benefits** for the population and economy of the region and for the forest ecosystem. From economic point of view, it is preferred that the **adaptation measures having maximum clean present value** in terms of **costs and benefits** over the life of the project.

$$\text{Clean discounted society income from the project} = \sum_{t=0}^{n} \frac{\textit{benefits of the project minus the costs of the project}}{(1 + \textit{discount rate})^{t}}$$

For the implementation of investment projects over a period of 25-30 years (i.e. for the majority of adaptation to climate change projects) can be used the simplified formula:

$$\text{Clean discounted society income from the project} = \frac{\textit{benefits of the project minus the costs of the project}}{\textit{discount rate}}$$

Choosing the discount rate. In the evaluations of natural resources in Russia, different discount rates were applied: 10%, 2%, 1.2% (Bobylev et al., 1999). Ratio of 10% was taken in view of the average value of the current bank deposit rates on foreign currency deposits. Second rate is more closed to the real evaluation, because it shows the amount received as a result of the accumulation of 50 years. Typically, this ratio is traditionally applied in financial investigations related to the assessment of land and efficiency of their long-term use. Third capitalization ratio was taken on the basis of full recovery of destroyed ecosystems of the mixed forest within 81 years.

The latter presented the most viable option from the environmental point, since the period of disposal of forest plots with reproduction on them plant communities requires just such a period of time, that is associated with a potential shortfall of revenue from the lease of land at least for 50 and 80 years.

Determining the relationship between the development plans of the countries surveyed and necessary adaptation measures to climate change. Review existing plans for the development of forestry and other sectors of the economy in studied countries and identification of possible ways to integrate climate change reduction measures and adaptation to existing development plans for the economy were conducted.

Timely and successful accounting of the risks posed by climate change will prevent many types of damage and avoid additional costs of adaptation in future. This will require co-ordination between the authorities of the countries studied and other stakeholder groups - the local population, businesses, and civil society organizations. It is necessary to provide a platform for dialogue among all stakeholders and coordination among them; such coordination is currently underdeveloped.

3. Results & Discussion

a. Brief characteristics of the key areas of research.

Characteristics of the Selenga river basin.

Selenga river basin is located in the mountainous central part of the Asian continent, on the cross-border area between the two states - Russia (Buryatia) and Mongolia. The total area of the basin is 447 thousand square km. 299 km^2 or 67% of the basin accounts for Mongolia, and 148 km^2 or 33% - for Russia.

According to the forest fund data of Buryat Republic Forestry Agency, total forest area of the Selenga river basin is 9.6 million hectares (32.5% of the total forest area) within the borders of the Republic of Buryatia. Forest area is estimated at 8.8 million hectares, timber reserves - 720.0 million m^3. Total forest area of the Selenga river basin within the boundaries of Mongolia is 11.5 million hectares (82.5% of the total forest area). Forested area is 9.5 million hectares, wood-stock is 1152.5 million m^3.

Characteristics of Yellow River delta.

The Yellow River Delta locates in the southern coast of the Bohai Gulf and the western Laizhou Bay with an area of approximately 5400 km^2. Yellow River has changed its major watercourse (about 600 km from the river mouth) 26 times in the last 2200 years.

The natural vegetation is salt meadow mainly; with more than 85% species are salt tolerant plants and aquatic plants. The predominant species in the region are *Suaeda heteropter Kitag*, *Phragmites australis*, *Tamarix chinensis Lour*., *Aeluropus sinenis* and *Imperata cylindrica (Linn.) Beauv* (He et al, 2007). At present there is no natural forest at all, the main secondary forest is the beach *Tamarix chinensis* and the plantations include mainly *Robinia pseudoacacia*. The vegetation is formed only for a short time, with a poor community stability and monotonous species group, and mainly including herb ecosystem, so wholly it is an unstable, fragile terrestrial ecosystem.

b. Climate change.

1) According to Limnological Institute of SB RAS, increase in annual temperature in *Buryatia* (1.2°C for 100 years) was twice higher than the average for the globe (0.7 °C), which is consistent with the known fact amplification rate of warming from low to moderate and high latitudes. It can be expected that the annual air temperature in 2025 will rise by 2° C, and in 2100 by 4° C.
2) Climate warming is estimated by temperature increase of 2.5°C according to the weather station in Ulan-Ude for 103 years (1900-2003). At the same time the average annual temperature in Novoselenginsk has increased by 1.8°C and in Kyakhta by 1.6°C.
3) Global warming has a greater impact on Mongolia in comparison with other regions of the world. The average annual temperature has increased by 2.14° C because of the global warming since 1940, and it is expected to increase to 5°C by the end of the 21st century. However, in the period 1990-2006 there was a small (0.119 ° C / year) decrease in average winter temperature. Analysis of climate trends showed that amid long-term trend of global warming may be a 10-20-year period without an increase in

air temperature and even with its decline. The general tendency of climate change was warming and drying with regional and seasonal differences in the last 100 years in China.

- In Northeast China temperature has increased by 1.43 ° C during the last 100 years.
- Northern coastal areas experienced a similar climate change temperature increase and decrease in precipitation over the last 100 years.
- Central Coastal Region: temperature rising but increase of precipitation in the southern part during the last 100 years.
- Southern Coastal Region: remarkable increase of both temperature and precipitation during the last 100 years.

There is a set of measures to contain the global warming in Russia (Buryatia).

Reforestation was performed on treeless areas, in particular derived from the turnover of agricultural lands, creating erosion and shelterbelt forest plantations. Also important is the preservation of old-growth and intact forests.

Drought frequency and duration of which increased in recent years, contribute to the emergence and spread of forest fires and prevent forest regeneration, so we need to strengthen the prevention and control of forest fires.

There is a range of measures in production forests conducive to increasing forest carbon sequestration:

1) Modification technology for preventing logging of carbon losses litter and soil;
2) Transition from clear cutting to selective;
3) Complete utilization of harvested timber, such as the use of branches and other forest residues for biofuel production;
4) Strengthening action on reforestation on clearings, ensuring the formation of productive plants with desired properties;
5) Use in reforestation fastest growing breeds and varieties of trees.

It is important that forest management planning should be carried out with regard to future climatic situation.

Adaptation measures in the forestry sector in Mongolia.

Carried out afforestation activities in at least 12 thousand ha areas in a year and implementation of the Government 'Green Belt' program on land of at least 200 ha. Besides is conducted the production of trees, shrubs seeds at least 5 tonnes and plant 30 million seedlings a year.

Pest and diseases control is important in mitigating climate change, so surveys are conducted allocation of forest pests and diseases on the territory of 1200 hectares and is operated against harmful forest insects and diseases on 68,500 hectares of land per year.

Great importance is the regulation limit of annual logging (cutting area can be installed as 20-30 thousand hectares per year in connection with the types of trees, their number and power), and the introduction of improved methods of forestry management. Communal ownership of 20% of the total forest communities and forest groups should be established to ensure the recovery of forest protection and proper use of forest resources, etc.

Adaptation measures in the forestry sector in China

The forest industry has developed rapidly, rapidly growing production of the wood, afforestation is support in the fight against desertification and loss of biodiversity. Afforestation is carried out in a comprehensive forest management focus. Pursuant to the Twelfth Five Year Plan, the socio-economic development of China (2010, 2015). New afforestation to increase by 12.5 million hectares.

It was strengthened further development of forest legislation of enforcement and monitoring capabilities in 2011, a modification made "Forest Act", the legislation introduced "The protection of wetlands."

Substantial increase investment in forestry, initial establishment of long-term mechanism for forestry supporting by public financial. 2011, investment in forestry: 274.4 billion yuan, State budget: 130.2billion yuan, 47.45% of total investment. 2011, 0.69 billion yuan invested in national Forestry Workstation.

Each of the participating countries implements projects related to the effects of climate change on forest ecosystems.

Climate change studies and impacts on ecosystems have been conducted for the comparative analysis of the reaction of different forest ecosystems APR in key areas of Russia, Mongolia and China.

Impact of climate change on forest ecosystems. Floristic-geobotanic studies were conducted **in the Russian part of the Selenga river basin** in connection with climate change. The results showed that on the forest areas composed of conifers the changes were not revealed in the state on coenotic community level, no visible changes were surveyed at the landscape level and at the level of vitality of individuals in all areas. Moreover, since the mid-1980s, the expansion of pine tree occurs in steppe landscapes. According to the observations, the pine tree actively occupies fields that abandoned from 1990s, which currently represent the deposits of tall weeds.

Deciduous species - *Betula pendula, B. davurica* - have a tendency to degradation. Deciduous trees, located on the periphery of birch communities, as well as the freestanding trees are withering away. *Populus tremula* dies being in the middle part of the forest areas. These phenomena are observed in almost all areas where there is a birch forest-steppe: in the Yeravninsky and Khorinsky regions of Buryatia and in northern Mongolia.

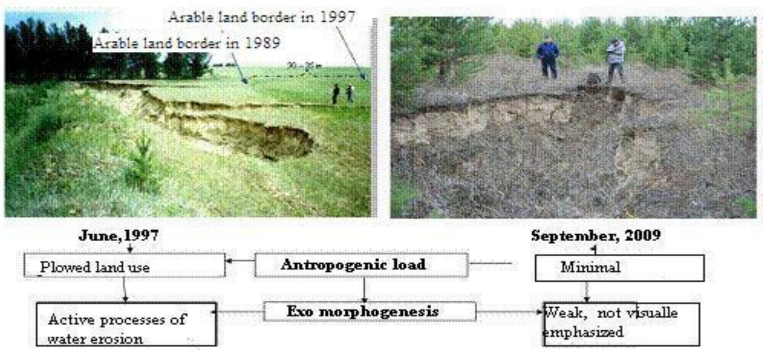

Fig. 2. Changing patterns of exo-morphogenesis depending on the anthropogenic load in the Chikoi basin.

Upon identifying the causes of birch mortality in forest-steppe it became clear that it does not involve pyrogenesis, i.e. fires. Another factor of drying birch in forest-steppe may be the deterioration of moisture conditions, i.e. climate change. In general, we can assume that throughout the territory of Transbaikal in recent decades, arid climate occurs along with warming. This phenomenon reflects the overall situation on which background there was a partial degradation of birch forest-steppe in Transbaikalia and northern Mongolia. This deficit exacerbated by high air temperatures in May. The proof of this assumption is a fact that processes of small-leaved deciduous species drying out in the forest-steppe zone observed across a wide area of the Transbaikalia and Northern Mongolia occurs identically.

Conducted expedition studies on the model firing fields and key areas of the Russian part of the river Selenga basin revealed the reduction of desertification processes, especially within the dry sub-humid climatic zone. On fallow lands cultivated 20 years ago there is an active reforestation by areals of pine (Pinus silvestris), that existed here before plowing and deforestation.

As it can be seen, there is a definite reaction of the forest ecosystem to climate change in the Buryat part of the Selenga river basin. This reaction is multidirectional. There is resistant tree species like the pine, and there are vulnerable deciduous species, especially the birch. The invasion of pine forest to steppe ecosystems is observed, and it associated with increased rainfall, a good ability to reforestation of forest areas as well as reduction of anthropogenic factors plays an important role in this process.

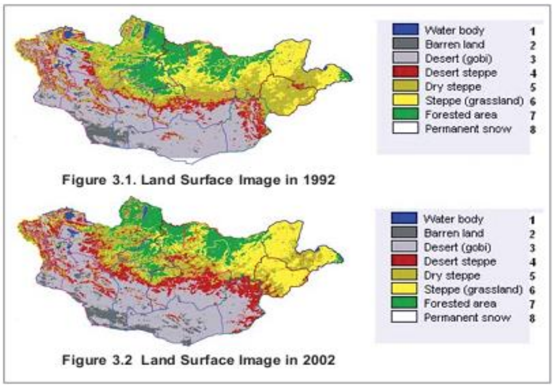

Fig. 3. Comparison of satellite data in 1992 (above) and 2002 (below)

Climate change has an enormous influence on ecosystem, including plant communities **in the Mongolian part of the Selenga river basin.** Comparison of satellite data in 1992 and 2002 as shown in Fig 3. shows that the surface of the earth has changed significantly for 10 years: area of the desert zone has increased and forest area has decreased The land surface was evaluated using satellite data MODIS, which has 16 times higher resolution than the satellite data NOAA in 2006. Data from 2006 showed that the barren area has increased almost three times, while in previous years from 1992 to 2002 area of lands without grass increased by only 46%, and forest area declined by more than 26% over the same period.

Forecast of changes every vegetation zones on the value of precipitation and temperature. Taiga forest area is expected to increase in 2020 and 2050, if there are favorable conditions for the growth of trees in the absence of human influence;

- By 2080 forest area is likely to turn into steppe;
- Steppes is likely will be pressed from the south by semi desert area, and thus the area of the steppes will greatly reduce;
- Semi-desert zones will grow to the north into steppe zone in 2080 due to global warming;

- Reduction of the forest-steppe and steppe areas by 2080 will be caused by the lack of rainfall and rise of temperature during the growing season (June, July and September).

Future climate change scenarios proposed on the basis of calculations: vegetation zones will move to the north, semi-desert and steppe zones are likely to expand. Under various negative factors (climate change, lack of moisture, drought, forest-steppe fires, logging, livestock production) forest ecosystems are changing in the direction of reducing the ecological functions, including regulation of water and soil protection. Thus, the northern part of the Mongolian part of the Selenga river basin is vulnerable terrain.

The overall result of scenarios identified in assessments of climate change is the ability to reduce the area of boreal forests and forest-steppe areas due to expansion of steppe and desert zones. Below there are the results of the Mongolian Program of the 21st century, 1998:

- Area of alpine tundra and taiga fall to 0.1-5.0% in 2020 and to 4.0-14.0% in 2050;
- Area of forest-steppe zone of Khangai, Khentii, Hovsgol, mountainous regions Altai to decrease by 3% in the first and by 7% in the second quarter of the XXI century.

Impact of climate change on forests and natural ecosystems in China can be described as follows:

Firstly, the geographical distribution of major forest types will shift northward and the vertical spectrum of mountain forest belts will move upward. The distribution range of major tree species for afforestation or reforestation and some rare tree species is likely to shrink. **Secondly**, forest productivity and output will increase to different extents, by 1-2% in tropical and subtropical forests, about 2% in warm temperate forests, 5-6% in temperate forests, and approximately 10% in cold temperate forests. **Thirdly**, the frequency and intensity of forest fires and insect and disease outbreaks are likely to increase. **Fourthly**, the drying of inland lakes and wetlands will accelerate. A few glacier-dependent alpine and mountain lakes will eventually decrease in volume. The area of coastal wetlands will reduce and the structure and function of coastal ecosystems will be affected. **Fifthly**, the area of glaciers and frozen earth is expected to decrease more rapidly. It is estimated that glacier in western China will reduce by 27.7% by the year 2050, and the spatial distribution pattern of permafrost will alter significantly on Qinghai-Tibet Plateau. **Sixthly**, snow cover is subjected to reduce largely with significantly larger inter-annual variation. **Seventhly**, biodiversity will be threatened. The giant panda, Yunnan snub-nose monkey, Tibet antelope and others are likely to be greatly affected.

To determine a suitable habitat for separate species, as climate change is likely to lead to changes in suitable habitat for many common species used Tree Atlas. The possible potential changes for tree species under climate change in total North China based on results from the Climate Change Tree Atlas are as follows:

- **Extirpated possibly:** The suitable habitat may disappear by 2100 for Mountain maple;
- **Large Decline possibly:** Balsam fir; Eastern hemlock; Sugar maple; Bigtooth aspen; Northern white-cedar; Tamarack; Black ash; Paper birch; White spruce; Black spruce; Quaking aspen; Yellow birch
- **Small Decrease possibly:** Balsam poplar; Eastern white; pine Red maple; Butternut; Jack pine; Rock elm;

- **No Change possibly:** Basswood; Green ash; Northern red oak; Chokecherry; Northern pin oak; Red pine
- **Small Increase possibly:** Eastern hophornbeam; White ash; Hornbeam
- **Large Increase possibly:** Beech; Boxelder; Shagbark hickory; Bittemut hickory; Bur oak; Silver maple; Black cherry; Eastern cottonwood; Slippery elm; Black oak; Eastern red cedar; Swamp white oak; Black walnut; Hackberry; White oak; Black willow; Osage orange
- **New Entry under High and Low Emissions Scenarios possibly:** Black locust; Ohio buckeye; River birch; Flowering dogwood; Pignut hickory; Sassafras; Honey locust; Pin oak; Yellow poplar; Mockernut hickory; Red mulberry

Some species may have never or very rarely been detected, but show potential suitable habitat entering the region under high emissions such as: Black hickory; Eastern redbud; Scarlet oak; Blackgum; Northern catalpa; Shingle oak; Blackjack oak; Peachleaf willow; Sugarberry; Chestnut oak; Pecan; Sycamore; Chinkapin oak; Post oak; Wild plum; Common persimmon

Based on the analysis of the reaction of different forest ecosystems to global climate change on the territory of the key areas of the participating countries have identified:

1. Forest areas composed of conifers, are not revealed changes in the status of communities and hardwoods tend to degradation;
2. Different scenarios projected offset geographical distribution of plants, especially trees due to climate change;
3. There are various scenarios for potential changes in tree species to climate change (some species may disappear completely or partially, for other species may increase their number).

CO2 balance in the atmosphere depends on the functioning of forest ecosystems - the processes of photosynthesis, respiration and decomposition of organic matter.

Forest ecosystem consists of many subsystems. Accounting for carbon fluxes between all subsystems, including tree stand, understory, ground cover and soil lets us know whether the forest ecosystem carbon sink or source.

Natural and human disturbance of forest ecosystems: forest fires, outbreaks of pests, forestry (mainly deforestation) lead to the release of carbon dioxide into the atmosphere.

Different types of forest ecosystems (boreal and tropical forests, tundra, etc.) react differently to climate change. Functions of forests as sinks of greenhouse gases recognized the UN Framework Convention on Climate Change and the Kyoto Protocol. Approaches to offset forest sink actively discussed in the negotiations on climate agreement, which will replace the Kyoto Protocol.

Laboratory productivity and biospheric functions of forests of the Center for Ecology and Productivity of Forests RAS designed custom educational scientific models for the evaluation of Russian forest carbon budget on the local and regional level. It was developed with the support of the project "Assessment and prediction of climate-change functions of forests Russia" under the Federal Program "Research and scientific-pedagogical personnel of innovative Russia" for 2009-2013. (Ministry of Education and Science of the Russian Federation "

Software development of regional assessment of forest carbon budget (ROBUL) was worked out with the support of the project "Improving estimates of carbon in the forests of Russia" (ICF international).

It was determined two goals for the workshop. **The first** is to provide a regional assessment methodology forest carbon budget (ROBUL). **The second** objective is based on the characterization of the dynamics of the carbon budget by ROBUL in the forests of the key areas.

The value of forest ecosystem services for socio-economic development of the Selenga river basin in Russia.

Ecosystem services of forests play a crucial role in climate change mitigation and adaptation:

- forests, forest-steppe, wetlands and other water bodies and soil are natural stores of carbon, which in the case of destruction of ecosystems move into the atmosphere as CO2 and other greenhouse gas emissions and contribute to climate change;
- forest ecosystems buffer, weak the "hits" of extreme natural phenomena increasingly frequent due to climate change;
- in conditions of economic crisis, which reduce the standard of living of people, ecosystems continue to perform its function to ensure, as a source of water, food, medicines and building materials to the public.

Below there are the results of the assessment of forest ecosystem services most relevant to the region. "The Millennium Ecosystem Assessment" international project approaches are used for their analysis and evaluation. In determining the value of ecosystem services in terms of value in each case used the most appropriate from a number of available techniques. To transfer monetary value of the flow of ecosystem services for the year in the value of the total forest capital (capitalizing annual flows of ecosystem goods) and inverse calculations used the rate of return from the fifty-year maturity, i.e. 2% and simple discounting formula (see the methodological part of the report).

The results of calculations of the forest ecosystem services evaluation are shown in Table. 1.

Table 4. Economic estimates and trends of forest ecosystem services in the Russian part of the Selenga River Basin due to climate change (in current prices**)**

Ecosystem services	Provision of services due to climate change	The demand for services due to climate change	The value of the flow of services for the year, mln USD.	Value forest equity *(stock)*, mln. USD	%
Provision by timber and firewood	+ / -	+/-	20.6	1030.3	9, 4
Providing by forest products	-	+	7.3	363, 05	3.3
Providing by hunting products	-	+	2.3	114.0	1.0
Deposition of	+/-	+	78.3	3913.1	35, 7

Ecosystem services	Provision of services due to climate change	The demand for services due to climate change	The value of the flow of services for the year, mln USD.	Value forest equity *(stock)*, mln. USD	%
carbon					
The filtration function of wetlands	-	+	29.4	1471.25	13 4
Water regulation function of forest ecosystems	-	+	52.1	2605.6	23, 8
Cultural and recreational services	+ / -	+ / -	24.3	1217.4	11 1
Preservation natural conditions for biodiversity	-	+	4.8	238.6	2.2

Note: trends: - decrease; + increase; + - unchanged

The calculations show the real possibility of significant revenue from the use of the forest ecosystem of the Selenga river basin (SRB). These calculations clearly show that the value of forest ecosystem services of the SRB comparable to the gross national product of the area.

Currently, GDP is generated mainly due to the mining of non-renewable natural resources, in particular coal and metals, and the ecosystem services provided by sustainable forest management and successful adaptation to climate change, in principle, are inexhaustible. Plans for the economic development of the region and the global trend for natural resources prices rising suggest that the value of ecosystem services will continue to grow, and their role in the process of adaptation to climate change - increase.

Calculation of the services

i. Provision by timber and firewood

Type of service : providing

The importance for the local population : high

(In accordance with the approaches of the international project "Millennium Ecosystem Assessment": high, medium or low)

Current status : within the normal range

Basic indicators.

According to official statistics in 2014 it was harvested 1,749.3 thousand m^3, including commercial timber – 1,269 thousand m^3. The main suppliers of wood are the central areas of the SRB (Pribaikalskiy, Khorinsky, Bichursky, Kizhinginsky, Kabansky, Zaigraevsky), where the most productive timber plantations are situated, and also it exists a high percentage of forest cover, developed transport infrastructure, proximity to markets for forest products. Table 5 gives the planned volumes of forest felling in the SRB in the short term.

Table 5 The planned volume of logging, thousand m^3

Areas	The planned volume of logging	Including		Including	
		timber	Firewood	Clear-cutting	selective logging
Bichursky	334.2	250.7	83.6	172.9	161.3

Areas	The planned volume of logging	Including		Including	
		timber	Firewood	Clear-cutting	selective logging
Dzhidinsky	28.6	21.5	7.2	18.2	10.4
Yeravninsky	245.1	183.8	61.3	96.4	160.8
Zaigraevsky	257.2	192.9	64.3	110.5	35.5
Zakamensky	146	109.5	36.5	35.1	59.0
Ivolginsky	94.1	70.6	23.5	15.1	357.2
Kabansky	372.3	279.2	93.1	88.5	102.8
Kizhinginsky	191.3	143.5	47.8	26.7	29.4
Kyakhtinsky	56.1	42.1	14.0	57.0	63.3
Mukhorshibirsky	120.3	90.2	30.1	434.7	689.0
Pribaikalskiy	1123.7	842.8	280.9	16.8	41.8
Selenge	58.6	44.0	14.7	81.0	11.7
Tarbagatai	92.7	69.5	23.2	156.2	205.6
Khorinsky	361.8	271.4	90.5	198.0	47.1
TOTAL	**3482**	**2611.5**	**870.5**	**1507.1**	**1974.9**

Source: Republic of Buryatia Forest Plan, Ulan-Ude, 2015.

Valuation.
To assess timber resources, it was used data on planned timber volumes and rental rates for standing timber on the forest areas in the prices of 2013 (tables. 5 and 6). Table 6 shows the value of rental rates for the standing timber in the context of forest economic districts and sub-districts and their respective administrative regions. Indexing royalty rates for timber prices in 2015 made by the ratios established by the Government of the Russian Federation: 2015 year - 1.37. The average rental rate per cubic meter of commercial timber amounted to 450 rubles / m^3, a cubic meter of firewood - 100 rubles.

Table 6 The calculation of payment rates for standing timber based on the rent, rub. / m^3

Forest economic area	Administrative region	Charges for standing timber based on the rent (2013)	Charges for standing timber with coefficient of 1.37
Central	Pribaikalskiy	396.8	544
	Kabansky	416.5	571
	Bichursky, Mukhorshibirsky	244.8	335
	By izhinginsky, Yeravninsky	302.1	414
	Zaigr aevsky, Khorinsky	374.0	512
	Ivol ginskiT, Selenge, Tarbagatai	322.1	441
South	By yahtinsky, Zakamensky, Dzhidinsky	278.1	381

Estimation of wood products by region is presented in Table. 7.

Table 7 Estimation of wood products, thousand US dollars

Areas	Total	Including		%
		Timber	Firewood	
Bichursky	1420.4	1291.8	128.5	7.1
Dzhidinsky	136.7	125.7	11.0	0.7
Yeravninsky	1265.1	1170.8	94.3	6.2
Zaigraevsky	1618.4	1519.5	98.9	7.8
Zakamensky	698.0	641.8	56.2	3.4
Ivolginsky	515.0	478.8	36.2	2.5
Kabansky	2596.1	2452.9	143.2	12.5
Kizhinginsky	987.4	913.8	73.6	4.8
Kyakhtinsky	268.2	246.6	21.6	1.3
Mukhorshibirsky	511.3	465.0	46.3	2.5
Pribaikalskiy	7485.6	7053.4	432.2	36.1
Selenge	320.7	298.2	22.5	1.6
Tarbagatai	507.4	471.7	35.7	2.5
Khorinsky	2276.6	2137.4	139.2	11.0
TOTAL	**20606.7**	**19267.5**	**1339.2**	**100.0**

The value of ecosystem services to ensure the business of timber is US $ 19.3 million per year, to ensure that the wood -. US $ 1.3 million per year for a total of -.US $ - 20.6 million a year.With capitalization of the flow of goods at the rate of 2%, the value of forest capital for the purpose of providing timber and firewood is not less than 1.0303 million US dollars. This assessment is incomplete because it does not take into account the volume of illegal logging.

Tendencies of development.
In general, the region's development plans do not carry with them the threat of an ecosystem service to provide the population of timber and firewood. The volume of timber in the SRB remain well below the annual allowable cut, but will gradually increase due to the increased demand for it both within the region and from overseas markets, especially China. It should be noted that illegal logging is a threat to sustainable forest management and reforestation in the SRB.

The observed and potential impacts of climate change on the service.
The results of research and observation conducted within the project show that in general in the medium and long term the basin forests have high internal capacity for adaptation, and good adaptability to climate change due to belt growth at different altitudes.

Regarding forest fires, it should be said that the during last 15 years period, a large fires decline from 10-12 years to 5-6 years. The reason - global climate change, which affects on the increase of the number of dangerous weather events, which include periods of hot and dry weather, which creates conditions for catastrophic fires. According to Roshydromet of the Russian Federation over the past 15 years, the number of dangerous weather events has increased in 2 times. On the spread of forest fires in large areas a big negative influence makes imperfection of the existing forest legislation for the protection of forests from fires. At the site of the former well-established structure of protection and suppression of forest fires is not an effective system to combat fires. As a result, it violated the basic principle of the protection of forests against fire - early detection of combustion sources - low costs for extinguishing fires due to the small size of it. Second, the lack of financial resources - the allocation of subventions from the federal budget for the prevention and suppression of forest fires each year decreases. It also has a direct impact on the increase of burning forests. On the other hand, forest fires "programmed" by nature as part of the evolution of the forest ecosystem, but excessive they occur and spread in conditions of extreme weather and unfavourable distribution of forest resources by grade of natural fire danger, the accumulation of "dry" fuels in the forest, she becomes the victim , carrying huge losses. In addition, these fires are a threat to the population and human settlements, economic objects.

