The Strategies, Policies and Methods of Mainstreaming and scaling out Land Degradation and Sustainable Land Management of China

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Abbreviations

BOT	Build-operate-transfer
EU	European Union
FAO	UN Food and Agriculture Organization
GEF	Global Environmental Facility
GHG	Greenhouse gases
IDA	Integrated Demonstration Plot
IPCC	Intergovernmental Panel On Climate Change
LADA	Land degradation assessment in dryland
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental Organization
NPP	net primary productivity
RUE	rain utilization efficiency
SFA	State Forestry Administration
SLM	Sustainable land management
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
USD	United States dollars
WOCAT	World Overview of Conservation Approaches and Technology

Content

Preface

Desertification and land degradation are serious environmental challenges to the whole mankind. Protection of the land resources of farmland, forestland, grassland, wetland and human residential settlements on which the mankind depends has become the prime task for sustainable development. Over the past decades, the Chinese government and its people have achieved remarkable achievements in combating land degradation and desertification. The shift from the “human retreated as the sand expanded” to “sand retreated as human progressed” indicates the overall reversion from the deteriorating condition of desertification and sandification. The livelihood improvement and poverty alleviation of the local people in desertified area have contributed to global desertification control and sustainable development for which abundant experiences have been accumulated.

Sustainable land management (SLM) measures are basic instruments for combating desertification and land degradation. In the long-term efforts against desertification and land degradation, China has built up numerous land management models, technologies which are best practices for modern land management. Scaling up SLM in China, based on globally conducted land degradation assessment (LADA) of dryland as well as the inventory monitoring that illustrated the status of land degradation and desertification, analyzed the vegetation growth trends over the past 15 years of China using remote sensing Normalized Difference Vegetation Index (NDVI) methods and identified the land degradation deteriorating areas (hot spots) and the revision area (bright spots). Based on the analysis and assessment of the land management measures in China in terms of technological models, investment models, economic benefits, scaling up areas and execution models, the SLM models are classified for scaling up models with formulated methods and models.

Firstly, the SLM measures should be incorporated into national laws and policy systems for enhancing scaling up capabilities through project implementation, investment, scientific and technological development, social participation, capacity building and international cooperation. Secondly, by demonstration at selected sites, 1 to 2 land management models should be identified for analyzing the obstacles of SLM model dissemination and for studying the possible scaling up models and methods. The experiences obtained through demonstration provide technical support for the future large-scale dissemination of SLM measures. Thirdly, the management platform for SLM measures should be established for standardization of the management measures and for promotion of international exchanges.

This report focuses on strategic review and top-level design of SLM technological scaling up at the national level, with proposed methods on achieving SLM implementation capabilities regarding laws, policies, funds, and science and technology. The collected diverse SLM technological measures of China are classified, and the technical models, implementation methods, inputs-outputs, and appropriate scaling up areas for various measures were collated and analyzed, which lays a foundation for implementation of the next phase of the project.

I Land degradation condition of China

China is of the countries with serious harms from widespread land degradation in the world, and arid area that suffers the most from land degradation has been key construction area for large-scale land restoration projects in China. The main land degradation types in the arid regions of China include mainly the land sandification (wind erosion), soil and water erosion (water erosion).

1.1 Land sandification (wind erosion)

According to the results of the National Desertification and Land Sandification Monitoring and by 2014, the total land area of sandification was 172.117 million hectares (17.93% of the total land area of China) which was 990,200 hectares less than the area for the fourth monitoring (2009), with an average annual reduction of 1980 square kilometers. Land sandification in China occurred in 8,146 townships of 920 counties of 30 provinces. Among of provinces, Xinjiang, Inner Mongolia, Tibet, Qinghai and Gansu provinces have the most serious land sandification with meantime the most extensive land degradation area. The land sandification areas for the provinces are 7,470.64 million hectares, 40,787.99 hectares, 21,583,600 hectares, 12,461,700 hectares, 12.1702 million hectares accounting for 43.40%, 23.70%, 12.54%, 7.24% and 7.07% respectively of the total area of land sandification of China.

Chinese land sandification types are dominated by sand dunes and Gobi. Of the sandification land area, the dune area is 8,574,800 hectares, accounting for 49.82% of the land area of land sandification (migratory sandy land or dune area 39.868 million hectares, accounting for 23.17% of the total land sandification area of the country; semi-fixed sandy land or dunes 16431600 hectares, accounting for 9.55%; fixed sandy land or dunes 29,343,000 hectares, accounting for 17.05%); Gobi 66,115,800 hectares, accounting for 38.41%; sandificated farmland 4,850,000 hectares, accounting for 2.82%; other 15401900 hectares accounting for 9.22% .

Another feature of land sandification of China lies in its high severity of degradation and difficulty in management. The sandificated land categorized as “extremely severe” and “severe” account jointly for 70.09% of the total sandification acreage. For the areas of different levels of severity for land sandification, the “light sandification” land is 26.1313 million hectares accounting for 15.17% of the total sandification land of China; 25.536 million hectares for “medium severity” accounting for 14.74%; 33.352 million hectares for “severe”, accounting for 19.38%; and 28.273 million hectares for “extremely severe “account for 50.71%.

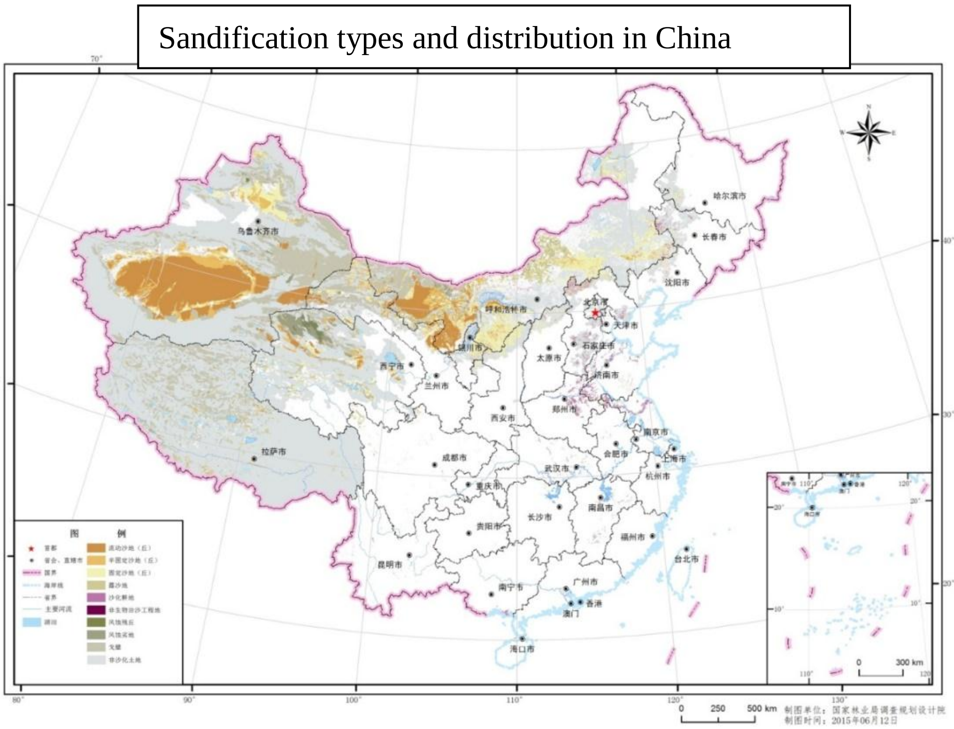

Figure 1-1 Land sandification types and distribution in China (2014)

For the first time, both the inventory acreage and severity for land sandification China were reduced in 2004, and this trend was maintained in 2009 and 2014. Land sandification area in China expanded annually by 3,436 square kilometers in the 1990s and at present it shrinks annually by 1980 square kilometers. As of 2014, 20.37 square kilometers of land sandification was put under effective control in China.

1.2 Soil and water erosion (water erosion)

According to the inventory results by the Ministry of Water Resources[1] and by 2011, the area of soil and water erosion in China was 1.2932 million square kilometers. Water erosion occurs in all provinces (municipalities and autonomous regions) and almost all watersheds. Among them, the Loess Plateau in northern China, the limestone region in the southwestern China, and the rocky earth uplands with limited vegetation are the regions with serious soil and water erosion. In terms of severity, the erosion is generally intense with large acreage. For the hydraulic erosion, the areas for the severities of “light”, “moderate”, “severe” , “extremely severe” and “violent” were 666,600 square kilometers, 351,400 square kilometers, 168,700 square kilometers, 76,300 square kilometers and 29,200 square kilometers respectively, accounting for 51.62%, 27.18%, 13.04%, 5.90% and 2.26% respectively of the total area of water erosion area of the country.

1 Ministry of Water Resources, National Bureau of Statistics, First National Water Resources Census Bulletin issued on March2013 http://www.mwr.gov.cn/2013pcgb/index.html

Soil and water erosion Distribution map of China

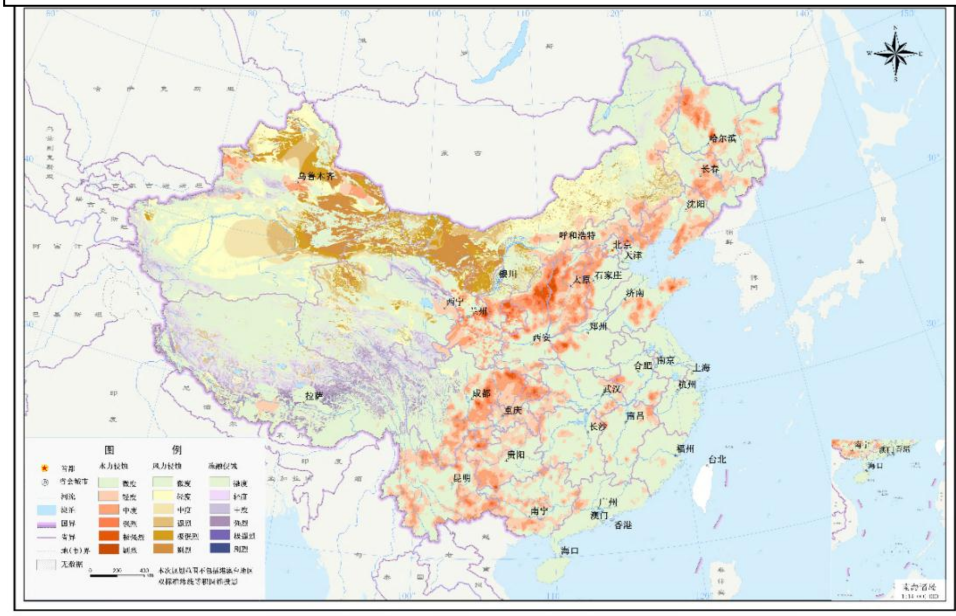

Figure 1-2 Current situation of soil and water erosion of China (2011)

Remarkable achievements have been made in soil and water erosion prevention and control in China. As of 2016, the integrated treated soil and water erosion area exceeded 1.2 million square kilometers with the 820,000 square kilometers enclosed for rehabilitation. The water erosion area decreased gradually from 1,741,100 square kilometers in 1985 and 1,648,800 square kilometers in 2000 to 1,293,200 square kilometers in 2011.

II Bright spots and hot spots of land degradation of China

Changes in vegetation growth are the most important indicator of the condition of land degradation. Vegetation affects the energy balance of ecosystems so plays an important role in climatic, hydrological and biochemical cycles. Satellite remote sensing as an effective quantification means for monitoring global vegetation, helps study the human activities and climate change impacts on regional or global land degradation. The vegetation index as a comprehensive indicator reflecting the vegetation coverage and growth of the land surface has been simple, effective and empirical in measuring of the vegetation condition. The dynamic monitoring of vegetation index reflects the vegetation growth in certain period of time for quantitative assessment of land degradation. NDVI can eliminate most changes associated with instrument calibration, solar angle, topography, cloud shadow, atmospheric condition related solar radiation etc. to enhance the response performance to vegetation. With sensitive response to vegetation coverage and strong detection capability, NDVI has been most widely used among over 40 kinds of existent vegetation indices.

2.1 Vegetation dynamic condition 2000-2014

2.1.1 National vegetation dynamic condition

With the MODIS NDVI data of the vegetation growth season from 2000 to 2014 and based on the Mann-Kendall non-parametric estimation method, the gradient changes of NDVI are calculated for significance level analysis. The area with NDVI significantly increased is defined as the vegetation recovery area (bright spot), and the area with NDVI significantly decreased is defined as the vegetation degraded area (hot spot).

The results showed that the vegetation in arid and semi-arid regions displayed trend of “overall recovery with ongoing local degradation” from 2000 to 2014. By calculating the magnitude of changes, it is found that the average vegetation index in arid and semi-arid regions increased by 0.0008 annually with significant growth. The area of vegetation recovery represented 43.6% of the total distributed mainly in southern Xinjiang and most parts of Qinghai, Gansu, Ningxia, Shaanxi, Shanxi, eastern Inner Mongolia and with its Hulunbeier Sandy Land, northern Hebei, Western Liaoning, Western Jilin and southwestern Heilongjiang. The area with vegetation degradation comprised 8.4% distributed mainly in Xinjiang (most part of Ili, northern Korla, most part of Urumqi, part of Altai, part of Tacheng), northeast Inner Mongolia and northwestern Heilongjiang.

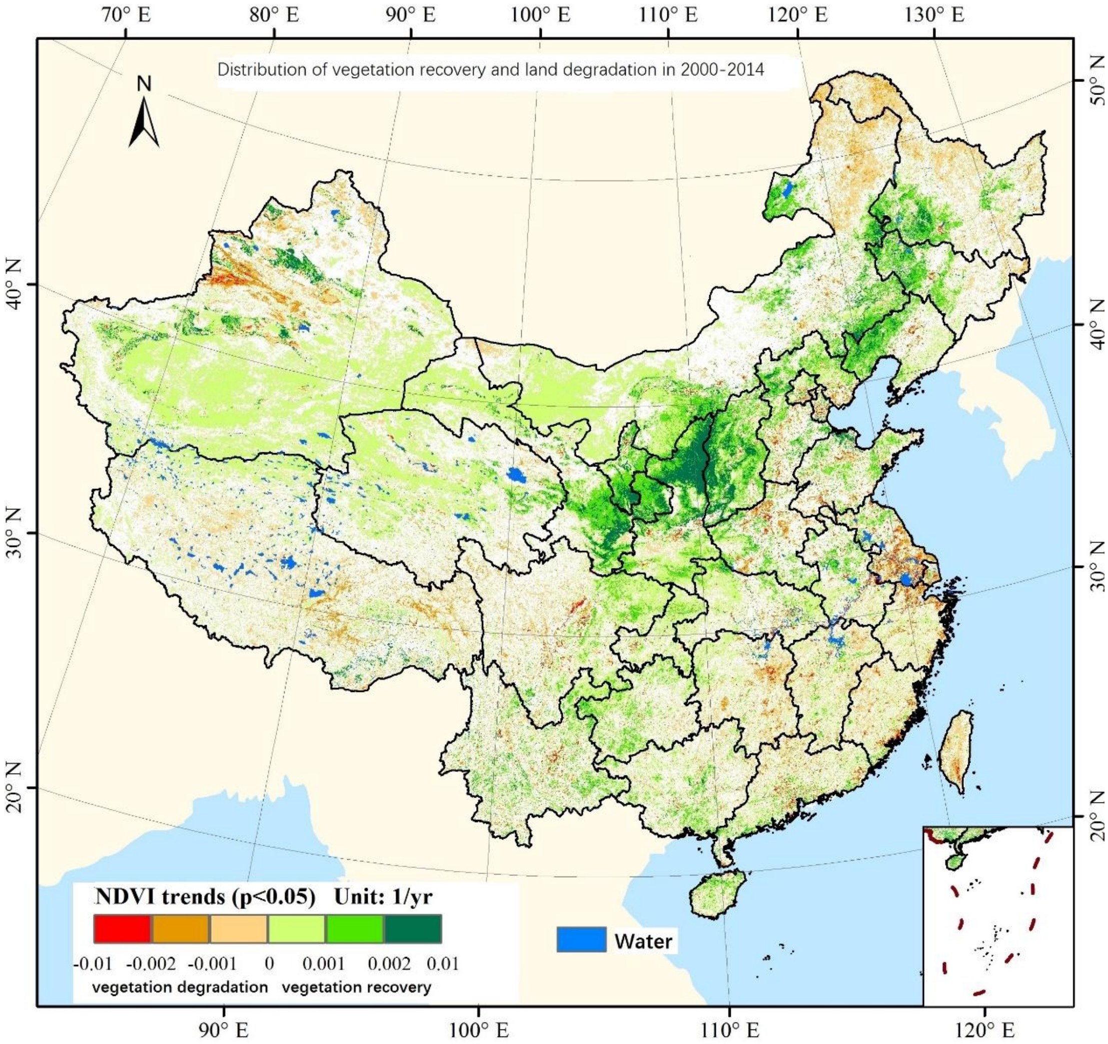

Figure 2-1 Distribution of vegetation recovery and land degradation in 2000-2014

2.1.2 Vegetation dynamic condition for each climate type

From 2000 to 2014, the vegetation recovery rate of the extreme-arid area reached 55.9% the highest while that for the arid and semi-arid areas was 37.5% and 37.3% respectively. The area of vegetation degradation in extreme-arid area was the lowest, for 4.1% only. In arid and semi-arid areas, the vegetation degradation acreage represented 8.8% and 12.2% respectively of the total areas. For the amplitude of changes of NDVI, there were significant increases of vegetation indices for the semi-arid, arid and extreme-arid areas from 2000 to 2014, with an average annual growth rate of 0.0014, 0.0007 and 0.0005 respectively.

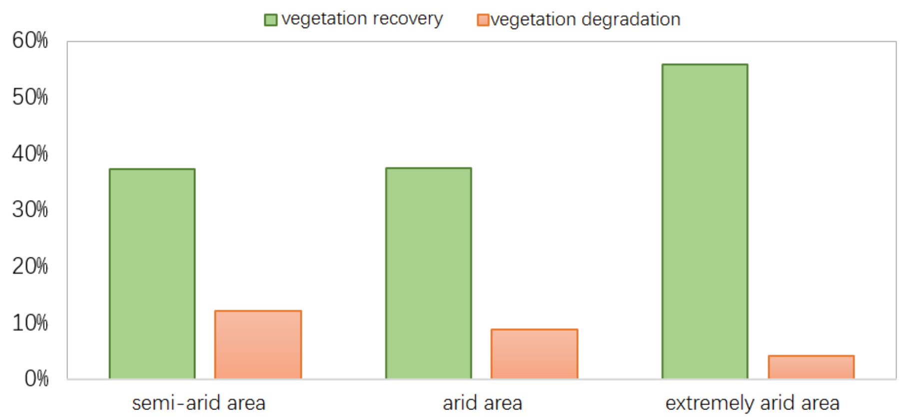

Figure 2-2 Proportion of vegetation recovery acreage in degraded area by climate types from 2000 to 2014

For the annual changes in vegetation growth for different climatic types and from 2000 to 2014, the NDVI was highest in extreme-arid, arid and semi-arid regions in 2012 while the lowest NDVI all in 2001. This shows that the annual variation of vegetation growth for different climatic types in northern China from 2000 to 2014 has similar trends.

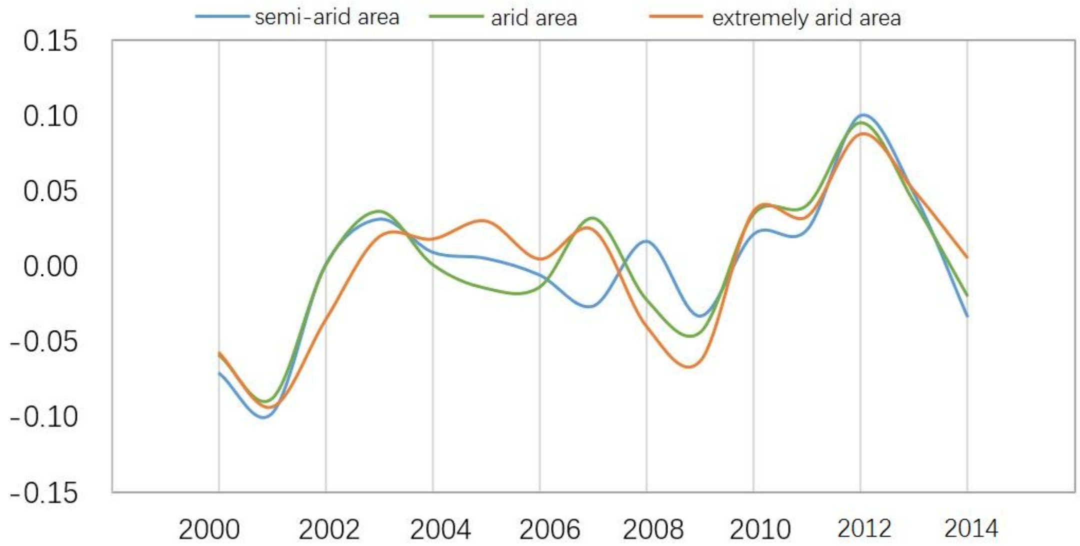

Figure 2-3 Anomaly trend of vegetation index by climate types from 2000 to 2014

2. 2 Response of vegetation changes to climate

The relationship between vegetation cover and climate change has been an important part of global change research. Over the past 30 years, temperatures in Northeast Asia (China, Russia, and Mongolia) have changed significantly, and this region has been one of the regions with the most intense global warming signals. Analysis of the impact of climatic factors on the vegetation change of China is important to the ecological construction programs.

Temperature, moisture and solar radiation act together on the growth of terrestrial vegetation. With total precipitation, mean temperature and average cloud coverage as the assessment indicators for vegetation growth season (May to October), the climate change of China from 2000 to 2014 was analyzed along with the impacts of both individual climate factor and multiple climatic factors on vegetation changes.

2.2.1 Overall condition of climate change from 2000 to 2014

The precipitation of semi-arid regions in China from 2000 to 2014 was similar to that for the same period from 1991 to 1999. The temperature in 2000-2014 was higher than that for the same period in 1991-1999. The cloud coverage was higher in 2000-2014 than for the same period in 1991-1999. From 2000 to 2014, there was insignificant increase of precipitation for the arid and semi-arid regions and the precipitation trends for different climate types were similar. From 2000 to 2014, there was insignificant decrease of temperature for aid and semi-arid regions in China and the trend of temperature in each climatic type is similar. During 2000-2014, there was insignificant increase of cloud coverage in extreme-arid and semi-arid regions and there was insignificant decrease of cloud coverage in arid regions.

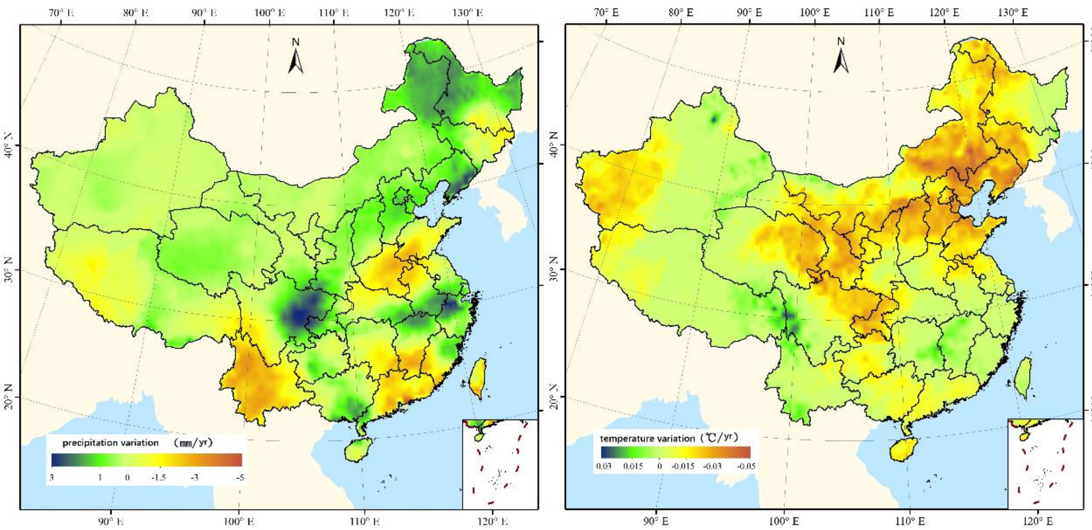

Figure 2-4 Precipitation and temperature trend of vegetation growth season from 2000 to 2014

2.2.2 Annual aridness analysis from 1991 to 2014

The results of standardized precipitation index based arid condition monitoring showed that the semi-arid region of China experienced moderate drought in 2006, 2009 and 2014, and light drought in 2000 and 2001. Light drought occurred in arid regions in 2006 and 2009, moderate drought occurred in 2014. The extreme-arid regions experienced severe drought in 2001 and light drought in 2004, 2006 and 2011, moderate drought in 2009 and 2014. Overally speaking, the arid and semi-arid regions of China did not have years-continuous droughts from 2000 to 2014. And compared with arid regions, the semi-arid and extreme-arid regions had relatively serious droughts from 2000 to 2014.

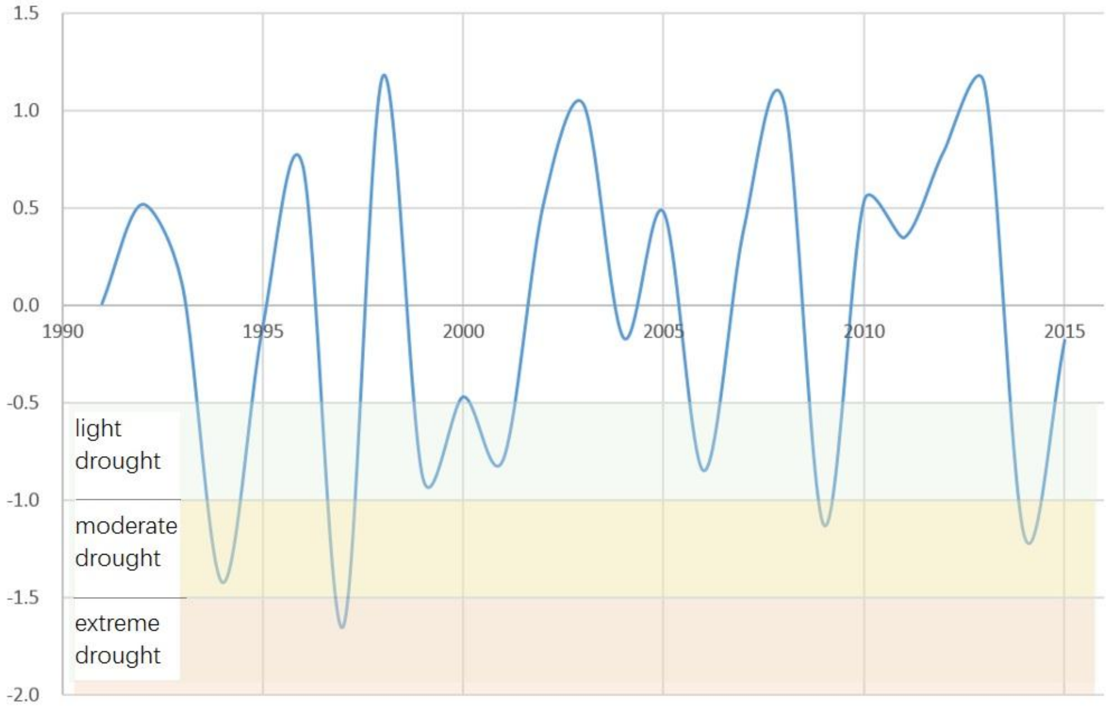

Figure 2-5 Standardized precipitation index and arid severities in annum for arid and semi-arid regions in China from 1991 to 2015

2.2.3. Influence of climate factors on vegetation growth

For the period from 2000 to 2014, there was a substantial positive correlation between vegetation growth and precipitation in arid and semi-arid regions of China, and there was insignificant negative correlation with temperature, and insignificant positive correlation with cloud coverage. This shows that vegetation growth in arid and semi-arid regions is heavily dependent on moisture availability and the increase in precipitation will greatly promote vegetation recovery. The higher temperature has both positive and negative effects on vegetation growth: the positive effect is the prolonged growing season and increased photosynthesis efficiency and water use efficiency for promoted growth of vegetation; and the negative effect is mainly the increase of water consumption to trigger drought so unconducive to the growth of vegetation. In arid and semi-arid regions in China, there is a negative correlation between temperature and vegetation index which is reflected by the downward trend of vegetation growth caused by temperature increase in the region. As indicated by the analysis, the temperature increase in the region leads to increased evapotranspiration of land surface resulting in surface water content reduction and vegetation growth decline.

Based on the normalized multiple regression analysis of vegetation index and temperature, precipitation and cloud coverage, the spatial distribution map of dominant climate factors affecting the growth of vegetation in China was obtained. The results showed that the dominant climate factors of vegetation change in different climatic regions are different. The dominant climatic factor that affects vegetation changes of arid and semi-arid regions for 2000-2014 is precipitation.

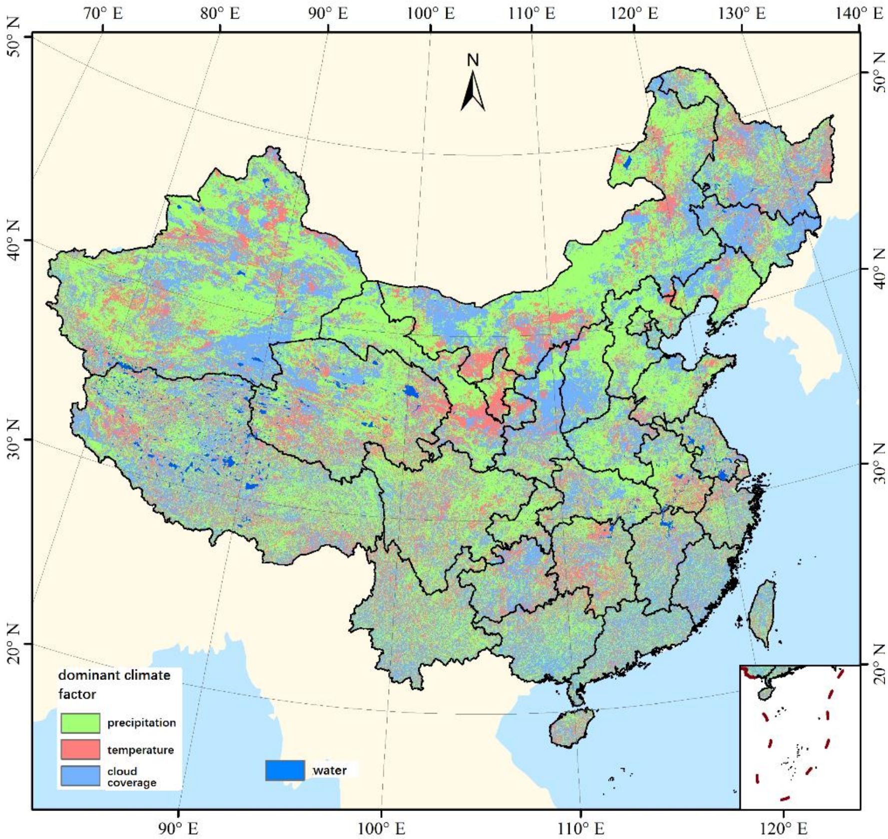

Figure 2-6 Distribution of dominant climatic factor affecting vegetation growth in China for 2000-2014

Table 2-1 Acreage proportion of vegetation growth dominant climate factor for different climatic regions in China for 2000-2014

Climate regions	Dominant climate factor		
	precipitation	temperature	sunshine
Semi-arid	48.2%	20.2%	31.6%
Arid	53.2%	18.9%	27.9%
Extreme-arid	47.8%	16.0%	36.1%

2.3 Remote sensing analysis of artificial contribution to vegetation changes

Although quantitative study of the impact of human factors on vegetation changes is very difficult, the knowledge of the causes and processes of vegetation changes is a prerequisite for related governmental management decision-making. The rapid development of remote sensing technology provides new research models and technical means for timely monitoring of vegetation changes and the impact of climatic factors and human factors on vegetation changes. By utilizing long-term serial MODIS NDVI data and climate data, and based on precipitation utilization efficiency and NDVI residual error trend analysis methods, the driving mechanism of vegetation change can be studied to objectively assess the impact of human factors on prevention and control of land degradation, so with significant scientific and applicative values for regional ecological construction and local sustainable development.

2.3.1 Analysis of changes of vegetation precipitation utilization efficiency

The increase of the rain utilization efficiency of (RUE) vegetation (i.e., under the same rainfall condition the vegetation growth in the area has increased) shows that human factors contributed to vegetation recovery. To the opposite, the decrease of utilization efficiency of precipitation (i.e., with the same rainfall the vegetation growth in the area has declined) indicates that human factors have contributed to regional vegetation degradation.

The results of the study indicate that from 2000 to 2014, the rate of human factors to the arid and semi-arid vegetation recovery reached 67.0% which occurred mainly in eastern Xinjiang, most parts of Tibet, eastern Qinghai, eastern Gansu, western Inner Mongolia, most parts of Ningxia, most parts of Shaanxi, and most parts of Shanxi. The rate of human factors to the acreage of local vegetation degradation reached 3.4%, which occurred mainly in northern part of Tianshan Mountains of Xinjiang, the Ali area of northern part of Tibet, eastern Gansu, most parts of Ningxia, Mu Us Sandland of Inner Mongolia and northern Shaanxi.

Overaly speaking and from 2000 to 2014, the proportion of the acreage for human-induced vegetation recovery was much higher than the acreage for human-induced vegetation degradation. This shows that the human factors played major role in improving vegetation cover in arid and semi-arid regions for preventing land degradation in northern China. These influencing factors are mainly reflected in a series of key ecological construction projects implemented in China since 2000 including the Beijing-Tianjin Sandsource Control Project, the Three-north Shelterbelt Protection Forest Project, the Farmland Conversions into Revegetation Project, and the Natural Forest Protection Project that all produced remarkable results

Table 2-2 Acreage percentages of rain utilization efficiency (RUE) changes by Climate region in China from 2000 to 2014

Climatic regions	RUE rises by	RUE falls by	RUE significant rise by	RUE significant fall by
Semi-arid	58.7%	41.3%	5.9%	4.2%
Arid	71.9%	28.1%	3.5%	1.5%
Extreme-arid	70.4%	29.6%	0.7%	0.3%

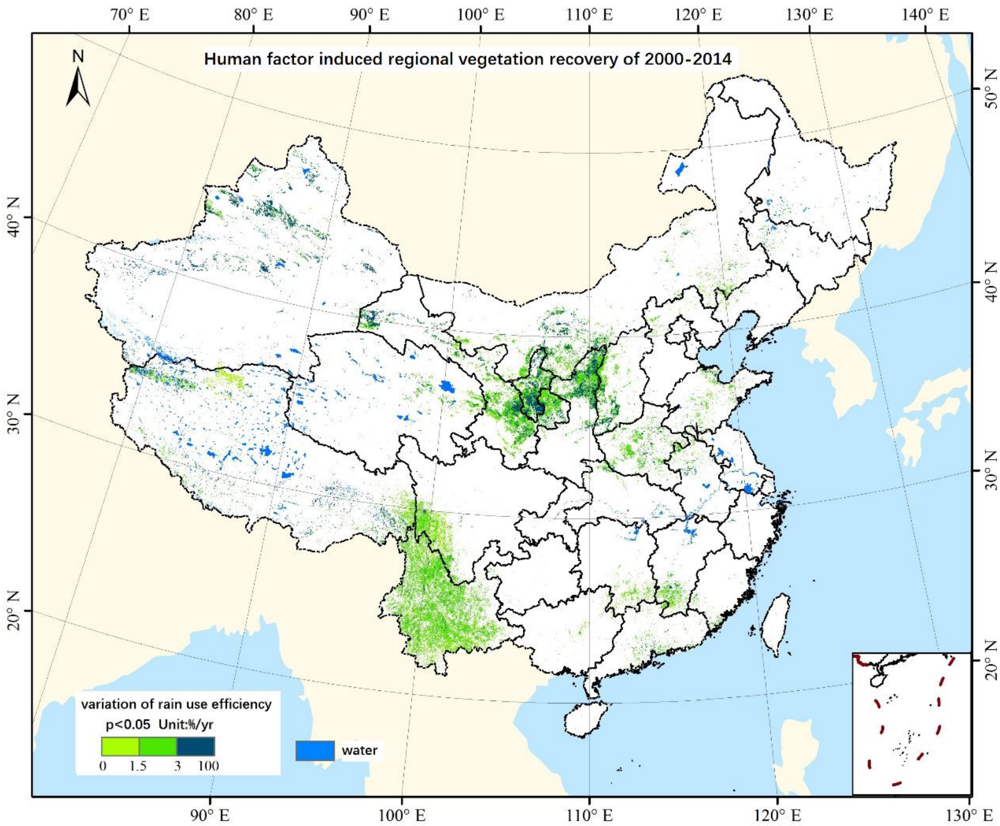

Figure 2-7 Human factor induced regional vegetation recovery of 2000-2014 based on model of precipitation utilization efficiency

2.3.2. Analysis of residual error trend based on NDVI

The NDVI residual is the difference between the time series NDVI observation values and the NDVI simulation values. The area with significant increase of NDVI residuals is defined as areas where human factors contribute to vegetation recovery while the NDVI residuals are significantly reduced as the human-induced vegetation degradation area. .

The study results showed that acreage with human-induced factor vegetation recovery in the arid and semi-arid regions from 2000 to 2014 was 29.8%, and that human-induced factor vegetation degradation in arid and semi-arid was 4.5%. This research results also proved that from 2000 to 2014, the human factors have played a significant role in promoting vegetation recovery and preventing land degradation in arid and semi-arid areas of China.

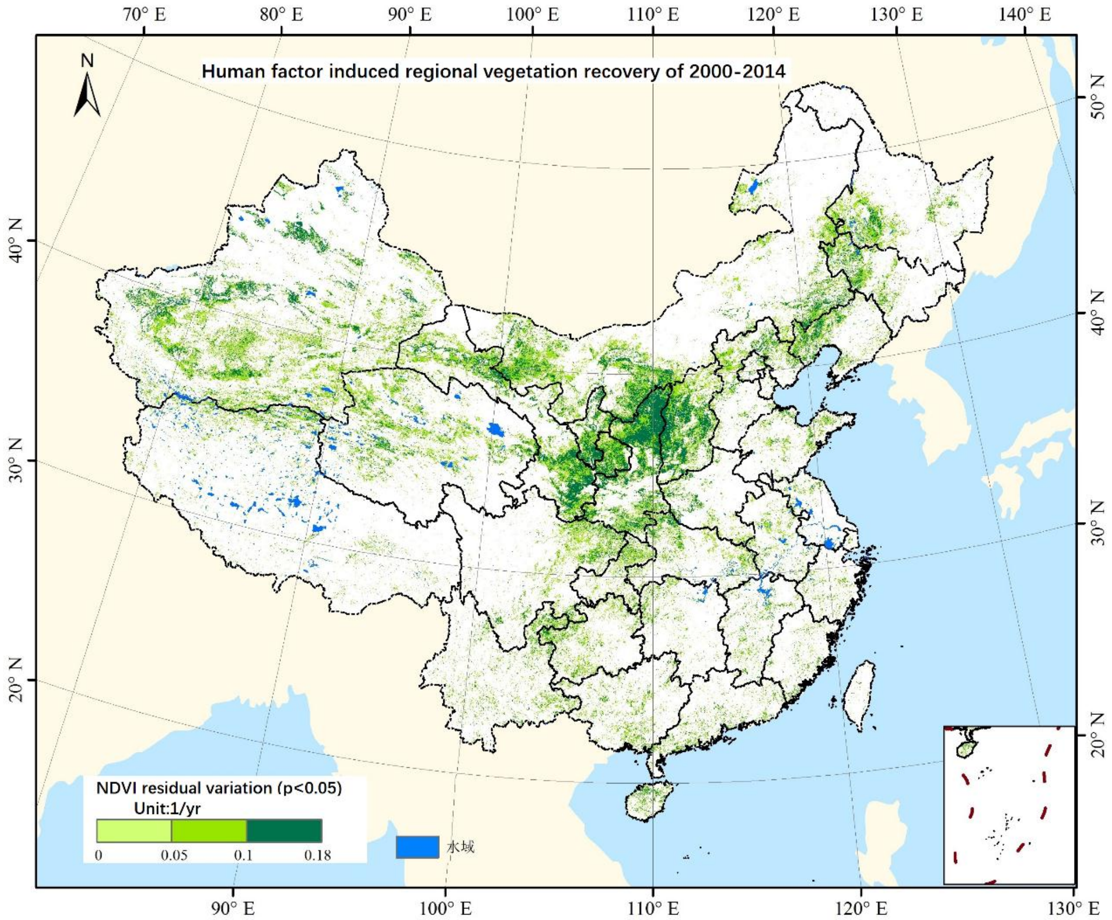

Figure 2-8 Human factor induced regional vegetation recovery of 2000-2014 based on NDVI residual error trend

Table 2-3 Acreage percentages of NDVI residuals changes by Climate region in China from 2000 to 2014

Climatic regions	NDVI rises by	NDVI falls by	NDVI significant rise by	NDVI significant fall by
Semi-arid	64.2%	35.8%	27.2%	6.7%
Arid	67.1%	32.9%	24.9%	4.7%
Extreme-arid	84.1%	15.9%	37.3%	2.2%

2.4 Typical area analysis

The above research results based on changes in vegetation use efficiency and the NDVI residual trend analysis model show that human factors played a significant role in preventing and controlling vegetation degradation in arid and semi-arid regions during 2000-2014. In order to further analyze the bright spots and hot spots, three typical areas were selected for the human factor-induced vegetation recovery area, namely Cuogang of New Barag Left Banner, Duolun County, and Ulan Buh Desert in Bayan Nur City in Inner Mongolia for analysis of effects of prevention and control measures on land degradation. For the vegetation degradation area caused by human factors, Tacheng of Xinjiang was selected as the typical area to further analyze the causes of land degradation. Of the above venues, Cuogang of New Barag Left Banner, and Duolun County belong to the semi-arid climatic region, Bayan Nur city of Ulan Buh desert and Tacheng region belong to arid climatic region.