Under favourable conditions, forest fires should promote the substitution of some other types of vegetation, more adapted to the new climate.

However, fires, pests and other negative impacts of climate change can cause significant damage to the forest sector of the economy in terms of timber and wood supply (Table. 8)

Table 8 The consequences of climate change in SRB for ecosystem services to ensure timber and firewood

The threats posed by climate change	The observed and potential impacts
Primary climate threat	
Droughts, heat waves	The emergence of fire-in summer conditions, the spread of fire
Heavy rains, snowfalls, storms, hurricanes, and spring thaw, snowless winters	Damage and loss of trees, the accumulation of flammable deadwood and fallen trees
The long-term rise in temperature	Changing the composition of plant complexes
Indirect climate threat	
Floods, landslides, avalanches and mudflows	The difficulty of access to the felling
The spread of diseases and pests	Damage and loss of trees, the accumulation of flammable deadwood and fallen trees
The spread of alien plant species	Changing the composition of plant complexes

ii. Provision of forest products

Type of service *:* providing
The importance for the local population *:* high
Current state ***:*** within the normal *range*
Basic indicators.
Harvesting food forest resources and collection of medicinal plants on the lands of the forest fund of the SRB does in two ways: by individual entrepreneurs under lease agreements for forest parcels - a fee in the form of rent and by local population for their own needs - free of charge. The main products of the forest (use side) are wild berries, mushrooms, pine nuts, medicinal plants.

Annual allowable harvesting of forest food resources and medicinal plants in the territory of the SRB by districts is shown in the table 6. Data source - forest inventory materials.

Volumes are determined based on the area of productive berries, mushrooms, cedar kernel production, the average biological productivity of food per 1 hectare, taking into account biological loss, inaccessibility and remoteness of places for food gathering.

Table 9 Possible annual harvesting food forest resources and medicinal plants, ton

areas	pine nut	Berries	mushrooms	Medicinal raw materials	in total
Bichursky	1800	26.5	15.8	5.86	1848.16
Dzhidinsky	300	5.06	1.8	0.15	307.01
Yeravninsky	0	4.84	0 14	0.29	5.13
Zaigraevsky	50	0.1	0.59	0.02	50.71
Zakamensky	500	1.05	0	0.12	501.17
Ivolginsky	51.2	5.8	12	1.96	70.96
Kabansky	21	6.3	1.85	1.35	30.5
Kizhinginsky	eleven	2.26	1.07	0.55	14.88
Kyakhtinsky	7	26.54	2.2	0.02	35.76
Mukhorshibirsky	3	0.36	1.8	0.09	5.25
Pribaikalskiy	600	5.04	1	0.64	606.68
Selenge	500	3	2.35	0.45	505.8
Tarbagatai	3	7.53	1.17	0.66	12.36
Khorinsky	1003.5	21.14	11.86	2.03	1038.53
in total	4849.7	115.52	53.49	14.19	5032.9

Source: Republic of Buryatia Forest Plan, Ulan-Ude, 2015 Forest forestry regulations of the Republic of Buryatia, Ulan-Ude, 2013 - 2015.

Valuation.

Assessment of forest food products are produced based on the amount of food and medicinal raw materials, the average prices for them, the average level for the procurement cost, transportation and marketing, which are accepted, depending on the type of product from 40% to 60% of the sales price.

Prices for wild berries in the markets of the city of Ulan-Ude were: blueberries, currants - 250 rubles / kg, blueberries - 350 rubles / kg, cranberries - 300 rubles / kg, cranberries - 200 rubles / kg. In the season of collecting mushrooms sold at a price of 350-500 rubles for 1 kg, depending on the fungal species. Prices for pine nuts varied in the range of 300-400 rubles / kg. Prices of medicinal raw materials - from 80 to 3600 rubles per 1 kg, depending on the plant.

Economic evaluation of the forest and medicinal raw food has been made on the basis of these data, which amounted to 472,029.4 thousand. rub. (table 10). In this the greatest economic value occupies the proportion of pine nuts.

Table 10 Economic evaluation of food forest resources and medicinal plants by the districts (thousand Rubles).

Areas	Cedar nut	Berries	Mushrooms,	Lek.rast.,	Total, thousand. Rub.	In $ US ($ 1 = 65 rubles).	Specific weight,%
Bichursky	162000	4240	3318	2399.7	171,957.7	2645.5	36.4
Dzhidinsky	27000	809.6	378	61.4	28249	434.6	6
Yeravninsky	0	774.4	29.4	118.8	922.6	14.2	0.2
Zaigraevsky	4500	16	123.9	8.2	4648.1	71.5	1
Zakamensky	45000	168	0	49.1	45217.1	695.6	9.6
Ivolginsky	4608	928	2520	802.6	8858.6	136.3	1.9
Kabansky	1890	1008	388.5	552.8	3839.3	59.1	0.8
Kizhinginsky	990	361.6	224.7	225.2	1801.5	27.7	0.4
Kyakhtinsky	630	4246.4	462	8.2	5346.6	82.3	1.1
Mukhorshibirsky	270	57.6	378	36.9	742.5	11.4	0.2
Pribaikalskiy	54000	806.4	210	262.1	55278.5	850.4	11.7
Selenge	45000	480	493.5	184.3	46157.8	710.1	9.8
Tarbagatai	270	1204.8	245.7	270.3	1990.8	30.6	0.4
Khorinsky	90315	3382.4	2490.6	831.3	97019.3	1492.6	20.6
in total	**436473**	**18483.2**	**11262.3**	**5810.8**	**472,029.4**	**7261.9**	**100**

The value of this ecosystem services might be estimated at 7.3 million US $ in the year. With capitalization of the flow of goods at the rate of 2%, the value of SRB forest capital for the purpose of providing the population with food gathering can be estimated at US $ 363,050,000.

Tendencies of development.
Not only in the SRB, but everywhere in the world fishing activity (gathering) increases in periods of economic downturn. People who lost their jobs and other sources of income, especially in a weak economy SRB, return to subsistence farming. Currently, collective activity in the region is normal and does not affect adversely on the reproduction of the ecosystem service. The future use of the ecosystem services depends on the success of measures to reduce unemployment and economic diversification in the region.

The observed and potential impacts of climate change on the service.
In terms of climate change crop failures may become more frequent - lack of food - it will enhance the role of forests in providing food and forest herbs for the treatment of men, so it is necessary to strengthen their protection. Forest fires, landslides, avalanches, mudslides, and other extreme events may make it difficult to access objects of collecting. Reducing access to forest foods and medicinal plants and other non-timber products may have an impact on human health directly (by reducing the availability of medicinal plants) or indirectly (loss of products for sale on the market to generate income). In addition, climate change may alter the conditions of growth and reproduction of food and some rare species of plants.

The effects of climate change on ecosystem services related to the mentioned activities (gathering, hunting) are shown in table 13 (see below).

iii. Provision of hunting products

Type of service : providing
The importance for the local population : *average*
Current state : within the normal range
Basic indicators.

Objects of commercial hunting both legal and illegal can be roughly divided into three categories - fur and hoofed animals and poultry. The main of them - squirrel, rabbit, sable, muskrat, wild boar, roe deer, musk deer, elk, moose, wolf, fox, groundhog, musk deer, bear, lynx, badger, many bird species.

Dynamics of the main commercial animal shows growth in the number of hoofed animals from 2002 to 2015 on the average from 15 to 43%. Changes in the number of fur-bearing animals at the same time are in different directions. Squirrel, wolverine, weasel, ermine show a decline, the largest drop seen among populations of squirrel (almost two times). Other (sable, fox, muskrat, rabbit, and lynx) increased their number. Data on the number of wolves in the dynamics are contradictory: it values fluctuate with the difference in year-on-year from 600 to 1000 individuals. Brown Bear, as well as among birds there is a steady trend of population growth.

The physical volume of hunting is quite difficult to assess, especially in view of the fact that the tangible part of it is carried out illegally, endangering the rare and endangered species. An important factor in harvesting of wild species in the region is external demand, especially from China, where they are used in folk medicine. Below are the official data on the production of animals in the SRB in 2015.

Table 11 Production of game animals in the Selenga River Basin in 2015, individuals

№ p / p	Area	Fur	Hoof	Birds
1	Bichursky	2195	255	1701
2	Dzhidinsky	1426	171	4821
3	Yeravninsky	4186	170	3450
4	Zaigraevsky	3434	500	5507
5	Zakamensky	3907	223	2728
6	Ivolginsky	1005	122	2294
7	Kabansky	2999	128	6247
8	Kizhinginsky	3829	202	926
9	Kyakhtinsky	1280	142	2151
10	Mukhorshibirsky	1129	107	1347
11	Pribaikalskiy	6516	311	1668
12	Selenge	2320	269	2862
13	Tarbagatai	854	131	873
14	Khorinsky	10081	323	1823
	in total	**45161**	**3054**	**38398**

Source: Departmental materials of Burprirodnadzor, RB

The valuation formula is used to calculate the economic evaluation of commercial hunting resources:

$$Э_{жс} = \sum_{j=1}^{n} Q_{\partial j} * P_{жсj} - TC,$$ where

Q $_{Aj}$ – volume of production of j-th species of wildlife resources; n - number of species of wildlife (j = 1, 2, 3 ... n); P $_{zhj}$ - the cost of hunting products of j-th species of wildlife resources, TC- overall cost of hunting farms, taking into account the normal profit.

Total costs for hunting management consist of the cost of biotechnical measures on protection and reproduction of hunting resources, accounting for the number of hunting resources, to establish infrastructure and hunting and others.

Below is the valuation of hunting animals by type (table 12). Hunting unit production cost is made up of average prices for skins, meat and other ingredients (fat, musk gland, etc.). When calculating the cost of hunting resources used data on production of a particular type of animal (Table 11).

Table 12 Evaluation of hunting resources SRB

Area	The cost of hunting resources, thousand Rubles				Specific weight,%	Thousands USD
	fur	hoof	Birds	Total		
1. Bichursky	1849.2	9410.4	367.5	11627.1	7.8	178.9
2. Dzhidinsky	803.3	5752.8	950.5	7506.6	5.1	115.5
3. Yeravninsky	960.9	6652.8	790.7	8404.4	5.7	129.3
4. Zaigraevsky	1925.7	19353.6	1146.4	22425.7	15.1	345.0
5. Zakamensky	2062.0	8495.2	632.5	11189.8	7.5	172.1
6. Ivolginsky	834.7	4480.0	395.7	5710.3	3.9	87.9
7. Kabansky	3030.2	4382.4	1020.8	8433.5	5.7	129.7
8. Kizhinginsky	1688.8	7262.4	193.9	9145.1	6.2	140.7
9. Kyakhtinsky	993.6	5918.4	421.1	7333.1	4.9	112.8
10. Mukhorshibirsky	955050	4322.4	274.3	5551.8	3.7	85.4
11. Pribaikalskiy	5262.6	12600.8	379.4	18242.7	12.3	280.7
12. Selenge	1220.4	9960.0	600.6	11781.0	7.9	181.2
13. Tarbagatai	590.5	3860.0	175.6	4626.0	3.1	71.2
14. Khorinsky	4537.1	11296.8	405.8	16239.8	11.0	249.8
in total	**26714.2**	**113,748.0**	**7754.8**	**148,217.0**	**100.0**	**2280.3**

The value of this ecosystem service can be estimated at 2.3 million US$ per year, with capitalization of the flow of goods at the rate of 2%, the value of SRB forest capital for the purpose of providing the population with products of hunting is US $ 114.0 million.

Tendencies of development.
Assessing the modern structure of the distribution area of the hunting farms and animal production data it may be noted the extensive mode of production, based on granting in rent of the hunting grounds. As a result, there is a low level of use of the potential of natural productivity of hunting grounds, low cost and small biotech event activities in the field of expanded reproduction resources.

During the surveys of district units of Burprirodnadzor conducted in the 2005-2015 period it was revealed that the most negative impact in the field of harvesting of fur animals have: poaching - 8 out of 14 districts, forest fires - 5, fishing - 2, felling timber - 2 districts. According to the personal data collected in the 14 hunting regions of Buryatia, 226 hunters legally extract of wild animals and illegal hunting carried out 380 hunters.

Hunting activity increases in times of economic crisis. This trend is clearly shown after the collapse of the socialist system in the early 1990s and during the financial-economic crisis, 2008-2011, 2014-2015. Currently, hunting activity, linked to illegal hunting can harm reproduction of the ecosystem service. Therefore, the future use of this ecosystem service depends on lowering unemployment, economic recovery in the region, measures to combat poaching and illegal export of wild animals outside the region.

The observed and potential impacts of climate change on the service.
The fires, landslides, avalanches, mudslides, and other extreme events, more frequent due by climate change, may hamper access to hunting sites. In addition, climate change may complicate the conditions for the existence and reproduction of some rare species of animals, which also are the subject to illegal hunting, so it needs to enhance their protection. The effects of climate change on ecosystem services related to the mentioned activities (gathering, hunting) are shown in Table 13.

Table 13 The effects of climate change on ecosystem services to ensure non-timber products in the RBS

The threats posed by climate change	The observed and potential impacts
Primary threats	
The long-term rise in temperature	The increase in terms of the hunting season, more favourable conditions for many kinds of foods, plants and hunting objects
Droughts, heat waves	Damage and loss of food, and hunting objects and forest products
Showers, snow, storms, hurricanes, and the spring thaw, snowless winters	Damage and loss of food, and hunting objects and forest products
Indirect threats	
Floods, landslides, avalanches and mudflows	The difficulty of access to food, forest products, and hunting objects
Distribution of wildfires	Damage and loss of food, and hunting objects, medical plants
Distribution of pests and diseases (including the Colorado potato beetle, and grasshoppers)	Damage and loss of food, and hunting objects, medical plants
The increase in demand for non-wood products	The growth of operating food, l medical plants and hunting objects

4. Carbon sequestration

Type of service *:* regulating, supporting
The importance for the local population : *average*

Current state *: within the normal range*
Basic indicators.
The calculation of annual carbon sequestration produced using materials of forest accounting at 01.01.2013 - forest distribution of land categories, species and age of forest stands (area and volume). Calculations by the method ROBUL showed that in 2013 the carbon stock in the forests of the SRB is 1.2773 billion tons, including living biomass of -. 351 1 million tons, dead - 77.7 million tons, 46.9 million tons of litter, in a layer of soil -. 769,9 million tons (table 14).

In stock and annual carbon sequestration in forests of SRB an important role plays breeds composition and especially the age structure of the wood. A more detailed analysis shows that the largest carbon reserves are concentrated in larch and pine forests, as they are predominant for the SRB. In considering the specific carbon stocks it is that the greatest value of this indicator reaches for the cedar - 81.3 t / ha, the smallest - to birch (37.6 t / ha) and shrubs (29.6 t / ha). It is obvious that differentiation of this indicator is directly related to the average inventory for each breed, which in turn are determined by the site class and age structure of forest stands of each breed.

Table 14 The distribution of the value of stocks and annual carbon sequestration by administrative districts of the SRB (all pools)

areas	The stock of carbon 10^6 t C year $^{-1}$		Carbon sequestration 10^6 t C year $^{-1}$	
	Total	Specific gravity	Total	Specific gravity
Bichursky	69.934	5.5	0.301304	5.7
Dzhidinsky	67.518	5.3	0.195593	3.7
Zaigraevsky	66.451	5.2	0.437431	8.3
Zakamensky	209.229	16.4	0.320852	6.1
Ivolginsky	29.537	2.3	0.165838	3.1
Kabansky	98.309	7.7	0.308924	5.8
Kizhinginsky	74.437	5.8	0.534852	10.1
Kyakhtinsky	26.524	2.1	0.123323	2.3
Mukhorshibirsky	29.703	2.3	0.188428	3.6
Pribaikalskiy	204.647	16.0	0.696627	13.2
Selenge	74.869	5.9	0.435257	8.2
Tarbagatai	29.225	2.3	0.145097	2.7
Khorinsky	158.910	12.4	0.840996	15.9
Yeravninsky	137.996	10.8	0.600674	11.3
TOTAL	**1277.287**	**100.0**	**5.595196**	**100.0**

Annual carbon sequestration by the basin Forest Fund is 5.6 million tons, including living biomass of -. 3,8 million tons, dead - 0.7 million tons, litter -0.1 million tons, in the layer of soil - 0.9 million tonnes (table 14). The highest values have pine (0.81 t / ha), the least - spruce (0.25 t / ha).

Valuation.
Currently in Russia, in contrast to majority of developed and some developing countries, there is no domestic market of mandatory or voluntary quotas for greenhouse gas emissions. In addition, the forest sector in Russia is not connected to international carbon

markets. Therefore, monetary valuation of ecosystem services for carbon sequestration in the SRB is difficult.

However, in the case of connecting Russia to international processes for the implementation of carbon sequestration economic incentives in forestry the value of the ecosystem services in the SRB can be enormous.

For evaluation of this function value we determined the size of depositing carbon by multiplying of volumes of carbon on 3.66 (carbon dioxide molar weight molecules as compared to a carbon atom). The total deposition of CO_2 amounts to 15,652.35 thousand tonnes per year. Taking into consideration the expert evaluation of possible sales price of 1 ton of CO_2 in the carbon market at $ 5., we obtain the value of ecosystem services of SRB forests pool for carbon sequestration in US $ 78.3 million (tab. 15). In terms of the value of the forest capital (annualizing the stock of natural capital) at a rate of 2%, the value of the flow of this type of goods for the year is $ 3,913,100,000.

Table 15 Evaluation of the carbon sequestration ability of forests in SRB

Area	Carbon sequestration, 10^6 t C yr-1			Valuation of carbon sequestration functions of forests		
	Total	including		Carbon dioxide, ths. tons	Cost, thous. USD.	
		Biomass	Dead wood			%
Bichursky	0.253517	0.212345	0.041172	927.9	4639.4	5.9
Dzhidinsky	0.171572	0.143042	0.02853	627.9	3139.8	4.0
Zaigraevsky	0.353787	0.281556	0.072231	1294.9	6474.3	8.3
Zakamensky	0.220286	0.229052	-0.008766	806.2	4031.3	5.2
Ivolginsky	0.151095	0.121291	0.029804	553.0	2765.1	3.5
Kabansky	0.29499	0.250858	0.044132	1079.7	5398.3	6.9
Kizhinginsky	0.406325	0.330555	0.07577	1487.1	7435.8	9.5
Kyakhtinsky	0.111433	0.085794	0.025639	407.8	2039.2	2.6
Mukhorshibirsky	0.147984	0.123199	0.024785	541.6	2708.1	3.5
Pribaikalskiy	0.625554	0.541408	0.084146	2289.5	11447.7	14.6
Selenge	0.368715	0.297071	0.071644	1349.5	6747.5	8.6
Tarbagatai	0.12903	0.101357	0.027673	472.2	2361.3	3.0
Khorinsky	0.648036	0.532482	0.115554	2371.8	11859.1	15.2
Yeravninsky	0.394274	0.337925	0.056349	1443.0	7215.2	9.2
TOTAL	4.276598	3.587935	0.688663	15652.3	78261.7	100.0

If the world price of greenhouse gas emissions will continue to grow, and the value of forest ecosystem services of the SRB for carbon sequestration will increase.

The observed and potential impacts of climate change on the service.
Bioclimatic models predict an increase in biomass of the region as a result of climate change and, thus, increase the mass of carbon-related vegetation. However, the worsening fire situation in the region due to climate change, increasing the logging will contribute to an increase in CO2 emissions by forests in the SRB. Also on this service will negatively affect the consequences of further development of the local hydrocarbon resources, especially

coal deposits in Mukhorshibirsky, Bichursky, Selenginsky, and other districts. In particular, Tugnuisky and Nikolsky coal deposits have more than 70% of the volume of coal produced in Buryatia. Total in 2013, they were taken 20 million tons of coal, in terms of carbon it is about 14-16 million tonnes (conversion factor of 0.7-0.8), and in terms of CO2 - about 50 million tons (conversion factor 3.66). That's more than the entire deposited by whole phytomass in SRB.

5. The filtration function of wetlands.

Type of service	*: regulating*
The importance for the local population	**:** *average*
Current state	*:* within the normal range

Basic indicators.

Marshes are a natural filter, absorbing capacity of which in relation to weigh different for different types of wetlands. For lowland it is 0.5 t/ha/year, for mixed - 1.5 t/ha/year, for riding - 2.5 t / ha / year. Surface water of rivers, lakes and reservoirs contain 10-15 mg/l of suspended solids, while the water in the marshes contain 5-9 mg/l of suspended solids. In this way:

1) the most contaminated river water swamp as a filter cleanse the concentration of suspended solids of the order 15-5 = 10 mg/l;
2) the cleanest surface water is cleared by swamp, having a maximum filtration possibilities and giving the outlet mist concentration of the order of 10-9 = 1 mg/l. Based of the above cases, it can be concluded that wetlands purified water from the bog suspensions, bringing them up to a concentration of 1-10 mg / l.

The ecological value of wetlands is of paramount importance due to the fact that the purity of Baikal water is saved thanks largely to their filter paper. On the territory of the Selenga river basin according to forest inventory documents swamps cover an area of 92,5 thousand hectares (0.8% of the total area of forest). Table 16 shows the area of wetlands in the context of the district. In all districts are dominating upland marshes (50863.5 ha), followed by the grassroots (27,743.7 ha) and mixed (13,871.8 ha).

Valuation.

For the economic evaluation of filtration abilities of marshes, they are compared with the industrial sewage treatment plant with a capacity of 1500 m^3/day (50-70 m^3 of water per hour at 2-3 shifts). The price of one mentioned plant reaches an average of $ 50 thousand. Reduced installation cost for one year calculated from the formula of capitalization of *the PV* = *the R* / *i* , according to which the present value of the annual installation (*the R*) is determined by formula

$$R = PV \cdot i$$

where *the PV* - the cost of installation, *i* - the interest rate is equal to 1 / *T* (years).

It is assumed that one plant will operate at least 50 years, i.e. *T* = 50, *i* = 0.02.
Now consider what area of wetlands is equivalent to a plant, and then we can define the total cost related to the use of swamps.

Calculations show that the grass-roots wetlands have a bandwidth equal to 137 m^3/day/ha, i.e 11 hectares of swamp purified waste water is equivalent to a 1 plant, the annual present value of which is US$ 1 thousand/year. Thus, grass-roots wetlands save on water treatment to about US$ 2.52 million/year (27.7 thousand ha / 11 ha * $ 1 thousand). Mixed wetlands are three times more effective than low-lying, so the cost related to the use of mixed swamps is about $ 3.78 million/Year (13.9 thousand ha / 11 ha * 3 * $ 1 thousand/year). Upland wetlands are effective five times, so the cost related to the use of them can be estimated at $ 23,120,000 / year (50.9 thousand ha / 11 ha * 5 * $ 1 thousand / year). Table 16 shows the results of calculating the value of filtration ability of wetlands in the context of districts.

Table 16 Areas of wetlands and evaluation of its filtering capacity in the SRB, ha

Area	The area of swamps, ha	Including			Evaluation of the ability of the filter marshes thousand USD	%
		Grass-roots	mixed	upland		
Bichursky	107	32.1	16.1	58.9	34.0	0.1
Dzhidinsky	1656	496.8	248.4	910.8	526.9	1.8
Yeravninsky	18271	5481.3	2 740.7	10049.1	5813.5	19.8
Zaigraevsky	202	60.6	30.3	111.1	64.3	0.2
Zakamensky	6501	1950.3	975.2	3575.6	2068.5	7.0
Ivolginsky	17	5.1	2.6	9.4	5.4	0.0
Kabansky	46953	14085.9	7 043.0	25824.2	14939.6	50.8
Kizhinginsky	4700	1410	705.0	2585.0	1495.5	5.1
Kyakhtinsky	21	6.3	3.2	11.6	6.7	0.0
Mukhorshibirsky	thirty	9	4.5	16.5	9.5	0.0
Pribaikalskiy	12847	3854.1	1 927.1	7065.9	4087.7	13.9
Selenge	301	90.3	45.2	165.6	95.8	0.3
Tarbagatai	0	0	-	0.0	0.0	0.0
Khorinsky	873	261.9	131.0	480.2	277.8	0.9
in total	**92479**	**27743.7**	**13871.8**	**50863.5**	**29425.1**	**100**

Thus, the total value of indirect use of wetlands in the SRB is estimated at US$ 29.4 million in a year. The greatest contribution is made by the wetlands of Kabansky, Pribaikalsky and Yeravninsky districts (84.5% of the total). If the capitalization of services taking into account with the discount rate of 2%, value of the forest capital of this service is US$ 1,471,250,000.

The observed and potential impacts of climate change on the service.
This service is greatly affected by the cyclical processes of water, global climate change, one of its characteristics - low rainfall. These factors impact on river flows, groundwater sources, and including marshes - the guarantor of stability and purity of the hydro- and ecosystems. Increased fire danger leads to burning of peat lands, which is what happens in Kabansky district. Selenga River and Lake Baikal are depended on the cleaning services of the marshes and the value of the considered ecosystem services will increase.

6. Water regulation function of forest ecosystems

Type of service *: regulating*
The importance for the local population *:* high
Current state *:* within the normal range

Basic indicators.
Influence of forest vegetation to increase water availability through increased river flow is large. The water permeability of forest soils is very high, which allows to convert almost all rainfall in runoff.

On the water regulation capacity of forests to a large negative influence make clear cuts of forests. Clear cutting effects almost on the entire area of the cutting area, only 10-20% is stored in intact form. During selective felling up to 80% of allowable cut area remains in undisturbed state [12].

It was found that runoff from areas untouched by logging virtually is absent, on clearings with slightly damaged soil surface flow is 1-2%, with the damaged soil - from 15-25% to 55-65%, with the main, heavily compacted trails - comes to 80-98% of the amount of precipitation [6].

Valuation.
To evaluate the water regulating functions of forests, make a number of assumptions:

1. The main burden of the implementation of this function have forests located in water protection zones, restricted forest belts along water bodies, forests spawning bands (Table 17)
2. Only selective logging in the water protection forests are carried out with the withdrawal of up to 30% on wood cutting area. The volume of selective logging - is planned volumes of timber harvesting in the near future (see table 5)
3. Forest area, performing water-regulating function is adjusted downward by the surface area of selective logging. To this end, the volume of sample cuttings is transferred to area (ha). Translation Formula - felling volume divided by the value obtained by multiplying the average stock of wood per 1 ha in the % of the sample timber in the felling area.

Table 17 Square of the SRB forests perform water protection function, ha

	Forest area performing water-regulating function, ha	Including		
		Forests located in water protection zones	Restrictive strips of woods along the water bodies	Spawning forest belts
Bichursky	38.3	-	30.2	8.1
Dzhidinsky	25.6	-	5.5	20.1
Yeravninsky	69.4	-	19.0	50.3
Zaigraevsky	45.9	-	43.3	2.6
Zakamensky	256.4	-	193.6	62.7
Ivolginsky	23.4	-	15.0	8.4
Kabansky	539.6	539.6	-	-
Kizhinginsky	58.8	-	46.8	12.1
Kyakhtinsky	4.3	-	-	4.3
Mukhorshibirsky	1.7	-	-	1.7
Pribaikalskiy	687.6	483.3	154.5	49.9
Selenge	88.2	46.9	22.8	18.4
Tarbagatai	6.0	-	1.7	4.3

	Forest area performing water-regulating function, ha	Including		
		Forests located in water protection zones	Restrictive strips of woods along the water bodies	Spawning forest belts
Khorinsky	115.8	-	87.8	28.0
Total	**1961.0**	**1069.8**	**620.2**	**271.0**

Source: Materials of the State Forest Registry, Republican Agency of Forestry

The cost of water regulating functions of forests is determined as the difference between the total amount of precipitation and volume of surface runoff*:*

$$Ct = ((Os * 10 * Tb) - (\square\square\square(Ki * Si) * Tb)) * So,$$

Os - the amount of annual precipitation in the region, mm

10 - conversion factor of rainfall mm in m3;

Tb - the tariff for 1 m3 of water taken from the water system by enterprises operating in the region, rub.