2.4.1 National protected sandification area by land enclosure

The National protected area of sandification enclosure located at Cuogang of New Barag Left Banner of Inner Mongolia was selected to analyze the protection effort performance.

(a) Briefing of the Cuogang national protected area of sandification land enclosure

Cuogang National Protected Area of Sandification by Land Enclosure is located at Cuogang Township, New Barag Left Banner, Hulunbuir city of Inner Mongolian Autonomous Region, bordering the Old Barag Banner on the east, Djiboulangtu Township on the south, Manzhouli City on the west and the Ergun River to the north to Russia. The geographic coordinates are 117°52′25″-118°22′18″ east longitude and 49°08′34″-49°32′66″ north latitude. Cuogang Town has a total land area of 3,260 square kilometers. New Barag Left Banner Hulunbeier Sandy Land interland area for sandification enclosure reaches 10006 hectares. Inside this protected acreage, the vegetation was seriously degraded with land surface barren and sand in wide spreads. There are only a few herbaceous plants such as Ajriophyllum squarrosum and Stipa aliena. On the semi-fixed sandy soil, there are sparse distribution of natural shrubs such as Salix gordejevii and Caragana microphylla. Cuogang Township is of semi-arid climatic region with an average annual temperature of -1 degrees Celsius, dry and windy in spring and autumn, average annual rainfall 281 millimeters and annual maximum rainfall 300 millimeters, and an average annual evaporation of 1546 millimeters.

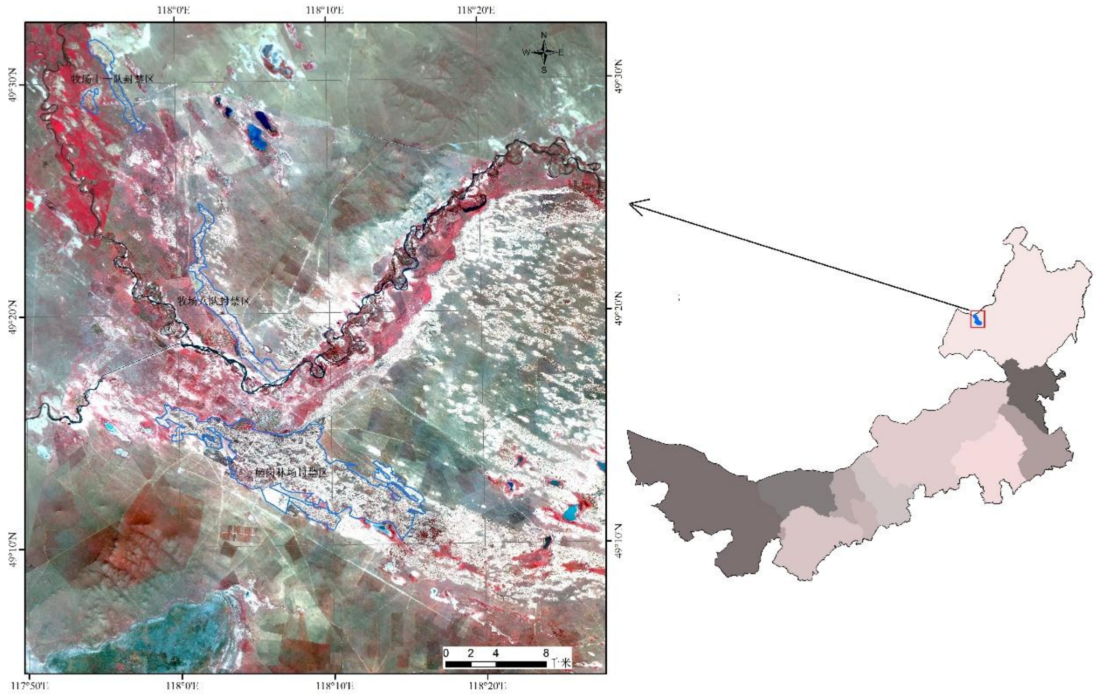

Figure 2-9. Location of National Protected Area of Sandification Land Enclosure with the false color imge based on ZY3 satellite

(b) Remote sensed achievements for the closure for rehabilitation

Considering the high difficulty for sandification land closure for rehabilitation of the Cuogang, the high sandification severity and the poorer vegetation growth inside the enclosed area than the outside, the simple comparison of the vegetation growth inside the enclosed area with the average growth of Cuogang Township is not sufficient to reflect the difference inside and outside the enclosed area. To objectively reflect the difference inside and outside the enclosed area for rehabilitation, the NDVI anomaly percentages for the vegetation growth season of 2001-2017 inside and outside the enclosed area were calculated separately (the difference between NDVI for certain period and average NDVI for long time series gets divided by average NDVI for long time series). Refer to Figure 3-10 for the NDVI anomaly percentage in the growing season inside and outside the enclosed area. In 2013-2016, after three years of enclosure for protection, clear vegetation recovery occurred inside the enclosed area, which was reflected by the higher NDVI anomaly percentage in growth season in 2016-2017 in the enclosed area than that for Cuogang Township.

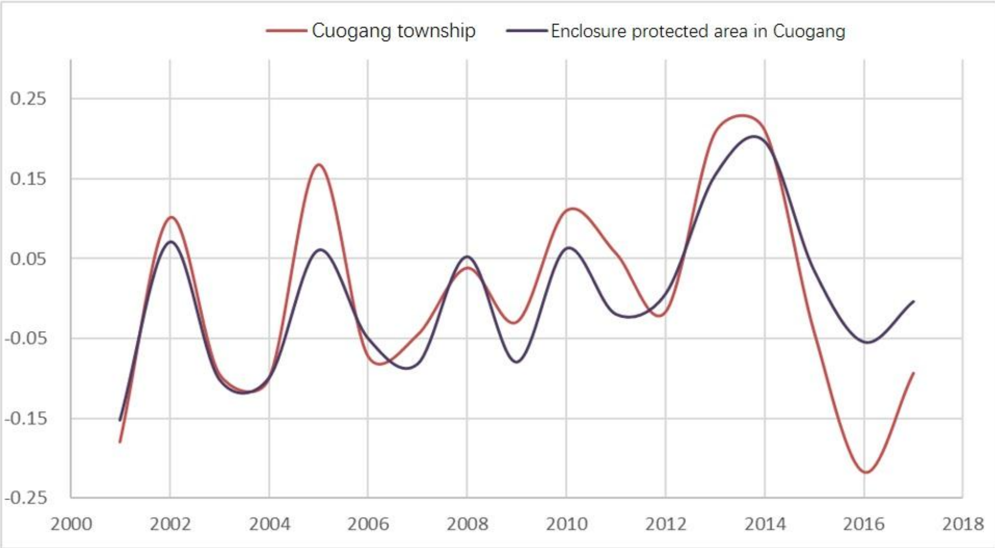

Figure 2-10 Comparison of NDVI anomaly percentage for growth season inside the Cuogang enclosed area than that for the Cuogang township for 2001-2017

For the changing trend of vegetation growth, by breaking the duration into two periods of 2001-2013 and 2013-2017, the Mann-kendall time series nonparametric estimation model is used to calculate the vegetation growth trend before and after implementing the rehabilitation closure.

The results showed that before the closure for rehabilitation (2001-2013), the acreage with significant increase of vegetation growth in the enclosed represented 27.03% while the acreage with significant decrease of vegetation growth in the enclosed represented 0.45%. The acreage with significant increase of vegetation growth outside the enclosed represented 24.34%, and the acreage with significant decrease of vegetation growth outside the enclosed represented 0.95%. This showed that before the implementation of the project, the trends of vegetation growth change inside and outside the enclosed area are similar. The vegetation recovery in enclosed area was slightly better than the outside because some sand control measures were implemented to the enclosed sandification land before the enclosure for rehabilitation in 2013, which to certain extent promoted local vegetation recovery. In 2013-2017 for the implementation of the closure for rehabilitation project, the acreage with vegetation degradation area in closed area represented 8.85% while the acreage with vegetation degradation area outside the enclosed area represented 18.18%. The area of vegetation degradation inside is far below that of the outside indicates that the implementation of closure for rehabilitation project effectively protected the sandy land vegetation.

(1) Achievement analysis with the model of vegetation precipitation efficiency

The arid severity of annual growing season is defined by calculating the standardized precipitation index to obtain annual arid severity. The results show that since 1999 there were frequent droughts in the township including three consecutive droughts in 1999, 2000 and 2001, with another three consecutive years of drought in 2015, 2016 and 2017 of which “light drought” happened in 2015 while “moderate droughts” happened in 2016 and 2017. Drought is the most unfavorable factor for the vegetation recovery inside the closed area.

Similarly to vegetation growth change analysis, by breaking the duration into two periods of 2001-2013 and 2013-2017, the Mann-kendall time series nonparametric estimation model is used to calculate the vegetation precipitation efficiency before and after implementing the rehabilitation closure.

From 2001 to 2013, the acreage with significant increase of vegetation precipitation utilization efficiency in the enclosed represented 0.51%，the acreage with significant decrease of vegetation precipitation utilization efficiency in the enclosed represented 1.64%; The acreage with significant increase of vegetation precipitation utilization efficiency outside the enclosed represented 0%, and the acreage with significant decrease of vegetation precipitation utilization efficiency outside the enclosed represented 1.03%. It shows that before the implementation of the closure for rehabilitation project, the vegetation precipitation utilization efficiency inside and outside the protected area is similar.

In 2013-2017, the acreage with significant increase of vegetation precipitation utilization efficiency in the Cuogang enclosed area represented 60.51%, and the acreage with significant decrease of vegetation precipitation utilization efficiency outside the Cuogang enclosed area represented 10.61%. After the implementation of the closure for rehabilitation project, the acreage with rates of significant increase of the vegetation precipitation utilization efficiency in the closed area was much higher than that of the outside indicated that closure for rehabilitation significantly increased the efficiency of vegetation precipitation utilization, and that the closure for rehabilitation protection project effectively protected the sandy land vegetation.

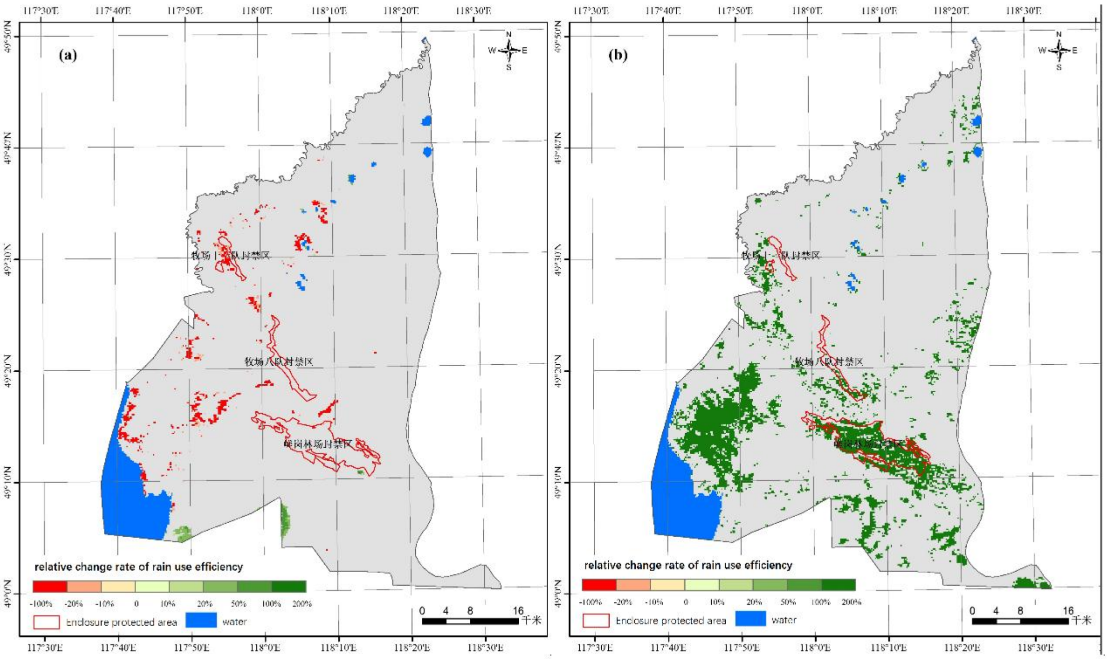

Figure 2-11. Spatial distribution of significant trends of rain use efficiency from 2001 to 2013 (a), and from 2013 to 2017 (b)

（2） Achievements analysis based on the residual error trend

The NDVI residual error trend analysis method was used to analyze the change trend of the NDVI residuals inside and outside the Cuogang Enclosed Protection Area during 2001-2017. The acreage with significant increase of NDVI residual error in the enclosed represented 1.6%, and the acreage with significant decrease of NDVI residual error in the enclosed represented 35.4%. The acreage with significant increase of NDVI residual error outside the enclosed represented 4.6%, and the acreage with significant decrease of NDVI residual error outside the enclosed represented 5.6%. The results show that without considering the influence of precipitation factors on the NDVI, the vegetation index residuals in the closed area remains in significant increase. This indicated that closure for rehabilitation can minimize the impact of drought on vegetation growth.

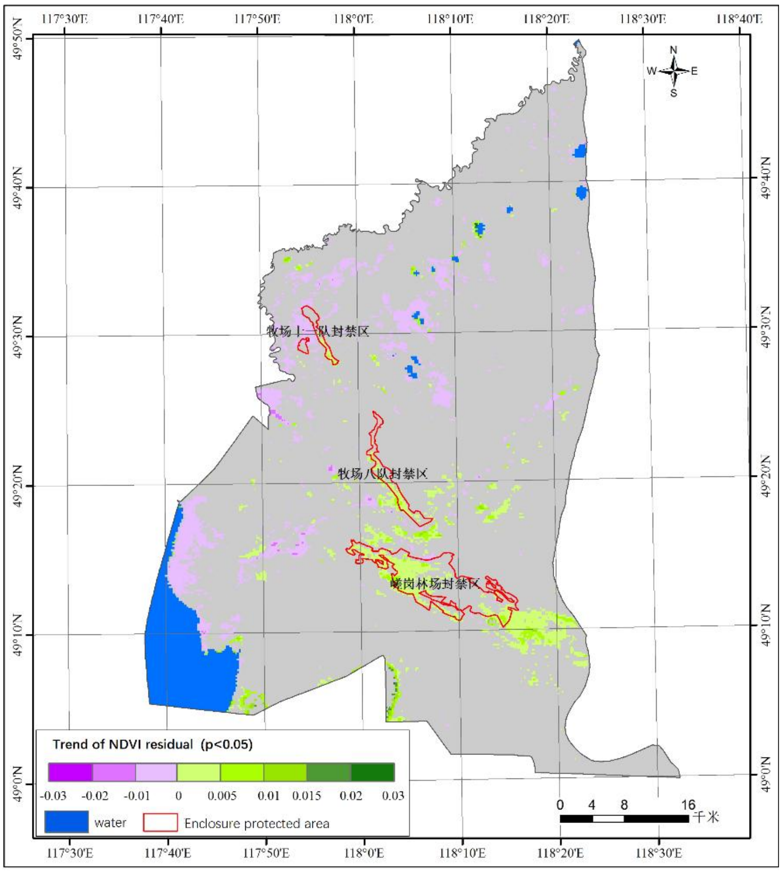

Figure 2-12. Spatial distribution of NDVI residual significant trend from 2001 to 2017

(c) Causes for land degradation control achievements and the achievements

To further verify the role of land enclosure for rehabilitation in combating land degradation, a survey study was carried out from July 30 to August 4, 2017 at Cuogang Enclosed Protected Area regarding the comparison of vegetation growth, vegetation coverage inside and outside the protection fences. Figure 3-13 shows the vegetation inside and outside the mechanical sand barrier and the protection fences. The photo clearly showed that the vegetation coverage of the enclosed area is significantly higher than that out of the fence. Since the project approval in 2013, the main methods for the project for the four consecutive years were the installation of additional fences, mechanical sand barriers to support the biological measures of enrichment planting. The sand barrier is made of reed with the sizes of 200×200 cm, 35 cm high (above the ground) and 15 cm deep (under the ground).


Figure 2-13. The mechanical sand barrier inside the enclsoed area and vegetation growth in comparison with the outside in August 2017

The pilot project for National Sandification Land Enclosure for Rehabilitation started in 2013. The monitoring results show that the implementation of the project has significantly increased the vegetation efficiency of precipitation utilization, improved the capability of sandland vegetation in adapting to climate change, effectively protected the sandland vegetation by minimizing the drought impact on vegetation growth. In relatively contiguous, ecologically important areas where human activities led to serious ecological damages and treatment measures are hardly possible, strict enclosure for rehabilitation protection measures can be adopted to effectively control human interference, curb the expansion of land sandification and promote natural recovery of vegetation for improving the regional ecological condition.

2.4.2. Establishment of arbor, shrubs, grasses in sandy areas

Duolun County is taken as an example to analyze the effect of vegetation establishment of arbors, shrubs and grasses on the prevention and control of land degradation in arid regions.

(a) Duolun County briefing

Duolun County is located to the eastern end of northern Yinshan Mountain and to the south of Xilingol League, with Eastern Longitude 115°30′-116°55′ and northern longitude 41°45′-42°39′. To its west is the Zhenglan Banner, the north Hexietang Banner of Chifeng City, and the south Wuyuan County, Fengning County and Weichang County. According to the climate zone, Duolun belongs to semi-arid climate zone. The annual average temperature is 1.6 degrees Celsius, accumulated effective temperature of and over 10 degrees Celsius 1970 degrees, frost-free period 95 days, annual precipitation 386.2 millimeters, annual average relative humidity 62%. The annual average evaporation is 1761.0 millimeters, annual average wind speed 3.6

m/s, the annual wind days 69.8 days and maximum wind speed 24 m/s. There are 350,000 Mu natural secondary forests in Duolun with tree species of poplar, sassafras, birch, maple, buckthorn, apricot, hazelnut and Prunus padus etc. Natural elm woodland is a typical regional landscape. Affected by natural conditions and human factors, in 2000 Duolun has sandification area of 3365 square kilometers, accounting for 89.2% of its total land area.

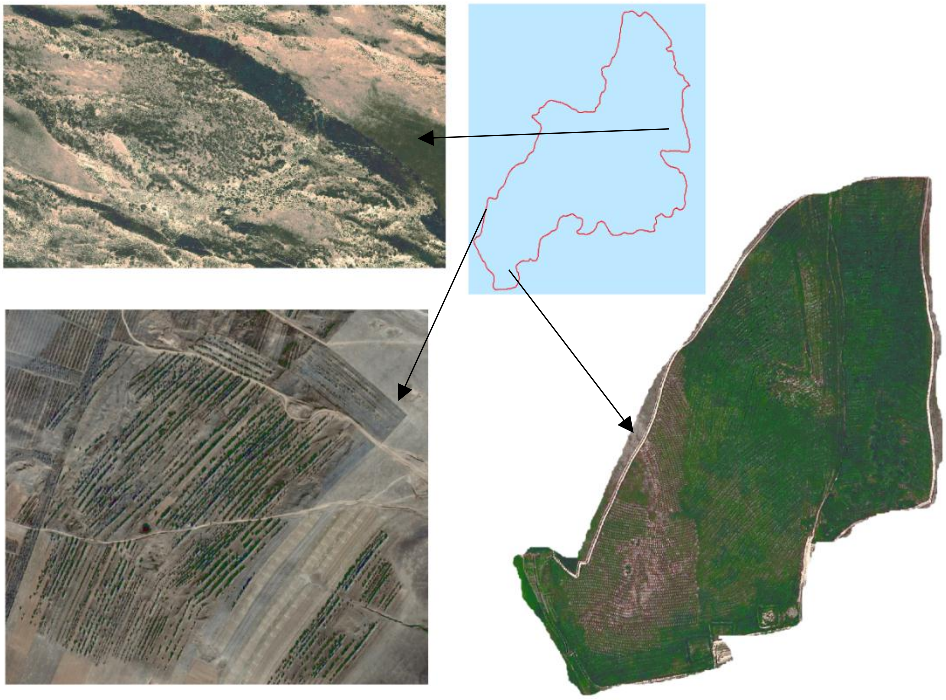

Figure 2-14 High-resolution remote sensing of Duolun County forestation Area

(b) Results of remote sensed forestation in sandy areas

Duolun County is located in the semi-arid area, with sandy land area accounting for more than 50% of the total land area. Precipitation conditions play an important role in the growth of local vegetation. By analyzing the precipitation and arid condition of Duolun County from 1981 to 2017, it can be seen that Duolun had better precipitation conditions during 1981-1999, and drought occurred only in 1984 and 1989 and both were light droughts. Since 2000, Duolun County was struck by droughts frequently with droughts occurred in 2001, 2002, 2005, 2007, 2009, and 2011. Among them, severe drought occurred in 2009 and 2011, moderate drought in 2007, and the droughts for other years are light. Frequent droughts since 2000 had adverse effects on the survival rate of forestation and vegetation growth in Duolun County.

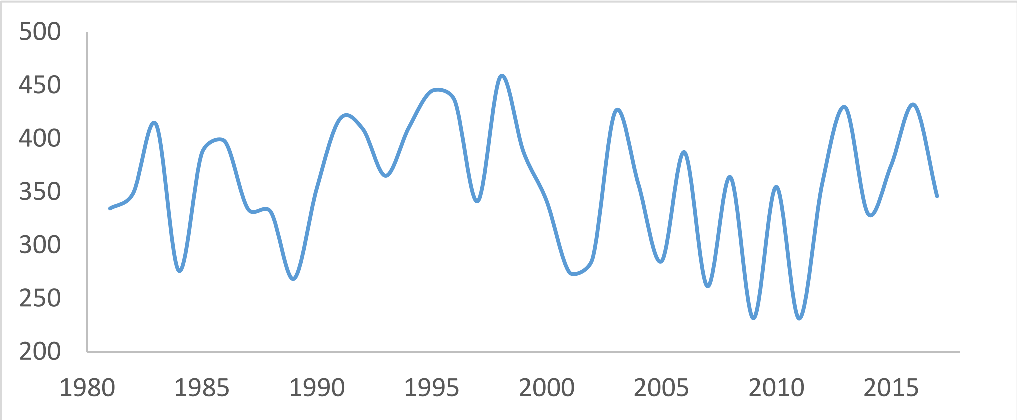

Figure 2-15 Rainfall trend of Duolun County in 1981-2017

The remote sensing monitoring results of vegetation growth in Duolun County from 2000 to 2014 indicate that the vegetation growth in Duolun County shows a significant growth increase occurred from 2000 to 2014 indicating that vegetation recovery is obvious. For the annual changes of vegetation growth, the Duolun County Vegetation Index reached its peak value 0.456 in 2013. From 2000 to 2006, the vegetation index showed a continuous increase trend (the vegetation index in 2005 was basically the same as in 2004). Affected by droughts, the vegetation growth in 2007 and 2009 decreased significantly, and the vegetation growth continued to increase in 2009-2013. In 2013, vegetation growth reached the peak over the past 15 years. The precipitation in 2014 decreased significantly compared with that of 2013, so the vegetation growth in 2014 was affected. It is worth noting that the precipitation in Duolun County in 2014 was basically the same as that in 2000, and the vegetation index in 2014 was 0.42 higher than that of 0.36 in 2000 by 16.7%, indicating that both the vegetation coverage and the vegetation growth in Duolun County increased significantly in 2000.

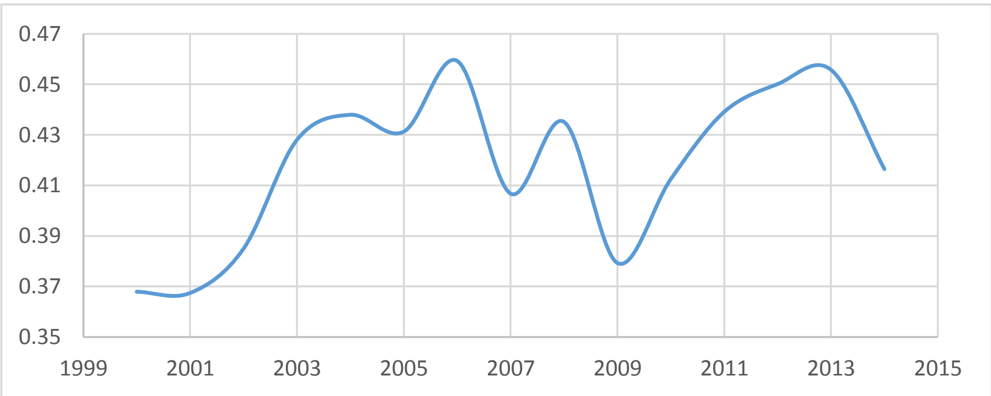

Figure 2-16 Trends of vegetation index of Duolun County in 1981-2017

Based on the analysis results of NDVI residual error trend and from 2000 to 2014, the human-induced vegetation recovery acreage in Duolun County represented 46.4%, and the human-induced vegetation degradation acreage in Duolun County represented was 2.6%. This shows that human factors played a significant role in promoting vegetation recovery in Duolun County from 2000 to 2014.

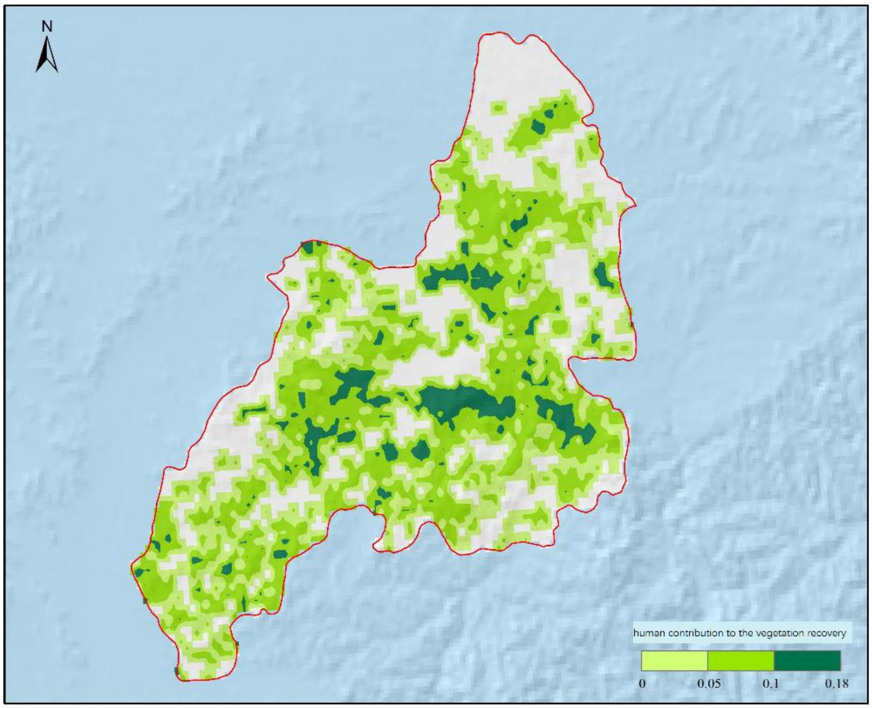

Figure 2-17 Human-induced vegetation recovery distribution of Duolun County

(c) Analysis of causes of land treatment achievements

Remote sensing monitoring results show that human factors have played a significant role in promoting vegetation recovery in Duolun County. Since 2000 and with frequent droughts, the forestation of Duolun County remains very fruitful. This shows that the construction project of Duolun County forestry not only increased the regional vegetation coverage, but also enhanced the capability of regional vegetation and ecosystems in adapting to climate change. The acreage of sandification land was significantly reduced, and the efforts for combating land degradation in semi-arid area have achieved remarkable successes.

The actual natural ecological situation of Duolun County indicates that vegetation establishment of arbors, shrubs and grasses is the main measure for preventing land degradation. Since 2000, Duolun has implemented various forestation projects. The local forestry department has implemented the "high-density afforestation for tending model". Since 2010, the "Pinus sylvesris L.var.mongolica alternate transplant model" was extended to allow the forestland owners get transplant sales revenue by selling the thinned saplings by retaining the minimum standard number of trees per Mu. In 2011, Duolun County started the “million mu of Pinus sylvestris forestation project” to improve forest quality and add management benefits by following the county development strategies of “building up the forestry ecological county, the landscape forestry tourist county and the economic forestry for full better-off”. Statistics show that the area of forestland of Duolun County has increased dramatically, from 360 square kilometers in 2000 to 1,953.33 square kilometers in 2015. This change forestland area is closely related to the dynamic condition of the sandification land. The area change of Duolun County forestland and the dynamics of sandification land show a pseudo-curve relationship, i.e., as the area of forestland increases, the area of sandification area continues to decrease.

Duolun County by adapting forestation measures to local conditions succeeded in reversing the land degradation, in promoting the restoration of local vegetation and ecosystems, and in enhancing the quality of the regional ecological condition. It shows that on the basis of following the laws of nature and the laws of socioeconomic development and on the premise of rational use of regional water resources, and specifically by adapting vegetation establishment of arbors, shrubs and grasses to local conditions, significant improvement of ecological condition and land degradation condition can be achieved for the semi-arid areas. The good practice of Duolun County in fighting against land degradation has demonstration significance to other arid and semi-arid areas that are widely threatened by land degradation.

2.4.3. Forest windbreak network for farmland in desert oasis

Taking the construction of the farmland forest shelterbelt network in the Ulan Buh desert of Bayan Nur city as an example, the effect of farmland shelterbelt construction on combating land degradation was analyzed.

(a) Overview of Ulan Buh Desert, Bayan Nur city

Ulan Buh Desert is located in the western part of the Inner Mongolia Autonomous Region. It is located in the Bayern Nur city and Western Union in the west of the autonomous region. To its north lies the Longshan Mountain, the northeast adjacent to the Hetao Plain, the east to Yellow River, the south to northern Helan Mountain and the west bordering Yanchi of Gilantai. The total area is about 15 million mu, with altitudes ranging from 1028 to 1054 meters. The terrain is inclined from the south to the west. The Ulan Buh sandland in Bayan Nur city as part of the northeastern Ulan Buh desert is located between longitude 106°09′-107°10′ and latitude 40°9′-40°55′ with Yiyinshan mountain to the northwest, Hetao Plains to the northeast, the Erdos City to the southeast across the Yellow River, and Alex League to the southwest, including most part of the Dengkou County, the northwest part of the Hangjinhou Banner, and some parts of the Hewendur Town of Urat Rear Banner. The

Ulan Buh desert belongs to typical continental climate with high temperature, long windy period and limited precipitation. The sandland extends from east to west with rainfall on decrease. The annual precipitation decreases from 144.6 mm to 116 mm and the annual evaporation increases gradually from 2380 mm in the east to 3005 mm in the west. The temperature rises gradually from east to west, i.e., the annual average temperature increases from 7.6℃ to 8.6℃. According to the climate zone, the Ulan Buh desert in Bayan Nur city belongs to arid climate zone in China.

Since the kickoff of the Three-north Shelterbelt Protection Forest Project in 1978, Ulan Buh Desert has been included in the project scope with growing intensity of sandland combating efforts. Since 2000 when the key national forestry projects became national forestry priorities, Ulan Buh sandland has successively implemented a series of national ecological projects inclusive of the “Key ecological county” “Natural forest protection”, “Farmland conversions into revegetation”, “Three-north shelterbelts” and “Japan overseas loans for forestation” etc. The Ulan Buh Desert in Bayan Nur city is adjacent to the Yellow River so containing 100 sites of wetlands. The Yellow River irrigation plain areas located in the eastern and northeast parts of Ulan Buh Desert of Bayan Nur city has relatively favorable hydro-thermal conditions, with the acreage of desert oasis farmland accounting for 50% of the total farmland area.

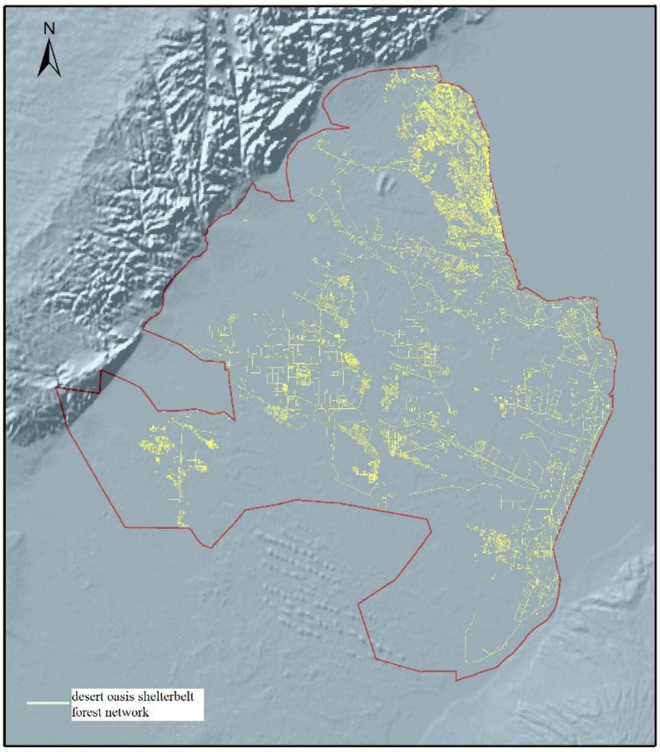

Figure 2-18 Distribution of Ulan Buh desert oasis shelterbelt forest network

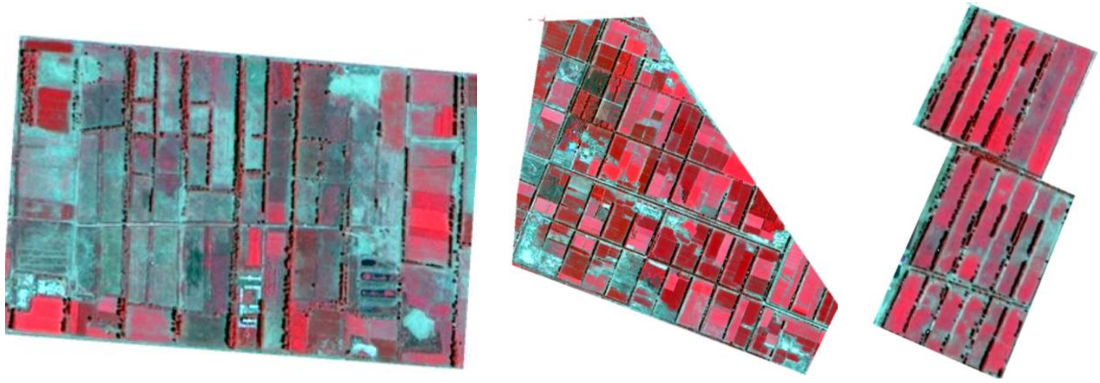

Figure 2-19 False color synthesis of ZY3 images of farmland forest network in Ulan Buh desert oasis, Bayan Nur city

(b) Remote sensed achievements of farmland forest windbreak network

The sandland vegetation growth monitoring based on time-series remote sensing data shows that vegetation growth has been on significant increase from 2000 to 2017. In particular, since 2014, the vegetation index in the sandy area has increased continuously. In the growth season, NDVI reached value 0.24 in 2017the highest over the past 10 years.

Ulan Buh Desert is located in arid area so the achievements of preventing land degradation shall depend on the natural precipitation. Therefore, the local rainfall and historical droughts were analyzed. From 1991 to 2000, the precipitation of the sandland was in satisfactory condition, with droughts occurred in 4 years of which moderate drought occurred in 1991 and light droughts occurred in 1993, 1999 and 2000. From 2001 to 2010, the precipitation in the sandland was in satisfactory condition with two light droughts occurred in 2005 and 2009 respectively. During the seven years from 2011 and 2017, the precipitation in the sandland remained in satisfactory condition, with only one moderate drought in 2011. It can be concluded that since 2000, the precipitation in the sandland has been relatively high than the historical average of for the same periods, which is favorable for vegetation recovery and conduction of various land degradation control measures in sandy area.

Based on the results of NDVI residual error trend analysis, within the project area of the farmland forest windbreak network of the Ulan Buh desert, the acreage of human-induced vegetation recovery from 2000 to 2014 represented 74.6% while acreage of human-induced vegetation degradation from 2000 to 2014 represented 0.212%. This shows that the contribution of human factors to vegetation recovery is high and the achievements of desertification prevention and control has been significant.

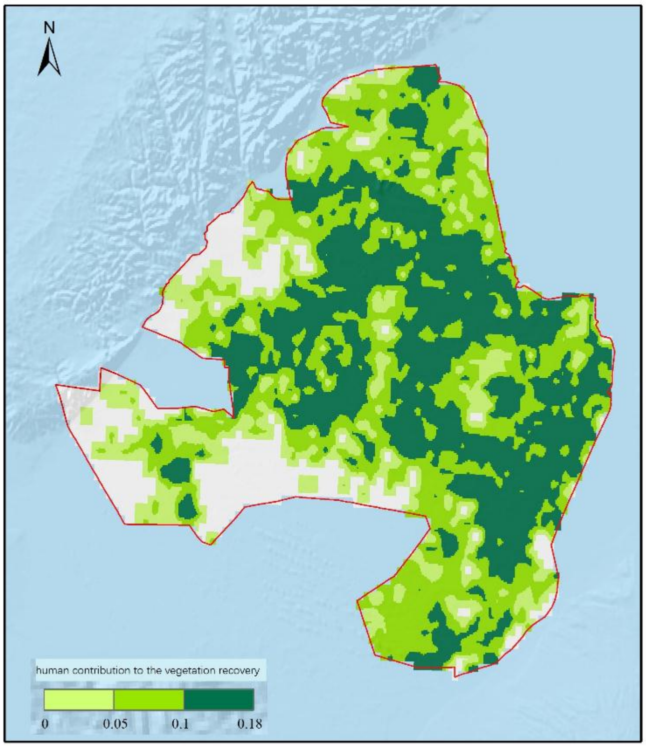

Figure 2-20 Human-induced vegetation recovery in the desert of Ulan Buh, Bayan Nur city

(c) Execution analysis and achievements for land degradation control

Bayan Nur City implemented Network Project by utilizing the facilities of the canals, roads, forests, farmlands and houses. Relying on the farmland forest networks, courtyard economic forests and roadside engreening forestation, a complete set of oasis internal protection forest systems were established. The study results show that human-induced vegetation recovery area is consistent with the spatial distribution of the farmland forest windbreak networks. This proves that the farmland forest windbreak network has played an important role in increasing the growth of local trees, shrubs and crops. It is so because the Oasis shelterbelt network reduces the site wind speed, increases the relative humidity, lowers the evaporation, ameliorates the soil structure so adds the grain production. Therefore, the farmland forest network in the desert oasis has not only increased the forest coverage but also provided guarantees for the better growth of grain crops. Observation data for years provided by the forestry department indicted that compared with open areas where there is no farmland forest shelberbelt network, the wind speed can be reduced by 20% to 40% for sits with relatively complete forest network, and the average temperature in the cold season is 0.4 to 2.3 degrees Celsius higher and the average temperature during the summer season is 0.1 to 1.8 degrees Celsius lower, and evaporation is reduced on average by 10% to 20%, and relative humidity increased by 5% to 10%. Compared with farmlands with similar fertility and management intensity, the early rice yield of the farmland with the protection of forest shelterbelt has increased by 12.7%, the yield of late rice increased by 6.9%, the yield of rapeseed was 13.8% higher, and the yield of ramie increased by 20.8%.

The plain area has the most concentrated farmlands and the highest grain production in China. It is also the main production base for essential agricultural products such as cotton and oil. Raising the farmland grain production of the plain area to higher stable levels is of vital significance of food supply in China. Considering the continuously decreasing acreage of farmland, the growing pressure in maintaining farmland acreage, the forestation of oasis farmland through construction of the farmland shelterbelt system for improved food security and improved ecological condition has strategic and practical significance.

2.4.4. Analysis of vegetation degradation in Tacheng of Xinjiang

Tacheng area in Xinjiang is selected as an example to analyze the causes of land degradation in arid areas.