Ki - coefficient of surface runoff, depending on the type of soil, the degree of damage to the soil and the annual precipitation;

Si - area of forest plots with different categories of damage passed by selective cutting, ha

So - forest area, performing water-regulating function, ha

Thus, the value of this function depends on an adjusted forest area, performing this function, the degree of damage to the soil (the ratio of damaged and undamaged soil surface), mechanical composition of the soil, the amount of precipitation.

To carry out the practical calculations it was used gradation of area covered by logging, developed in the methodology quantifying the impact of logging on the forest environment [6]:

S_0 - cutting area with the intact soil. Surface runoff coefficient = 0;

S_1 - cutting area on which damage of the soil depth does not exceed 10 cm, surface runoff coefficient is less than 0.1;

S_2 . - cutting area on which damage of the soil depth is 11-20 cm, surface runoff coefficient = 0,11- 0,50;

S_3 - the area occupied by loading ramps, top warehouses, fuel depots, cultural and community facilities. Surface runoff coefficient = 0,51- 0,70;

S_4 - cutting area occupied by main and bee dies. Surface runoff coefficient = 0,71- 0,98.

Initial data for the calculation and the calculation itself are shown in table 18.

Table 18 Calculation of unit cost of water regulating functions of forests

Indicators	Selective logging (30% sample)
Initial data	
1. Soil Category	easy
2. The amount of annual precipitation, mm	356
3. The conversion factor of precipitation in mm m3	10

4. The rate for the fence 1 m ^{3} of water, rub.	0.576
5. The coefficients of surface runoff, depending on the amount of rainfall head, m3	application number
Calculation	
1. The total unit cost function, rub. / Ha	365 * 10 * 0.576 = 2102.4
2. The average size S1 soil damage with selective felling, in% S2 and decimal S3 S4	10 (0.10) 10 (0.10) 5 (0.05) 10 (0.10)
3. The amount of surface runoff, thousand. M ^{3} S1 S2 S3 S4	0.10 * 0.5 = 0.050 0.10 * 1.0 = 0.100 0.05 * 2.5 = 0.120 0.10 * 3.5 = 0.350
Total thous. M ^{3} / ha	0,600
4. The cost of the loss of precipitation, rub. / Ha	600 * 0.576 = 345.6
5. The unit cost function net loss rub. / Ha	2102.4 - 345.6 = 1756.8

Calculation of areas			
areas	Adjusted forest area, performing water-regulating function, thous. Ha	Value function, ths. Rub.	Value functions thousand. Dollars. USA
Bichursky	35.6	62562.6	962.5
Dzhidinsky	25.4	44669.6	687.2
Yeravninsky	66.7	117,213.7	1803.3
Zaigraevsky	45.3	79597.7	1224.6
Zakamensky	255.4	448,716.0	6903.3
Ivolginsky	17.4	30650.3	471.5
Kabansky	537.9	944,959.3	14537.8
Kizhinginsky	58.3	102,439.0	1576.0
Kyakhtinsky	3.2	5700.8	87.7
Mukhorshibirsky	-9.8	-17,187.4	-264.4
Pribaikalskiy	686.9	1206751.8	18565.4
Selenge	88.0	154,607.2	2378.6
Tarbagatai	2.6	4520.8	69.6
Khorinsky	115.0	202,058.4	3108.6
Total	**1928.1**	**3387259.7**	**52111.7**

Hence, the additional volume of water entering the water system of SRB, can be estimated at RUB 3,387,300,000 per year, or $ 52.1 millions. When the flow of capitalization, taking into account the discount rate 2%, the value of forest capital for this service is $ 2,605,600,000.

The observed and potential impacts of climate change on the service.
Unlike many regions of the world, in the SRB is not expected occurrence of water scarcity. However, the hydrological cycle analysis of the lake Baikal shows the ability to change the level of the lake regime (decrease), which affects negatively on the reduction of moisture in

forest soil, and thereby increase the mass of dry combustible forest materials and helps to increase the fire danger in the forest. Also, an increase in the frequency and magnitude of extreme weather events affects on the service. There is the risk of drought in the summer, so it can increase the demand for artificial irrigation and watering of wells for people and livestock.

Logging, frequent forest fires, increasing anthropogenic pressure on forests (tourism, recreation) reduces the amount of forests water regulation functions. On the other hand, environmental restrictions on logging in the central ecological zone of the Baikal Natural Territory (ban on clear-cutting) contribute to reducing the burden on water conservation forests, and thereby increase the ability of forests to perform water-regulating function. The combined influence of climate change and changes in the hydrological regime of the lake Baikal and Buryatia rivers reinforce dependence on the water regulating services of forests and the value of the considered ecosystem services will increase.

7. Cultural and recreational services

Type of service *: cultural and regulatory*
The importance for the local population *: high.*
Current state *: within the normal range*
Basic indicators.

In the region there are great opportunities for the organization of medical and health, cognitive agricultural, scientific, ethnographic, religious tourism, eco-tourism. In recent years, it is observed the trend of increasing numbers of tourists, the number of travel agencies, accommodation facilities, updating the material and technical base of tourism from its own sources and cost of capital investments, the active involvement of local communities in the tourism organization. Thus, the annual rate of growth of domestic tourism accounted for 15%, entrance to the SRB - 7%. In the structure of tourist traffic, domestic tourism is 85.0%, incoming tourism - 10%, outbound tourism - 5%.

Potential demand for recreational services is due, above all, by the rest on the lake Baikal, which is 60% of the coast is used for tourism and recreation. List and description of the recreational resources within the boundaries of the SRB is given in Table 19.

Table 19 Recreational areas in the territory of the SRB

No	Area	The name of the recreational areas	Year	Area, ha
1.	Kabansky	Baikal surf -Kultushnaya	2001	10.5
		Lemasovo	2001	0.9
2.	Pribaikalskiy Kabansky	Baikal Coast	2013	879.4
3.	Selenge	Lake Shchuchye	2006	The water area of the lake and the coast

Valuation. In order to determine the value of cultural and recreational ecosystem services commonly used method of travel cost (travel cost method). To assess the recreational resources of the SRB it is adopted the direct method to get recreational services expenditures. Key indicators: the average duration and average cost of staying in places of recreation, the number of tourists.

Table 20 shows the number and capacity of one-time treatment - health and recreation facilities in 5 districts of the SRB, where the most significant recreational potential is presented.

Table 20 Recreation objects

	Kabansky	Pribaikalsky	Selenginsky	Zakamensky	Kyahtinsky	Total
The amount						
Hotels	2	6		1	5	14
Health Resorts		1		1		2
Holiday Houses			2	1		3
Tourist camps	43	4	eleven	1		59
Sport - health camps	3		4			7
Guest House	17	16	1		5	39
Total	**65**	**27**	**18**	**4**	**10**	**124**
One-time capacity, beds						
Hotels	105	202		39	118	464
Health Resorts		537		50		587
Holiday Houses			147	thirty		177
Tourist camps	2873	284	784	50		3991
Sports - health camps	500		1080			1580
Guest House	553	511	18		60	1142
Total	**4031**	**1534**	**2029**	**169**	**178**	**7941**

Compiled according to the Committee for Tourism of the Ministry of Economy

Organized and disorganized recreation.

The number of rested tourists in organized and unorganized way in 2013 amounted to 303 thous. people. On the basis of average duration, the daily cost of staying on-site recreation, the number of rested direct cost of using of recreational resources was calculated in organized and unorganized manner, which amounted to 1,582,600,000 rubles, or on the current dollar exchange rate - US $ 24.3 million per year (Table 21). If the capitalization, the value of the cultural and recreational services of the forest ecosystem of the SRB is US$ 1,217,400,000.

Table 21 Direct cost of using recreational resources

District	Direct cost of use, thousand Roubles.	Direct cost of use, Thousand USD
Kabansky total	**746,300.4**	**11481.5**
organized	681,612.4	10486.3
unorganized	64688	995.2
Pribaikalskiy total	**584,899.2**	**8998.4**
organized	519,399.2	7990.8
unorganized	65500	1007.7

District	Direct cost of use, thousand Roubles.	Direct cost of use, Thousand USD
Selenge, all	**138,599.6**	**2132.3**
organized	100,799.6	1550.8
unorganized	37800	581.5
Zakamensky total	**76148**	**1171.5**
organized	74008	1138.6
unorganized	2140	32.9
Kyakhtinsky total	**36675.2**	**564.2**
organized	15243.2	234.5
unorganized	21432	329.7
in total	**1582622.4**	**24348.0**

Tendencies of development.
In recent years, the Republic of Buryatia acquires the value of one of the international centres of tourism in the east of Russia, as evidenced by an increasing pace of tourism development of the territory, qualitative and quantitative changes in tourism. The flow of tourists in the SRB is developing steadily.

A significant contribution to this process brings unorganized, uncontrolled tourism, creating a threat to the conservation of ecosystems. Growth in the number of tourists increases the pressure on the ecosystem of the lake Baikal, which is a major concern of its ecological condition. The fault of tourists accumulated household waste, an increasing number of forest and steppe fires, polluted rivers and lakes, being uncontrolled construction of residential premises and other infrastructure. Some tourists are engaged in illegal hunting and fishing. In particular, the inflow of tourists poses a threat to biodiversity in areas around Lake Baikal, Lake Shchuchye. It is exists the goal is for the development of infrastructure for sustainable tourism development without compromising the ecosystem.

However, tourism revenues are an important source of deficit budgets of cultural and historical sites and protected areas. The regional development programs attach great importance to the development of tourism as a means of diversifying the economy and bring additional income, especially in depressed rural areas. At the present time on the territory of the SRB created the special economic zone of tourist-recreational type "Baikal gates". For the formation of the modern tourist and recreational complex it is used cluster approach. The federal target program "Development of domestic tourism in the Russian Federation" (2011-2018 years) provides the establishment of tourist-recreational cluster "Podlemorye" (Kabansky district) avtoturist clusters "Baikal" (Ivolginsky District), "Kyakhta" (Kyakhtinsky District).

The observed and potential impacts of climate change on the service.
Climate change has both positive and negative consequences for cultural and recreational ecosystem services in the SRB. On the one hand, the increase in average temperatures will cause a slight increase in the duration of the summer tourist season and the influx of tourists. This will increase the value of the service, but in the conditions of uncontrolled tourism it can lead to the destruction of natural ecosystems.

On the other hand, increase in the frequency and scale of severe weather events pose a threat to tourism. The long-term rise in temperature could also adversely affect on the development of some forms of tourism, such as the ski, which in some regions is considered as a priority for investment.

8. Preserving the natural environment for biodiversity

Type of service **:** *provides; regulating.*
The importance for the local population **:** *high.*
Current state **:** *satisfactory.*
Basic indicators.

For the protection of biodiversity, it is established network of protected areas. The list of rare and endangered species, birds, plants, t. h. endemic, is shown in table 22. It is saved 1279 species of higher plants, more than 800 species of lichens, 200 species of fungi. Of the species of plants 76 are included in the Red Book of Buryatia and 20 species included in the Red Book of Russia. The oldest group of evergreens - moss (6 types). It is distributed families of horsetails, ferns (of 25 species), ophioglossaceae - 5 species, “sizohvoynaya” form of ate - blue spruce, entered in the Red Book of the Republic of Buryatia.

Table 22 Species diversity in the SRB

Group	Rare and endangered species	endemics
Trees	Blue spruce	
Plants (vascular)	Rodendron Adams, grouse Dagan, Corydalis pritsvetkovaya, club mosses, family ophioglossaceae, clover Dark brown	Svertsiya baykalskaya (family of gentianaceae) and stemmakanta hamarskaya (family of slozhnotsvetnyh).
Mammals	Pallas, reindeer (Altai-Sayan group), Korsak, tolai hare, Daurian hedgehog, jerboa-jumper, otter	
Birds	White-tailed Eagle, Asian Dowitcher, gray and black cranes, demoiselle, peregrine falcon, tawny eagle, lesser kestrel, great bustard, whooper swan, black stork, bittern, osprey, pygmy owl, saker	

The existence of rare and endangered species of mammals, birds is an indicator of the health of the entire ecosystem of the region.

Valuation.

In determining the value of biodiversity in monetary terms, the most controversial is what is meant by it. Genetic diversity of species is important as a resource for agriculture and pharmaceutical industries. From this viewpoint, this function can be defined as the value of the direct use of biodiversity. However, biodiversity also has a regulatory function for maintaining the health of ecosystems as a whole. From this standpoint, this feature can be determined as a value related to the indirect use of biodiversity.

To assess the value of conserving the biodiversity in natural conditions it is used more often the method of "willingness to pay". It is usually assumed that the indicators of "willingness to pay" for the preservation of the entire spectrum of biodiversity are the direct funding of protected areas through federal and regional budgets, financing of various environmental programs, projections, payments for recreational services, donations and sponsorship, etc.

From this point of view, in practice in the Republic of Buryatia one national reserve and two federal reserve receive significant financial resources in comparison with the protected areas of republican significance (Table 23).

Using the method of "willingness to pay" through public expenditure on protected areas, the value of ecosystem services for the conservation of the natural environment for biodiversity is estimated at 310.2 million rub., or US$ 4.8 million per year. When capitalization (at discount rate of 2%) of this flow, the value of forest capital for this service is US $ 238 600 000. This estimate is very low, as the cost of overseas protection of comparable natural areas many times larger.

Table 23 Evaluation of biodiversity through protected areas financing

District	Protected Areas Orientation	Budget financing, thousand. rub.	Budget financing, thousand.US$
1 . Kabansky	Biosphere Reserve "Baikal"	150400	2313.8
	complex reserve "Kabansky"	50300	773.8
	biological reserve "Enhaluksky"	5600	86.2
2 . Muhoshibirsky	biological reserve "Altacheysky"	45000	692.3
	biological reserve " Tugnuisky"	5300	81.5
3 . Pribaikalskiy	biological reserve "Pribaikalskiy"	7700	118.5
	Secured territory	4700	72.3
4 . Bichursky	biological reserve "Uzkolugsky"	6100	93.8
5 . Zaigraevky	biological reserve " Angirsky"	6090	93.7
6 . Zakamensky	biological reserve " Snezhinsk"	10300	158.5
7 . Dzhidinsky	biological reserve "Borgoysky"	6000	92.3
8 . Kizhinginsky	biological reserve "Kizhinginsky"	6500	100.0
9. Khorinsky	biological reserve "Hudaksky"	6200	95.4
in total		**310190**	**4772.2**

Trends in the development.
The development of plans for the development of mineral deposits, the construction of large infrastructure objects, tourist complexes, cross-border oil and gas pipelines are often conducted without a full environmental impact assessment and public consultation. Experience shows that local people often learn about these projects later, which leads to conflicts. If you ignore the interests of nature protection when implement plans of economic development of the region it could lead to the fragmentation of the natural habitats of animals, including animals listed in the Red Book of the Republic, and to reduce their number. As a consequence, they may cause degradation and genetic extinction.

The observed and potential impacts of climate change on the service.
Given the mountainous terrain SRB, natural way of adaptation of forest ecosystems to climate change - move up the mountain slopes. However, in terms of climate change, this adaptation may be complicated, since the rate of "vertical" promotion of plants and animals

may be different. For some species move up the slopes of the mountains meant reduction in the area of habitat and fragmentation of habitat.

The greatest negative impact on biodiversity has economic activity - illegal logging of wood, over-harvesting of medicinal plants, overgrazing rangelands, poaching, tourism, etc. On the other hand, with the support of the authorities, the protected areas network is gradually expanding in the region, it is indicating the manifestation of care for the preservation of this ecosystem service.

In connection with climate change it is projected to increase public demand for ecosystem services for the conservation of biodiversity. While this trend may be expressed poorly among the local population of the SRB, but it appears from the international community (UNESCO World Natural Heritage "Lake. Baikal").

In recent years, noted that climate change is a global factor of external impacts on biodiversity, ecosystems and their services (Table 24).

Table 24 The impact of climate change on the preservation of the natural environment biodiversity in BRC

The threats posed by climate change	The observed and potential impacts
Primary climate threat	
The long-term rise in temperature	Promotion of "belts" of ecosystems up the mountain slopes, reducing the area of natural habitat for alpine species, fragmentation of their habitats. Increasing the duration of the summer season, when relieved obtaining feed
Snowfalls and spring thaws, veduschiek formation of ice crust	The difficulty of access to animal feed
Snowless winters	Damage and destruction of plants, reducing animal feed base
Droughts, heat waves, heavy rains, storms and hurricanes	Damage and death of plants. Deterioration of animal life support conditions, including forage
Indirect climate threat	
Floods, landslides, avalanches and mudflows	The crux of the movement of animals
Distribution of forest and steppe fires	Damage and death of plants. Deterioration of animal life support conditions, including forage
The spread of diseases and pests	Damage and death of plants. Increase in the number of sick animals, deterioration of their conditions of life support including food base
The spread of alien species	Displacement of native species

The value of forest ecosystem services for socio-economic development on the territory of Mongolia.

1. Wood products income and output

While the commercial harvesting potential of boreal forest was estimated by MEGD at just over 0.8 million m^3 in 2010, actual harvest volumes were somewhat less than this at 0.68 million m^3 - although have been growing steadily over the last decade. The wood generated from thinning and cleaning operations was equivalent to just under 0.4 million m^3 or more than half as much again as the harvest from commercial utilization activities.

At the present time total wood removal from commercial harvesting, thinning and cleaning are estimated as of 271,100 m^3 of timber and 956,020 m^3 of fuel wood.

This figure represents licensed wood utilization. Much of the timber and fuelwood that is harvested each year in Mongolia however takes place on an informal basis, outside the permit system. Some sources put the figure that between a quarter and 80% of harvests are illegal (Crisp *et al* 2004, WWF 2002).

We base our estimates of total timber removals on national sawnwood consumption figures for 2004 of between 100,000 and 400,000 m^3 (Crisp *et al* 2004), conservatively assumed to have increased in line with population growth. This gives a now days figure of just over 0.4 million m^3 of processed balks, poles, sleepers and planks, equivalent to around 0.74 million m^3 of raw logs. It is assumed that all commercial timber is extracted from boreal forests. No round logs or sawn timber are legally exported from Mongolia or are recorded as imports, and there seems to be no indications of an illegal cross-border timber trade (Crisp *et al* 2004). It can therefore be assumed that all timber harvested from boreal forests is for use within Mongolia, and that all domestically-consumed timber is sourced within the country.

Our estimate of fuel wood removals is based on actual demand from aimags with significant boreal forest cover. Calculations take account of demand from rural households as well as ger dwellers in Ulaanbaatar, differentiating consumption volumes between households which are wholly dependent on wood fuel and those who also use livestock dung (Foppes 2012). This yields a figure of just over 2.3 million m^3 of fuel wood consumed, equivalent to some 3 million m^3 of raw wood removals.

Putting these figures together suggests that around 3.7 million m^3 of raw wood a year may currently be removed from boreal forests, of which timber accounts for 0.74 million m^3 or 20% of the total, and fuelwood 2.92 million m^3 or 80% (Table 25). Around a third of the timber and fuelwood consumed is sourced through licensed use, meaning that there is an unlicensed harvest of around 0.47 million of timber and 1.96 million m^3 of fuelwood. Total removals, both licensed and unlicensed, are worth some MNT 66 billion (US$ 48 million) in earnings to producers and have a retail value of almost MNT 200 billion (US$ 142 million). It should be emphasised that a high proportion of wood extraction - more than half – is unlicensed.

Table 25 Timber and fuelwood values

	Timber	Fuel wood	Total
Licensed removals from commercial harvesting (m^3 '000 raw wood equivalent)	235.10	596.01	831.11
Licensed removals from thinning and cleaning production (m^3 '000 roundlog equivalent)	36.00	360.00	396.00

Unlicensed removals (m^3 '000 raw wood equivalent)	469.32	1,964.39	2,433.71
Total removals (m^3 '000 raw wood equivalent)	740.42	2,920.40	3,660.82
Operating margins to producers (MNT million)	42,719	23,358	66,077.52
Retail value (MNT million)	93,470	103,628	197,097.38

As already mentioned, the sustainability of current harvests is unclear. There seems little doubt that some sites and species are being heavily over-utilised as a result of unlicensed wood removals. However, the sustainable annual harvest volume for Mongolia's forest has not yet been unequivocally determined (Ykhanbai 2009a). Several authors have noted that licensed wood removals are low as compared to the recommended annual allowable cut and production levels of between 2-3 million m^3 in the 1970s, 1980s and 1990s (FAO 2006, WWF 2002). The current area designated as production forest is thought by some authors to be unnecessarily nail. The World Bank's 2004 Forestry Sector Review for example implies that the area allocated for commercial utilization does not reflect a scientific assessment of the sustainable annual allowable cut, and uses a rough estimation process to suggest that that this could be up to 1.4 million m^3 if 25% of the current protects zone were released for utilization, and more if further areas were opened up for sustainable harvesting (Crisp *et al* 2004).

Available data do not permit a detailed breakdown of these value figures between different participants in the timber and fuel wood industry (contributions to public revenues are analyzed later in this chapter). It is however known that almost 700,000 ha of boreal forest are contracted out to more than 100 private forest enterprise (PFE), and around 2.2 million ha is managed by around 900 forest user group (FUG).

There are no data available on the volume or value of forest products used by FUG. Although FUG can harvest and sell forest resources to generate income (the potential for livelihood improvement or future income is cited as an important motivation for FUG members; Fisher *et al* 2012), actual harvests and earnings currently remain very low (Foppes 2012). We can therefore assume that very little of the market value of wood removals is accruing to FUG (although a significant portion of the consumption value may be). The bulk of commercial harvest values are likely being captured by PFEs and other participants in the timber an fuelwood marketing chain.

In addition to the one hundred or more PFEs licensed to harvest timber in production forests, at least as many businesses are registered in boreal forest aimags which deal with the processing, marketing, transport and sale of timber and non-timber forest products. Most of these are small and medium-sized enterprises (SME), employing fewer than ten workers and with an average annual turnover of MNT 20 million (US$ 15,000) or less. The total income generated by registered forest enterprises in boreal forest aimags is recorded as being just over MNT 4 billion, with a combined operating margin of some MNT 614 million. This represents only a small proportion of the total value of the wood harvest in terms of producer operating margins (Table 25). Other unregistered forest businesses also operate, without licenses.

Almost 1,000 wood-based industries are thought to exist at the national level, including both timber harvesting and processing/marketing enterprises. Although a detailed breakdown of the composition of forest industries was not available to the study, records from 2004 indicate that of the 678 mills and manufacturers operating at that time, 175 were producers of construction materials and components, 207 were producers of other wooden and woven products, 48 were producers of wooden panels, 36 were producers of wooden crates and containers, 123 were producers of timber and 89 were logging companies (Ykhanbai 2009a).

Comparing these figures with the estimates provided above indicates that only a tiny proportion of forest values is being captured locally. Timber and fuel wood earnings are spread over a wide range of market participants, and a broad chain slue-addition.

2. Utilisation of non-timber forest products by local communities

MEGD records show that just over 300 tones of spruce and pine nuts, wild berries and other NTFP 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.

As is the case for wood products, a large proportion of NTFP harvesting takes place outside the permit system. It is known that herder communities collect a wide range of plant products. Recent work among FUG has found that members are harvesting fruits, berries, mushrooms, wild vegetables, pine nuts, preserved berries and medicinal herbs for home consumption and sale on local markets (FAO 2006, Foppes 2012). Detailed surveys of the use and value of NTFP for rural households have been carried out in Bayan-Ulgii (Lkhagvadorj *et al* 2013), Khentii, Selenge and Tuv aimags (Emerton *et al* 2009). Extrapolating these findings to the total rural population living in soums with boreal forests suggests that almost 65,000 households may be regularly collecting up to 4,250 tonnes of fruits, berries, wild vegetables, nuts and medicinal plants, to a total value of almost MNT 16.5 billion (US$ 12.18 million) a year.

Just over MNT 12 billion (US$ 9.13 million) or 75% of this value is accounted for by home-consumed products, while MNT 4 billion (US$ 3.05 million) is earned as cash income from sales in local markets or to middlemen. Typically, much of the cash earned from NTFP sales is captured by richer households: while the poor function primarily as labourers, better-endowed households are able to process products, and through value addition and transport to markets can command much higher prices (FAO 2006, Fisher *et al* 2012).

3. Forest pasture

Another important economic value of boreal forests for surrounding communities is as a source of pasture for grazing and hay-making. Forest grazing appears to have been intensifying over recent years, as herders have become more sedentary and have reduced their seasonal migration patterns (Lkhagvadorj et *al* 2013).

Based on data provided by soum administrations on livestock ownership and production and on the incidence and frequency of forest grazing, it is possible to come up with an approximate figure for the value of forest pasture. Various estimates exist of forest carrying capacity, actual and optimal stocking rates. Actual rates are recorded as something around 1.1 SEU/ha in forest-steppe zones and 0.62 SEU/ha in high mountain meadows in and above the forest belt (Jamsranjav 2009), somewhat over the suggested carrying capacity of 0.63 SEU/ha and 0.71/ha respectively (Jigmed 2006). Work carried out in four northern boreal forest aimags (Bulgan, Tov, Uvs and Zavhan) cites an actual stocking rate of an average of 0.85 SEU[12]/ha as compared to a biologically optimal stocking rate of 0.70 SEU/ha; and an economically optimal stocking rate of 0.66 SEU/ha (Hezik 2002).

In line with a concern to ensure that value estimates reflect sustainable values, we apply an average stocking rate of 0.7 SEU/ha for the 10% of forest area (including glades, meadows and logged areas) that are assumed to make a contributor towards local herders' annual hay and pasture needs[13]. This gives a total value of MNT 34.5 billion (US$ 24.70 million) for the contribution of forest pasture to herders' gross margins. Boreal forest pasture provides partial support for about 12.5% of herds, and accounts for around 5% of the total annual value of livestock production in soums with boreal forest. It can be noted that this figure (MNT 6,250 or US$ 4.50/ha/year) is similar to the estimate of forest grazing value presented in Foppes 2012.

4. Hunting and wildlife trade

It is thought that more than a third of Mongolians use wildlife in some form, either commercially or for personal consumption (Wingard and Zahler 2006). Although most hunting focuses on grassland and steppe species, some birds and animals found in boreal forests are hunted. Much of this is unlicensed, in excess of quotas or involves listed species, and so there are few reliable or up-to-date figures on the level of hunting or the scale of the - largely illegal - wildlife trade. Surveys however indicate that the value of the wildlife trade is substantial: it is thought to be worth more than US$100 million a year (Wingard and Zahler 2006), supplying meat, skins, fur, medicinal products, live animals and animal parts both domestically and internationally (Kirkpatrick 2005, TRAFFIC 2003, Zahler et *al* 2004).

As much of this utilisation and trade is illegal, it is not considered sustainable, and therefore not included in calculations of the value of the forest sector. Only the income related to licensed hunting is included. The national hunting quota includes at least five bird and animal species which depend at least partly on boreal forest for their habitat. Applying average domestic trade prices and sport hunting values (from Wingard and Zahler 2006) to this offtake suggests that licensed forest hunting may have an annual market value of between MNT 91 million (US$ 65,000) if sold locally and MNT 2.7 billion (US$1.93 million) if hunted for sport.