(a) Briefing of Tacheng

Tacheng is located in the northwestern part of the Xinjiang Uygur Autonomous Region and with administrative jurisdiction of 5 counties and 2 cities. By straddling the northwest part of the Jungger Basin and western Jungger, Tacheng connects Altay in the northeast, faces Changji Hui Autonomous Prefecture in the east across the Manas River, borders the Yilianhabierga mountain watershed in the south, adjoins to the Bortala Mongolian Autonomous Prefecture in the west, and neighbors with Kazakhstan to the northwest.

Tacheng belongs to temperate arid climate with rapid temperature rise in spring and intensive fluctuations between cold and hot. The summer average temperature is above 20 degrees Celsius, with hot period up to 90 days and scorch hot period up to 29 days. The autumn temperature falls so rapidly that over a month the temperature may drop by 20 degrees Celsius. The winter is cold and as long as nearly half a year. The extreme maximum temperature is 40 degrees Celsius, and the extreme minimum temperature is minus 40 degrees Celsius. The Tacheng Basin has slightly more precipitation, with an annual average of 290 mm and an evaporation of 1600 mm. The 3 counties of Wusu, Shawan, and Buxell in Jungger Basin have average annual rainfall less than 150 mm and evaporation up to 2,100 mm. The annual average solar radiation is 135 kcal/cm^2, sunshine 2800 to 3000 hours, and frost-free period 130 to 190 days. The “Old Tori Air Outlet” and its wind line areas with gale lasting as long as 7 days and maximum wind speed of 40 m/s, are well known throughout Xinjiang,

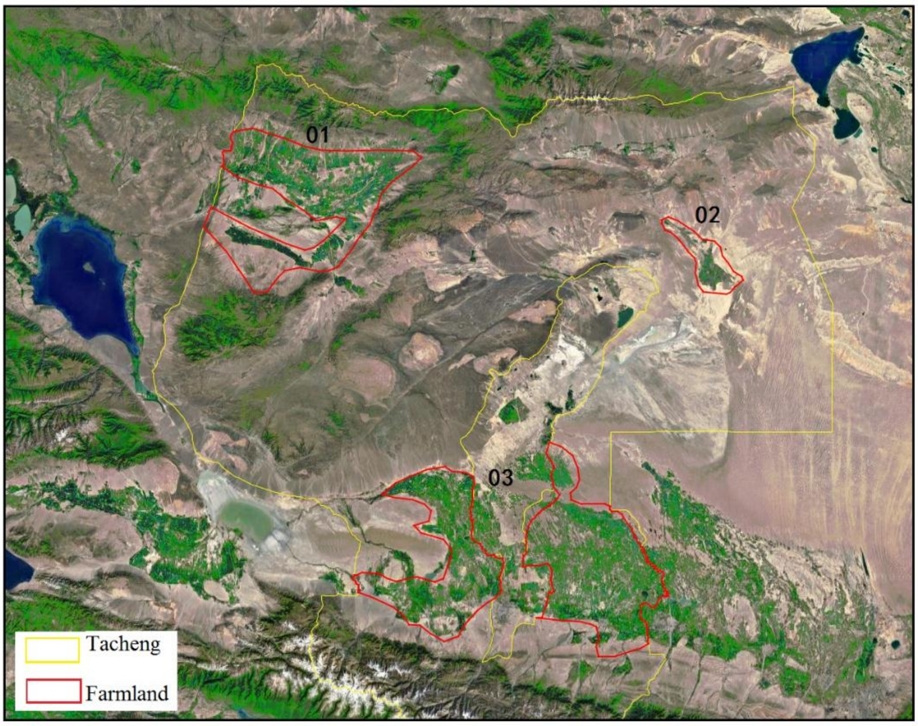

Figure 2-21 Major farmlands in Tacheng with true color remote sensing image

Tacheng has complicated terrains. The northern Khatakhti Mountain the peak of Tacheng has an elevation of 2148 meters. The northwest part lies the western Jungger Mountain and Tayung Basint, the southern part Tianshan Mountain, and the eastern part Jungger Basin with varied topographies. The acreage with high mountain, dense forests, deep vallies and clean water covers 8.2% of the total area; the low-elevation hills with luxuriant fodder grasses and rich minieral resoruces account for 32.9% of the total area; the grasslands with abundent sunshine and thermal resourses for production accounts for 46.8%; the deserts with fish-scale dunes and open sandy wilderness accounts for 12.1%. Tacheng has 14 rivers. The Emin River runs from the east to the west across the southern part of Tacheng, with large areas of saline-alkali lands on both banks of the river. The Karagul River, the Ulastai River, the Abdullah River, and the Xibotu River flows through Tacheng from north to south into the Emin River.

Tacheng has more than 1,200,000 Mu of arable land, of which the Grade I and Grade II lands account for 64.28% of the total. The current farmland sizes 6.2 million Mu, and forestland 3.525 million Mu. The per capita farmland for rural population reaches 10.5 Mu. The soils include mainly irrigated brown calcareous soil, chestnut-calcium soil and grey desert soil. The soil layer is deep with flat terrain and well-built farmland infrastructure.

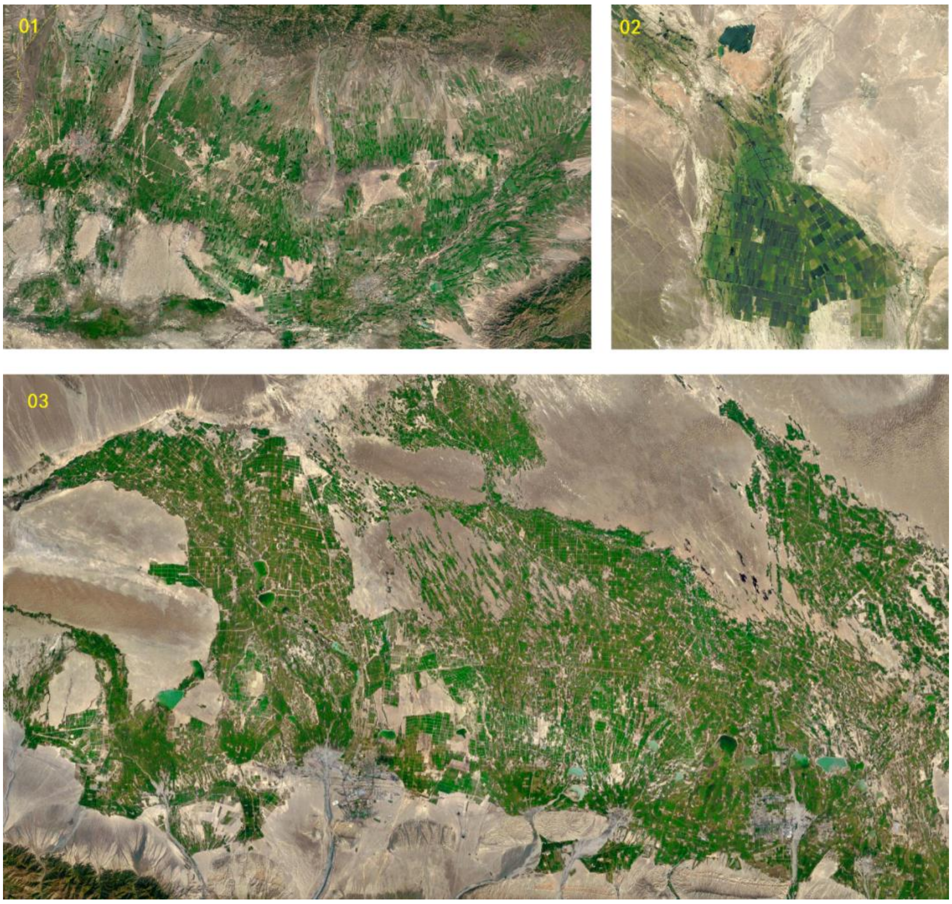

Figure 2-22 High Resolution remote sensing of major farmland blocks of Tacheng

(b) Land degradation remote sensing of Tacheng

The vegetation growth monitoring results of Tacheng based on time-series remote sensing data indicate that there is a high spatial heterogeneity for the change trend of the vegetation index during the growing season from 2000 to 2014. The areas where the vegetation index increased significantly are mainly located in the farmland region, and the regions where the vegetation index decreased significantly are mainly distributed in sandy lands, bare lands, and wind-eroded inferior areas in the Jungger Basin. Statistics show that the acreage with significant vegetation index increase in the farmland region from 2000 to 2014 comprised 87.7% of the total area of the farmland while in the non-farmland region, the acreage where the vegetation index decreased significantly accounted for 50.02% of the total area. This shows that the local crops were growing well from 2000 to 2014, and the vegetation in the non-farmland areas demonstrated a degradation trend. Through analyzing the annual changes of vegetation growth, it is found that from 2000 to 2014, the vegetation growth in the farmland area has a continuous rising trend with the vegetation index increasing continuously from 0.32 in 2000 to 0.50 in 2013, and the vegetation index in farmland area in 2014 was slightly lower than that in 2013. Contrary to the trend of the vegetation index in the farmland areas, the vegetation index in sandy lands, bare lands, wind erosion inferior lands continued to decline from 2000 to 2014.

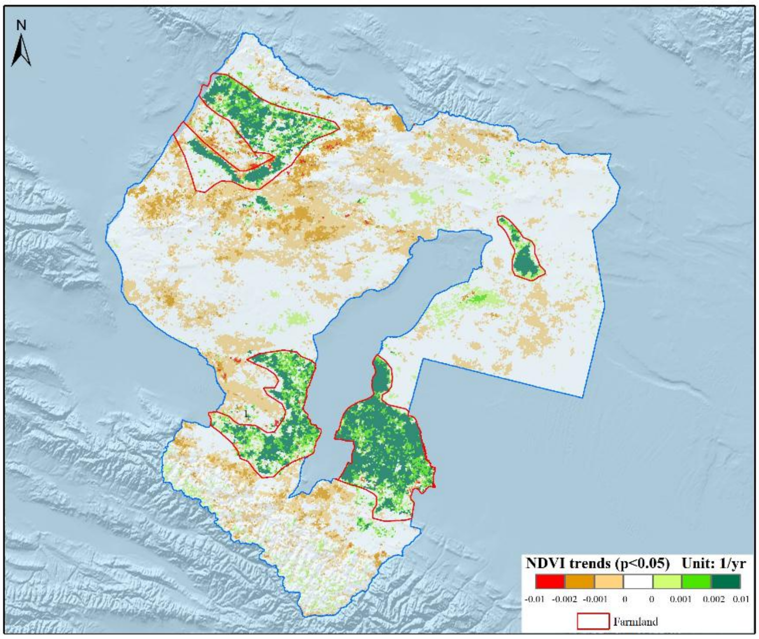

Figure 2-23 Spatial distribution of vegetation recovery and degradation in Tacheng

（NDVI 变化趋势 NDVI change trend 单位 年 unit: /yr 耕地 farmland ）

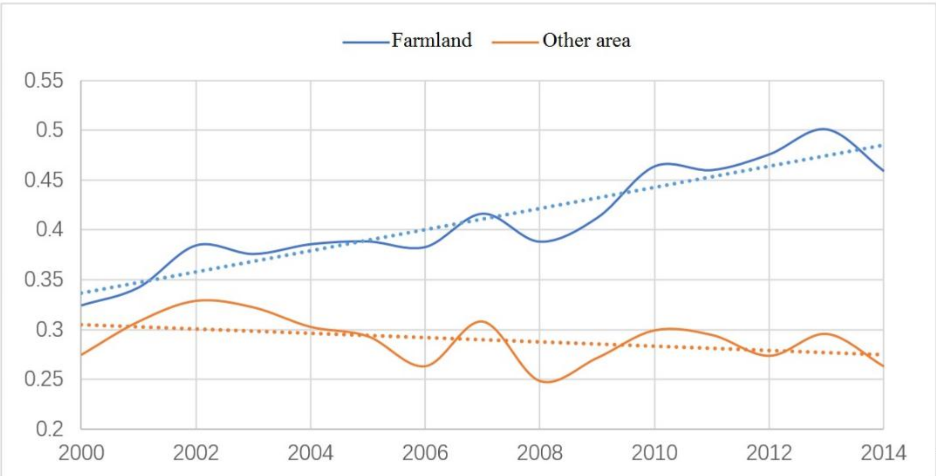

Figure 2-24 NDVI trends of the farmland area and non-farmland area of Tacheng from 2000 to 2014

Tacheng belongs to moderate temperate arid climatic region, with average annual precipitation less than 200 mm and the annual evaporation over 1500 mm. Therefore, the local farmland is highly dependent on precipitation and irrigation, and the vegetation growth and land degradation in non-irrigated sandy lands, bare lands and wind erosion areas are directly related to precipitation. Analysis of precipitation of

Tacheng over years indicates that the precipitation has been satisfactory since 2000 with the precipitation in 2006 and 2008 lower than the average of previous years. The precipitation in other years is close to or higher than the historical average. The monitoring results show that from 2000 to 2014, the vegetation in the non-farmland area of Tacheng remains in serious degradation condition despite the favorable precipitation condition.

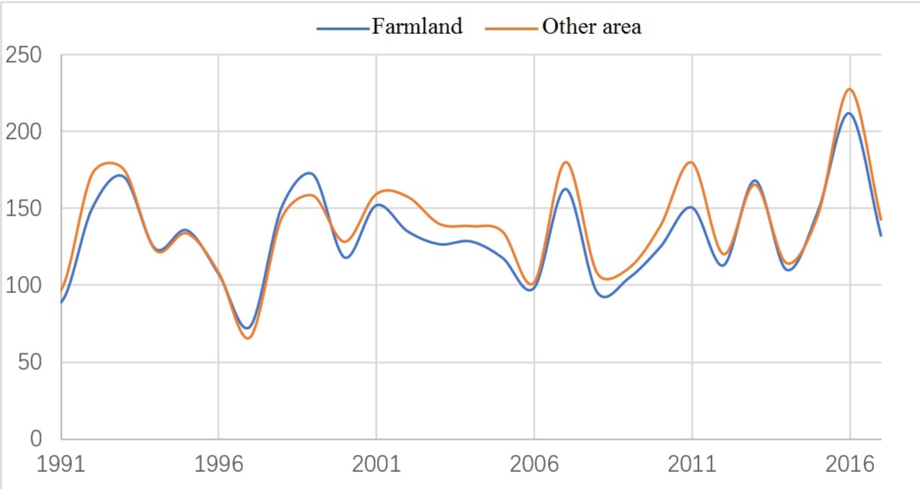

Figure 2-25 Precipitation trend in farmland and non-farmland areas in Tacheng, 1981-2017

(c) Land degradation causes analysis and the lessons learnt

The long-term serial remote-sensing data analysis indicates that from 2000 to 2014, the vegetation growth in non-farmland areas of Tacheng declined and tended for degradation. The main reason is that most farmlands in Tacheng must be irrigated because due to the climatic droughts and even in the years with better precipitation, the rainfall cannot meet the growth demand of farmlands. By relying on groundwater for irrigation, overtapping of groundwater has led to drop of the groundwater level. Consequently the growth of vegetation in sandy land, bare land, wind eroded lands is constrained leading to land degradation. Tacheng has large farmland area but the water conservancy facilities are incomplete so engineering and seasonal water shortages have severely stricter the development agriculture and animal husbandry. Overexploitation of groundwater for agriculture is by all means to quench a thirst with poison and the development of water-saving irrigation in Tacheng is a matter of great urgency.

Due to scarce water resources in arid areas, the more rational water-saving agriculture should be developed and the farmland acreage expansion should be controlled. Irrational use of groundwater for agricultural development in arid areas will cause irreversible damage to the ecological condition bringing about a series of problems such as groundwater depletion, soil and water erosion and land desertification.

III Review and assessment of land degradation control of China

3.1 Chinese history of combating land degradation

Land degradation is the most serious ecological problem in China, and the Chinese government has kept attaching high priority for combating land degradation. The land degradation combating in China has undergone four main stages namely the difficult launch stage, key area treatment stage, rapid development stage, and comprehensive progress stage. The significant achievements made have been globally recognized.

In early 1950s, with the difficulties in manpower, materials and financial resources, the land degradation prevention and control started. Several national thematic meetings were held to study the deployment of prevention and control of sandification, soil and water erosion and land salinization. The organized scientific and technological personnel conducted site studies and experiments and farmland forest shelterbelts, sand-fixing and wind-breaking forests were constructed and small watershed management was carried out.

In the late 1970s, the Three-north Shelterbelt Forest Protection Construction Project, National Sandification Prevention and Control Project, and the Loess Plateau Soil and Water Erosion Treatment Project were launched, with specialized planning and treatment to prioritized areas, which brought land degradation into new stage.

Beginning from this century, a number of national key ecological projects were launched including the projects of Natural Forest Protection, Farmland Conversions into Revegetation, Beijing-Tianjin Sandsource Control, Grassland Construction and Protection, Conservation Tillage, and Dryland Water-saving Agriculture etc. With the rapid treatment efforts remarkable achievements were made.

In 2012, the “construction of ecological civilization” along with the economic construction, political construction, cultural construction, and social construction. were taken as the “five in one” strategy of socialist cause with Chinese characteristics. A number of new conceptions were put forwards including "ecological protection means protecting productivity, improving ecological condition means developing productivity", "lucid waters and lush mountains are invaluable resources" and "Landscape management of mountains, rivers, forests, farmlands, lakes and grasses". The “red lines” for the ecological protection of forests, wetlands and desert vegetation were delineated and key control projects continued to fully promote land degradation prevention and control.

3.2 Achievements of land degradation prevention and control

3.2.1 Areas of land degradation reduced with the severity alleviated

The land degradation treatment of China as part of its ecological construction strategy has followed the laws of nature and the economic laws. The government has gradually increased the public investment in ecological construction with a series of effective measures. As the result, the "four fundamental shifts" were made, from scattered individual measure treatment to regional integrated management, from traditional treatment methods to advanced technological management models, from protective treatment to the comprehensive control of the sources. By these means, the historic shift of land degradation of China has been generally achieved from land degradation expansion to reduction.

3.2.2 Vegetation recovered and ecological condition improved in degraded areas

In 2015, the carrying capacity of national key natural grassland in China was 13.5% which is 16.5 percentage points lower than that in 2010. The integrated grassland vegetation coverage of the country is 54% and has remained at 50% or above for five consecutive years. The fresh grass production of the natural grasslands totals 1.028 billion tons and has exceeded 1 billion tons for five consecutive years. The vegetation in the sandy area obviously recovered. The average vegetation coverage of sandification land increased from 17.03% in 2004 to 17.63% in 2009 and to 18.33% in 2014. In particular, the grassland vegetation coverage in Inner Mongolia increased from 34.43% in 2009 to 40.37% in 2014 with increase of 5.94 percentage points. The productivity of vegetation increased significantly. From 2009 to 2014, the net primary productivity (NPP) of the four sandy lands of Kubuqi Desert, Mu Us Sandy Land, Hunshandake Sandy Land and Horqin Sandy Land increased by 13%, 12%, 33% and 12% respectively. In Yangtze River Basin, the coverage of the lower Jinsha River and neighboring Bijie region, the middle and lower reaches of Jialing River, the southern parts Gansu and Shaanxi, the Three Gorges reservoir area have increased by about 30% and the acreage of barren hills and slopes has decreased by 70%. The water flow of half of the coarse sediment concentration area of the Yellow River has changed from "yellow" to "clear" with the vegetation coverage generally increased by 10% to 30% (some local areas increased by 30% to 50%); The Beijing-Tianjin Sandsource Control Project over its 12-year-long implementation has completed farmland conversions into revegetation for total acreage of 7.52 million hectares plus 9.33 million hectares treatment of grassland, and the forest coverage rate has increased to over 15%.