We discuss the value of forest tourism in the next section. In relation to hunting, it should however be noted that recreational or trophy hunting comprises a significant segment of Mongolia's tourism market. Although it is not possible to quantify this value as distinct from that of forest-based leisure tourism more generally, hunting tourism generates substantial values. A wide range of domestic and international hunting outfitters offer trips in Mongolia, with several advertising “forest specials” targeting species such as maral stag, roe deer, bear, lynx, wild boar and wolf. This tends to be high-value, high-end tourism: the in-country price of a two week hunting trip averages US$5,000 per person (and can be priced as high as US$50,000 if including major trophy animals), plus additional charges of US$1,000 or more for permits, trophy fees, certificates and ammunition.

5. Tourism and recreation

Mongolia has become a popular global tourism destination, and nature-based recreation accounts for a growing share of this market. It is known that, for international tourists, natural areas (including forested landscapes) come high in the list of the most popular tourist attractions: for example, Gorkhi Terelj NP is the third most visited attraction, followed by Hovsgol Lake (Yu and Munhtuya 2006).

The Ministry of Roads, Transport and Tourism (MRTT) estimate that 44% of Mongolia's current tourism products are based on nature.

No specific data on forest-related tourism were available to the study. Very rough estimates of the value of forests for recreation can however be extrapolated from total leisure tourism figures. Around 0.5 million international arrivals were recorded in recent years; of which 90,000 are stated to be leisure tourists; average leisure tourist spending within Mongolia per is estimated to be US$ 581 per trip. The length of international leisure tourists' holidays in Mongolia averages 16 days, and it is assumed that just under a third, or 5 days, of a typical visit is spent in forested landscapes. Based on the share of leisure tourist days spent in forest areas, this translates into a possible annual value of MNT 22.73 billion (US$ 16.3 million) in direct spending on visits to forested areas. Forest-based leisure tourism may directly support up to 6,000 jobs and generate wage earnings of MNT 18.31 billion (US$ 13.17 million), and make a direct contribution to GDP of MNT 55.26 billion or US$ 39.73 million.

Both the United Nations Conference on Trade and Development (UNCTAD) and the World Travel & Tourism Council (WTTC) have, with MRTT, constructed tourism satellite accounts for Mongolia. These consider the wider indirect, induced and multiplier effects of the sector on the economy. Based on the contribution of forest recreation to all leisure tourism, the total contribution of forest-related leisure tourism to GDP may be in excess of MNT 144 billion or USS$ 103.75 million. This reflects the economic activity generated by industries such as hotels, travel agents, airlines and other passenger transportation services, as well as the restaurant and leisure industries directly supported by tourists. If the wider effects from investment, the supply chain and induced income impacts are included, forest-related leisure tourism may in total generate up to MNT 48.83 billion (US$35.11 million) in wage earnings, MNT 93.86 billion (US$ 67.48 million) in sales, MNT 28.07 billion (US$ 20.18 million) in value-added and MNT 17.07 billion (US$ 12.27 million) in capital formation.

6. Public revenues

Forest sector activities contribute directly to a number of public revenue streams. These include royalties, fees and charges earned from licensed timber, fuelwood and NTFP harvesting, hunting and protected area entry.

According to MEGD and NSO statistics, around MNT 1.5 billion (US$ 1.05 million) was earned from timber and fuelwood harvesting revenues in boreal forest aimags in 2010, rising to MNT 2.2 billion (US$ 1.6 million) in 2012 and MNT 2.6 billion (US$ 1.9 million) in 2014. Almost MNT 3.7 billion (US$ 2.7 million) was generated from hunting fees, of which MNT 0.42 billion (US$ 0.3 million) can be ascribed to forest-dwelling species. The state also earns revenues from the fines and penalties levied on illegal forest utilization. More than MNT 455 million (US$ 32,000) was collected in boreal forest areas. These revenues are not reinvested directly in the forest sector. Although a portion is earmarked for retention in the Nature Protection Fund, this is used to fund a variety of environmental and nature protection activities.

The government also earns revenues from the other sectors that depend on forest goods and services for raw materials or secondary inputs. It is not possible to quantify the total value of other sectoral revenues that depend on forest goods and services. Although the output from the tourism sector flowing as income to the government is thought to be fairly small at just 1.7% (UNCTAD 2012), the fiscal revenues from forest-related leisure tourism are estimated to be around MNT 1.59 billion (US$1.15 million).

It is worth noting that the illegal timber trade has implications for public revenues. Based on the figures presented earlier in this report, unlicensed wood removals from boreal forests cost the Government of Mongolia some MNT 6.68 billion (US$ 4.80 million) in foregone revenues a year. This is more than twice as much as the revenues that are currently collected from licensed timber harvesting, or a sum equivalent to more than 1% of all local government tax revenues.

7. The economic value of forest ecosystem services

Boreal forests provide a wide range of ecosystem services to Mongolia's population and economy. In addition to the provisioning services described in the sections above (timber, fuelwood, NTFP, hunting, grazing and recreation), forests generate supporting and regulating services such as carbon sequestration, soil erosion control, watershed protection, and habitat for rare and endangered species. A wide array of cultural, spiritual and existence values are also associated with forest sites and landscapes.

There are as yet no data on the value of forest supporting, regulating and cultural services. Some efforts are however currently being made to develop and apply ecosystem valuation methods in the country. The concept of "economic and ecological valuation" is now embedded in Mongolian law and practice. Its main use and application is envisaged in relation to calculating the levels of compensation that must be paid for ecological damage (for example, the Comprehensive National Development Strategy of Mongolia includes reference to making "ecological an economic assessment of deposits and improve standards for evaluating, imposing and making payable penalties for ecological damage, compensation and fees"). The Law on Forestry 2007 defines "forest ecological-economic valuation" as the monetary expression of ecological and economic benefits derived from the volume, quality and utilization of forest resources. A number of supporting rules and guidelines on forest ecological-economic valuation were approved in 2009 via Decree 394. However, as yet there has been little on-the-ground application of forest ecological-economic valuation in Mongolia, and there is as yet virtually no information available on the economic value of forest ecosystem services. Some rough estimates may however be made of key forest ecosystem service values based on figures calculated for similar sites and conditions elsewhere.

Mongolia's boreal forests constitute an important carbon sink. The total stock of forest carbon was estimated at 583 million tonnes in 2010 (FAO 2010, Table 29). This figure however represents a significant underestimate, as it does not include the pools of soil carbon, litter or deadwood which in boreal forests are estimated to contain approximately 60% of the forest carbon (MEGD 2013). Globally, the net carbon uptake of boreal forests is estimated to range between 0.34-0.56 tC/ ha/year[21], including both above-ground and below-ground storage. We apply the average of these estimates, 0.42 tC/ha/year, to the 10.898 million hectares of boreal forested areas in Mongolia.

Although it is difficult to find an accurate figure for the economic value of carbon sequestration, most studies use the market price of forest carbon as a proxy for people's willingness-to-pay. Applying the 2011 average voluntary carbon market price for forest management projects of US$12/tCO2e (Peters-Stanley and Hamilton 2012) suggests a total annual value of MNT 77.29 billion (US$ 55.57 million) for forest carbon sequestration services. It is worth noting that this figure (equivalent to US$5.10/ha/year) is in a similar range to that (US$7.87[22]) calculated for Canada's boreal forests using the Boreal Ecosystem Wealth Accounting System tool (Anielski and Wilson 2005). No up-to-date figures are available on the area under afforestation and reforestation activities, although an estimate of just over 7,000 ha is given for 2005 (FAO 2010), of which around 300 hectares is accounted for by Green Wall sites in southern Saxaul shrub forest (Ykhanbai 2009a). We assume that afforestation and reforestation activities are continuing today at a similar level. At an average voluntary carbon market price for afforestation/reforestation projects of US$9/tCO2e (Peters-Stanley and Hamilton 2012), this will equate to a value of some MNT 48 million MNT (US$ 35,000) once this forest is mature (as no data were available on the rates of carbon uptake by growing boreal forest, or on the past history of afforestation and reforestation activities, it is not possible to include this value in our calculations).

Many Mongolia's major river systems rise in the north of the country, and forests provide an important source of watershed catchment protection for both surface water and groundwater supplies. Forest cover helps to regulate both waterflow and water quality. A study carried out in 2008 by the World Bank (Emerton et al 2009) looked at the value of the forested Upper Tuul catchment for downstream groundwater supplies to Ulaanbaatar. This found that sustainable land management and forest conservation in the Tuul River's upper watershed contributes additional annual waterflow services worth MNT 58.8 billion (US$ 42.3 million) at today's prices to urban water users (including MNT 31.5 billion (US$ 27.7 million) in government revenues), over and above the water values yielded under continuing ecosystem degradation - a value equivalent to MNT 48,500/ha (or US$35) of upper watershed forest.

Although these figures cannot be extrapolated to other forested watersheds of Mongolia, because both hydrological conditions and levels/values of downstream water use vary considerably, it should be noted that a number of other river basins depend on forested upper catchments, including the Kherlen, Khuvsgul-Ed, Onon, Orkhon-Tamir, Selenge and Shishkid. It should be emphasised that the estimates of forest watershed protection values that are included in this study only look at the Upper Tuul ecosystem. It therefore only quantifies a small proportion of the total value of forest watershed protection. Many other forested watersheds also generate extremely high values. The total domestic, municipal, industrial and agricultural demand for water in Mongolia's forested basins, including the Tuul, is currently estimated to be more than 175 million m^3 a year.

8. Review of forest sector-economic linkages

Some of the calculations that are presented in the paragraphs above can be compared with official economic statistics in order to underline the importance of the forest sector in economic terms - and to highlight the substantial values that go unrecorded when these figures are omitted from decision-making.

The market value of wood products, NTFP, hunting and forest-based tourism is more than fifteen times as high as forest sector recorded sales values. For users, the largely unrecorded values accruing from forest goods and services are substantial when compared to official GDP: for example, the net value-added to rural households from fuelwood use, NTFP collection and forest grazing is equivalent to more than 12.5% of per recorded capita GDP. In total, the annual direct value-added from the forest sector is equivalent to a figure that is worth 3.1% the recorded value of GDP, while the public revenues directly generated are equivalent to around 1.4% of all tax revenues. Nation-wide forest carbon sequestration and watershed catchment protection services for Ulaanbaatar generate values that are, at more MNT 100 billion a year, almost seven times greater than the gross industrial output recorded for the wood manufacturing sector.

At current harvesting levels, timber may have an annual sale value of almost MNT 94billion (US$ 68 million) and fuelwood MNT 104 billion (US$ 75 million), generating MNT 43billion (US$ 31million) and MNT 23 billion (US$ 17 million) in operating profits to producers. More than half of this value comes from unlicensed removals.

Non-timber forest product collection has a total value of almost MNT 16.5 billion (US$ 12.18 million) a year, spread over around half of the rural population in soums with boreal forest. More than 90% of this value comes from unlicensed removals, and three quarters is accounted for by home-consumed products which never enter the market.

Forests provide an important seasonal source of pasture for livestock, to a value of more than MNT 34.5 billion (US$ 24.70 million) contribution to herders' gross margins. This comprises up to *5%* of the value of livestock production in soums with boreal forests.

Hunting under permit in boreal forest areas generates products with an annual market value of between MNT 91 million (US$ 65,000) if sold locally and MNT 2.7 billion (US$1.9 million) if hunted for sport.

Forest-based leisure tourism directly generates more than MNT 22.7 billion (US$ 16.34 million) in visitor spending and sales, supports up to 6,000 jobs and wage earnings of MNT 18.31 billion (US$ 13.17 million), and makes a direct contribution to GDP of MNT 55.26 billion (US$ 39.73 million). Its multiplier effects across the economy are substantial: the total contribution to GDP may be in excess of MNT 144 billion (USS$ 103.75 million), including MNT 48.83 billion (US$35.11 million) in wage earnings, MNT 93.86 billion (US$ 67.48 million) in sales, MNT 28.07 billion (US$ 20.18 million) in value-added and MNT 17.07 billion (US$ 12.27 million) in capital formation.

Boreal forests may sequester carbon worth some MNT 77.29 billion (US$ 55.57 million) a year. Although unquantified, they also have a storage value, particularly in the context of REDD+.

Forest watershed protection services in the Upper Tuul basin alone are worth MNT 27.2 billion (US$ 19.6 million) a year to water users in Ulaanbaatar.

The net value to users of the forest goods and services valued in this study is some MNT 395 billion (US$284 million), equivalent to an average of MNT 40,000/year per hectare of the boreal forest estate (US$ 28).

The government earns more than MNT 36 billion (US$26.3 million) in revenues from forest product harvesting and utilisation activities, including tourism and water but excluding the taxes paid by other forest-based enterprises. This is equivalent to an average of MNT 3,600/ year per hectare of the boreal forest estate (US$ 3).

The net value-added to rural households from fuelwood use, NTFP collection and forest grazing is equivalent to more than 12.5% of per recorded capita GDP.

The total annual direct value-added from the forest sector is equivalent to a figure that is around 3.1% the value of GDP, while public revenues are equivalent to around 1.4% of all tax revenues.

Effects of Climate Change on Forest Ecosystem and Sustainable Forest Management: the Case of China

1. Brief description of the object of research

The growth and provision of forest ecosystems, particularly facing increased variability in temperature and precipitation patterns due to climate change, is one of the greatest challenges around the world. As one effective kind of addressing measures of climate change, the impact of global climate change on forest ecosystems and sustainable forest development is gaining attraction worldwide, including Northeast Asia. The critical research of response of forest ecosystem on climate change and sustainable forest management aims to contribute new knowledge and understanding to the fields of human-environment geography, forest resources management, climate change adaptation, and other studies. The study is dedicated to providing insights for the (potential) sensitivity and vulnerability of forest ecosystem and its response on climate change within the socio-economic-environmental system in North China, especially in Yellow River Delta. The study is hoped to provide a understanding of the degree to which the climate-dependent plant species and threatened forest areas can be impacted, as well as the implications of forest ecosystem as the anticipated climate change adaptation and mitigation strategy. In addition, the focus on implementation of the instruments, rules and mechanisms of forest management is hoped to provide an in-depth analysis of organizational policies of forest management and the related driving issues.

2. The response of forest ecosystems on global climate change and economic activity and their sensitivity and vulnerability

2.1. General Overview of Climate Change

Global warming and climate change is largely attributed to emission of GHGs from natural or anthropogenic sources and changes in Albedo (reflection of radiation from different surfaces to the atmosphere that causes warming or cooling of the planet, with value between 0-1 http://en.wikipedia.org/wiki/Albedo). Climate change is one of the main drivers of terrestrial biotic change and has different effects, such as disturbances and loss of habitat, fragmentation, and increasing the incidence of photogenes. In addition, following a change in climate parameters (precipitation change, snow cover, humidity, sea level etc.) there is variation in exchange of different activities in symbiotic, prediction, parasitic and mutualistic relationships (Lepetz et al., 2009). As global mean temperature rise, it causes positive or negative effects on different processes and activities in earth systems (IPCC, 2007). Many activities and processes interlinked with each other, and cause an interrelated effects one after the other. These effects may affect ecosystem services, biodiversity, species composition, plant growth and forest productivity.

The effects of climate change have become obvious in the natural environment over the last decades years, together with other threats like habitat destruction, fragmentation, disturbance and loss in biodiversity (Lepetz et al., 2009). For instance, land use change (the most important impact) in forest can cause loss of biodiversity. Hence, overexploitation of natural resources, use of hardwood timber and forest clearing causes high loss in the amount and availability of habitats, and to extinction of species, especially which are endangered, and restricted in range.

Although it is difficult to make a causal link between changes of climate in relation to change in species richness, due to many other variables are also involved (Morris, 2010), species can interact both directly and indirectly and in most cases, indirect interaction is unpredictable (Yodzis, 2000; Montoya et al, 2005; Morris, 2010). Climate change affects species indirectly by reducing the amount and availability of habitats and by eliminating species that are essential to the species in question (Morris, 2010). As a result, the loss of one species can result in decrease, increase or extinction of other apparently unconnected species; however, human activities are causing secondary extinction at higher level than expected from random species losses. When species are lost from an ecosystem, it is not the only species that is lost, but the interaction and the general ecological functions, will be also lost (Morris, 2010).

According to FAO (2007) and Minura (2010) climate change impacts classified into two broad categories: 1) Biophysical impacts: indicates the physical impacts caused by climate change directly in physical environment; for example, drought and flooding, causes an effect on physical environment such as a) effects on quality and quantity of crops, pasture, forest and livestock. b) Change in natural resources quality and quantity of soil, land and water resources. c) Increased weed and insect pest challenges due to climate change. d) Shift in spatial and temporal distribution of impacts, (sea level rise, change in ocean salinity, and sea temperature rise causing fish to inhabit different ranges). 2) Socio-economic impacts: following the first biophysical impacts on environment there will be a secondary effect on socio economic systems. E.g. decline in yield and production, reduced marginal GDP from natural sector, fluctuation of world market price, change in geographical distribution of trade regimes, due to shortage of food in quality and quantity the number of people in hunger and risk increased, and cause migration.

Global warming causes higher evaporation rates and therefore, higher precipitation rates, but a large general increase in precipitation is not expected, there will be some regions where the precipitation will increase and others where it will decrease. According to IPCC (2007), more rain expected in the equatorial belt (humid tropics) and at higher-latitudes. While less precipitation projected at mid-latitudes, semiarid areas and dry tropics. The spatial extent of severe soil moisture deficits and frequency of short-term drought (due to shortage and absence of expected rain water for a short period of time) is expected to double until late 21 century and long-term drought become three times more common especially in regions with less precipitation (IPCC, 2007; Fussel, 2009). Warming of the earth do not uniformly distributed over the world; continents show more rapid temperature increase as compared to oceans. Temperature change will have very different impacts on vegetation and ecosystem productivity, structure and composition depending on the actual temperature range at the location (Morison and Lawrol, 1999). Global temperature has increased about 0.2 centigrade per decade for the past over 30 years and warming is larger in the western equatorial pacific than in the eastern equatorial pacific over the past century (IPCC, 2007).

Regional warming predicted to increase with increasing latitude. Temperature can affect photosynthesis through modulation of the rates of activities of photosynthetic enzymes and the electron transport chain and indirectly through leaf temperatures defining the magnitude of the leaf–to-air vapor pressure difference, which is a key factor influencing stomata conductance. Unlike the temperature sensitivity of processes like flowering and fruiting many other physiological processes have small genotypic variations, although some genetic adaptation have been observed on enzymes like Rubisco (Lloyd & Farquhar, 2008; Amedie, 2013).

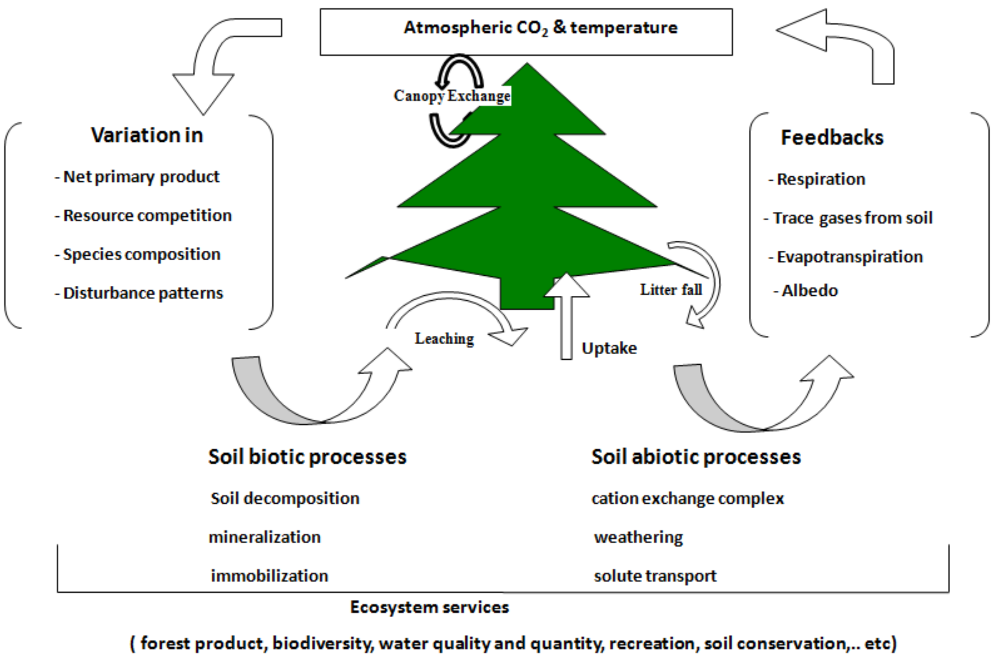

Figure 4. Schematic diagram showing the most important biogeochemical processes in plants and forest ecosystems affected by climate change (Lukac et al., 2010; Amedie, 2013).

2.2. Effects of climate change on ecosystems and ecosystem services

An ecosystem is a dynamic complex system of plant, animal, and microorganism communities and the non-living environment interacting with each other as a functional unit. Ecosystem services are the benefits that people get from ecosystems, like food, forest products, water quality and quantity, soil conservation, biodiversity, recreation, and other cultural values. In order to get good ecosystem services for human wellbeing there should be a mechanism, which maintain the nutrient cycles, production, soil formation, etc. in a good state, furthermore enhancing sustainability and conservation of natural as well as human made ecosystems is important. Any disruption or loss of natural ecosystems leads to breakdown of ecosystem functioning and causes loss of ecosystem services. Because of climate change (increased extreme events, e.g. drought and forest fire) large proportion of species are at risk of distinction. A fundamental difference between global ecosystems of the past and in the future is the dominating influence of human activity and intervention in natural environment, in addition, deforestation, agriculture and over grazing can fasten the processes of desertification especially in sub tropics and semiarid lands (Bolin et al., 1989; Amedie, 2013).

Ecosystems and ecosystem services affected by global climate change, both directly and indirectly. Many studies particularly on agricultural crops and forest shows that the enhanced atmospheric CO_2 directly increase productivity, because higher ambient CO_2 concentration stimulates net photosynthetic activity which have been called CO_2-fertilization effect. Transpiration decreases through a partial stomata closure resulting in increased water use efficiency of plants at least at a leaf scale; nevertheless, there are considerable differences between different species regarding their response. Some species in terrestrial ecosystems may in the long-term indirectly react negatively, perhaps fatal, to increased CO_2 concentration. The indirect responses of ecosystems are due to the effect of elevated CO_2 concentration is through effect on climate, such as change in temperature or radiation, humidity, precipitation or other climate variables. In most cases, this situation (the change in climate variables) can cause an impact on ecosystems (Bolin et al., 1989; Amedie, 2013).

As environmental exploitations by humans are increased, the global environmental change (increasing atmospheric CO_2 levels and associated climate changes fragmentation and loss of natural habitats) will also increase, which leads to rapid change on ecosystems in the world. Despite the large body of research showing effects of global environmental change on population abundances, community composition, and organism physiology, global environmental change may cause less obvious alterations to the networks of interactions among species. Yet complex networks of biotic interactions such as predation, parasitism and pollination play an important role in the maintenance of biodiversity, mediation of ecosystem responses to global environmental change, and the stability (resistance or resilience) of those ecosystem services on which human well-being is dependent (Tylianakis et al., 2008; Amedie, 2013).

The uptake of minerals, nutrient and water, canopy exchange of plants, absorption of light energy for the formation of carbohydrate through photosynthesis reactions as well as the breakdown and burning processes of carbohydrate for growth and development of the plant (respiration) is highly dependent on the amount of atmospheric CO_2 concentration and ambient temperature. The processes of transpiration (affected by the opening and closure of stomata), and evaporation from surface of plants determined by the level of temperature and CO_2. Soil biotic processes e.g. decomposition, mineralization, immobilization, and soil biotic processes such as solute transport, weathering, cat ion exchange, etc. in the soil affected by climate change. As a result, it causes a change in net primary production, species composition and resource competition; consequently, the general services, which we get from forest ecosystem; such as forest products, biodiversity, species composition, soil and water resources and recreation are affected.

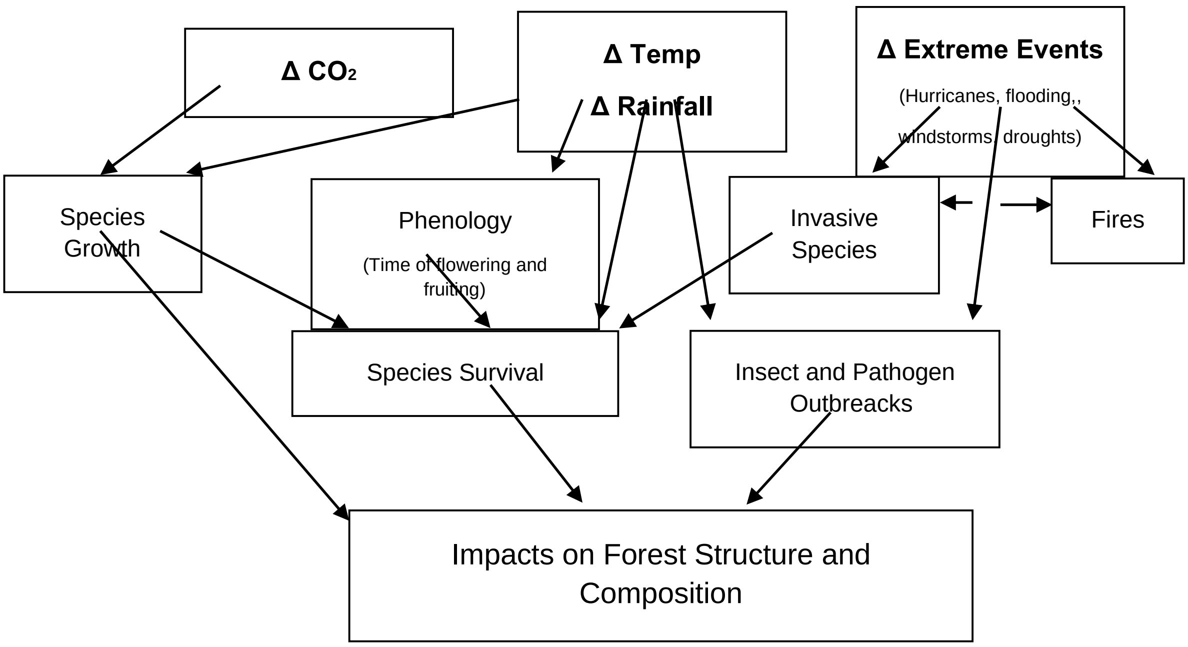

Figure 5. Potential impacts of climate change on forest ecosystems: a complex set of linked factors (CIFOR, World Agro-forestry Centre and USAID (2009) and authors' consideration)

2.3. Responses of forest trees to climate change.

Researchers have used ecological models to project the extent to which a specific climate change is expected to shift the geographic distribution of plants, particularly tree species (e.g., Emanuel et al., 1985; Solomon et al., 1996; Neilson and Marks, 1994). Forests have responded to past climate change with alterations in the ranges of important tree species (Shugart et al., 2003), but a critical issue is the rate at which tree species migrate. After the last glacial period, tree species migrated at rates of a few kilometers per decade or less, but the projected climate zones shift rate of 50 kilometers per decade could lead to massive loss of natural forests, with increased deforestation at the southern boundary of the boreal forests and a corresponding large carbon pulse (Malcolm et al., 2002). However, such a result could also lead to an increased rate of harvest to capture the value of the trees before it is lost to mortality. For typical timber production, with its managed forests and migration facilitated by human action, this negative effect of lagged migration might be of lesser importance than for natural forests.

The ecological literature suggests that warming is likely to result in an expansion of forest in high-latitude areas previously devoid of forest. In the mid-latitudes some forest species and types are likely to experience dieback while others migrate to areas with more suitable climates (Smith and Shugart, 1993; IPCC, 2007). Tree species at the edge of their ecological range may persist even if they are not able to regenerate in the new conditions (Clark, 1998).

Different processes in plants or forest ecosystems and their interaction with climate variability is complex, due to different response of physical, biological, and chemical processes. An increase in the ambient CO_2 concentration could reduce the opening of stomata required to allow a given amount of CO_2 to enter in the plant that might reduce transpiration of the trees. These could increase the efficiency of water use by forest plants and increase productivity to some extent (Bolin et al., 1989). Trees are capable of adjusting to a warmer climate, although the response expected from species are different and the effect on photo inhibition and photorespiration are more difficult to generalize (Saxe et al., 2001). As forest trees are characterized by the C_3 photosynthetic path way their productivity and demand for nutrient is highly affected by atmospheric CO_2 concentration and temperature. The total productivity expected from trees (especially from trees with indeterminate growth) growing under elevated CO_2 is larger than estimated in crops (Lukac et al., 2010). Estimated increased production from trees is higher than crops only achieved especially if the combination of absorption and increased nutrient use efficiency is attained (Tylianakis et al., 2008). However, the long-term response of forest to rising level of CO_2 is still uncertain. The current over all response of trees is positive and results from a review of many papers on effects of elevated CO_2 on different tree species shows that net primary production (NPP, photosynthesis minus plant respiration) on average increased with 23 % at an elevated CO_2 concentration of 550 ppm as compared with 370 ppm (Norby et al., 2005). Whereas, enhanced in temperatures can lead to heat and more water logging stress in bogs and cause more severe heat, drought and photo-inhibition stress periods in temperate bog and forest ecosystems (Niinemets, 2010). Climatic variability affects crop development and yield via linear and non-linear response to weather variables and exceeding of well-defined crop thresholds, particularly, temperature (Porter and Semenov, 2005).

1) Carbon Dioxide Fertilization

Climate change is also projected to alter tree productivity- in the aggregate, in a positive direction (see as Melillo et al., 1993). Although the science is still inconclusive and the effect appears to vary considerably (see Shugart et al. 2003, for a detailed discussion of the literature), increasing concentrations of atmospheric CO_2 may increase production through carbon dioxide fertilization. Early experiments in closed or open-top chambers demonstrated very high potential for CO_2-induced growth enhancement, such as an 80 percent increase in wood production for orange trees (Idso et al. 2001). The Free-Air CO_2 Enrichment experiments demonstrated a smaller effect of increased CO_2 concentration on tree growth. Long-term Free-Air CO_2 Enrichment studies suggest an average increase in net primary productivity of 23 percent (range, 0 to 35 percent) in response to doubling CO_2 concentration in young tree stands (Norby et al. 2005). However, another Free-Air CO_2 Enrichment study of mature, 100-year-old tree stands found little long-term increase in stem growth (Korner et al., 2005), which might be partially explained by the difficulties in controlling for constant CO_2 concentration in a large-scale experiment. However, economic models often presume high fertilization effects, as did Sohngen et al. (2001), who used projections of 35 percent more NPP. Regardless of the contradictory effects of variations in CO_2 concentration, however, empirical evidence indicates that forest growth rates have been increasing since the middle of the 20th century, as noted by Boisvenue and Running (2006).

Enhanced CO_2 and anthropogenic Nitrogen can directly increase short-term plant growth rates and change plant chemistry (C:N ratio and concentration of carbon-based compounds often increase), these physiological changes can affect a range of biotic interactions involving plants. Long-term ecosystem responses to elevated CO_2 may ultimately depend on nitrogen availability to plants and on the ability of plants to use nitrogen more efficiently under elevated CO_2 condition (Norby et al., 2001). In addition, larger supply of photosynthesis to mycorrhizal fungi shown to occur under elevated CO_2 (Lukac et al., 2010).

There are many processes in plant growth, affected by interaction of both enhanced temperature and carbon dioxide, in processes that determine carbon balance in the shorter term, from the long time scales of development and growth, which together lead to accumulation of biomass and yield. The two main reasons to expect progressively increasing CO_2 responsiveness of plant carbon balance at higher temperatures are 1) the decreased ratio of photosynthesis to photorespiration and 2) the decreased ratio of gross photosynthesis to dark respiration in warmer conditions (Morison and Lawlor, 1999).

The effect of elevated CO_2 on photosynthetic reactions are more pronounced in high temperature, e.g. around 20 centigrade than at 10 centigrade. Some predictions indicate that future increase in temperature may increase root mortality more in N-rich soils in temperate forests than in N poor soils in boreal forests areas with important implications for the cycling between plant and soil (Lukac et al., 2010). Some studies found that changes in activation state and catalytic constant occur due to both CO_2 and temperature, and there were an interaction, which affected the photosynthetic rate demonstrating the underlying complexity of the photosynthetic regulation mechanisms (Morison and Lawlor, 1999).

To sum up, environmental change has an impact on growth rate of individual trees and have a cumulative effect on different interactions and processes inside the forest and has the ability to change the amount of living materials in the forest ecosystem as a whole (Lukac et al., 2010). Temperature is one of the decisive factors in forming an effect on growth and productivity by accelerating the bud burst, flowering, and stems elongation during spring and then extend growing season, and it is one of the major factors controlling species distribution.

Increasing temperatures mostly associate with elevated CO_2, vapor pressure deficit and drought. Change in temperature will interact with other factors to form an effect; for e.g. nitrogen fixing nodule bacteria, mycorrhizal fungi and many other processes influenced by rising temperature. The long-term responses of climate change under higher CO_2 concentration, temperature and precipitation may differ from short-term effects because of the feedbacks involving nutrient cycling (Chen, 1996). Tree seedlings exposed in elevated CO_2 over time period of less than 1 year resulted in enhanced rate of photosynthesis, decreased in respiration and increased growth, with little increased in leaf area and small variation in carbon allocation. Exposure of woody species in elevated CO_2 over long time-period may result with higher rates of photosynthesis, but net carbon accumulation may not necessarily increase if CO_2 release from soil respiration increases (Luxmoore et al., 1993).

2) Effects of Temperature and Precipitation

Both temperature and the amount and pattern of precipitation are critical to forests. In general, warmer and wetter will enhance forest growth, while warmer and drier will likely be detrimental to growth. If drying is significant, grasses will often replace forests in natural systems (Bowes and Sedjo, 1993). Some biogeographical models demonstrate a poleward shift of vegetation by 500 km or more in the boreal zone (e.g., Solomon and Kirilenko, 1997). The equilibrium models and some dynamic vegetation models project that this vegetation shift toward newly available areas with favorable climate conditions will eventually expand forest area and replace up to 50 percent of current tundra area.

In general, climate change is likely to shift natural forests toward the poles. Most climate models indicate that temperature changes will be least at the equator and increase as the poles are approached. Thus, for forests, the changes should be greatest in the boreal and temperate countries as boreal forests migrate into areas formerly devoid of trees, such as parts of the tundra, and temperate forests move into former boreal forest areas where soils, photoperiod, and other growing conditions are appropriate. Although not often discussed, tropical forests may be affected differently, since the anticipated amount of temperature warming is lower at those latitudes. However, tropical forests may have less tolerance for adaptation. Perhaps more important than temperature are the changes in precipitation and moisture. Limits on moisture could result in forestlands' being converted to grasses. Although climate models are not generally regarded as good predictors of regional precipitation changes, the interiors of continents tend to be dry, and this tendency should be exacerbated under climate change and warming.

Environmental shift affects the extent of plant diseases and insect pests both the presently occurrence and infestation, introduced of the new species. Following these changes, a number of diseases, pests and weeds, preventing actions needed to reduce the effects on human health and ecosystems (Roos et al., 2010). Different chemical, biological and physical processes in earth systems need various temperature ranges; usually moderate and optimal temperature (for each processes) are essential for normal activities within the systems, a certain rise or lower from moderate temperature will affect many activities within the processes.

3) Disturbances and Extreme Events

Natural disturbances- including wildfires, outbreaks of insects and pathogens, and extreme events such as high winds- are an integral part of the forest environment. These disturbances are often stand-replacing events. As a changing climate creates new conditions and increases stress on the ecological systems, the forest adapts and evolves. Climate change will almost surely change the timing of the disturbances and will probably increase their severity. Indeed, climate-induced changes in disturbance regimes already appear to be occurring (e.g., van Mantgem et al., 2009; Westerling et al., 2006). Modifications of temperature and precipitation can weaken the forest and increase the frequency and intensity of infestation and fire; these indirect effects may be as important as the direct effects of higher temperatures and drier conditions. Many observers believe the beetle population has flourished because the warmer winters have dramatically reduced insect mortality. Note that extreme events generally are not independent but rather act in concert with forest system biological weakness. This weakness can reflect the age and/or health of the forest and may also be associated with the unsuitability of the forest types established under the earlier climate regime. New types may need to accompany climate change. Indeed, some have argued that extreme events in forestry often facilitate the replacement of an established forest with a new, perhaps more resilient forest (Sedjo, 1991).

Evidence indicates that natural forests have been migrating at least since the last glacial period as the earth warmed and moisture patterns changed. Tree species have migrated and adapted to changing environments, in some cases creating forests with a new combination of tree species (Shugart et al., 2003). However, climate changes have accelerated in recent decades, and if migration and adaptation cannot keep pace, some observers anticipate an increase in dieback toward the end of this century (IPCC, 2007). The IPCC Fourth Assessment of Climate Change (Easterling and Aggarwal, 2007) finds that globally, forest production will see "a modest increase to a slight decrease, although regional and local changes will be large." It also notes that the "production increase will shift from low-latitude regions in the short term to high-latitude regions in the long term." Although most of studies find that forest productivity and area increase modestly as the climate changes, uncertainties increase over the longer term. IPCC (2007) anticipates "significant forest dieback towards the end of the century." This dieback, exacerbated by climate change, is likely to become more severe as today's forests are replaced by forests more appropriate to the changing climate.

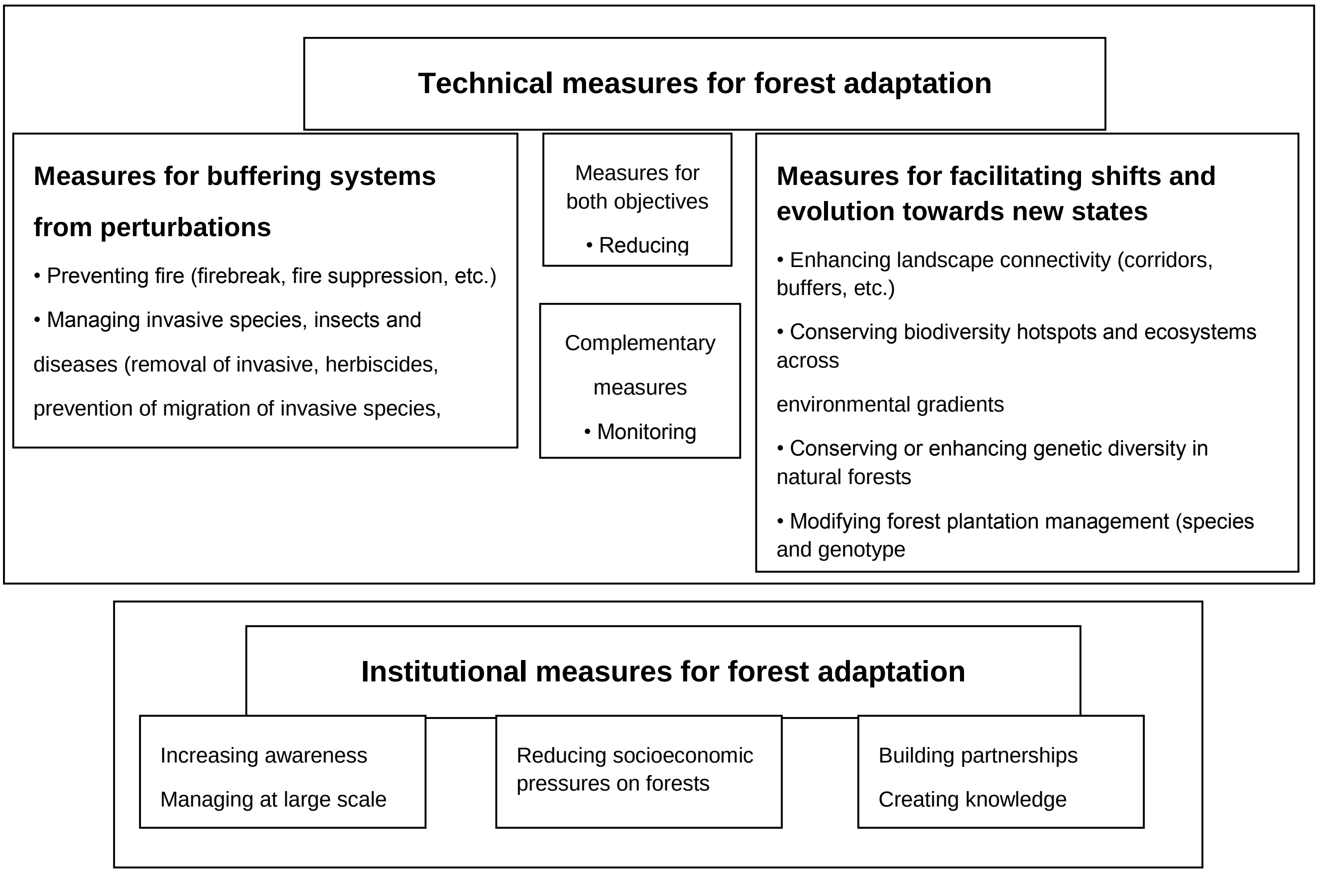

Figure 6. Examples of measures for forest adaptation (Locatelli et al., 2008 and authors' consideration)

2.4. Mitigation issues of forest to climate change

Forests and woodlands will play many roles in climate change mitigation through emissions reductions, carbon sequestration, and carbon substitution. In many places, reduced emissions from deforestation and forest degradation will be a necessary strategy for reducing emissions, but it will need to be complemented by other measures. Forest restoration can help remove greenhouse gases from the atmosphere (carbon sequestration) and also has many co-benefits, including biodiversity conservation, the provision of other ecosystem services and poverty alleviation. The increased use of wood-based biofuels and wood products are options for carbon substitution. A task of the international community is to help understand and finance the cost of reducing greenhouse gas emissions and enhancing carbon sinks through sustainable forest management. This will not only lead to good forest practice but also improve local livelihoods.

To reduce deforestation, the value of forests to landowners and forest users must be at least as great as alternative land uses. Incentives for reduced emissions from deforestation and forest degradation, therefore, must benefit the agents directly responsible for deforestation and forest degradation and act as an incentive for reducing this destructive behavior. In many places, identifying and involving these responsible agents are major challenges. Any potential reduced emissions from deforestation and forest degradation approaches must avoid perverse outcomes, such as encouraging poor forest practice.

Countries could identify hotspots- those forest areas most under deforestation pressure- for targeted reduced emissions from deforestation and forest degradation activities. sustainable forest management is not yet defined in the United Nations Framework Convention on Climate Change. To date, the Clean Development Mechanism has not sufficiently encouraged afforestation and reforestation (A/R, as defined by the Marrakesh Accords of the Kyoto Protocol). Unless procedures are improved and transaction costs reduced, it is unlikely that the A/R Clean Development Mechanism will contribute substantially to the enhancement of carbon sinks. Robust and credible strategies to mitigate climate change through sustainable forest management should recognize the historical forest management role of Indigenous and local communities and fully involve them in decision-making and benefit-sharing.

Studies are urgently needed on the implications of climate change for sustainable forest management in the tropics, on the role of tropical forests in mitigating climate change, and on national and international approaches to meeting the costs associated with managing tropical forests in the context of climate change.

The ability of countries to monitor carbon stocks in forests is highly variable. Tools are increasingly available to assist in this task but, in many countries, effective monitoring will require significant work and capacity building to establish reliable reference data for measuring deforestation and forest degradation. Wood is a carbon-neutral material and a renewable resource. Bioenergy production from forestry and the substitution of fossil-fuel-intensive products by wood products could be important approaches to mitigating climate change. Fuels produced from wood can have higher energy efficiency than other bioenergy sources, but production costs must be reduced and the environmental and socioeconomic impacts taken into account.

Wood is often more carbon-friendly than other commonly used building materials such as cement, plastics and steel. In certain cases, replacing one cubic meter of concrete or red brick with the same volume of timber can save around 1 ton of carbon dioxide. In many tropical countries, the traditional use of wood as fuel is still common and the industrial use of wood for biofuel production is also likely to increase dramatically in coming years. More information is needed on the ramifications of wood-based biofuels for the forests sector, the availability of land, and climate change.

Table 26. Considerations for forest vulnerability assessment

Dimension	Category	Elements (examples)
Environmental	forest structure	Species Composition Species Mix Tree arrangement in relation to infrastructure Tree arrangement in relation to each other (ecological connectivity) Age structure
	forest natural resilience	Degree of acclimatization (phenotypic change) Degree of biological adaptation (genotypic change) Ability of species to migrate
	forest stresses	Building activities Pruning Microclimate Soil availability Water availability
	Climate Change Scenario (predicted)	Temperature Frequency and intensity of precipitation Frequency and intensity of climate disturbances Sea-level rise
	Time horizon and space scale	
Social	Institutions	Number and kind of institutions Level of skill of staff Quantity of staff
	Ownership	Kinds and patterns of ownership
Economic	Valuation	Property values Saved infrastructure costs due to forest functions
	Institutions	Budget

Source: Locatelli et al (2008), Niinemets (2010), IPCC (2007), Amedie (2013) and authors' consideration

3. The forest condition, carbon sink and ecosystem services in one of the most important forest area of China

3.1. Forest condition of Yellow River Delta

The Yellow River flows across the arid inland regions of China into the Bohai Sea through the Yellow River Delta. The Yellow River is considered to have the highest sediment content in the world. The Yellow River Delta locates in the southern coast of the Bohai Gulf and the western Laizhou Bay (36°55′-38°16′N,117°31′-119°18′E) with an area of approximately 5400 km^2 (broadly speaking, 7923 km^2, Dongying City). Based on record of “Outline History of China Water Resources”, the Yellow River has changed its major watercourse (about 600 km from the river mouth) 26 times in the last 2200 years. As the Yellow River has changed its course frequently, there are several definitions of the Yellow River Delta boundary, and the delta continues to expand due to extremely high loads of silt carried by the river. The ancient Yellow River Delta comprised a large plain formed over the period 1128–1855, during which the river changed its course four times. Since 1855, with ten further changes of its course, the river shifted northward, leading to the formation of the present Yellow River Delta (Cheng, 1987, Cheng, Xue, 1997). The modern Yellow River Delta was formed since the watercourse of the Yellow River changed in 1855. Dongying, today the principal municipality of the Yellow River

Delta, did not exist until 50 years ago. Geographically speaking, the Yellow River Delta covers an area larger than the Dongying Municipality. Although the Yellow River Delta covers an area larger than Dongying Municipality in terms of geography, the study area for the project is the modern Yellow River Delta, including the coastal wetlands in the delta plain, the tidal flats and the subaqueous delta system. In the present report, the term Yellow River Delta and Dongying Municipality are used interchangeably.

The key economic resource of the Yellow River Delta is an oil field, administered by the Shengli Oil Administrative Bureau. Because of the frequent changes of the river's course, the Yellow River Delta remained an underdeveloped rural area before the discovery of the Shengli Oil Field in the 1960s. The climate of study region belongs to warm temperate continental monsoon climate with distinctive seasons and a rainy summer. The annual average temperature is 11.7-12.8 centigrade and the frost-free period lasts 206 days. The annual average rainfall is 530-630 mm, which of 70% is in the summer, and evaporation is 1900-2400 mm, and the drought index is up to 3.56 (Cui et al, 2009). Influenced by swing and seepage of the ocean and the Yellow river runoff and other climate-related factors in the Chinese Yellow River Delta, there formed one of the youngest, most extensive, most biodiversity-rich estuarine coastal wetlands in the warm temperate region. However, there is also serious natural disaster, while the adverse effects of human-induced affects the sustainable development process, restricting the Delta coordinated development. The soil type includes mainly fluvo-aquic soils and saline soils. Most of the land reserve resources presents a high saline soils and low-lying terrain, with neonatal severe soil secondary salinization. The natural vegetation is salt meadow mainly, with more than 85% species are salt tolerant plants and aquatic plants. The predominant species in the region are *Suaeda heteropter Kitag*, *Phragmites australis*, *Tamarix chinensis Lour*., *Aeluropus sinenis* and *Imperata cylindrica (Linn.) Beauv* (He et al, 2007). At present there is not natural forest at all, the main secondary forest is the beach *Tamarix chinensis* and the plantations include mainly *Robinia pseudoacacia*. The vegetation is formed only for a short time, with a poor community stability and monotonous species group, and mainly including herb ecosystem, so wholly it is a unstable, fragile terrestrial ecosystem.

3.2. The good practice of sustainable forest management in Yellow River Delta

There have been many measures for fundamental improvement of fragile ecosystem and carbon sink in Dongying, especially the project of the "Three Networks Greening" that has been proposed and is partly implemented since 2007. To improve the ecological environment in the YELLOW RIVER DELTA radically and to promote the establishment of a highly-efficient eco-economic zone, Dongying City of Shandong Province, proposed the project of the "Three Networks Greening", whose framework is composed of forest networks along roads, rivers and in cultivated areas. The overall layout of the Three Networks Greening project is divided into two levels, i.e., regional layouts and local establishment layouts. The regional distribution of the Three Networks Greening project in the Yellow River Delta is summarized as one center, four districts and 21 groups. The center refers to the region surrounding the east and west sides of Dongying City and Kenli County. The four districts are composed of three cultivated land regions and a coastal forest region. The 21 groups are taken to highlight and demonstrate the greening work by synthesizing each factor. The local establishment layout of the Three Networks Greening project in the Yellow River Delta is, in general, seen to consist of seven axes, two belts, one network and four eco-hubs. The seven axes represent seven greening axes, consisting of two main roads perpendicular to five horizontal drives. The two belts and the one network deal with coastal shelter belts surrounding the central city and plain standardized farmland forest networks. The four ecological function hubs represent four wetland ecosystems (Government of Dongying City, 2007). From 2007 to 2012, the city has invested 4.2 billion CNY in afforestation area of 70,000 hm^2, exceeding the cumulative afforestation area since city construction, with forest coverage of from 3.7% to 13.6%. The main tree species are *velvet ash*, *black locust*, *siberian elm* (*Ulmus pumila*), tree of heaven (*Ailanthus altissima*), and so on, mainly with mixed plantations of *black locust* and other species. The good practice of sustainable forest management can include as follows four aspects,

- Attaching great importance to scientific planning of forestry sector within Dongying local government scheme
- Breeding and promoting native and local plant species, introducing and domesticating exotic species, improving and rectifying saline-alkali soil, actively, to overcome difficult afforestation based on science and technology
- Accelerating the construction of forest ecological system in accordance with project-driven overall planning
  - Project of the “Three Networks Greening” in Dongying city since 2007
  - Project of the highly-efficient eco-economic zone in Yellow River Delta
  - Project of the coastal forest shelterbelt
- Constructing ecological forest station to promote ecological construction with sustainable social and economic incentive mechanism
-

3.3. Carbon sink assessment of natural ecosystem in wetland vegetation

To address climate change, the China government commit, by 2020, carbon intensity per unit of GDP will reduced by 40 to 45% compared to that in 2005. According to calculations, to complete this object, energy elasticity coefficient must drop to 0.6, but, comparing the experience of developed countries in the past, it is difficult to achieve this goal within the rapid industrialization and urbanization national stage. From the point of "Carbon Reduction Commitments" view in the world, many countries will deal with the promise by ecological construction of carbon sink project. There is the recovery conditions of the natural forest ecosystem in Yellow River Delta region and the carbon sink project will be needed.

The Key Laboratory of Ecosystem Network Observation and Modeling of Chinese Academy of Science was established in 1999 to address China's ecological health and to promote sustainable development of China's resources. It comprises Synthesis Research Center, Sub-Center for Water, Yucheng Intergraded Agricultural Experimental Station, Qianyanzhou Experimental Station of Red Soil and Hilly Land, and Lasa Plateau Ecosystem Research Station, where carbon fluxes are measured by eddy covariance method. So we accessed the carbon sink based on observation and literatire in China.

The flora of the Yellow River Delta Nature Reserve represents the natural flora in the Yellow River Delta. In the reserve, there are 393 species of plants, among which there are: 4 divisions and 116 species of phytoplankton; 3 families, 3 genera and 4 species of fern; 2 genera and 2 species of gymnosperm; 54 families, 179 genera and 271 species of angiosperm (11 families, 58 genera and 87 species of monocotyledons and 43 families, 121 genera and 184 species of dicotyledons) (Zhao, Song 1995, Hou et al, 2012). According to the classification in ‘*China Vegetation*’, the Yellow River Delta reserve occurs in the warm temperate broad-leaf forest zone, northern deciduous *Quercus* spp. subzone, Yellow River plain cultivation area. The flora in the reserve mainly comprises temperate components.

Based on the classification system in ‘*China Vegetation*’, the vegetation in the delta has been divided into five vegetation type groups, with 9 vegetation types, 26 plant formations and plant association, as outlined in table 4 (Zhao, Song 1995, Xu et al, 1997). The main artificial vegetation in the reserve is *Robinia pseudoacacia* (Black Loquat) plantation, which joins the *Robinia pseudoacacia* plantation around the reserve, forming the largest *Robinia pseudoacacia* plantation in coastal China. The total area of Yellow River Delta wetland is approximately 833,000 hm^2. The natural wetland vegetation in Yellow River Delta wetland includes two subtypes of vegetation with shrubs/Missy lumber and grass, including vegetation subtypes of willow of *Salix integra*, *Tamarix chinensis*, and *Nitraria tangutorum* in the first type.

Based on carbon storage and carbon fixation capacity of coastal wetland vegetations in the Yellow River Delta, the total delta wetland carbon storage and carbon sink can be calculated. Using research methods of Fang J, Dai J (2010) and others, in accordance with the translation factor function, biomass of main vegetation species can be estimated.

Then, according to carbon stocks (C) and carbon sequestration (CO_2) formulas provided in *United Nations Framework Convention on Climate Change (UNFCCC)*:

The carbon stock (C) = 50% of biomass;

The carbon sink (CO_2) = carbon content of biomass × 3.667.

So, the total carbon sink equation for vegetation is as follows,

$$CS_i = p \times q \times A_i \times B_i$$

where CS_i is the amount of carbon sink for the vegetation *i*, A_i is the area of vegetation *i*, B_i is the biomass for the vegetation *i*. And, *p* means the carbon transformation coefficient (≈0.5), *q* is 3.667.

The total carbon storage and carbon sink of the wetland vegetations and paddy fields in the Delta area are around 2,010,000 t and 7,353,800 t, with its carbon fixation of the hydromorphic vegetations and paddy fields much higher than the mean carbon fixation of the global terrestrial vegetation and the all China terrestrial vegetations. However, the carbon fixation of the hydromorphic vegetations remains lower than that of the corresponding local latitudinal deciduous broad-leaved forest. The carbon storage and carbon sink of the vegetations of coastal wetland in the Yellow River Delta remains low, which is likely to reflect the fragility of the coastal wetland ecosystem of the area.