3.2.3 Ecosystem structure optimized and eco-service function enhanced

The ecosystem structure of the water source areas and headwater sites of the major rivers have been optimized with increased capability of conserving water resources and maintaining water quality. The soil and water conservation measures such as terraces, dam beach lands, arbor forests, shrub forests, economic forests, grass plantations etc. helped maintain a total quantity of water 660.4 billion cubic meters with an annual average of 12 billion cubic meters. By 2016, nearly 1,000 clean small watersheds have been built in China which effectively maintained the water quality. After the completion of the first stage of the conservation project of Danjiangkou reservoir and the upstream, the water source conservation capacity has been further enhanced, and the non-point source pollutants entering the reservoir have been significantly reduced. According to the analysis of seven water quality monitoring sections of the Shaanxi Hydrology Bureau, the annual water quality of the Hanjiang and Danjiang rivers has been stably rated as Class II or higher. From 2009 to 2015, the central government has subsidized 18.733 million hectares of forests for tending. Totally 53.351 million hectares of forest were tended which effectively changed the situation of Chinese forest management by filling the historical gap of forest tending for improved forest structure, improved forest stands quality and for better play of the forestland potential for production. Over the past 15 years, the dust weather in northern China has been significantly reduced. The average annual number of sanddust days has decreased by 15 days, and the average number of sanddust days has decreased by 4 times a year. From 2009 to 2014, the amount of wind erosion on surface soils of deserts and sandlands in the eastern part of northern China fell from 886 million tons in 2009 to 592 million tons in 2014, a decrease of about 33%, and the amount of dust release from the ground decreased from 22.89 million tons to 15.05 million tons, a decrease of about 40%. By properly deploying soil and water conservation measures, the amount of soil loss can be reduced by 1.5 billion tons per year for enhancing the capability to maintain local water and soil and to intercept sediment entering rivers and lakes which helps extend the service life of water conservancy infrastructure such as reservoirs. In the upper and middle reaches of the Yellow River, comprehensive treatment measures such as warping dams, slope-to-terraces etc. were adopted, and the average annual reduction of sediment into the Yellow River reached 400 million tons; the key prevention and control project for the middle and upper reaches of Yangtze River have executed soil and water erosion measures for 80000 square kilometers, with the soil water storage capacity increased by 2 billion cubic meters. The first phase of the Danjiangkou reservoir and the upstream conservation project has treated an eroded area of 14500 square kilometers, with the annual average soil conservation capacity in project area for 50 million tons, water storage capacity to 430 million cubic meters reducing the amount of sediment entering the Danjiangkou Reservoir by more than 20 million tons.

3.2.4 Production and living conditions improved with livelihood guaranteed

Through the investment in infrastructure construction and inputs of ecological construction projects, and relying on projects such as ecological migration, poverty alleviation, crop structure restructuring, economic forests development, and high-quality forest fruits, solar energy, wind energy and other new energy sources, some local special industrial belts came into being in Xinjiang Oasis, Gansu Hexi Corridor, Qinghai Qaidam Basin,Ningxia Hetao Plain, Inner Mongolia Alex Plateau, Erdos Plateau, West Liaoning, Huanghuaihai Plain. These industrial belts promoted the rural industrial restructuring, added local job opportunities, expanded the channels of income generation, and prospered the economic development of the sandy area and local people's living standards improvement. The income of farmers and herdsmen in the sandy area has grown at an annual rate of 18.6%. The number of poverty-stricken population has decreased from 51.43 million in 2010 to 15.97 million in 2015. The poverty rate has dropped from 40.7% to 12.4%. The 13 grassland pastoral provinces of Inner Mongolia etc. have developed modern grassland animal husbandry in line with the ideologies of"livestock determined grass carrying capacity, adding fodder grass production for more livestock, promoting penned livestock feeding, relying on science and technology, speeding up livestock slaughter to ensure supply". In 2015, the scale-based animal husbandry units (the baselines are 100 cows in stock, 50 beef cattle for slaughter, 100 sheep for slaughterer) represented 42.8%, 30.6%, and 43.0% respectively. The production of cattle, mutton and milk reached 4.07 million tons, 3.03 million tons and 26.94 million tons respectively, and wool (cashmere) production reached 444,000 tons. Through soil and water conservation comprehensive treatment projects, a large number of slope farmlands are transformed into terraces, with farmland roads and water conservancy facilities built to improve land productivity. The barren hills and slopes are converted into forestlands or grasslands, and the basic conditions for rural production and rural life are improved. Meanwhile, the integration of soil and water conservation with the development of local featured industries has promoted the industrial restructuring in rural areas and improved significantly the general agricultural production capacity. As of 2013, more than 18 million hectares of terraces had been built in China accumulatively to increase grain production by more than 300 billion kilograms. It is estimated that soil and water conservation measures will achieve accumulatively 560 billion yuan benefits in forms of forest products and fodder grass. In the past decade, the per capita net income in the treatment areas was generally 30% to 50% higher than that of the untreated areas, and 150 million people benefited directly and livelihood problem resolved for more than 20 million residents in hilly areas.

3.2.5 Social enthusiasm inspired in participating in ecological protection

The efforts of combating land degradation helps create a green barrier for the local people which changed the inferior ecological landscape and played roles in changing people's ecological ideologies, enhancing people's awareness of forestation for environmental improvement to mobilize the entire society in participating in land degradation treatment career. The four sandification combating heroes of Shi Guangyin, Wang Youde, Niu Yuqin and Shi Shuzhu along with as other model figures emerged in course of sandification prevention and control, combined to create the sand-combating spirit of "persistence and perseverance for combating desertification to end the sand disasters".

3.2.6 Contributions to land degradation treatment in other countries

Through long-term trials and practice, land degradation prevention and control in China has resulted in a complete set of systems inclusive of the legal system, policy system, planning system, assessment system and project construction system, research and technological scaling up system, monitoring and early warning system, international convention compliance for cooperation system, which demonstrates the sandification prevention and control pathway with Chinese characteristics. To effectively combat land degradation, it is necessary to formulate top-level design to pilot the directions, to improve the regulations system construction, to encourage the application of scientific and technological innovation achievements, and to establish the monitoring system to support national prime decisions regarding ecological construction and land degradation. As a signatory country to the UNCCD, China actively fulfilled its obligations stipulated in the Convention, promoted the UNCCD processes and international exchanges and cooperation demonstrating the image of a responsible large country. The 17th Sustainable Development Conference of the United Nations recognized the leading position of China in combating desertification in the world. And the secretariat of UNCCD stated that the world should refer to China for desertification prevention and control, and for two times China State Forestry Administration has been awarded the Outstanding Contribution Award.

3.3 Land degradation combating policies

3.3.1 Land management policy

The most stringent land management regulations were adopted for strengthening land management, implementing land use control, promoting land-saving and intensive utilization. By taking farmland protection as basic national policy and specifically by defining the Basic Farmland Preservation Area for strict observation of the red line of farmland acreage, the dynamic balance of total farmland acreage is maintained; Strict control is executed to the total amount and structure of construction lands to curb the reckless expansion of cities, promote the coordinated development of urban and rural areas. It is necessary to strengthen land law enforcement by strengthened planning and management, improved responsibility system, strict control of the development and acquisition of natural wetland; It is useful to strengthen the management of natural wetland development and utilization and to actively promote natural wetland salvage protection with fortified organization and leadership; It is necessary to increase the governance and territorial protection of grassland, desertificated land, soil and water eroded land along the railway lines and highways; The management and uses of compensation fees from the acquisition of collectively-owned land should be specially investigated and inspected and the legal rights and interests of farmers with land acquired should be protected with stipulated regulations on issues regarding compensation and resettlement for land acquisition; The revenues for land leasing should be incorporated into local budgets, for separate income-expenses financial management, with part of the land lease income for use of agricultural land development; The national land supervision system should be set up to strengthen the land use management in line with formulated master plan of land use; The land survey, measurement and registration regulations should be established or improved to achieve the socialized information services of land resources.

3.3.2 Desertification prevention and control policy

Combating land degradation is a strategy for improving the ecological condition, expanding the space for survival and development and promoting economic and social coordination and sustainable development. Therefore, the legal, policy, and scientific and technological measures should be mobilized to jointly curb the expansion of sandification; Rational planning should be conducted to construct government-led diversified models for sandification prevention and control; The state forestry authorities in face of the destruction of forests, grasslands etc. by indiscriminate livestock grazing, excavation and harvesting which seriously damaged forest and grass vegetation, had particularly promulgated orders to effectively stop the destructive behaviors by prohibiting related destructive behaviors and activities; At the same time, conscientious efforts should be made in sandstorm disaster emergency management by active responsive actions to safeguards the lives and properties of the general public.

3.3.3 Soil and water conservation policy

To fundamentally resolve soil and water erosion problem, it is necessary to finalize the responsivities of prevention, control and supervision by clarifying goals, tasks, overall design and countermeasures to comprehensively promote soil and water conservation of the country. In order to speed up poverty-stricken in mountainous areas, territorial protection and the improvement of the ecological condition, the principle of "prevention as the mainstay and protection as the first priority "is adopted to fully mobilize the local people in developing the collectively-owned "four types of wastelands" (barren hills, ditches, dunes and beaches) in rural areas. To raise the local enthusiasm there have formulated the polices such as "Establishment and improvement of the responsibility mechanism for environmental restoration and management of hydropower, mining and other enterprises" which requires that some development income from hydropower and mining should be arranged for funding the recovery treatment of the environment where the enterprise is located. In the meantime, soil and water conservation are further strengthened in course of the land development and mineral resources development with established or improved the ecological compensation mechanisms.

3.3.4 Grassland resources protection policy

To protecting grassland resources and promote virtuous cycle of grassland ecology, the grassland legislation and policy system was initially form with the grassland law as mainstay and regulations, rules, and normative documents as supplements. For the purpose of improving the grassland ecological condition for positive cycle of grassland ecology, the grassland grazing ban system, the rotational natural grassland grazing system and rest grazing system have been fully promoted for balanced grassland carrying capacity; Key grassland ecological construction projects regarding grass seed, grazing conversion into grass regeneration, artificial grass cultivation, and grassland improvement should be developed for projecting the natural grasslands. The fodder grass production bases should be built and penned livestock raising technology be disseminated for enhanced development capacity of the grassland animal husbandry.

3.3.5 Forest resources protection and sustainable management policy

The ecological construction oriented forestry development strategy was formed to conduct large-scale forestation, strengthen natural forest protection. With the strict forest cutting quota management system, over-consumption of forest resources is controlled by improved management mechanisms; It is proved necessary to strengthen forestland management by preventing the forestland conversion to other uses, and by implementing the forestland total use control system. Severe punishment should be exerted to deforestation and illegal use of forestland by adhering to lawful forest management and by strengthened capacity building of the grassroots law enforcement teams; Establishment and improvement of forestry laws and regulations should be prioritized to put forest resources protection and management under the constraints of laws and regulations to standardize and institutionalize the protection and management of forest resources, promote sustainable forest management, protect focally the forests at the source sites of major rivers including that on such natural disasters from pests and diseases, forest fires, etc. Middle-age and young forests should be tended through project implementation to improve forest quality. The collective forest tenure system reform should be further strengthened in terms of forest rights registration, certification management and to guarantee the accuracy of registered forest rights to safeguard the legitimate interests of forest owners.

3.3.6 Water resources protection policy

In protection and utilization of water resources and saving water, importance is attached to legislation and policy measures to enhance the protection and use of water resources. The most stringent water resources management system is enforced by strengthened management of water resources development and utilization red line for control and by strict implementation of the total water consumption control system. The red line control based management of water use efficiency is enforced to comprehensively promote the construction of a water-saving society; The red line limit based water function zone management is enforced to strictly control the total amount of pollutants discharged into rivers and lakes; The responsibility assessment system for water resources management is set up to improve the water resources monitoring system, the water resources management system, the input mechanism for water resources management, the policies and regulations to ensure the actual implementation of social supervision mechanisms and the requirement regarding the most stringent water resources regulation. It is vital to safeguard the security in terms of management of river basin floods, water supply, food and ecological condition. Integrated river basin planning and water resources management should be conducted with scientific scheduling for ecological water uses. In areas with groundwater overtapped, it is to limit the use of groundwater with recharge measures. The development and construction project management should adopt the environmental impact assessment system with reformative improved policy system, input methods and organizational forms for farmland water conservancy projects to promote the adaptive healthy development of farmland water conservancy construction in the new era.

3.4 Combating actions of land degradation

3.4.1 Forestry projects

In 2001, with the approval of the State Council, China consolidated the previous forestry ecological construction system into “Six key forestry projects” which planned, for the first decade this century, to fulfill forestation for 76 million hectares with total project investment reached several hundred billion yuan. The Natural Forest Protection Project, the Farmland Conversions into Revegetation Project, the Beijing-Tianjin Sandsource Control Project, the Key Protection Forest in Three-north and Middle and Lower Reaches of the Yangtze River, and the Wildlife Conservation and Nature Reserve Project all involve land degradation prevention and treatment in western parts of China. These projects, by means of artificial forestation, grass plantation, mountain (sandy area) closure for revegetation, low-benefit forest restoration and pastureland construction, intended to control land degradation. In the meantime, grassland protection policies such as grazing ban, rotational grazing, and rest grazing are gradually implemented which promoted large acreage of ecological rehabilitation. The Farmland Conversions into Revegetation Project policy provides appropriate subsidies to farmers who have retired slope farming which resolved the difficulties of long-term livelihood of farmers. The pilot projects of ecological migration were also implemented. In addition, the National Comprehensive Agricultural Development Project has played an important role in demonstrating and promoting the improvement of middle and low-yield farmland for increased grain production. In course of the forest ecological construction, the development of forestry industry is emphasized to strengthen the collective economy and increase farmers' income.

3.4.2 Grassland protection and construction project

Large amount of investments should be mobilized to implementation of project measures of grassland protection and construction, and to promote the establishment of grassland protection, construction and utilization policy system. A number of projects were successively implemented inclusive of the grassland ecological protection award subsidies, the natural grassland vegetation recovery and construction, the pasture seed bases, the grassland fences, the pastureland conversion into grassland, grassland ecological construction under the Beijing-Tianjin Sandsource Control Project, the grass breeding fund, the grassland fire prevention, the grassland pest control and rodent control etc. From 2011 to 2015, with the promotion of grassland ecological protection subsidies and other policies, the implementation of practices of grassland contracting, capital grassland protection, grass-animal capacity balance, the grazing ban, the rest grazing have sped up. The cumulative contracted grassland of the country totaled 4.37 billion mu, accounting for 72.8% of the total grassland area, and an increase of 850 million mu compared with that in 2010; The accumulative acreage for implementing the grazing ban (and rotational grazing, rest grazing) reached 2.4 billion mu, an increase of 7.7 billion mu over year 2010; The implementation area of the practice of balanced grass-livestock capacity reached 25.6 million mu, with demarcated capital grassland area of 3.54 billion mu. Through the measures of central government direct subsidies and production support to farmers etc, the farmers and herdsmen are encouraged to protect grassland for production to ensure sustainable stable income addition on the basis of ecological protection. In 2015, the per capita net income of farmers and herdsmen in semi-pastoral and pastoral areas was 8,078 yuan, an increase by 79.7% over 2010; Continuous efforts are made to strengthen infrastructure building for disaster prevention and reduction of the grassland and the capability to prevent and mitigate natural disasters has increased significantly. The rate of grassland fire extermination rate within 24 hours is over 90%, with the fire damage rate and severe grassland fire incidence ranging from 3‰ to 3%; The pest biological control has expanded in use year by year, with the grassland rodent and pest control rate at 80% and 50% respectively; The capability to deal with grassland snowstorms and droughts has been intensified. The grassland ecological recovery is accelerated, biodiversity continuously enriched, carbon storage and nitrogen sink and water retaining capability were significantly enhanced.

3.4.3 Soil and water conservation project

The integrated management of soil and water erosion has been taken as a legality requirement. The soil and water erosion treatment in key areas have achieved remarkable achievements with initial successes in vegetation protection and restoration. The Farmland Conversions into Revegetation Project has expanded with sustainable achievements and with erosion acreages decreased and intensity reduced year by year. Through integrated management, a large area of slope farmland was transformed into terraces. The farmland roads and water conservancy facilities built have helped increase land productivity. The barren hills and slopes are turned into forestlands, grasslands and the basic conditions for rural production and living are improved; Meanwhile, soil and water conservation has been integrated with local featured industry development which promoted the industrial restructuring in rural areas, increased the agricultural production capacity, and added the income of the farmers. It is necessary to conduct unified planning to mountains, rivers, forests, farmlands and roads with coordination and cooperation among the management departments, to increase forest and grass vegetation coverage through large-scale enclosure for rehabilitation, afforestation and grass plantation, grassland conversion into revegetation and treatment of degraded pastures.

3.4.4 Inland river integrated management project

In order to deal with the occurrences of the cutoff and dryup of tail-end lakes in the lower reaches of the inland rivers to avoid the incidence of ecological imbalance, the central government has invested tens of billions Yuan in the development of the Tarim River, Heihe River, Shiyang River, and Shule River for integrated renovation. According to the characteristics of the river ecosystems and water circulation of the inland river basins, limited targets for ecological restoration of the watershed management were formulated with the main objective of ecological water conservancy project, unified distribution, scheduling, optimal allocation of water resources of the river basins were implemented. By water-saving renovation upstream and downstream, rehabilitation improvement of the mainstreams, the farmland conversions into revegetation, enclosure to protect natural forest, rational utilization of groundwater, the water flow into the downstreams are added. With these measures, emergent ecological water supply for rescue by the upstream to downstream be realized which helped replenish the groundwater for higher groundwater level in downstream basins. Consequently some wetlands and watersheds have appeared at Tetema Lake and Dongjuyanhai lake, and the destruction or disappearance tendency of the Green Corridor at the lower reaches of the Tarim River and the Ejina Oasis at the lower reaches of the Heihe River are shifted.

3.4.5 Integrated Demonstration Plot for sandification prevention and control

A number of typical areas were selected areas of different land sandification types for project implementation of the sandification prevention and control in IDAs. The project is initiated for in-depth exploration of good practices of sandification prevention and control policy mechanisms, technology models, industrial development and management systems of different land sandification types and zones in order to advance pathway demonstration, speed up the ecological improvement pace in key sandy areas, and promote the national sustainable development in sandification prevention control with win-wins of quality and benefit and of ecological achievement and economic achievement. The governments at different levels has successively approved the establishment of 46 IDAs, including 2 inter-regional demonstration zones, 1 provincial-level demonstration zone, 8 prefecture-level demonstration zones, and 35 county-level demonstration zones, involving in total 159 counties (cities, districts, and groups) of 24 provinces (autonomous regions, municipalities) and Xinjiang Construction Coprs. With the accumulative investment to 313 million yuan, 169 million mu forestation was assigned and a series of prevention and control models were disseminated; The enthusiasm of all walks of life are mobilized in participating in sandification prevention and control which added the inputs to the sandy area for quicker improvement of regional ecology and better income of the farmers in the sandy area.

3.4.6 Closure for rehabilitation projects in the sandification areas

The operational mechanism are innovated for active implementation the nationally assigned sandification prevention and control tasks to explore new pathways of protecting the sandy ecology while improving local people's livelihood. In 2013, the sandland enclosure project was officially launched. The pilot project covered 7 provinces and autonomous regions namely Inner Mongolia, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. By 2015, the project has started totally 53 pilot projects with accumulative investment of 600 million yuan from central government subsidies to construct 1.117 million hectares of enclosed areas for rehabilitation. In 2016, another 61 new projects were launched, bringing the total number of projects of the country to 114 ones. By strict closure for rehabilitation protection measures, all production or development activities that jargonize the vegetation growth are prohibited, the human damages were curbed, and natural restoration of vegetation process and the process of formation of land surface crusts in the protected areas were observed. At the same time, the pilot projects explored the workability of the models of closure for rehabilitation, especially by formulating relevant technical standards, improving relevant policies and management mechanisms , which accumulated rich experience in comprehensively promoting implementation of future projects.

3.4.7 National desert park construction project

In order to improve the sandification land management for higher performance, the construction project of the national desert park started in 2014. Through the development of vegetation recovery in the desert park, the sandification prevention and control got effectively integrated with publicity and education. In this way the common sand treatment measures such as sandification by fixing is upgraded to the improvement of ecological culture and the national initiative of “ecological civilization” so very helpful in raising the awareness of sandification prevention and control; Through park management, the social investment were attracted for combined funding with the public finances. The diversified inputs resolved the funds shortage for management and protection and helped maintain the vegetation construction achievements which were usually a weak linkage of the project. The construction of desert parks has become an effective model in promoting ecological protection and rational use of resources in sandy areas. By the end of 2017, 104 national desert parks were established across 13 provinces and autonomous regions, covering all types of deserts in China.

3.4.8 Land reclamation project

From 2011 to 2015, the land reclamation projects were vigorously promoted to strengthen the construction of high-standard farmland. As the result, 530 million mu agricultural land of China were consolidated, 403 million mu of high-standard farmland built, 27.67 million mu of farmland added which ensured the stability of the acreage and production of farmland with additional grain production capacity of 37.368 billion kilograms. Totally 2.337 million mu of idle, scattered, or extensively used construction land were recovered in rural areas, 9.36 million mu abandoned industrial and mining land reclaimed, 1.5 million mu of low-benefit urban development land reconstructed. By land consolidation, integrated uses are promoted and the supporting infrastructure for agricultural got strengthened. The land use structure and layout for urban and rural were optimized. From 2011 to 2015, the land reclamation accumulative investment reached more than 550 billion yuan, with 101 million farmers paid or benefited for their participation in land reclamation. The total labor payment reached more than 110 billion yuan with the per capita annual income of farmers in the project area over 900 yuan, which stimulated rural investment and farmer employment. At the same time, land reclamation strengthened the construction of farmland infrastructure, with 8.688 million kilometers field road built, and 8.674 million kilometers of irrigation and drainage ditches constructed, 110 million farmland ecological protection trees planted; By taking soil work, biological and other measures to lands of sandification, salinization, rocky desertification, soil and water erosion, 4.13 million mu of degraded lands were treated in addition to the effective recovery of industrial, mining or abandoned lands for ecological improvement. Through land reclamation, the ecosystem is restored and protected by achieving ecological security and food security for the improvement of the ecological quality and people’s wellbeing.