Table 27. Total carbon storage and carbon fixation of coastal wetland vegetations in the Yellow River Delta

Vegetation type	Area (hm^2)	Carbon storage (t)	Carbon sink (t)
Tamarix chinensis	50,000	295,000	1,081,765
Nitraria tangutorum	6,600	204,600	750,268
Suaeda salsa	101,900	326,100	1,195,809
Salix integra	5,200	71,200	261,090.4
Phragmites australis	27,200	636,500	2,334,046
Altoherbiprata except *Phragmites australis*	16,800	275,500	1,010,259
Floating-leaved aquatic vegetation	14,900	25,300	92,775
Submerged aquatic vegetation	11,000	8,800	32,269
Paddy field	19,100	162,400	595,521
Total	312,100	2,010,000	7,353,800

Source: Authors' calculations and Zhang et al (2009), Wu , Gu (2005), Tian et al (2005), Li, Ji (2001), Zhang et al (2012), Wang et al (2010)

The carbon stock and carbon sink of wetland vegetation in Yellow River Delta should be maintained and continuously improved by protecting natural wetland vegetation as far as possible, especially protecting the *Phragmites australis* group and other wetland vegetation of the large carbon stocks, carbon sink ability, avoiding the mining oil, reclaiming land and other industrial and agricultural production, not to take up reed swamp. In addition, ecological engineering measures of the fresh water resources should be carried out to restore degraded wetland *Phragmites australis* group (Zhang et al, 2011).

3.4. Carbon sink potential assessment of plantation in Yellow River Delta

According to the principles of sustainable land development and the demands of ecological economic impacts, based on the rule of social-economic-natural complex ecosystems and environmental regional differentiation, from beach to terrene, an analysis of land resources was drawn up by matching a 1:100000 scale map of 2005 with a land suitability evaluation map, especially taking the characteristics of ecological functional zones and high impact ecological envelopment into consideration. It is calculated that there is an area of 225,600 hm^2, for forest scheme of land resources, adjusted from cultivated land and unused land, which should be afforested. From an overall view point of a highly-efficient economic zone development in the Yellow River Delta (Dongying section), valuable strategies should be put forward to improve and perfect the project of Three Networks Greening. The overall plan of the Three Networks Greening project is deployed and implemented by administrative regions. Based on the analysis scheme of land resources, the amount of the ungreened land is shown: Hekou District, Kenli County, Lijin County, Dongying District and Guangrao County are 580.6 km^2 , 526.4 km^2, 483.8 km^2 , 449.9km^2 and 215.4 km^2 , respectively.

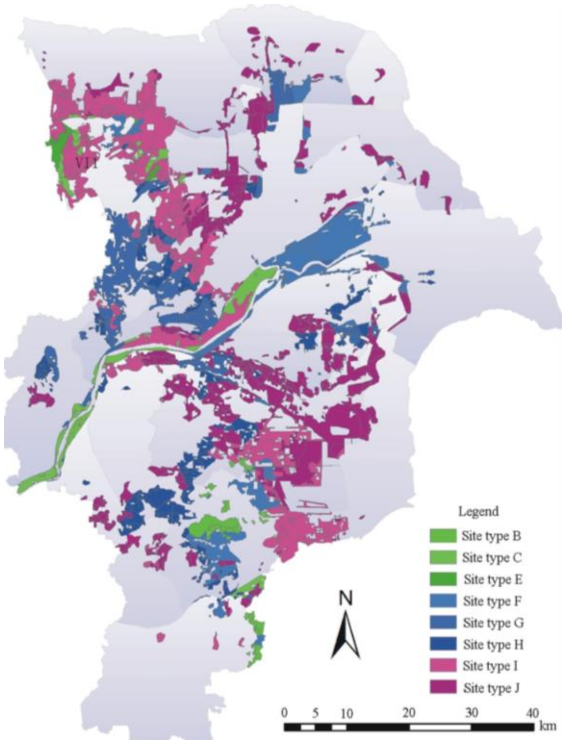

Figure 7. Spatial distribution of land resources in the Yellow River Delta

Source: Authors' calculation and Xu (2000), DMG and SFMPI (2007), Zhao et al (2010), Yu et al (2012)

Table 28. Soil condition type classification of Yellow River Delta

Type	Microrelief	Soil conditions	
		Land type	Salinity
A	Plain, depression land	Calcaric cambisols; gleyic cambisols	Non (< 0.1)
B	Terrace land, plain	Calcaric fluvisols	Non (< 0.1)
C	Flood plain	Calcaric fluvisols; gleyic calcaric fluvisols; luvisols	Light (0.1–0.2)
D	Depression land	Calcic vertisols	Non (< 0.1)
E	Flood plain, terrace land	Calcic fluvisols	Light (0.1−0.2)
F	Plain, depression land	Salic fluvisols	Middle (0.2−0.4)
G	Depression land	Salic fluvisols; gleyic solonchaks	Middle or heavy (0.2−0.8)
H	Depression land	Salic fluvisols; gleyic solonchaks	Heavier (0.4−0.8)
I	Depression land	Gleyic solonchaks	Heaviest (> 0.8)
J	Coast beach	Gleyic solonchaks	Heaviest (> 0.8)

Source: Xu (2000), DMG and SFMPI (2007), Zhao et al (2010), Yu et al (2012) and authors' consideration

The carbon sink potential of forest development is large in Yellow River Delta, with about 150,000 hm^2 possibly used for returning farmland to forest land or use of land of afforestation, by the implementation of the forest project of carbon sinks.

The amount of biomass, carbon storage and carbon fixation can be estimated according to main plantation species of *Robinia pseudoacacia, Fraxinus velutina, Ulmus pumila, Ailanthus altissima.* The forest mode of *Robinia pseudoacacia* mixed *with Fraxinus velutina* with 3:1 proportion, and mode of *Robinia pseudoacacia* mixed with *Ulmus pumila, Ailanthus altissima* with 1:1 proportion are modeled. Using research methods of Fang J, Dai J (2010) and others, in accordance with the translation factor function, biomass of main tree species can be estimated as: *Robinia pseudoacacia*: 208(t/hm^2) , *Fraxinus velutina*: 324(t/hm^2) , *Ulmus pumila*: 170(t/hm^2) , *Ailanthus altissima*: 108 (t/hm^2). The results are in the table 4 as below. The forest carbon sink of 43.50～65.10 million tons is available. With natural ecosystem vegetation in wetland, the total available carbon sink could reach approximately 72.4 million tons.

Table 29. The carbon storage and carbon sink of forest available in Yellow River Delta

	Unit	*Robinia pseudoacacia*	*Fraxinus velutina*	*Ulmus pumila*	*Ailanthus altissima*	Results
The available forest land	hm^2	-	-	-	-	150, 000
The biomass amount per unit area	t/ hm^2	208	324	170	108	158～237
The carbon storage per unit area（C）	t/ hm^2	104	162	85	54	79～119
The carbon sink per unit area（CO_2）	t/ hm^2	381	594	312	198	290～434
Total available biomass	million t	-	-	-	-	23.70～35.55
Total available carbon storage（C）	million t	-	-	-	-	11.85～17.85
Total available carbon sink（CO_2）	million t	-	-	-	-	43.50～65.10

3.5 Value Assessment of Ecosystem Services in Yellow River Delta

3.5.1 Value Assessment of Ecosystem Services for High-efficiency Ecological Economic Zone in Yellow River Delta

1) Research methods

According to the equivalent factor table of China's ecological service value and the regional correction coefficient of ecological service value by Xie Gaodi (2003), the ecological service unit area of the terrestrial ecosystem value table is studied.

2) Estimation of ecosystem service value in the study area

The total value of Ecosystem Services in the Yellow River Delta is 70 billion RMB. The value of the services provided by the wetlands, forests, farmland and grassland ecosystems were $ 45 billion, $ 15 billion, $ 9.5 billion and $ 500 million respectively.

Comparison of two methods of value evaluation of ecosystem services is also proceeded, According to Costanza et al.(1997) classification system and assessment method, the ecosystem services value of the Yellow River Delta was evaluated using the ecological value of ecological units such as wetland, farmland, forest and grassland. The total value was calculated as 60 billion RMB. Among them, wetlands provide the most value, accounting for 90% of the total value, that by this method of wetland service value is too high, and the value of the estimated value of the forest, farmland is too low. In contrast, according to Xie Gaodi classification system and the evaluation results are closer to the actual situation of the Yellow River Delta.

3.5.2 Evaluation of Ecosystem Service Value for Plantations in Saline-alkali Soils of the Yellow River Delta

The typical long-term plantation of saline-alkali soil in the Yellow River Delta was selected as the research object, and the ecosystem services of Robinia pseudoacacia, Fraxinus spp., Ulmus pumila, Ailanthus altissima forest and mixed forest were evaluated according to "Evaluation Criteria of Forest Ecosystem Service Function" of SFA. The research results can effectively guide the forest conservation, vegetation restoration and its sustainable management in the ecologically fragile areas of saline-alkali land, and provide a strong guarantee for the healthy development of the forest ecosystem in the Yellow River Delta.

1) Research methods

The seven typical long-term plantations in this area were selected as the study objects. Four of the pure stands were Robinia pseudoacacia, Fraxinus mandshurica, Yulin and Ailanthus altissima, the other three for the Robinia pseudoacacia and other three tree species to build a mixed forest.

2) Evaluation index system

The evaluation index system of Forest Ecosystem Service Function Evaluation of State Forestry Administration includes 8 categories and 14 indicators. Based on the site conditions and characteristics of saline-alkali plantations in the Yellow River Delta, five types of indicators of water supply, carbon sequestration and release, nutrient accumulation, air purification, and biodiversity conservation were selected to evaluate the effects of typical plantations of the ecological service value.

a) Conservation of water value: Based on the water balance method, the study measures the capacity of water conservation in the forest, and then use the shadow engineering method to estimate the ecological system of water conservation of indirect economic value.
b) Carbon Fixation and Oxygen Release Value in forest ecosystems.
c) Accumulation of nutrients in forest ecosystem refers to the absorption of N, P, K and other nutrients by various plants in the forest, and its storage function plays an important role in alleviating non-point source pollution and reducing eutrophication of water bodies.
d) Purification of Atmospheric Environmental Values: Five major indicators of SO2, fluoride, nitrogen oxides, dust retention, and negative ions were selected to assess the atmospheric environmental values of different long-term plantations in the Yellow River Delta.
e) Conservation value of biodiversity.

3) Total value of long-term plantation ecosystem service value in Yellow River Delta

The total value of ecosystem service value of long - term plantation ecosystem in the Yellow River Delta was calculated by the cumulative value of all types of ecological services. The total value of Fraxinus mandshurica forest was the highest, followed by Robinia pseudoacacia plantation, which was 60,000 yuan / (hm2. a) and 50,000 yuan / (hm2. A). The lowest value was Ailanthus altissima. The total ecological service value of all the seven stands was as follows: Fraxinus mandshurica> Robinia pseudoacacia> Ailanthus altissima mixed forest> Robinia pseudoacacia L.> Mixed forest> White Yulin> Robinia pseudoacacia mixed forest> Ailanthus altissima.

The average value of the ecological services of the seven stand stands is 45000 RMB / (hm^2. a). Among the five functional index values, the value of water conservation function was the highest, accounting for 60% of the total value, followed by the value of carbon fixation and oxygen release, while the two values of environmental protection and biodiversity conservation were relatively small, accounting for only 10% of the total value. The five service values of the long-term plantation in the Yellow River Delta are quite different. They are ranked as follows: conservation water value> fixation and release oxygen value> accumulation nutrient value> biodiversity conservation value> purification atmospheric environmental value. It can be seen that the plantation in the Yellow River Delta has a high conservation water and carbon sequestration and oxygen release value. Therefore, it is necessary to renovate and develop the forest in the Yellow River Delta, which is more serious in salinization. It is beneficial to conserve water and reduce soil salinization. Meanwhile, it is helpful for the region to cope with climate change.

The total ecological benefit of P. xylophilus was the best. For the afforestation tree species such as Ulmus pumila, Ailanthus altissima and so on, the ecological service value could be improved by constructing the mixed forest with the better tree species.

4) Solutions

Reasonable development and utilization of land, reduce the degree of salinization, improve productivity and improve the value of direct use.

Reasonable allocation of agricultural, forestry, animal husbandry structure ratio. Increase the area of forest land and grassland, and adjust the structure of forest species and grass species so as to obtain the stable ecological service value.

Improve the regulatory capacity of invasive alien species. The establishment of alien species invasion risk assessment system, alien invasive species early warning and monitoring system is necessary, with timely control measures.

Reduce the effects of oil, salt and other activities on the ecological environment.

3.5 The forest issues in Xishuangbanna tropical forest

Tropical rainforests harbor the world's most species-rich plant communities and are vulnerable to deforestation and forest degradation (LaFrankie et al., 2006). Tropical climatic conditions occur over a small proportion of China's landmass. Species-rich tropical forests covered much of China's southern border, from southeastern Xizang (Tibet) to southern Yunnan, extending to southwestern Guangxi, including southern Taiwan and Hainan Island. Forest cover was 42.5 percent in tropical China with a total area of 11.257 million ha, of which about 5.44 million ha are secondary forests (Hou, 2003). There are only about 633,800 ha of old growth high diversity lowland tropical rain forests in China today, and much of these old growth lowland tropical forests are located in Xishuangbanna of southern Yunnan Province.

1) Geography conditions in Xishuangbanna

Xishuangbanna lies between 21◦08'N and 22◦36'N, 99◦56'E and 101◦50 E, situated in the southwestern Yunnan Province of China. The region has an area of 19,120 km2. It borders Myanmar in the southwest and Laos in the southeast, and has mountainous topography, with mountain ridges running in a north–south direction, decreasing in elevation southward. Its elevation ranges from 491 m at the bottom of the lowest valley in the south (Mekong River) to 2429.5 m at the top of the mountains in the north. Xishuangbanna has a typical monsoon climate with three distinct seasons: a humid hot rainy season (May-October), a foggy cool-dry season (November-February), and a hot-dry season (March-April). The foggy cool-dry season and hot-dry season together represent the annual dry season (Cao et al. 2006). The annual solar radiation in the region is 116.724 Kcal/cm2/yr, and annual sunshine averages 1858.7 h. The annual mean temperature ranges from 21.7◦C at an elevation of 550 m to 15.1◦C at 1979 m, and the 20◦C isotherm is equal to the 850-m elevation isoline. Temperature can exceed 38◦C inMarch and April when relative humidity is below 40 percent. Annual precipitation increases from 1193 mm at Mengyang at 740 m elevation to 2491 mm at the summit of Nangongshan at 1979 m elevation.

Xishuangbanna' soils are derived from both igneous and sedimentary rocks. There are three main soil types in the Xishuangbanna region (Wang et al. 1996). A laterite soil developed from siliceous rocks, such as granite and gneiss, occurs between 600 and 1000 m elevation with a deep solum and thin humus horizon. A lateritic red soil, derived from sandstone substrates, occurs in areas above 1000 m elevation. Limestone hills have soil derived from a hard limestone substrate of Permian origin with a pH of 6.75. Other soil types are found in a limited area. The tropical rain forest and themontane evergreen–broad leaved forest of Xishuangbanna occur mainly on laterite and lateritic red soils with pH values of 4.5–5.5. Tropical seasonal moist forest occurs on the limestone-derived soils. Tropical monsoon forest is often associated with young soils along the riverbanks.

2) The tropical forest conditions in Xishuangbanna

Tropical seasonal rain forest is one of the main primary forest vegetation types in Xishuangbanna (Zhang & Cao 1995, Zhu et al. 2006). There are three tropical seasonal rain forest formations in this region: (1) Terminalia myriocarpa and Pometia tomentosa formation (2) Antiaris toxicaria, Pouteria grandifolia, and Canarium album formation; and (3) Shorea wangtianshuea formation. Among the three formations, T myriocarpa and P tomentosa formation occupies the largest area. It usually occurs in valleys or on foothills, with altitudes ranging from 500 to 900 m (Liu 1987). In Xishuangbanna, areas on hills and mountains have been used for shifting agriculture for centuries, and most of the seasonal rain forest remains on northern slopes and in steep valleys. The seasonal rain forest is confined to below 900 m on northern slopes due to deficiencies of light and temperature. However, on the southern slopes of large mountains, this forest can extend to an elevation of about 1100 m along valleys (Zhu et al. 2000). The habitat is wet, so it is locally termed as "tropical ravine rain forest" (Liu 1987). In Mengla County, this type of rain forest extends in long, narrow strips along valleys. Features of this rain forest habitat include narrow terrain with less solar radiation and abundant soil moisture, and the forest has vegetative characteristics typical of other Southeast Asian rain forests (Liu 1987).

Two subtypes of tropical rainforests were registered in Xishuangbanna, namely, tropical seasonal rainforest and tropical mountain rainforest (Wu et al. 1987, Zhu et al. 2006). The tropical seasonal rainforest occurs in lowlands (below 900 m asl), whereas tropical mountain rainforest is found at higher elevation. Tropical seasonal rainforests in Xishuangbanna are floristically dissimilar from other forests in the equatorial tropics as they contain tree species of both tropical and temperate regions (Cao & Zhang 1997). They are also different from the tropical rainforests in South-East Asia because they are not dominated by species of the Dipterocarpaceae family (Zhu et al. 2006).

3) Biomass and ecosystem carbon storage of the tropical forest in Xishuangbanna

Tropical forests are recognized for their high biodiversity and the roles they play in carbon (C) storage and their influence on climate. Very little information about the forests of Xishuangbanna was available prior to the 1950s due to limited access to this remote region. The existence of true lowland tropical rain forest in Xishuangbanna was somewhat debated by botanists, because of its northern latitude (21–22◦N) and seasonal climate. The first botanist who described the tropical forests in southwestern Yunnan was Wang (1939). Few efforts had been made to study the Xishuangbanna forests since then, until a joint Chinese–Russian expedition during the late 1950s and early 1960s led to publications in Russian and Chinese on the flora and fauna of Xishuangbanna (see as Zhu et al. 2006). The forests of Xishuangbanna harbor biodiversity that is important both globally and nationally. Xishuangbanna is included in the Indo-Burma biodiversity hotspots and contains over 5000 species of vascular plants, comprising 16 percent of China's total plant diversity (Li et al. 1996, Cao & Zhang 1997, Myers et al. 2000). The fauna of Xishuangbanna are no less diverse, as 36.2, 21.7, and 14.6 percent of China's birds, mammals, and reptiles, and amphibians occur in the region, respectively (Kou & Zhang 1987, Wang & Jin 1987, Yang et al. 1987). Despite Xishuangbanna's high biodiversity, general ecological information about the forests of the region has rarely been published for an international audience. Zhu et al. (2006) provide an extensive review on the floristic composition and structure of forests in the region. Zheng et al. (2006a) estimate the biomass of a dominant tropical seasonal rain forest in Xishuangbanna. Tang et al. (2006) describe soil seedbanks in a dipterocarp forest that reaches up to 70 m in height, and Zhang et al. (2006) describe the phenology of fig trees in the area. Zheng et al. (2006b) examined the decomposition of plant litter. Recently, Lü et al. (2010) described the tree species diversity and floristic composition of a tropical seasonal rainforest located in Xishuangbanna, based on a census of all trees with diameter at breast height (dbh)≥10 cm in three 1-ha plots. Tang et al. (2011, 2012) recently also presented an analysis of floristic composition patterns and assessed the ecosystem C stocks for limestone tropical forests in Xishuangbanna. Tropical forests over limestone take up 40% of the total area of tropical Asia. The forest biomass and its allocation patterns were estimated in five 0.185–1.0 ha plots in tropical seasonal rain forests of Xishuangbanna (Zheng et al, 2006). Forest biomass ranged from 362.1 to 692.6 Mg/ha. Biomass of Pometia tomentosa, a dominant species, accounted for 19.7–21.1 percent of the total tree biomass. The average density of large trees (DBH ≥100 cm) was 9.4 stems/ha on two small plots and 3.5 stems/ha on two large plots in Xishuangbanna tropical forest. In Xishuangbanna tropical forest over limestone, the mean total ecosystem C stock was estimated at 214 ± 28 t C ha-1 (± SE). The contribution of plant biomass in storing C was substantial, accounting for 80% of the total ecosystem C storage. The mean C stock of tree layer was 155 ± 24 t C ha-1. Soil C stocks in tropical forests over limestone in this area (50 ± 10 t C ha-1) were much lower than those in tropical forests from South-East Asia. Higher percentage of C stock in plant biomass while lower percentage in mineral soil indicated that C stocks of the tropical forests over limestone would be more vulnerable to vegetation destruction than other tropical forests on non-limestone substrate (Tang et al, 2012).

3.6 The climate change-dependent forest issues

It is important to note that often the opposite characteristics of what makes systems vulnerable to change might make certain species, communities, and ecosystems more accommodating to change, and to take an active and efficient forest scheme. Ecosystems better able to accommodate change may include the following:

- Species that are currently increasing
- Species with a wider ecological range of tolerances
- Species with greater genetic diversity
- Species and ecosystems adapted to disturbances
- Species and ecosystems adapted to warmer, drier climates
- Species in the middle or northern extent of their range
- Diverse communities and species

- Habitats within larger, contiguous blocks

The Climate Change Tree Atlas uses an ensemble of species distribution models to examine the features that contribute to a tree species' current habitat and then project where similar habitat conditions are likely to occur in the future. The Tree Atlas does not predict where species will be present in the future, but rather where suitable habitat for individual tree species may be present. climate change will likely lead to changes in the suitable habitat of many common tree species. The ways in which tree species will actually respond to climate change, however, is influenced by a number of "modifying factors" including site conditions, competition from other species, landscape connectivity, the degree of disturbance, and the ability of species to disperse, many of which cannot be modeled directly by the Tree Atlas (Prasad et al., 2007). The possible potential changes for tree species under climate change in total North China based on results from the Climate Change Tree Atlas are as follows.

- **Extirpated possibly:** The suitable habitat may disappear by 2100 for Mountain maple
- **Large Decline possibly:** Some species may show large declines in suitable habitat, especially under the high emissions scenarios such as: Balsam fir; Eastern hemlock; Sugar maple; Bigtooth aspen; Northern white-cedar; Tamarack; Black ash; Paper birch; White spruce; Black spruce; Quaking aspen; Yellow birch
- **Small Decrease possibly:** Some species may show smaller declines, mostly apparent in the high emissions scenarios such as: Balsam poplar; Eastern white; pine Red maple; Butternut; Jack pine; Rock elm
- **No Change possibly:** Some species may show roughly similar suitable habitat now and in the future such as: Basswood; Green ash; Northern red oak; Chokecherry; Northern pin oak; Red pine
- **Small Increase possibly:** Some species may have an increased amount of suitable habitat in the future as compared to current, especially under the higher emissions scenarios such as: Eastern hophornbeam; White ash; Hornbeam
- **Large Increase possibly:** Some species may have much higher estimates of suitable habitat in the future as compared to current, especially with the higher emissions scenarios such as: Beech; Boxelder; Shagbark hickory; Bitternut hickory; Bur oak; Silver maple; Black cherry; Eastern cottonwood; Slippery elm; Black oak; Eastern red cedar; Swamp white oak; Black walnut; Hackberry; White oak; Black willow; Osage orange
- **New Entry under High and Low Emissions Scenarios possibly:** Some species may have never or very rarely been detected, but show potential suitable habitat entering the region, even under the low emission scenarios such as: Black locust; Ohio buckeye; River birch; Flowering dogwood; Pignut hickory; Sassafras; Honey locust; Pin oak; Yellow poplar; Mockernut hickory; Red mulberry
- **New Entry under High Emissions Scenarios possibly:** Some species may have never or very rarely been detected, but show potential suitable habitat entering the region under high emissions such as: Black hickory; Eastern redbud; Scarlet oak; Blackgum; Northern catalpa; Shingle oak; Blackjack oak; Peachleaf willow; Sugarberry; Chestnut oak; Pecan; Sycamore; Chinkapin oak; Post oak; Wild plum; Common persimmon

Table 30. Climate change-related threats, vulnerabilities, and responses for main forests

Extent	Potential threats from climatic changes	Potential vulnerabilities to threats	Responses that may accommodate change
All forests in northeast Asia	Warmer temperatures Longer growing	Decline of associated rare species	Species with wider ecological amplitude,

Extent	Potential threats from climatic changes	Potential vulnerabilities to threats	Responses that may accommodate change
	seasons Altered precipitation regimes Drier soils during summer	Decline of associated wildlife species Increased threats from insects, diseases, and invasive plants Altered disturbance regimes may lead to changes in successional trajectories Many common tree species are projected to have reduced habitat suitability	especially those suited to warmer and drier conditions, may be more resilient to changes
Aspen	Increased medium and large-scale disturbances	Decline of quaking aspen abundance or productivity Low within-stand diversity may increase risk of substantial aspen declines Medium-scale disturbances may not adequately allow for reestablishment Lack of genetic diversity within clones may be a disadvantage	Reliance on large-scale and stand-replacing disturbances may buffer some impacts Wide ecological amplitude and clonal nature of aspen may increase resilience
Balsam fir		Habitat suitability may be substantially decreased Forest is less resilient to disturbances Increased competition with shade tolerant species, such as red maple	Cooler or wetter site conditions or microclimates may be present and serve as refugia
Hemlock	More summer storms and wind events may lead to shifts in prevailing natural disturbance regimes	Acceleration of current decline Drier conditions and increased disturbances may exacerbate current regeneration limitations from dispersal, competition, and browsing Static ecosystem is	Forest may fare better on the edges of streams, lakes, and wetlands

Extent	Potential threats from climatic changes	Potential vulnerabilities to threats	Responses that may accommodate change
		less resilient to disturbance	
Jack pine	Increased risk of fire occurrence	Decline in productivity, especially on very dry sites	Fire may benefit jack pine establishment and competitiveness
Lowland conifer	Altered hydrology and precipitation patterns may lead to reduced duration of soil saturation or ponding Increased risk of fire occurrence in dried organic soils	Habitat suitability may be substantially decreased Reduced soil moisture or saturation may cause declines in hydrophytic tree species Static ecosystem is less resilient to disturbance	Non-peatland sites may fare better Cooler or wetter site conditions or microclimates may be present and serve as refugia
Lowland hardwood	Altered hydrology and precipitation patterns may lead to reduced duration of soil saturation or ponding	Black ash habitat suitability may be substantially decreased Low within-stand diversity may increase risk if black ash declines substantially Drier conditions may lead to increased competition from other tree and plant species Emerald ash borer may interact with other stressors to cause widespread mortality	Decline of black ash may be buffered where other species are present, such as red maple Cooler or wetter site conditions or microclimates may be present and serve as refugia
Northern hardwood	More summer storms and wind events may alter prevailing natural disturbance regimes Increased root damage from altered freeze-thaw cycles	Decline of sugar maple productivity, especially on drier sites Increased disturbances may accelerate current decline of eastern hemlock and yellow birch Drying of ephemeral ponds may increase stress on associated species	Decline of some species may be buffered where tree species composition is diverse
Oak		Decline in productivity, especially on very dry sites	Warmer and drier conditions may favor oak species on a

Extent	Potential threats from climatic changes	Potential vulnerabilities to threats	Responses that may accommodate change
			variety of sites Oak species not currently present may expand into new areas, but extent is limited by dispersal, winter temperatures, competition, and browsing
Paper Birch	Increased fire and wind disturbance	Increased disturbances may accelerate current decline Wind or other medium-scale disturbances may not adequately allow for reestablishment	Fire may create conditions needed for paper birch establishment
Red pine	Increased risk of fire occurrence	Low within-stand diversity may increase risk of substantial declines Younger stands may be vulnerable to pests that are currently present in warmer locations, especially under drought conditions Increased competition from some deciduous species, such as red maple and red oak	Fire may benefit red pine establishment and competitiveness Mature stands at appropriate densities are often less susceptible to pests Competition from some species, such as beaked hazelnut and balsam fir, may decrease
Spruce		Habitat suitability may be substantially decreased for white spruce and several associated species Drier soils may affect shallow-rooted white spruce Interactions among pests, drought, and other stressors may exacerbate current declines	
White pine		Decline on drier sites due to drought intolerance	White pine can persist on a range of sites in the absence of severe

Extent	Potential threats from climatic changes	Potential vulnerabilities to threats	Responses that may accommodate change
		Super-canopy structure may increase individual tree mortality Increased competition from some associated species, such as red oak	drought

Source: Scheller and Mladenoff (2008), Iverson et al (2008), USDA (2003), Prasad et al (2007), Amedie (2013), Sedjo (2010) and authors' consideration

4. The organizational structure and mechanisms of forest management in China

China has a variety of geographic and ecological and climatic conditions. Since the late 1970s, China's forests have made a remarkable recovery in large part because of the government-sponsored program to establish large areas of planted forest. Indeed, China has been the world's leading country in the planting of new and restored forests, both to increase industrial wood production and for other reforested and afforested purposes. FAO (2005) reports that China's man-made forests have increased from 28 million ha in 1986 to 48 million in 2001, or an average of about 1.33 million ha annually. About 45 million ha of China's forest area is planted (FAO, 2005), and China's forested land area increased from 107.2 million ha to 158.5 million ha between 1986 and 2005. In a separate study that draws on the FAO data, Kauppi et al. (2006) estimate that China's forest area has been increasing by about 1.5 percent annually in recent years, among the most rapid worldwide. China has the fifth-largest forest area in the world with 207 million hectares. (According to FAO (2012), in 2010 Russia had 809 million, Brazil 520 million, Canada 310 million, and the United States 304 million.)On the other hand, forests account for only 22 percent of its territory, below the 31 percent global average. Forests in China are unevenly distributed, with the majority- about 68 million ha- located in the South and about 43 million ha the Northeast. China's forest structure is diverse. While 83 percent of the forestland in the Northeast is natural forest, that ratio decreases to just 37 percent in the North. As a result of massive afforestation implemented by the government of China since the early 1900s, about one-third of China forests are plantations, about half of which are located in the South. It is anticipated that China will continue to expand its forest even in the absence of climate change. A declining portion of the forest was dedicated to firewood. China's forests are located largely in the northeast, which is temperate, and the southeast, which is subtropical. The Haldey map suggests that both regions will be modestly advantaged by climate change to the mid-21st century. More generally, IPCC (2007) projects that most of China will experience increased precipitation, the west being the exception. This view is consistent with the estimates of Sohngen et al. (2008). Although China is an important producer and exporter of industrial wood products, it is a relatively modest producer of raw industrial wood. Even though its forest planting programs target production of more industrial wood (protection forests being the other main goal), increasing the amount of domestic wood for domestic processing is not critical, provided that wood imports continue unobstructed.