3.4.9 International cooperation projects

The Chinese government has successively reached cooperative agreements with Japan, Germany, Australia, the Netherlands, South Korea, Israel, Belgium, Canada etc. as well as the UNDP, FAO, UNEP, the World Bank, the Asian Development Bank etc. to conduct a series of grant based projects in China for land degradation prevention and treatment. These projects covered sanddust storm control, desertification monitoring, local actions, formulation of national policies and supporting regulations, and demonstration of prevention and control of desertification, NGO social participation etc. These projects have been equipped with technical support from international experts for the implementation. For example, Chinese partnership with GEF Dryland Partnership jointly developed a 10-year national plan framework. Under the guidance of this framework, a series of projects of land degradation control will be executed in arid ecosystems by phases and priorities with the Integrated Ecosystem Management approach to solve the cross-sector and cross-administrative problems in land degradation combating and natural resource management. With both technical and financial support, the first project has covered 6 provinces and autonomous regions in western China namely Shaanxi, Gansu, Qinghai, Ningxia, Inner Mongolia and Xinjiang.

IV Assessment of sustainable land management models in arid regions

4.1 Sustainable land management models for arid land

Based on the practices and traditions of land degradation prevention and control and by referring to the treatment objectives and project tasks, the technologies for combating land degradation in arid and semi-arid areas in China can be broadly classified into five major technological systems namely the soil and water erosion, desertification, salinization, grassland degradation, and agricultural ecosystems degradation.

4.1.1 Ecological construction and resources utilization technological system

The technical system is aimed at the improvement of the degradation of agricultural ecosystems. The treatment focuses on building up harmonious high-quality ecological integrity by centering on the production activities of farmers and herdsmen. Environmental degradation starts from excessive irrational use of natural resources by human beings to form initial land degradation. The related ecological destructive activities include indiscriminate uses, deforestation, overgrazing, excessive exploitation etc. While the ecological construction and higher-quality land use models and utilization of renewable energy are emphasized, local people’s necessities of food and energy should be considered when dealing land degradation, for that the survival and development of land users are addressed to sustain the ecological construction. The ecological construction technology system covers forestation, agroforest compound management, and the development utilization of renewable energy.

(a) Forestation technologies in arid area

Based on the water carrying capacity and on basis of the establishing stable forest stands with appropriate structure, density and functions, the revegetation process is sped up to improve the vegetation coverage of drylands, enhance ecosystem services, improve environmental quality and upgrade the living standards of the farmers and herdsmen in arid areas..

(1) "Two lines for one belt" forestation model

Basic model: Plant two rows of trees or shrubs to form one belt, and plant grain crops or grasses between the two belts, for maximizing the use of natural resources of light, heat and water and for maximizing the biomass production of forests and grasses.

Problem solved: this model intends to resolve the contradiction between forest growth and thermos -water in arid and semi-arid areas, and solve the problem of “small old tree “prone to these areas. The tree planting density used to be very high, and due to the insufficiency of the supply of nutrients, moisture, and light and heat, the planted trees would grow into “small old trees”.

Scope of application: The technology is suitable for use in severe wind erosion areas.

Overall assessment: The "two lines for one belt" model has the characteristics of rapid forest growth, short cutting cycle, and high comprehensive forestland benefits. The shrub plantation can be used for “two lines for one belt” by integrating the planting of shrubs and grasses to prevent land degradation and improve land utilization intensity. This model should adapts to the local climate, soil, distribution of natural vegetation etc., take into account both economic benefits and ecological benefits, and thus be welcomed by farmers. The technological investment was US$182 per hectare in Inner Mongolia in 2000.

(2) Arid farmland shelter

Basic model: farmland shelterbelt system constructed in chessboard forms for dryland farmland that has no irrigation condition.

Problem solved: it intends to resolve the problem that dry farmland with poor natural condition is often affected by strong winds and cold waves in spring leading to low harvest or no harvest.

Scope of application: suitable for wind erosion dry hilly lands and sand-covered fields.

Overall assessment: after using this technology, the wind erosion in farmland is reduced, and the capability to resist natural disasters enhanced. At the same time, the technology has the characteristics of low investment, good protection results in curbing wind erosion, adding soil fertility. The forest stands can also be thinned for economic returns. In the 1990s, the cost per hectare for the technology was USD701.3 with maintenance cost USD114.9 per hectare per year.

(b) Agroforest compound system

The efficient, stable and diverse agroforest system is conducive to the rational use of natural resources and human resources, to the coordinated development of the environment, economy and society for highest integrated benefits, is therefore specific practice of the sustainable development theory.

(1) Oasis agroforestry

Basic model: at extremely arid oasis of the warm-temperate zone there is high population but limited land. Walnuts are planted at high density along farmland irrigation ditches or on farmland for agroforest compound management.

Problem solved: to resolve the low productivity land, or farmlands with serious sandification or wind erosion.

Scope of application: suitable for the oasis of arid zone in warm temperate zone.

Overall assessment: the compound management of walnuts with grain crops increased the field vegetation coverage, reduced field wind speed, controlled wind erosion induced sandification for higher land productivity and improved utilization of agricultural natural resources of land, water, fertilizer, and solar energy. The higher land output value per unit area shall increase the annual income of farmers. The implementation cost is based on the deployment of walnuts, with irrigation ditch for USD86/ha with maintenance cost of USD120 per hectare per year, a higher-density planting for USD590/ha with the maintenance cost of USD600 per hectare per year. .

(2) Oasis farmland shelterbelt

Basic model: In the farmland with severe wind and sand damages, forests are planted along the canals or roads to form protective shelters.

Problem solved: it helps improve the oasis ecological conditions and agricultural production conditions, prevent the expansion of the desert from encroaching oasis, reduce the hazards of wind and sand, stabilize the oasis, and maintain the higher yield of grain crops.

Scope of application: The technology suitable to the farmlands with wind erosion or direct threats of desertification in arid areas with low crop yield.

Overall assessment: following the establishment of the forest shelter network for the farmland, the oasis ecological deterioration shall shifted to a virtuous cycle. The living standards and quality of the farmers can be improved for socioeconomic sustainable development. In the 1980s, the cost of implementing the technology USD1600 with the maintenance cost of USD90 per hectare per year.

(3) Agroforest based wine grape cultivation

Basic model: by studying the effects of soil factors on grape growth, the soil improvement measures of green manure pressed cultivation, straw returning to farmland, suitable grape varieties are selected for planting in combination with penned livestock and renewable energy development for optimized agricultural planting structure.

Problem solved: to address the problems of fragile ecological and environment production condition and the low level of economic development.

Scope of application: suitable for areas with sufficient land and light and heat resources.

Overall assessment: after coordinated development, the local grape growing in Helan Mountain of Ningxia flourished to become a multi-functional industry integrating grape cultivation, brewing and processing, business communication, eco-tourism, and wine culture dissemination, which jointly increased the local people's economic benefits and promoting the healthy ecological benefits.

(c) Development and utilization of renewable energy

Renewable energy including the development and utilization of biogas, biomass, solar energy etc. helps reduce excessive exploitation of natural resources by farmers and herdsmen and mitigate environmental pollution. To protect the ecological quality while addressing the energy needs of farmers and herdsmen for improved livelihood, the development and utilization of renewable energy is a must. Actually nowadays f renewable energy has become an irreplaceable part of the energy sustainable development strategy. Over the years, with the promotion of governments at all levels, the renewable energy has been widely extended. The technology has meanwhile improved, and the market demand has continued to grow.

(1) Utilization of wind energy

Basic model: in agricultural and pastoral areas with abundant wind resources, wind energy is converted into electrical energy through mechanical devices to serve the production and living uses of local farmers and herdsmen.

Problem solved: it solved the alternative energy problem of farmers and herdsmen in remote areas that are unable to access electricity through the power grid, and at the same time reduce peasants' firewood cutting for protecting the ecological condition.

Scope of application: agricultural and pastoral areas with abundant wind resources.

Overall assessment: wind power has the unparalleled advantages of conventional power generation, so an energy-saving option for the power industry to realize sustainable development. Meantime, the technology helps promote economic development in remote areas. This technology is applicable to all agricultural and pastoral areas with abundant wind resources. In the 1990s, the cost of a small wind turbine was about USD327.5 with the annual maintenance cost USD19.75.

(2) Solar cooker

By using the parabolic focusing mechanism, the sunlight is reflected to the focal point to heat the food or water cookers. The solar cooker as a cooking utensil that uses solar energy has the advantages of environmental protection, pollution-free, low price, simple operation and maintenance, safe and convenient use. When implemented in project area, the solar cooker helps save firewood and resolves the shortage of fuels in rural pastoral areas. The consumption of firewood, grain straws are thereby reduced so the vegetation damage pressure is lower, which is favorable for protection of the environment. This technology is suitable to areas with high solar radiation. In 2005, the cost of each solar cooker was USD25 with the maintenance cost USD6.5 per year.

(3) Biogas digester

Basic model: the livestock manure, human feces, plant straw and other organic matter are anaerobically fermented inside utilities to produce flammable biogases for lighting and cooking, etc., with the biogas slurry and residues as organic fertilizer.

Problem solved: The energy shortage of farmers' life.

Scope of application: Rural areas with suitable temperatures.

Overall assessment: The technology of biogas digesters is playing an increasingly important role in solving rural life energy problem while protecting vegetation and helping farmers out of poverty. The technology has certain requirements on temperature so some prior assessment is necessary. The cost for one biogas digester sized 8 to 12 cubic meters in 2003 is USD347 with the maintenance cost USD80 per year.

(4) Corn straw returning to field

Basic model: by using the straw returning machinery to chop corn straws for cultivation burial in farmland to increase soil organic matter content and soil fertility.

Problem solved: heavy use of fertilizers that leads to soil compaction.

Scope of application: all regions.

Overall assessment: The return of straws to the field reduces the air pollution caused by straw burning, and adds soil fertility with higher organic matter content. With soil aggregates formed, the physical and chemical properties are improved for higher soil functions in water retention, air permeability and heat preservation. This technology is particularly suitable for areas where the use of large amount of chemical fertilizers has resulted in soil compaction. The cost for the technology is USD170 per hectare with the maintenance cost of USD1 per hectare per year.

(5) Cultivation of green manure crop

Basic model: plant green manure crops for burial the biomass into the soil, for improving soil fertility and reducing erosion.

Problem solved: excessive use of chemical fertilizers, insufficient use of organic fertilizer, soil compaction, and decreased soil fertility.

Scope of application: No requirements.

Overall assessment: Large-scale cultivation of green manure can increase soil organic matter, improve soil aggregate structure, reduce the weeding input of farmland, add vegetation coverage, better farmland environment and microclimate, and lower the environmental pollution occurred during farmland idle period. The technology is suitable for areas with excessive use of chemical fertilizers and insufficient use of organic fertilizers. The cost is about USD400 per hectare, and the maintenance cos USD65 per hectare per year.

(6) Mechanical recycling of residual plastic film

Basic model: the residual plastic film recovery machine is used to collect the residual film on and in the farmland to reduce land contamination.

Problem solved: the residual plastic in the soil that does not decompose during a long period of time tends to form a barrier layer to change the physical properties of the soil affecting the crop growth and leading to lower production and serious environmental pollution.

Scope of application: farmlands those are cultivated with plastic film.

Overall assessment: the mechanical residual film recovery technology has no specific requirements on climate, soil texture, fertility and tillage technology. The technology helps protect farmland soil, improve soil physical and chemical properties, achieve higher and stable crop yield of improved quality. The technology has more social benefits than direct economic benefits so requiring support of national and local government. By raising ecological awareness in the recycling and reusing of residual plastic films, the farmers have benefited significantly. Recycling residual plastics has in many areas become a normal agricultural practice for local farmers.

4.1.2 Technical system for preventing soil and water erosion

This technical system aims to reduce the slope runoff quantity and speed, improve the soil water retaining capacity and anti-flashing capability of the slope surface at areas prone to soil and water erosion. The system through site preparation, enhanced afforestation and civil works measures can play roles in improving the ecological condition and raising people's production and living standards.

(1) Anti-slope fish-scale pit site preparation

Basic model: to change the macro terrain of the slope with gradient over 20°, into fish-scale pit form against the slope when performing the soil preparation, for forest or shrubs plantation to control soil and water erosion.

Problem solved: slope runoff in low utilization, lower soil water storage capacity and low survival rate of afforestation.

Scope of application: large steep slope surfaces of hilly areas with fragmented terrains

Overall assessment: the technology is easy to operate, low in cost and significant in effect of intercepting rainwater for improved soil moisture. It is the main measure for improving the ecological condition in the soil and water erosion areas in the Loess Plateau. The technology has no direct economic benefits so farmers are may be passively adopting the technology which explains the rational for its financially subsidized adoption. With the forest tenure reform, the lands ownership is shifted to the farmers so their enthusiasm for soil and water conservation and ecological construction gest improved. This technology is suitable for areas with steep slopes with poor soil water storage. The cost of fish-scale pit site preparation is mainly labor costs. At the beginning of this century, the labor cost per hectare was 253 US dollars.

(2) Caged forest plantation

Basic model: after establishment of the tree seedling, a cage woven from tree branches is put to protect the tree from rats, rabbits and livestock from eating or damaging to improve the forestation maintenance rate.

Problem solved: damages to seedlings from rats, rabbits and livestock.

Scope of application: This technology is suitable for areas with threats from rats, rabbits and livestock.

Overall assessment: The project is functional in improving the maintenance rate of planted seedlings and in reducing wind erosion, evaporation and dust sources for sustainable land management. At the beginning of this century, the cost per hectare was USD279 and the maintenance cost $13 per hectare per year.

(3) Mountainous farmland shelter forest

Basic model: planting trees along the ridges, slopes and the roads of the farmland to form net-strip-plot patterned farmland forest shelterbelts.

Problem solved: serious soil and water erosion in mountainous farmland.

Scope of application: mountainous farmland.

Overall assessment: farmland shelterbelts can improve the microclimate of the farmland, increase crop yields, prevent wind and sand, reduce soil and water erosion , and mitigate impact of dust weather in surrounding areas. By the use of fast-growing tree species, timber felled can also bring income to farmers. The technology is suitable for serious wind or water erosion slopes of farmland. In the 1980s, the cost per hectare of the technology was 312USD and the maintenance cost per hectare was 64 USD per year.

(4) Plastic film mulched plantation

Basic mode: to lay plastic film in funnel shape over the land surface of the planting hole to reduce soil evaporation, increase soil temperature for increased survival rate of afforestation.

Problem solved: increase the temperature for assured planting quality and afforestation survival rate and maintenance rate.

Scope of application: suitable for afforestation in areas with dry soils and low temperatures.

Overall assessment: the technology can significantly increase soil moisture and temperature, improve the survival rate of planted seedlings and tree growth for the higher ecological quality. The cost per hectare of this century was USD444.13 (including the cost for seedlings) and the maintenance cost per hectare was USD50.32 per year.

(5) Terrace shrub plus tableland economic forest

Basic model: plant horticultural forest at tableland with supplemented planting of shrubs at field ridges are established at site favorable barren hills to prevent and control soil and water erosion.

Problem solved: control soil and water erosion, conservation of water sources.

Scope of application: suitable for areas subject to severe erosion but with good site condition.

Overall assessment: "terrace shrub plus tableland forest "reduces soil and water erosion of slopes favorable for soil structure improvement and significant in achieving economic benefits, so an appropriate combination of ecological protection and soil and water conservation. At the beginning of the century, the cost per hectare was USD2753 and the maintenance cost was USD40.56 per hectare per year.

(6)Sandy land farming

Basic model: the sandy land is a farming technique created to adapt to the arid salinity soil condition by utilizing the stony sandy land.

Problem solved: the technology helps absorb rainwater, reduce evaporation, improve soil water storage capacity and water content. It can increase land temperature, promote early sprouting and growth of the crop, increase the temperature difference between day and night which help improve crop yield and quality; it helps prevent wind and water erosion of soil, and reduce damages from the salinity, pests and weeds.

Scope of application: arid and semi-arid area.

Overall assessment: the stony sand used covers the land to prevent soil loss while reducing the incidence of sanddust storm. The technology is convenient and simple achieving relatively high and stable yields and the quality and palatability of the melons and vegetables are enhanced for increased sales revenues. The cost for technology at the beginning of this century is USD376 (including cost for seeds) per hectare with USD 7 for maintenance per hectare per year.

(7) Hidden-pipe drainage

Basic model: the technology is used in extremely arid climatic region by laying water pipe with bound with seepage material at a certain depth below the ground surface at the irrigation agricultural area for controlling groundwater level, regulating soil moisture and improving soil physical-chemical properties.

Problem solved: to reduce groundwater level of the irrigation areas and to control soil secondary salinization.

Scope of application: suitable for extremely arid areas with high groundwater level and severe soil salinization.

Overall assessment: the technology has obvious effects in controlling waterlogging and soil salinization fit for the heavily salinized arid areas of western China without taking over additional land so convenient for farming. In the 1990s, the implementation cost was USD600 per hectare and the maintenance cost was USD50 per hectare per year.

(8) Plastic sheet mulched drip irrigation

Basic model: drip irrigation is conducted with the irrigator to allow the water or fertilized water penetrate slowly into the soil capillary at the root zone of the crop for diffusion into the root layer for absorption utilization by the planted crop.

Problem solved: the technology tends to overcome the irrigation water leakage problems for increased survival rate of afforestation.

Scope of application: suitable for sandy lands that are seriously affected by wind, salinity and drought.

Overall assessment: the technology is used at the edge of desert to resolve the serious leakage problem for water conservation to ensure survival rate of afforestation, so useful for wind-breaking and sand fixing. When planting the ecological-ecological forests such as red dates and apricots, mulch of plastic film is added to the installed drip irrigation facilities. The technology helps save water and retain water so a much environmental friendly technology. At the beginning of the century, the implementation cost was USD2619 per hectare and the maintenance cost was USD213 per hectare per year.

(9) Warping dam

Basic model: known also as production dam, it is a gully-treating measure for purposes of retaining silt and forming production land. It helps curb floods, block mud silt, store water, make land for agricultural production by reducing the sediment into the Yellow River. Constructing a series of warping dams in one valley is an important and unique technology in the seriously eroded areas in Loess Plateau of China.

Problem solved: the valley is divided into sections for flood blocking and sediment retaining and for stabilizing formed production land.

Suitable area: for gully upland areas with serious soil and water erosion.

Overall assessment: warping dam is an effective soil and water conservation engineering measure created by the people of the Loess Plateau in their long-term struggle against land degradation and the main valley treatment measure for small watersheds. It is direct and effective in reducing siltation in the lower reaches of Yellow River, much facilitative for improving the environment of the project area and for promoting the development of economy. It also helps promote the Farmland Conversions into Revegetation Project in river basins by adding forest and grass coverage. In the 1990s, the cost for building one small warping dam was USD38500 and the maintenance cost was USD75-150 per year.

(10) Check dam

Basic model: it is the earth and stone based buildings constructed in erosion-prone gulley for fixing the gully bed.

Problem solved: protect against debris flows, reduce erosion and control soil and water erosion.

Suitable areas: erosion-prone valleys and ditches.

Overall assessment: with the check dam built the damages from mudslide hazards can be significantly reduced by reducing the destructive strength. This has also largely contributive to the reduction of local soil erosion which is helpful for application of diverse production models to boom local economy. At the beginning of this century, the implementation cost of one check dam was USD4000.

(11) Rainwater cellar

Basic model: using gardens, roofs, road surfaces, slopes, etc. as water gathering fields to collect rainwater for water storage in artificially built facilities for later uses as drinking water by humans and livestock and for farmland irrigation .

Problem solved: Solve domestic water and develop dry farming.

Suitable area: areas with serious shortages of both surface water and groundwater.

Overall assessment: water cellars help collect rainwater and play an important role in supplying drinking water, developing dryland agriculture, conserving soil, and ecological restoration. It meets local practical requirement with broad application prospect.

(12) Terraced farmland

Basic model: the eroded or degraded slopelands are transformed into farmlands with continuous platforms.

Problem solved: improve soil moisture, ease the difficulty of farming, create better crop growing environment.