For China, the challenges of climate change to its industrial wood producing forests appear modest. The exception could be insect infestations, which have tended to affect largely the non-timber-producing poplar forests in the interior. China is responding to this threat with generically engineered poplar trees that are resistant to the infestation. Most timber trees have not been seriously affected. However, infestations and genetic adaptations could raise the costs of adaptation. The effects of climate change on forestry anticipated by 2050, as reflected in Sohngen et al. (2001) and in the IPCC map, suggest an overall improving situation for forestry and industrial wood production in China. This situation should be enhanced by the active policies of forest establishment, management, and protection being undertaken by the Chinese government. Adaptation costs that might be required by climate change may be modest. Productivity in the relevant regions is anticipated to increase, benefiting regions currently in forest cover. Additionally, China is continuing to establish planted forests for both environmental and industrial wood purposes. Thus, should climate-related problems occur in forest production, modest changes in the choice of new tree planting stock should be sufficient to adjust to the modified climate. In recent years the World Bank has provided financial assistance to China for at least two forestry development projects that involved planting trees. However, the impacts of climate change on China's industrial forestry sector through 2050 appear to be minimal. There seems to be little reason to anticipate any serious investments in offsetting the effects of climate change on China's industrial forests, since it is unlikely that China's industrial wood situation will deteriorate significantly over the next 50 years because of climate change.

Since the 1950s, timber needs for China's economic and social development have been high. To supply the growing demand, the government has gradually established 135 state forest enterprises in forest-resource-rich regions of the Northeast, Northwest, and Southwest. The single focus on timber extraction defined the nature of the State Forest Enterprises, including their capital investments, infrastructure development, forest management, technology development, and staffing. Forest areas were sparsely populated and included few local communities, thus the State Forest Enterprises also became the dominant form of administrative and social organization. They often functioned as local governments, relied on revenues from timber extraction, and provided public and social services such as hospitals and schools to the employees and their families. The need to address the growing demand for timber and generate revenue led the State Forest Enterprises to adopt unsustainable timber extraction practices to maximize short- to medium-term production. These practices resulted in severe ecological degradation of forest areas (World Bank, 2010).

The government of China, recognizing the forest resource and economic crises caused by overexploitation, began in the mid-1980s to adopt a series of forest sector policy reforms, starting with the Forest Law to require reforestation after commercial harvests and including a logging ban established in 1998. Those reforms aimed at improving the quantity and quality of forests and striking a better balance between forests for production and conservation.

Those reforms resulted in an 88 percent increase in forest cover between 1981 and 2010, especially in forest conservation areas, which increased from about 6 percent to 46 percent in the same period. On the other hand, the necessary decrease in harvest as the forests recover (young and middle-aged forests represent about 66 percent of the forested areas; World Bank 2010) impacted the State Forest Enterprises, which lost their main source of revenue. Therefore, further reforms are needed to avoid or mitigate economic and social crises in areas operated mainly by the State Forest Enterprises.

4.1 General practice of forestry development in China

(1) Forestry industry develops fast, timber production is growing rapidly, and afforestation is sustaining. The remarkable success has achieved in anti-desertification and biodiversity conservation. Afforestation has been keeping in focus, comprehensively forest management has been strengthen. By 2020, continuing afforest land resource & energy saving policy.

Reduction volume of CO_2 by 40% to 45% of the CO_2 total emission volume in 2005.

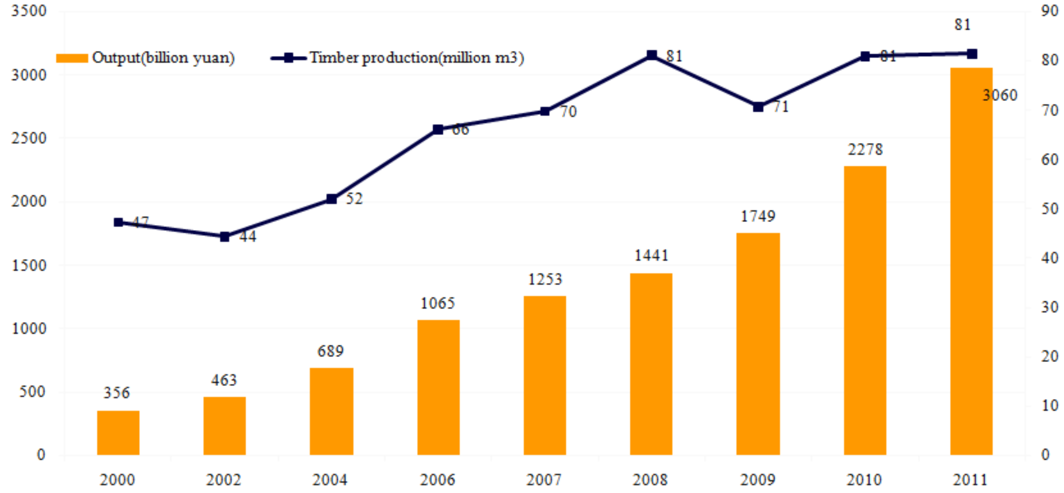

Figure 8. Annual forestry industry output and timber production

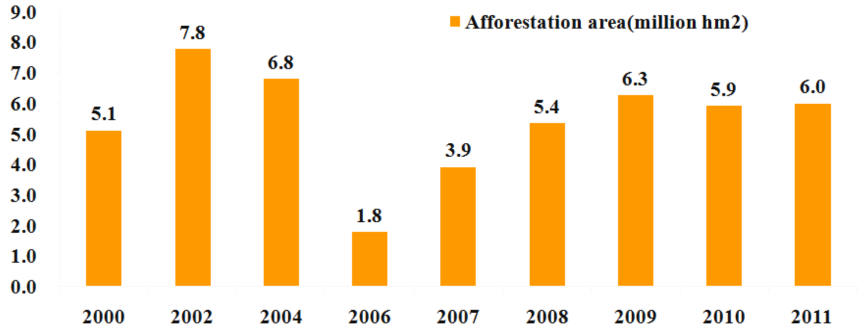

Figure 9. Annual afforestation area

(2) Forestry reform is steadily promoted, forestry policy has made new progress. Area of collective forest land with authorized property reached178.47 hm^2, 97.8% of total collective forest land.

(3) Further progress of forestry legislation, enforcement and monitoring capacity has been significantly strengthen. In 2011, Modification of “Forest Law” and legislation of “Wetland Protection Regulations” were finished.

(4) Substantial increase investment in forestry, initial establishment of long-term mechanism for forestry supporting by public financial. In 2011, investment in forestry was 274.4 billion CNY. State budget was 130.2 billion CNY, 47.45% of total investment.

(5) More strict supervision of woodland management levy occupy and forest resources. Carried out to check the use of forest land, 15 station monitoring forest resources.

(6) Increase investment in forestry station construction, more support efforts to the state-owned forest. In 2011, 0.69 billion CNY were invested in national forestry workstation.

Problems of forestry development are as follows,

(1) Economic accounting flawed: lack of ecological impacts accounting resulting from economic activities and accurate ecological compensation for the upper reach of watershed.

(2) Lack of multi ways of financing: forestry construction funds jointly financed by state and local government, businesses contribute less to fund.

(3) Lack of market mechanisms: forestry management mechanism mainly based on

authority ways, which is difficult to adapt to the market economy.

(4) Classification system affect the overall planning: complex composition of forestry properties: state-owned, collective owned, private owned, forestry ownership disagreement affect the overall planning.

(5) Fuzzy property rights, incomplete Property, as an intangible asset, the calculation of the compensation, fund levy and the scope is difficult to determine.

4.2 The Forest Resources Ownership in China

China has two different ownerships: “forest ownership” and “land ownership”. Forest ownership means who owns the forest or tree.

- State-owned (national)
- Collective-owned (collective)
- Individual-owned or joint-owned (private)

Management entities can be state or collective economic institutions, schools, organizations, foreign or domestic enterprises or individuals. These entities have what is called a “management right” to the trees on the land. Land ownership means who owns the actual land that the forest rests on.

- State-owned (national)
- Collective-owned (collective): Local townships and villages own collective forest land on behalf of the members of the township or the village. 34% of collective forestland was allocated to individual households before the forestland tenure reform.

“User rights” of forest land can be state or collective institution, enterprise or individual.

4.3 Forest resources administrative structure

When the state forest enterprises were established, enterprise management was part of China’s centralized economic command and control system. The Ministry of Forestry, the responsible authority of the central government, was allowed to directly intervene in the operation of the enterprises. Over time, administrative responsibilities gradually devolved to provincial authorities as part of broader reforms that decentralized administrative responsibility for state-owned enterprises. During this decentralization process, provincial authorities increasingly assumed decision-making power for such aspects as manager appointments, financial decisions, and production planning.

The central government, however, continued to play a dominant role through the State Forestry Administration. Although the Ministry of Forestry was downgraded to the State Forestry Administration during a general government reform in 1998, it retained final decision-making authority in all key matters of forest enterprise management. To exercise this authority, the State Forestry Administration established State Forest Resource Monitoring Offices to monitor timber production, forest protection, and the implementation of national forest policies and regulations. Today, the State Forest Enterprises are thus controlled by State Forest Resource Monitoring Offices of State Forestry Administration and, at the same time, the provincial authorities, which have been handed management responsibilities from the central government. These two key actors compete for the control of the State Forest Enterprises although they do not have the same focus. The State Forest Resource Monitoring Offices primarily monitor the ecological functions of the enterprises; that is, their ability to protect and use the forest resources sustainably. The provincial forest authorities focus on the social and economic aspects of enterprise management, including employment provision, social stability, and revenue generation, including revenue sharing with the provincial authorities.

In practice, the State Forest Enterprises generally prioritize economic performance over ecological protection. This is mainly because the contracts and arrangements between the enterprises and the provincial authorities are more binding and enforceable, because it is straightforward to assess performance on employment, social stability, and profit sharing, and these factors relate directly to the business interests of the enterprises. In contrast, ecological performance, which generally does not immediately affect people's welfare, is harder to measure, and, because of the accumulated impacts of resource degradation, performance of forest managers cannot easily be measured by ecological indicators.

4.4 Reform initiatives and developments

In response to the combined resource and economic crises and the institutional weaknesses in state forest management, various formal and informal reform experiments have been carried out over the past 30 years, and especially since the late 1990s.

A. Natural Forest Protection Program

The Natural Forest Protection Program, created in 1998, is one of the key programs providing support to the SFE across China. In its first phase from 1998 to 2010, the Natural Forest Protection Program introduced a logging ban in natural forest areas (including state forest areas), which was later lifted although harvest restrictions remained in place in many areas. The Natural Forest Protection Program also provided support to forest protection and replanting, and the resettlement of redundant employees of the State Forest Enterprises. Although some central government agencies expressed a strong desire to include forest management mechanism reforms into the Natural Forest Protection Program to create incentives for the State Forest Enterprises to adopt sustainable forest management practices, this proposal was not included. A second phase of the Natural Forest Protection Program began in 2011 and will last until 2020.

Discussion of reforming China's state forest management system started in late 2003, during the government's midterm evaluation of the Natural Forest Protection Program. Although the Natural Forest Protection Program was seen as reasonably effective in reducing deforestation in the state forest regions, and there was evidence that forest resources had begun to recover, the evaluation indicated a lack of effort to reform actual management mechanisms and practices and to change the incentive system in the forest sector. Around this time, the State Forest Administration also conducted a formal study to put forward a road map for state forest reform.

The Natural Forest Protection Program has been instituted to address forest resource degradation and the economic crisis, particularly in the Northeast. It has been criticized because of its primary focus on subsidizing the status quo and for the way subsidies are being provided, in particular, on the basis deforestation rates and numbers of laid-off workers. Because areas without major deforestation do not receive Natural Forest Protection Program subsidies, the program is criticized for giving the wrong incentives and for contributing to poor ecological performance in the state-owned forest sector.

Several decisions by the Communist Party of China Central Committee and State Council provided the basis for China's forest management system reform considerations, in particular, in the northeastern region. The most important ones are summarized below:

- In 2003, Central Policy Document No. 9: CPC Central Committee and State Council Decision on the Development of Forestry stated the determination to deepen institutional reform in key state forest regions and to establish a forest resource management system with consolidated responsibilities and interests as well as an incorporated mechanism for administering assets, personnel, and operational affairs.

- In 2003, the State Forest Region of the Northeast was included in the Revitalization Plan for the Old Industrial Base of the Northeast.
- In 2004, the State Council defined forest resource management reform tasks in its work plan.
- In 2010, Document No. 1: Several Comments on the Intensification of Rural and Urban Development and Further Consolidating the Foundation for Rural and Agricultural Development called for pilot reforms of state forest management systems and for the centralization of state forest resources management.

B. Green Program of Return Grain grow land to forest & grass land

(1) Introduction: Grain for Green Project is China's most extensive forestry construction, as well as most complex processes, the highest degree of ecological construction with people involved in, mainly to solve the problem of soil erosion in key areas.

(2) Aims: solve the problem of soil erosion in key areas.

(3) Period: pilot regions: 1999, Shan'xi, Gansu, Sichuan. 2000, upper reach of Yangtze River, upper-middle reaches of Yellow River; Official implement, 2002.

(4) Areas: 25 provinces(Autonomous Region, municipality, XPCC), 1897 counties, areas: 0.71 billion hectares, 73.91% of whole country.

(5) Achievement: National Grain tasks were arranged 19,165,500 hectares, farmland afforestation: 7,886,200 hectares, afforestation of barren hills and wasteland: 11,279,300 hectares .

C. Key Shelterbelt Construction Program in North, Northeast and Northwest China and the Lower-Middle Reaches of the Yangtze River

(1) Aims: Fundamentally change our sand and soil erosion hazard situation in North, Northeast and Northwest China and the Lower-Middle Reaches of the Yangtze River.

(2) Period: Official implement, 1978.

(3) Areas: 13 provinces(Autonomous Region, municipality, XPCC) in North, Northeast and Northwest China, 551 counties, areas: 0.406 billion hectares, 42.4% of whole country.

(4) Achievement: Western China: 2386159.15 hectares, Shelterbelt Construction in Yangtze River: 50565.27 hectares, Shelterbelt Construction in Pearl River: 34930.79 hectares.

D. Fast growing and high yielding timber base construction program in key areas

(1) Objective: To solve the problem of supply of timber and forest products

(2) Implementation Date: August 2002

(3) Scope: Guangdong, Guangxi, Hainan and Fujian area, north of the Yangtze River region subtropical, temperate zone of the Yellow River region (including the Huaihe River, Haihe River Basin) and boreal regions of northeastern Inner Mongolia. Concrete construction covering 18 provinces of Hebei, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hunan, Hubei, Guangdong, Guangxi, Hainan, Yunnan, 1,000 counties (cities , area).

(4) Achievements: By the end of 2004, the fast growing timber base construction 18 key provinces (regions) of creating a fast growing timber 224,500 hm2

5. Existing policy and institutional framework in the field of climate change with respect to forests in China

5.1 Impact of climate change on forest and natural ecosystems in China

Climate change has brought impacts on forests and other natural ecosystems in China.

For example, the glacier area in the northwestern China shrunk by 21% and the thickness of frozen earth in Qinghai-Tibet Plateau reduced a maximum of 4-5 meters in recent 50 years. Future climate change will continue to impact these ecosystems to some extent. Firstly, the geographical distribution of major forest types will shift northward and the vertical spectrum of mountain forest belts will move upward. The distribution range of major tree species for afforestation or reforestation and some rare tree species is likely to shrink. Secondly, forest productivity and output will increase to different extents, by 1-2% in tropical and subtropical forests, about 2% in warm temperate forests, 5-6% in temperate forests, and approximately 10% in cold temperate forests. Thirdly, the frequency and intensity of forest fires and insect and disease outbreaks are likely to increase. Fourthly, the drying of inland lakes and wetlands will accelerate. A few glacier-dependent alpine and mountain lakes will eventually decrease in volume. The area of coastal wetlands will reduce and the structure and function of coastal ecosystems will be affected. Fifthly, the area of glaciers and frozen earth is expected to decrease more rapidly. It is estimated that glacier in western China will reduce by 27.7% by the year 2050, and the spatial distribution pattern of permafrost will alter significantly on Qinghai-Tibet Plateau. Sixthly, snow cover is subjected to reduce largely with significantly larger inter-annual variation. Seventhly, biodiversity will be threatened. The giant panda, Yunnan snub-nose monkey, Tibet antelope and others are likely to be greatly affected.

5.2 Challenges on the conservation and development of forest and natural resources

To combat climate change, it is necessary for China, on one hand, to strengthen forest and ecosystem conservation to enhance capacities for climate change adaptation; and on the other hand, to strengthen forest and wetland restoration and afforestation to enhance capacities for carbon sequestration. Forest resources in China are far below the needs for social and economic development. With the acceleration of industrialization and urbanization, the quest for forest and wetland conservation is increasing. Aridification, desertification, soil erosion, and wetland degradation remain as severe environmental problems. Lands available for afforestation/ reforestation are mostly located in areas suffering from sandy or rocky desertification, which pose a great challenge to forestation and ecological restoration.

5.3 Endeavors and effects on the conservation and development of forest and natural resources

1) Further improving institutions and mechanisms, Launching national wide tree-planting and afforestation campaign and enhancing ecology restoration and protection

To address newly-emerging issues in recent years, the Government of China has advocated for the Scientific Approach of Development and Strategic Thoughts of Building a Harmonious Society, and accelerated the building of a resource-conserving and environmentally friendly society, thus further reinforcing the policies and measures relevant to addressing climate change. China established the National Coordination Committee on Climate Change, which presently comprises 17 ministries and agencies. The National Coordination Committee on Climate Change has done lots of work in the formulation and coordination of China’s important climate change-related policies and measures, providing guidance for central and local governments’ response to climate change. In order to fulfill conscientiously China’s commitment under the United Nations Framework Convention on Climate Change, beginning from 2001, the National Coordination Committee on Climate Change organized the work on the compilation of the Initial National Communication on Climate Change of the People’s Republic of China, and presented the report to United Nations Framework Convention on Climate Change at the tenth session of the Conference of the

Parties (COP10) in December 2004. In recent years, the Government of China has strengthened its comprehensive management of ecosystem that is closely related to addressing climate change.

Since the reform and opening up to the outside world, tremendous achievement has been made in tree-planting and afforestation along with the implementation of key forest ecological projects. According to the Sixth National Forest Survey, the acreage of conserved artificial forests in China was 54 million hectares, ranking the top one in the world, and the amount of growing stock was 1505 million cubic meters. Total area of forest cover in China was 174.91 million hectares, and the percentage of forest coverage increased from 13.92% to 18.21% during the period from early 1990s to 2005. In addition to tree-planning and afforestation, China initiated many other policies for ecology restoration and protection, including natural forest protection, reclaiming cultivated land to forest or grassland, pasture restoration and protection, further enhancing the capacity of forest as the sinks of greenhouse gas. Meanwhile, urban green area grew rapidly in China as well. By the end of 2005, total green area in the built-up urban area in the whole country reached 1.06 million hectares with a 33% green coverage and 8.1 square meters of public green area per capita. The green area helps absorbing CO_2 in the atmosphere. Estimated by relevant experts, from 1980 to 2005, a total of 3.06 billion ton CO_2 absorption was achieved by afforestation, a total of 1.62 million ton CO_2 absorption by forest management, and 430 million tons of CO_2 from deforestation were saved.

2) Attaching great importance to climate change research and capacity building

The Government of China highly values its capability and capacity to support scientific studies and researches on climate change, and constantly enhances them. It has implemented a number of key research projects, such as Study on Forecasting, Impact and Countermeasures of Global Climate Change, Study on Global Climate Change and Environmental Policies, etc. Under the National Climbing Program and the National Key Fundamental Research Program, projects such as Study on Formation and Prediction Theory of Key Climate and Weather Disasters in China, and Study on Carbon Cycle in China's Terrestrial Ecosystems and Its Driving Mechanism were conducted. Under the Innovative Research Program, Carbon Balance Study in China's Land and Offshore Area has been accomplished. Other key projects related to climate change were also conducted, including China's Climate, Sea Level Change and Their Trend and Impact. China's National Assessment Report on Climate Change has been completed. All those studies and researches provide scientific basis for developing national policies to address climate change and for China's participation in negotiations under the United Nations Framework Convention on Climate Change. Several projects on international cooperation in Clean Development Mechanism capacity building were also conducted by relevant departments of China.

5.4 China's Policies and Measures to Address forest management with Climate Change

In accordance with the requirement of carrying out the Scientific Approach of Development, China will combine its efforts to address forest management with climate change with the implementation of sustainable development strategy, the acceleration of building-up a resource-conserving and environmentally-friendly society, and an innovative country, which will be integrated into the overall national economic and social development plan and regional plan; and China will mitigate greenhouse gas emissions and in the meantime improve its capacity to adapt to climate change.

1)Mitigation

- Improving formulation and implementation of laws and regulations: to accelerate the formulation, amendment, and streamline of forestry related laws and regulations, including development of regulations on conservation of natural forests, regulations on transfer rights of forests, forest products, and forest land use, etc.; and to enhance the implementation of laws and regulations, by means of improving the system, strengthening inspection, and expanding social supervision of law enforcement.
- Reforming and optimizing current industrial policies: to optimize target-oriented management responsibility system for afforestation by governments at all levels and forestry sectors, to probe ways of national voluntary tree-planting under market economy, and to establish related policies to promote voluntary planting and governmental afforestation, so as to increase forest resources and carbon sequestration.
- Strengthening key forestry ecological programs: to continuously implement key forestry programs, such as the Natural Forest Protection Program, the Conversion of Cropland to Forest Program, the Sandification Control Program for Areas in the Vicinity of Beijing & Tianjin, Key Shelterbelt Development Program in Such Regions as the Three North & the Middle and Lower Reaches of the Yangtze River, the Wildlife Conservation & Nature Reserve Development Program, so as to protect existing forest carbon stock and enhance carbon sequestration.

2)Adaptation

- Formulating and implementing laws and regulations relevant to climate change adaptation. Accelerate the amendment of Forest Law of the People's Republic of China and Law of the People's Republic of China on the Protection of Wildlife. Draft Law of Nature Reserve and Regulations on Wetland Protection of the People's Republic of China, etc. Add and/or strengthen articles relevant to climate change adaptation to provide a legal guarantee for improving the capacity of forests and other natural ecosystems to adapt to climate change.
- Strengthening the effective protection of existing forest resources and other natural ecosystems. Strictly protect natural forests in logging ban areas to convert natural forest ecosystems from degradation to progressive succession. Conduct wetland conservation by effectively reducing human disturbance and damage to stop the declining trend of wetland area. Expand total area and improve the quality of nature reserves and develop bio-corridors among reserves. Strengthen forest fire control by establishing perfect systems for forest fire forecasting, monitoring, suppressing, saving, fuel breaking and hazard assessing. Effectively integrate existing forestry monitoring systems into a comprehensive one for forest resources and other ecosystems. Enhance forest insect and disease control by improving systems for forecasting, early-warning, monitoring, quarantining of forest insect and disease, enhancing comprehensive control, and enlarging biological control.
- Strengthening technology development and extension. Research and develop technologies for forest fire control and forest insect and disease control. Select and breed tree species with high cold-resistance, drought-resistance and pest and disease-resistance to enhance the adaptation capacities of forest vegetations to climate change. Develop technologies for biodiversity conservation and restoration, particularly those technologies related to management of forest and wildlife nature reserves, wetland conservation and restoration, and conservation of endangered wild animals and plants to alleviate the impact of climate change on biodiversity. Promote technologies for monitoring forest resources and forest ecosystems, including those for forest environments, desertification, wild animals and plants, wetlands, forest fire, forest pest

and disease. Improve monitoring network and management system to enhance forecasting, early-warning, and emergency responding capacities.

The fundamental challenge facing forest managers in the coming decades is how to sustain ecosystem function, products, and services even as forests are adapting to climate change.

- **Management will continue to be an important ecosystem driver (virtually certain).** Forests in northern range from intensively managed to relatively untouched, yet no forest is completely outside the influence of management. Many contemporary forests, such as red pine plantations, would not exist without human intervention and management. In addition, active management is maintaining systems- such as jack pine, aspen, and white spruce- in locations where they might otherwise be much less abundant. The influence of management will likely be even greater with changes in habitat suitability. For example, LANDIS-II results show that harvesting may be a more important driver of forest species composition than climate change over the next 40 to 50 years, especially because harvesting can slow species movement by removing competing tree species before they reproduce (Scheller and Mladenoff, 2008). Management can also reset successional trajectories or create artificial disturbances. Management factors need to be considered in conjunction with changes in climate, hydrology, and natural disturbance regimes.
- **Many current management objectives and practices will face substantial challenges (virtually certain).** Some management objectives and strategies may need to be reconsidered as a result of changing conditions on the landscape (Heller and Zavaleta, 2009; Joyce et al., 2009; Millar et al., 2007). Many commercially and economically important tree species—such as sugar maple and white spruce- may face increased stress and decreased productivity, which could affect their availability for some products. Markets and industries may need to be reexamined to avor new species that grow better under an altered climate (Irland et al., 2001; Kirilenko and Sedjo, 2007). conservation of certain threatened and endangered pieces will become more challenging as their current habitats become less suitable. If atypical climate regimes develop, current silvicultural understanding of species responses to management may need to be re-evaluated, since current knowledge is based on past climate regimes and observed species interactions.
- **More resources will be needed to sustain functioning ecosystems (virtually certain).** Shifts in management objectives and practices will place increasing demands on human and capital resources (Baron et al., 2008). For example, native species that could previously regenerate unassisted may need to be artificially regenerated. Increased planting may be necessary to facilitate colonization and establishment on new sites or supplement natural regeneration efforts. Management to control fire, nonnative invasive species, diseases, and pests may need to increase as well. All of these increasing demands will place additional burdens on already over-taxed budgets and personnel at all levels of government. Research is needed to quantify the costs of these additional actions, which may be less expensive than taking no action in the long run.

The forests are likely to experience dramatic changes during this century under a changing climate. Some species and forest types are particularly vulnerable, while others may ultimately be more successful. Importantly, all forests that experience new stressors and environmental conditions have the potential for decreased productivity or loss of forest species. Changes in forest communities will affect the ecosystem services they provide, such as clean drinking water, carbon sequestration, wildlife habitat, and recreational opportunities. Practicing long-term sustainable management and supporting ecosystem resilience are fundamental principles of forest stewardship. Applying these principles in the face of climate change will require both a focused effort to identify the ecosystems most vulnerable to climate change and an active dialogue about potential management responses to these vulnerabilities.

6. Activities of national governments, non-governmental organizations and the private sector to address climate change

6.1 Mitigating Climate Change

The China has reached its goal of reducing the energy consumption and CO_2 emissions per unit of GDP and has achieved positive results since 2012 by controlling greenhouse gas emissions by adjusting the industrial structure, improving the energy structure, making energy use more efficient and increasing carbon sinks.

1) Adjusting the Industrial Structure

- Transforming and upgrading traditional industries.
- Supporting the development of strategic and newly emerging industries.
- Vigorously developing the service industry.
- Speeding up the elimination of backward production capacity.

2) Optimizing Energy Structure

- Promoting the clean utilization of fossil fuel.
- Developing non-fossil fuel.

After efforts from all over the country, by the end of 2012, the one-time energy consumption of standard coal equivalent was 3.62 billion tons, among which, the coal accounted for 67.1 percent, dropping 1.3 percentage points compared with 2011; oil and natural gas was 18.9 percent and 5.5 percent, up 0.3 percentage points and 0.5 percentage points from the previous year; and non-fossil fuel made 9.1 percent, up 1.1 percentage points compared with 2011.

3) Conserving Energy and Improving Energy Efficiency

- Enhancing the evaluation of energy saving accountabilities.
- Implementing key energy conservative projects.
- Improving energy efficiency standard and labeling scheme.
- Expanding energy conservative technologies and products.
- Promoting energy conservation in construction industry.
- Driving energy conservation in transportation industry.

4) Increasing Forest Carbon Sinks

The State Council approved the second stage of the plan to curb the source of sandstorms in Beijing and Tianjin. The plan has been expanded to six provinces (autonomous regions, municipalities) and 138 towns. The State Forestry Administration issued the Plan on the Division of Work on Enhancing the Forest's Role in Tackling Climate Change to Implement the Durban Climate Change Conference Agreement, began to draft the fifth stage of the plan on the shelterbelt construction in northeast, northwest and northern China, announced the third stage plan on the shelterbelt construction along the Yangtze River, the Pearl River, as well as the greenery work on plains and Taihang Mountain. China will continue to improve forest management. Forestry subsidies from central fiscal revenue have been expanded from pilot regions to the whole country. China initiated a mid- and long-term plan to manage national forests, decided to build 15 model forests management bases, and issued measures on how to examine and evaluate the cultivation of forests as well as the regulations for their management. It launched a pilot program for sustainable management in 200 towns (forestry farms), taking lumbering as the center of the management. It also issued the Notice on Further Protection and Management of Forest Resources to proactively protect forest resources. The construction of the national monitoring system on forest sinks has made steady progress, as the program expanded from 17 pilot provinces (autonomous regions and municipalities) to the whole country from 2012 to 2013, and a national data base and parameter model base for forestry sink calculation has been built at the initial stage. From 2012 to the first half of 2013, a total area of 10.25 million hectares was greened in afforestation drive, and 4.96 billion trees were planted in volunteer tree-planting drive and 10.68 million hectares of forests were cultivated, further strengthening forest sink capabilities.

5) Controlling Emissions in Other Areas

- Controlling greenhouse emission from agriculture.
- Tightening control over CO_2 greenhouse gas.

6.2 Adapting to Climate Change

China has taken positive action in enhancing its capability across major sectors to adapt to climate change and respond to extreme weather and climate-related events. This has reduced the negative impact of climate change on both economic and social development, production and people's welfare.

1) Disaster Prevention and Mitigation

The Ministry of Civil Affairs formulated or revised policies like the Regulations on Disaster Relief and Emergency Work of the Ministry of Civil Affairs, Guidance on Strengthening Natural Disaster Relief Assessment of the Ministry of Civil Affairs and Interim Regulations on the Management of Central Relief Supplies Storages. The Ministry of Agriculture established a work system for early consultation, forecasting and prognosis. The Ministry of Water Resources advanced the county-level non-engineering measures of torrential flood prevention and control, as well as the Phase II project construction of the state flood control and drought relief command system. The State Forestry Administration issued the National Forest Fire Emergency Plan, strengthened the inspection of forest fire prevention and developed the responsibility system of pest prevention and control in local governments. The State Oceanic Administration reinforced the construction of the maritime disaster relief system, as well as launched the marine disaster risk assessment of major engineering work.

2) Monitoring and Early Warning

Member units of the Office of Flood Control and Drought Relief Headquarters and the National Disaster Reduction Committee further improved the monitoring and early warning system for various natural disasters, as well as strengthened the capacity to tackle extreme weather and climate-related disasters. The State Oceanic Administration strengthened the capacity to observe the coastal and offshore waters; improved and adjusted the dissemination channels for marine disaster warning; intensified the monitoring and evaluation of sea-level changes, seawater intrusion, soil salinization and coastal erosion in important areas; created the environmental protection services system of marine fisheries production safety; and carried out the pilot work for further refined weather forecasts of key coastal areas. The China Meteorological Administration issued China's Climate Change Monitoring Bulletin 2011. The administration also pushed for a general survey on climate disasters and risks, and assisted local governments in formulating their meteorological disaster prevention plans. It also improved the assessment of climate change in major areas and river basins and increased technical support to help characteristic industries adapt to climate change. It also launched a refined forecast service for urban rainstorm and water logging in major cities.

3) Agriculture

- Improving agricultural infrastructures. accelerating the construction of supporting facilities of large-scale, water-saving irrigation areas; maintain/promote field engineering quality; upgrade aging electromechanical equipment; and improve irrigation and drainage systems.
- Promoting adjustment of agricultural structure and cropping systems. Optimizing regional arrangement of agriculture.
- Breeding stress-resistant varieties. Selecting and cultivate new well-bred animal and crop varieties with high yield potential and quality, superior integrative stress resistance and wide adaptability.
- Preventing aggravation of grassland desertification. Preventing further development of desertification by building artificial grassland, controlling grazing intensity, recovering vegetation, and increasing vegetation coverage of grassland.
- Strengthening research and development of new technologies. Developing new technologies and strive to make greater progress in the areas of photosynthesis, biological nitrogen fixation, bio-technology, prevention of diseases and pests, stress resistance, and precision agriculture.

4) Water Resources

- Enhancing water resources management. Adopting the principle of harmony between human and nature in water resource management, to take more effort to convert farmland back into lake or river course, remove polder dikes for flood way, dredge river channel and lake, and rehabilitate and protect rivers with serious ecological problems while strengthening dike construction and key water control projects.
- Strengthening infrastructure planning and construction. Enhancing the construction and improvement of key water control projects (reservoirs, etc) and infrastructures in irrigation areas. Continuing the construction of regional water storage and water diversion projects.
- Promoting the development and extension of technologies for water allocation, water-saving, and sea water utilization.

5) Coastal Areas and Ecosystem

- Establishing and improving relevant laws and regulations. Formulating regional management regulations and detailed rules in accordance with Marine Environment Protection Law of the People's Republic of China, Law of the People's Republic of China on Administration of Sea Areas, etc., and characteristics of the specific localities in the coastal areas. Establish integrated coastal zone management system, the comprehensive decision-making mechanism and effective coordination mechanism. Handle
- Promoting technology development and extension. Strengthening research and development of technologies for protection and restoration of the marine ecosystems, with emphasis on cultivation, transplanting, and recovery of coastal mangroves, protection and restoration of coral reefs and coastal wetlands to reduce the vulnerability of ecosystems in coastal zones.
- Improving the capability in marine environmental monitoring and early-warning. Seting up more observation sites and networks in coastal areas and on islands.

- Strengthening adaptation strategies to address sea level rise. Adopting measures of combining slope protection with shore protection, combining engineering measures with biological measures.

6.3 Suggestions

1）Governments

- Increase the capacity of personnel working on forest-based climate change at the national and sub-national levels.
- Increase awareness among all stakeholders, including policymakers, of the importance of forest-based mitigation and adaptation options in national responses to climate change.
- Where lacking or insufficient, develop land-use mapping and planning, inventory and monitoring to assist adaptive land management.
- Promote community-based forest enterprises as a flexible strategy for assisting local people to adapt to climate change.
- Use participatory consultation processes to incorporate forests more fully in national development agendas and in approaches to the Millennium Development Goals.
- Support the involvement of civil society, communities and other relevant stakeholders in national policies and actions on forest-based climate change mitigation and adaptation.
- Ensure that forest-based approaches to climate change mitigation and adaptation fully consider the need for good governance, equity, the involvement of civil society and local communities, respect for human rights, and poverty reduction.
- Develop public awareness programs on the important and dynamic relationship between forests and climate change.
- Study the feasibility of wood-based biofuels in climate change mitigation compared to other energy alternatives.
- Where appropriate, encourage the development of community-based wood energy programs.
- Develop policies and guidelines to promote sustainable wood-based biofuels in a way that does not jeopardize food security and is consistent with the principles of sustainable forest management.

2）Non-governmental organizations

- Generate information on the relationship between forests and climate change and support national forest inventories and design monitoring methods to assist in generating such information.
- Strengthen research on the links between climate change, forests and human wellbeing.
- Provide information and guidelines on the management of forest types that are especially vulnerable to climate change.
- Develop and test options for adapting the forests sector to climate change.
- Raise awareness of the role of forests in climate change mitigation and adaptation.
- Facilitate free access to remote sensing for monitoring the role of forests in climate change mitigation and adaptation.

3）Building a international development study scheme between China, Russia and Mongolia

- Study the implications of climate change.
- Develop guidelines for climate change mitigation and adaptation options in forests and for accounting for carbon in forest management plans, reflect the current state of knowledge on climate change.
- Analyze the possibility of introducing the concept of forest restoration to the climate

change negotiation process within the *United Nations Framework Convention on Climate Change*.

- Study methods for accounting for the permanence of carbon in harvested wood products.
- Study on the substitution potential of wood products and their role in climate change mitigation.
- Analyze approaches to financing forest based initiatives to climate change mitigation and adaptation.
- Provide information and guidance on the management of forest types particularly vulnerable to climate change.
- Conduct a global review of best practice in rights-based approaches to forest development and forest based carbon enhancement in three countries.

Recommendations for the forest management adaptation to climate change

Climate change has an impact on the development and the state of forest ecosystems. On the other hand forests affect on the carbon balance by absorption and emission of carbon. Thus, the role of forests in climate-regulation processes from the point of view of climate change mitigation and adaptation to it is essential. Therefore, around the world it has recently been widely discussed scenario of climate change mitigation and adaptation of forest management to climate change.

Analysis of the existing good practices that contribute to the absorption and retention of carbon in forest pools shows that there are three main strategies (Table 31).

Table 31 Forest management strategies to mitigate climate change

Management types	Characteristics
Forests conservation.	**Carbon Retention,** i.e. prevention of carbon emissions into the atmosphere from existing carbon pools. It is reached by the following measures: the preservation of old-growth forests, increase of areas of forest protected areas, struggle against desertification, forest fires, pests of forests and other natural disasters that result in a reduction in the potential for carbon sequestration.
The use of forestry and forest industry activities for carbon sequestration.	**Increasing carbon sequestration** through the creation or expansion of carbon pools. This could include measures on reforestation on previously non-forested lands, clearings, burned areas, the use of improved forest management practices to increase forest growth; implementation of forestry work, deforestation reduction, preservation of biomass and soil carbon in existing forests through the use of advanced methods of logging (reduce the impact on soil state); increasing the duration of the functioning of wood products, forest management and forest products certification by the FSC system.
Substitution of hydrocarbon fuels and materials	**Substitution** means reduction of demand on hydrocarbon fuels by increasing the use of wood waste as a raw material for bio fuel production (pellets, briquettes), or instead of materials, the production of which is connected with the big costs, such as steel and concrete used in construction.

All of these strategies are not mutually exclusive, but they have different potential to reduce the carbon dioxide concentration in the atmosphere in the short and long term. The most effective way in the short term is to preserve the forests, especially in those regions where there are old-growth forests with a significant amount of carbon deposited threatened by logging and other forms of economic impact (production of oil and natural gas). In the long term boreal forest reaches a state of equilibrium when carbon emissions are equal to amounts of sequestered carbon by living biomass. At the same time the soil carbon sequestration cannot stop thousands of years.

Forestry and timber industry measures aimed at ensuring the climate functions of forests contributes to greater carbon sequestration, as well as improve the flow of the ecosystem as a whole. To the effect of events manifested –it is necessary time. For example, after logging carbon emissions are going on, but then it will be sequestered by young forest, actively growing on the cutting.

The benefit of substitution that when using fuel from the timber is released much less greenhouse gas emissions than the use of fossil fuels. It also relates to the use of wood in building in comparison with other materials (concrete and steel).

These strategies, of course, could be combined. Events in the forestry sector, aimed at carbon sequestration, may complement substitution.

As already mentioned, these methods produce different climatic effect depending on the time frame under consideration. Events that are considered optimal in the planning years 100-200 may have zero or even a negative effect in the short term. It should be considered to optimize the cost at present.

Adaptive capacity **- it is the system's ability to adapt to climate change.** Adaptive capacity of natural and human systems to climate change is highly dependent on the region, since the regions differ from one to another by financial, technological, institutional and other resources necessary to reduce the vulnerability of these systems to climate change. This problem is exacerbated if the economic structure of these regions is focused on sectors with very low adaptive capacity. In this case, the adaptation measures will have a significant social emphasis, as the population of these regions will depend on the success of measures to mitigate climate change and economic aid of the most developed countries.

There are several definitions of the term "climate change adaptation", but all of them are as follows: **adaptation to climate change refers to adjustment in natural or human systems to actual or expected climate change impacts, which can reduce the damage and / or use of positive opportunities (IPCC).** Adaptation reduces the vulnerability of ecosystems and people and increases its resistance to the effects of climate change

Adaptation measures implemented in order to reduce the adverse effects of climate on natural and human systems are different. Key strategies to adapt forest management to climate change are given in table 32.

Table 32 Forest management adaptation strategies to climate change

Type of adaptation	Characteristics
Forest conservation	Preserving old-growth forests, the creation of various protected areas. Special events are not held in tie with climate change.
Mating adaptation	It is passive. Towards to eliminating the consequences arising from the impact of climate change. Assumes adjustment of the estimated wood-cutting area, logging, reforestation and other measures
Preventive or planned adaptation	It is proactive. It has a place before the manifest of consequences of climate change. It assumes revaluation of the aims and targets of the forest management objectives, a departure from the traditional model of forest management based on "use" to the model of "sustainable livelihoods" in view of the uncertainties associated with climate change, the introduction of new technology and the forest sector governance

"Non-interference" involves the use of extensive forest management model based on the "production" of forest resources without making any adaptation measures.

"The response *adaptation"* - the adaptation, which is carried out after it has been detected the effects of climate change, mainly aimed at the elimination of the consequences of violations (windfall, insect outbreaks, drought, fire), as well as on the adjustment of subsequent forest management. These scenarios are prevalent in the modern practice of forest management.

Currently effects of climate change are such that necessitate the transition to the third scenario - *"planned adaptation."* According to it there is a task - to rethink seriously the goal of sustainable forest management, to shift the emphasis between its environmental, economic and social aspects, orienting the system of forest management to reduce the vulnerability of ecosystems and society and strengthening their resilience to climate change. In the Nordic countries actively developed methods of harvesting and transport, better adapted to mild warm winters with more precipitation. These include the development and improvement of new logging technology, changes in technology construction of forest roads and harvesting season.

The most likely ecological, economic and social consequences of climate change for the forest sector in the region. The analysis of climate risks affecting the ecological, economic and social aspects of forest management and forest industry development, has allowed systematizing the terms of their damage (see table 33). The main threats associated with global warming will increase of the frequency and intensity of extreme weather events, forest fires, the emergence of new and dissemination of traditional pests, which leads to the transformation of forest ecosystems, and, accordingly, to a risk of loss of biodiversity, reduction provided ecosystem services of the forest, high costs of forest management activities.

Table 33 Threats and socio-economic damage caused by climate change in the forest industry

	Threats	**Types of damage**
Ecology (forestry)	- Increased frequency of forest fires; - Large dissemination of forest pests and diseases; - Large-scale of natural disasters (hurricanes, tsunamis, etc.) - Transformation of forest ecosystems (changes in the distribution of species habitats and species plantations)	- The loss of biodiversity, - Increased costs for forest management activities (reforestation, forest fires, forest protection against pests) - Reducing the availability and quality of forest ecosystem benefits of forest products and services
Economy	- Reducing productivity of forest plantations; - Shortening of the winter season; - Reducing Permafrost; - Smoke over large areas by peat and forest fires;	- Economic losses and lost profits in the forest industry and in the export of forest products - Changes in the business environment, increased costs for the restoration of economic activities

	- Change the hydrologic cycle over land; - Reduction of soil fertility due to water erosion, salinization and water logging, desertification, pollution, etc.	- Destroying of buildings, infrastructure, industrial enterprises, utilities - Lack water resources in arid regions and increasing floods in regions with water abundance - Economic loss of products
Social sphere (population)	- Frequent extreme weather events - Increase the number of days of hot weather; - Air pollution by suspended particles and other dangerous components as a result of forest fires; - An increase in precipitation and wetland areas, changing the areas of the natural focal infections ranges; - Change in forest area for social and recreational services	- The deterioration of public health, - Increase the incidence and death rate of population - Increase in the number of infectious and parasitic diseases - Lack of forest products for the local population; - Deterioration of the environment and the extent of tourism in the regions - Changing the traditional hiking trails - Changes in people's employment in forestry and other sectors; - The deterioration of the living conditions of the population, etc.

Climate change may lead to a decrease in forest productivity, reduction of forest areas with valuable species of trees, which would entail economic losses and lost profits in the forestry sector, related to the difficulties of ensuring by wood. Shortening of winter season due to climate warming leads to reducing of harvesting period in the forest, reducing the seasonal period of service roads (winter roads), which in turn causes problems with transport, including cross-country. And, as a consequence, leads to significant violations of the vegetation cover, the inability to use the old track and the need for construction of a new road. In addition to the environmental damage in case of damage to large areas of soil, it will be need additional financial costs for the construction of roads.

Certain consequences may affect on the conditions and scope of tourism, realization of recreational functions of forests. The situation can cause increasing of social tension among the population employed in the forestry sector of the economy, reducing the number of jobs, lower income of workers. The most vulnerable will be the human community; culture and way of life of whom depend directly on the products and services provided by forests. It is expected negative consequences for settlements, infrastructure of forest areas, as well as to human health. Socio-economic and environmental consequences of climate change will be of a distinct regional character.

Adaptation planning: strategy development How can we adapt the management of forests for, at first, forest constraine climate change and, secondly, were more resistant to climate change? The idea is that the planning of forestry and timber operations should be carried out taking into account current and future climate situations. It can be offered the following measures facilitating greater absorption and carbon sequestration by forests and adaptation of forest management to climate change (see table 34).

Table 34 The package of measures contributing to strengthening of forest carbon stocks and the adaptation of forest management to climate change

	Events
Improving forest management to contain global warming	1. Preservation of old-age (old-growth) forests, expansion of the area of forest protected areas
	2. Scaling up the reforestation on the clearings and burnt areas, ensuring the formation of productive plants to increase biomass and carbon sequestration, the use of climate-fire resistant tree species and varieties
	3. Reforestation on treeless areas, including turnover derived from agricultural land, establishment of shelterbelts of forest plantations in the sparsely wooded areas
	4. When conducting forest inventories, the formation of the forest registry, compiling forest plans to assess the degree of climate resilience of forest plantations
	5.Strngthening prophylactic and fighting against forest fires, pests and diseases
Improving the management of the operational part of the forest fund	1. The introduction of harvesting technologies to prevent litter and soil carbon losses
	2. The transition from clear cutting to selective
	3. The more complete utilization of timber, including the use of branches and other forest residues for bio fuel production
	4. The development of voluntary forest certification under the FSC system

These events cannot be considered as a fundamentally new - they are well within the Russian system of forestry and forest management. The new measures may be called for improving the structure and tree species resistant to climate change, forest fires, increase biomass and carbon sequestration, as well as the development of voluntary forest FSC certification.

The need to implement certification of the forest management, forest products and forests according to the system of FSC related not only to more stringent environmental requirements of the market for forest products, but also with the fight against global climate change. FSC-certified forest companies by highlighting its resource base in high conservation value forests (HCVF) can receive income from forest ecosystem functions. These primarily revenues are from carbon emission reduction due to the failure of logging on a dedicated area of HCVF. Second is the preservation of biodiversity, the key habitats of rare species of animals and birds, conservation of forest food products for the local population. Thus, here combined measures like conservation and the rational use of forest resources, as well as it could be reached the balance the interests between ecology, economy and social sphere.

The development of these activities with varying degrees of success carried out by forestry authorities, forest companies in Russia.

In other countries, the impact of climate change may be different and accordingly, adaptive measures will be different from those applied in our country. It can be changed a set of adaptation measures. In general, climate change adaptation strategy remains a critical element in the fight against climate change, allowing to reduce the damage caused by its consequences.

We must say that if theoretical questions of the concept of sustainable forest management has long time been discussed in the world and in Russia, and they are relatively well developed, there is a distinct lack of recommendations for its practical implementation in the Russian forest sector.

Implementation of the measures will require appropriate public policies, special incentives, standards, rules, perhaps even coercion. Despite the greatest flexibility and adaptability, the private sector cannot take full responsibility for an adequate response to climate change. The government should establish clear targets of adaptation policies for citizens and companies in the medium and long term. Adaptation actions must be integrated into development policy and planning at every level. Without the joint efforts of state bodies, scientists, business and community organizations all can remain at the level of "paper-based" strategies and plans.

From an economic point of view, the adaptation question is calculating the cost of adaptation measures. For this we need to calculate the potential damage, the benefits of the event and choose the optimum between the cost of adaptation and the value of the residual negative effects. Full adaptation is probably economically inexpedient or impossible in principle.

4. Conclusions

- In accordance with the aims of the project it was collected and analysed different types of data in different levels – from municipality to province;
- It is culculated the carbon buget of the studied areas;
- It is determined and culculated ecosystem services on the studied areas;
- It is suggested the adaptation measures for the studied areas
- It was held 5 International workshops under the project in Ulan-Ude (Russia), Ulaan-Baatar (Mongolia), Beijing (China). Also it was held National workshops and seminars with local specialists and communities;
- The results of the project were presented in different Conferences in Russia, China and Mongolia;
- Main ideas, Methodology, and results of the project were published in Scientific journals, and Conferences Proceedings
- Different parts of the project were presented to the local authorities and communities in the key areas.

5. Future Directions

The project has big potential for further work. On the basis of established network between different institutions in Russia, Mongolia and China future investigations might include other ecosystems such as agricultural, protected areas and others according to structure of land-use. Also, the approaches used within the project for the territory of East Asia can be used on other territories.

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Appendix

Conferences/Symposia/Workshops

Five International Workshops was held:

1. **Inception Workshop (Russia (Buryatia), Ulan-Ude), 25-27 December 2013 -** current state and problems of forest management in the participating countries; main goals and objectives of the first year; schedules, web site creation.
2. **Second International Workshop (Mongolia, Ulan Bator), 17-18 April 2014** - comparative analysis of the responses of different forest ecosystems to global climate change and economic activity. Evaluation of the sensitivity and vulnerability of the studied ecosystems to climate change. Identifying the most dependent on climatic variability of ecosystems, species and vulnerable areas.
3. **Third International Workshop (China, Beijing), 17- 19 June 2014 -** data collection and analysis to assess the carbon balance; expedition to the crux section of the Yellow River delta.
4. **Fourth International Workshop (China, Beijing), 10-11 November 2015 -** theoretical and methodological approaches to assess the total economic value of forest and forest-steppe areas of the project, including ecosystem services.
5. **Fifth International Workshop (Mongolia, Ulan Bator), 29-30 July 2016** – discussing the content of the Final Report

1. Inception Workshop

The project operates from 6 November 2013. In accordance with the project timeline, the first workshop was held in the Baikal Institute of Nature Management of Russian Academy of Sciences (BINM), in Ulan-Ude, Russian Federation, 25-27 December 2013. The workshop was attended by scientists from the project participating countries China, Russia, Mongolia.

Fig.1 Inception Workshop (Russia (Buryatia), Ulan-Ude), 25-27 December 2013

2. Second International Workshop

The workshop was held in Ulan Bator (Mongolia) in the Institute of Geoecology MAS, 17-18 April 2014. Climate change studies and impacts on ecosystems have been conducted for the comparative analysis of the reaction of different forest ecosystems APR in key areas of Russia, Mongolia and China.

Fig. 2. Second International Workshop held in Ulan Bator at the Institute of Geoecology MAN, 17-18 April 2014

3. Third International Workshop

The Workshop was held in Beijing (China) at Institute of Geographical Science and Natural Resources Research, CAS, June 17, 2014, also within the seminar it was held on 18-19 of June the expedition to the crux section of the Yellow River delta.

Fig. 3. Third International Workshop in Beijing (China) at Institute of Geographic Science and Natural Resources Research, CAS June 17, 2014

4. Fourth International Workshop (China, Beijing)

The Workshop was held in Beijing (China) at Institute of Geographical Science and Natural Resources Research, CAS, November 10, 2015, The results of implementation of the project in 2013-2014 and the next stage work plan for the project were discussed, as well as theoretical and methodological approaches to assess the total economic value of forest and forest-steppe areas of the project.

Fig. 4. Forth International Workshop in Beijing (China) at Institute of of Geographic Science and Natural Resources Research, CAS, November 10, 2015

5. Fifth International Workshop (Mongolia, Ulan Bator)

The workshop was held in Ulan Bator (Mongolia) in the Institute of Geoecology MAS, July 29-30, 2016. During the workshop it was discussed the content of the final scientific report.

Fig. 5. Fifth International Workshop in Ulaanbaatar (Mongolia) at Institute of Geography-Geoecology, MAS, July 29-30, 2016

Also, project collaborators participated in different international, national and regional conferences.

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