Applicable areas: slopelands

Overall assessment: the terraces built on Loess Plateau in China have been a globally outstanding soil and water conservation measure. Summarization of the development of the technology should be deepened. The technology is contributive to improving the soil and water management and suitable for seriously eroded slope farmlands. In the 1990s, the per hectare cost of terraced land was USD1290 and the maintenance cost was USD35 per year.

4.1.3 Desertification prevention and control technological system

The technical system focuses mainly on the prevention of wind erosion and eolian sand pileup.

(1) Sandification control along desert railway lines

Basic model: the technology follows the principle of “focusing on sand fixation in combination with sand resistance". By using both mechanical measures and biological measures, the integrated railway line sand prevention and sand stabilization technology system is established. Specifically, the sand barrier with high vertical fence is established at the forefront of the shifting sand dunes, and the 1m×1m grass grids are built between the sand dune barrier and the railway lines. Plant drought-resistant shrubs are planted at appropriate density inside grids without irrigation.

Problem solved: wind erosion and sand burial solved by fixing sand dunes.

Suitable area: for areas with wind erosion and sand burial.

Overall assessment: This technology has been widely used in the construction of roads and railways in sandy area, and for the protection of cultural relics etc. such as Dunhuang Mogao Grottoes, Xinjiang Taklimakan oilfield highway, the Qinghai-Tibet Railway lines, and the" Green Corridoe"of the Republic of Mali. The low investment, quick effect, wide application scope and low protection management cost helps jointly improve the regional ecological condition. In the 1950s, the implementation cost was USD1420 per hectare and the maintenance cost USD35 per year.

(2) Desert highway sand prevention

Basic model: by establishing drip irrigation system with underground high salinity water, the resistant desert plants such as Haloxylon ammodendron, Tamarix chinensis and Calligonum are planted forming protection forest shelter belts that integrate sand fixation function and sand resistance function to intercept land surface wind and to prevent the formation of sand hazards.

Problem solved: the operaionality of the desert highways.

Suitable areas: the traffic lines in the desert or sandy areas.

Overall assessment: the technology includes the construction works of the irrigation system, electricity transmission line, well drilling, wellhouse, roads for residential area, valve wells and drainage wells; Auxiliary works of diesel power generation system, laying of grass grids and barriers; Seedling planting; Forestland maintenance management including irrigation, plant pest control, enrichment planting, etc. This is public welfare based technology that promotes the safe operation of roads the environmental quality of the sandy area. The technology can also be used for ecological industrial development to produce certain economic benefits; the technology can plays a role in improving people's ecological awareness in combating desertification. In 2005, the implementation cost of the technology was USD6363 per hectare and the maintenance cost USD555 per year.

(3) Grass grid sand barrier

Basic model. The crop straws, weeds or shrubs are used to lay grids as sand barrier on the shifting sand dunes for sand fixation and then planting trees and grasses inside the grids.

Problem solved: fix the shifting sand, restore vegetation and improve the ecological condition.

Suitable area: for areas with severe wind and sand hazards.

Overall assessment: the technology produces quick results and good benefits with low costs are particularly effective in treating high mobile sand dunes. At the beginning of the century, the implementation cost was USD872 dollars per hectare and the maintenance cost USD91.5 per year.

(4) High vertical live sand barrier

Basic model: psammophytes or xerophils are planted in strips in the wind or sand hazardous areas to form a protective barrier with appropriate height and penetrability. The wind flow velocity by passing the barrier is reduced strip by strip to facilitate pileup of shifting sand to protect the infrastructure.

Problem solved: intercept the migration of sand.

Suitable areas: areas with wind and sand hazards including edges of the oasis and main traffic routes.

Overall assessment: high vertical sand barrier is highly functional in fixing dune and accumulating sand so that a large amount of shifting sand is gathered to form large high dunes by slowing down dune migration economically and practically. It is an important technology for protecting key traffic lines and oasis farmlands. In the 1990s, the technology was implemented at a cost of USD660 per hectare and the maintenance cost was USD175 per year.

(5) Aerial seeding for sandification control

Basic model. use aircraft to load grass seed for broadcasting evenly on the sandland with the seed covered with the natural strength and wind, and natural precipitation will then promotes the germination, rooting, seedling growth, and recovery of sandy vegetation.

Problem solved: add vegetation of forest and grassland to curb the hazards of sandstorms and improve the local and surrounding ecological environment.

Suitable areas: traffic inconvenient areas with relatively wide inter-dune lands relatively concentrated and contiguous for forestation.

Overall assessment: in the semi-arid windy and ecologically fragile areas, forestation and grass plantation with aerial seeding is efficient and inexpensive suitable for restoring vegetation in large areas. At the beginning of this century, the implementation cost of the technology was USD91.7 per hectare and the maintenance cost was USD24.3 per year.

(6) Afforestation of Pinus sylvestris on sandy land

Basic model: carry out afforestation with natural regenerated seedlings of Pinus sylvestris in in sandy area for fixing the shifting sand and sheltering pastures.

Problem solved: vegetation degradation, serious sandification of land.

Suitable area: serious wind erosion and sandification area.

Overall assessment: Pinus sylvestris has strong adaptability and high benefit. The technology can help reduce wind erosion and sandification of the grassland with obvious ecological benefits. At the beginning of this century, the technology cost is USD183 per hectare and the maintenance cost is USD35.4 per year.

(7) Deep planting of poplar in high-elevation arid sandy land

Basic model: use cuttings of domestic poplar species for deep planning at plateau alpine sandlands for significant increase of the survival rate, increased vegetation coverage for wind breaking and sand fixing.

Problem solved: Increase the survival rate of afforestation, add vegetation cover of forests and grasslands and reduce the flow of dunes.

Suitable area: cold plateau sandy land.

Overall assessment: afforestation of poplar in arid sandy land can increase the survival rate of afforestation without irrigation, effectively increase vegetation, prevent wind erosion and sandification and reduce sand dune hazards. In the 1990s, the technology costed USD 448.83 per hectare, and the maintenance USD238.19 per year.

(8) Poplar pulpwood development in sandy area

Basic model: The mobile sand dune is leveled with mechanical measures and with irrigation in place for development of raw material forest of poplar for paper industry.

Problem solved: Improve the environmental condition while serving regional economic development.

Suitable area: Sand area with irrigation condition.

Overall assessment: The technology makes full use of the resources of sandification land to cultivating raw materials for papermaking companies, with roles in treating sandification land, increasing forest coverage, improving ecological condition, and generating income for enterprises and farmers. At the beginning of this century, the technology costs USD4438 per hectare, and maintenance cost at USD504 per year.

(9) Seed dressing for afforestation and grass cultivation

Basic model: Seeds of sand-fixing plants such as Hedysarum scoparium, Hedysarum mongolicum, Caragana korshinskii, Artemisia sphaerocephala, and Astragalus adsurgens are coated with a multi-functional coating agent for increasing germination rate of aerial/artificial seeding and maintenance rate of seedlings.

Problem solved: increase the seed germination rate and seedling maintenance rate.

Suitable area: suitable for artificial or aerial seeding.

Overall assessment: The technology helps improve the seedling rate and maintenance rate of aerial/artificial seeding with good effects in rapidly recovering forest vegetation, sand fixing and improving local ecological conditions. In 2010, the technology costs USD44 per hectare(including the cost of seeds).

(10) Licorice cultivation in sandy land

Basic model: Through artificially raising the planting stock and seedling transplanting, the licorice (Glycyrrhiza uralensis) plantations are cultivated on sandy land for preventing land sandification and increasing the income of farmers and herdsmen.

Problem solved: an alternative for the indiscriminate excavation of natural licorice, favorable for protection of the original vegetation on desert areas. While treating land sandification, the farmers are guided to get out of poverty.

Suitable area: sandy area with irrigation conditions.

Overall assessment: This technology based on farmer planting of licorice so that a large area of sandification farmland and sandification wasteland is effectively utilized. The primary vegetation and natural licorice resources are protected. At the beginning of this century, the technology costed USD2365 per hectare and the maintenance cost for USD192s per year.

(11) Forestation in rainy season

Basic model: the Caragana korshinskii seeds are sowed on suitable land in rainy season to prevent soil erosion on slope surface.

Problem solved: improve the survival rate of forestation, promote vegetation recovery in cold and dry upland with reduced soil and water erosion.

Suitable area: forestation-suitable with spring droughts.

Overall assessment: The technology is simple, cost-effective with quick results, and effective for forestation in arid mountainous areas. In 2010, the implementation cost of the technology was USD713.4 per hectare and the maintenance cost USD36.85 per year.

(12) Coniferous-broadleaf mixed forestation in semi-arid area

Basic model: Use a mixed species of conifer and broadleaf to create shelterbelts in semi-arid sandification area.

Problem solved: Improve ecosystem stability, prevent pests and diseases, prevent forest fire and improve soil fertility.

Suitable area: mixed cropping-pastoral areas with serious land sandification

Overall assessment: Coniferous and broad-leaved mixed forest has significant ecological benefits and is taken as better forest type than the single-species forest. At the beginning of this century, the implementation cost of this technology was USD 480.88 per hectare and the maintenance cost was USD 59.6 per year.

4.1.4 Grassland degradation control system

When degraded, the grassland nurtures much less good fodder species and available forages tends to deteriorate with reduced grass production per unit area.

Grassland degradation is a type of land degradation and the main form of desertification. To combat the degradation of grassland, the basic approach is to rationally develop the biological resources, land resources, and water resources in the grassland area by maintaining grass-livestock carrying capacity balance and by protecting the grassland ecological condition.

(1) Enclosed grassland (Caokulun)

Basic model: The sandificated grassland is enclosed in form of blocks for scientific treatment arrangements of grass, water, forest and fodder to realize the intensive development of sandification grassland treatment and animal husbandry development.

Problem solved: Restore the ecological condition of sandificated grassland in pastoral areas with improve the livelihood of the herders.

Suitable area: sandification land with comparatively good soil and water conditions.

Overall assessment: the technology has significant roles in managing the sandificated grassland, promoting grassland ecological restoration, improving pastoral ecological condition. It is also conducive to the in-depth cultivation of herbivorous livestock husbandry for sustainable socioeconomic development of the pastoral areas. In 2011, the implementation cost of one Caokulun was UDS 15531 and the maintenance cost was USD1088 per year.

(2) Penned livestock raising

Basic model: the ecological protection measures such as grazing ban is implemented on seriously degraded grassland pastures to decentralize the population and livestock in severely degraded areas, reduce grassland grazing pressure, promote natural grassland regeneration, and restore the vigor of degraded grassland.

Problem solved: the degraded grass is rehabilitated.

Suitable area: areas with severe carrying capacity imbalance of grass and livestock.

Overall assessment: This technology is significant for improving the ecological condition and ecological restoration and conducive to local industrial restructuring to realize socioeconomic sustainable development. The technology cost was USD73.5 per hectare at the beginning of the century and maintenance cost USD 5.1 per year.

(3) Planned rotational grazing

Basic model: By weighing the grassland productivity, the grazing land is divided into a number of plots. According to the pasture carrying capacity of each plot, the grazing duration is determined to each plot to form a system of rotational grazing.

Problem solved: all natural grassland with rehabilitation opportunities to rejuvenate.

Suitable areas: natural grasslands that have begun to degrade.

Overall assessment: the technology helps protect the natural grassland, speed up the recovery of degraded grassland vegetation and improve the ecological condition in targeted areas. It can increases the vegetation coverage and yield by more than 30%, and add livestock carrying capacity by 15% when the degraded grassland demonstrates the tendency of positive succession, which facilitates the herdsmen's income in long term. This technology is suitable for severely degraded areas of grassland. At the beginning of this century, the technology was implemented at a cost of USD 111 per hectare and the maintenance cost USD 0.9 per year.

(4) Mountain closure with grazing ban

Basic model: In order to protect site vegetation, the designated forestland, grassland etc. are enclosed while the grazing management measures are prohibited.

Problem solved: Serious soil and water erosion caused by overgrazing.

Suitable area: hilly areas with serious soil and water erosion.

Overall assessment: the technology as an effective management approach of preventing land degradation has low cost but significant ecological benefits. It is suitable for areas with severely degraded vegetation. At the beginning of this century, the technology cost was UDS 235 per hectare and the maintenance cost for USD10 per year.

(5) Supplementary sowing at degraded grassland

Basic model: use the seeds of superior Gramineae species for sowing at degraded grasslands of high-cold areas to improve vegetation coverage and pasture production.

Problem solved: grassland degradation.

Suitable area: heavily degraded alpine grasslands.

Overall assessment: The project can be funded by the government for quick recovery of grassland vegetation. The technology can increase vegetation coverage, reduce surface runoff, improve water retaining capacity, add grass production, generate labor income opportunity to herdsmen for better-off livelihood. The technology is simple to operate with high replicability. The herdsman can also learn how to plant fodder grass for improved livestock management. At the beginning of this century, the technology costed USD210 per hectare and the maintenance cost for USD14 per year.

(6) Protection forests on sandificated grassland

Basic model. Strips of shelter forest are planted on sandificated pasturelands to form a protective barrier with appropriate height and standing density, for preventing wind and sand, protecting the grassland and improving pasture production and quality.

Problem solved: the quality of the grassland declines and wind erosion and land sandification are serious.

Suitable area: grass pastures with serious wind erosion sandification.

Overall assessment: the technology is an useful approach in restoring degraded grassland ecosystem. As an effective way to increase the yield and quality of forage grass, it helps reduce wind erosion, preserve winter snow, increase soil moisture and soil fertility, and improve grassland ecological condition for higher productivity. The comparison of the project area and the non-project area indicates that the pasture grass height, coverage and yield of the project area are significantly improved. At the beginning of the century, the technology was implemented at a cost of USD1007.2 per hectare and the maintenance cost was USD201.4 per year.

(7) Mixed sowing of pasture grasses

Basic model: seeds of two or more species of pasture grass are mixed for sowing ad cultivation at the same time and on the same plot improve the degraded grassland.

Problem solved: the grassland is degraded with declining artificial fodder grass resources.

Suitable area: degraded grassland.

Overall assessment: the technology helps to improve the fodder grass quality and yield, extend grassland use period, improve soil condition by adding soil organic matter and reduce pests and diseases. The mixed sowing of legumes and Gramineae grasses is most economical. The technology requires long-term government investment. In 2008, the technology would cost USD 307 per hectare and the maintenance cost for USD 10 per year.

4.1.5 Land salinization control technology system

Land salinization is relevant to high spatial variability with direct affect from crops, soils and climate. The differences between regions are often obvious so adaptable specific analysis should be made to determine most suitable treatment methods.

(1) Salt drainage ditch

Basic model: the farmland drainage system is established to control the groundwater below level of the crop roots to troll the salinization.

Problem solved: Reduce the salty and alkalinity of the soil.

Suitable area: salinized land area.

Overall assessment: The technology helps improve soil fertility by facilitating the cultivation condition for increased economic income from crop yields. The technology is demonstrated at Gaotai of Gansu. At the beginning of this century, the technology costed USD 3,310 per hectare and the maintenance cost USD 366 per year.

(2) Transformation of saline-alkali land

Basic model: The demonstration area for this technology is at Urad Front Banner, Inner Mongolia of China. This technology is conducted by firstly digging salt-drainage ditch irrigated salt washing for then plantation of saline-alkali tolerant plants to further remove the alkali content for improved soil functionality.

Problem solved: low-lying terrain farmlands with poor drainage, irrational irrigation and serious salinity.

Suitable area: the Hetao irrigation area of China.

Overall assessment: The technology made it possible to reverse saline-alkali processes for land utilization. It reminds the farmers of the high necessity to drain farmland, rotate salt tolerant crops when cultivating the salinity prone lands. At the beginning of the century, the technology was implemented at a cost of USD 402.6 per hectare and the maintenance cost USD 137.2 per year.

4.2 Scaling up of sustainable land management technologies

China has been actively exploring countermeasures and approaches for land sandificaiotn prevention and control. The current technological scaling up) models integrates requirements regarding improving ecological condition, improving farmers' production and living conditions, increasing the income of farmers, restructuring the local industrial development and improving the governance and related capabilities. The sustainable land management technological dissemination deserves wide participation and diversity of investments. The current technological dissemination model of sustainable land management in China can be generally divided into the types driven by funds, policy, project, scientific and technological demonstrations and social forces.

4.2.1 Fund driven technological scaling up

(a) Government funded projects

This kind of project as full-public welfare project is financed by the central government. For example, the railway and highway sandification prevention and control technology is aimed at sand fixing on both sides of the railway lines or the highways to protect the traffic from sandy harms. With the state finances, the scientific research institutions conduct experiments and demonstrations to resolve the key technological constraints and designs. Afterwards, the Chinese Academy of Sciences and the railway and forestry departments will organize manpower and equipments to implement the project and the railway sand-fixing forest farm will be responsible for the post-completion management work of the project. The land of the project area belongs to the state, and the state investment contribution, scientific research department's technological contribution, and railway department's coordinative construction combines to put the sand control and ecological restoration technology into practice with establishing dissemination systems and theoretical models. This dissemination model is suitable for wholly public-welfare sandification prevention and control project. At present, this technology has been widely used in the construction of roads and railways in sandy areas, and in cultural heritage protection project such as the Dunhuang Mogao Grottoes protection project, Xinjiang Taklimakan Oilfield highway construction project, Qinghai-Tibetan Railway sandification prevention and control project, and the Green Corridor of the Republic of Mali and so on.

(b) Joint investment project by government and enterprises

Such projects are wholly public welfare projects funded jointly by the central government and enterprises such as the desert highway biological protection system. The purpose of the technology is to promote the safe operation of highways in sandy area, protect other construction projects from sand threats and damages. For example, with the joint investments of the National Development and Reform Commission and China National Petroleum Corporation and under the direct organization by the Tarim Oilfield Branch, the scientific researches were conducted by the Xinjiang Institute of Ecology and Geology, the Institute of Cold and Arid Regions Environmental and Engineering Research of Chinese Academy of Sciences and the Daqing Oilfield Construction and Design Institute with related scientific experiments and demonstrations to resolve key technologies and to complete technological design, for construction by eligible construction units by organizing manpower and equipment's and by establishing specialized forest plantation team to look after the planted vegetation. The technology has high inputs but low economic output. It is aimed mainly at the Tarim petroleum and gas exploitation by safeguarding the traffic lines located in Tarim desert. For which the oilfield company will sustainably use the technology by maintaining the forest shelters. The technology is suitable for enterprises or national projects with similar needs, and unfit for the scaling up to most farmers.

(c) Governmental investment project with land user participation

By this dissemination model, the project is financed by public finances but the land users can participate in the project implementation in different forms and provide post-completion tending services to get obtain economic revenues. There are two main types:

(1) BOT

BOT stands for Build-Operate-Transfer which means the government finances and construct the project with the land offered by the farmers who will be actually responsible for tending management following the completion acceptance of the project. The technologies suitable for this model includes “Tree planting side cages “in which the stated financed sandification control projects shall provide the seedlings and cages and organize the forestation, and when the checking indicate that the survival rate meets certain standard, the forestland management and protection rights are transferred to farmers free of charge. In this dissemination model, farmers should donate the land use right and forest tending services so their participation enthusiasm was high. This model has been adopted by the projects of Farmland Conversion, Natural Forest Protection etc. With the deepening of forest land tenure reform and with the advancement of forest ecological compensation mechanism, the farmer’s enthusiasm for BOT will be enhanced. With the demonstrated good maintenance rate of forestation, some private companies have also begun to use this technology. Due to the high quantity of farmers for participation, currently some researches are conducted to reduce the pressure of government investment by forest shareholding participation for better dissemination performance.

(2) Government funding with farmer labor

In this dissemination model, the project is funded by the government with unified organization and implementation of by finalizing the arrangements of land and participants etc. and the farmers provide free labor to project construction and maintenance with the project revenues belonging to the farmers. The dissemination model was adopted by the Qinghai Mountain Farmland Protection Forest project in 1980s, this project investment plan was arranged by the provincial Forestry Department arranged, and the county forestry bureau and the township government coordinated with the Village Committee to organize land users to carry out the forestation activities. The government provides seedling fees and farmers conduct the forest planting and maintenance free of charge. With the established farmland forest shelterbelts gradually expanding from the original terraced platforms to the farmland roadsides, farmland slopes and the forestation technology became matured and standard playing effective roles in controlling soil and water erosion, maintaining soil fertility with ecological and socioeconomic benefits. The technology has now been adopted by the Small Watershed Integrated Management project led by the water resources departments for the comprehensive management of forests, mountains, farmlands, water and roads. With the changes of social production structure, the rural labor force tends to conduct non-agricultural activities which makes labor cost rise so it is now very difficult to organize free labor services as in the 1980s. In addition, forestation of a single species with little economic benefit in the short term and vague forestland ownership etc. has affected farmers' enthusiasm for afforestation. To this end, the model should be practiced in combination with measures of clarifying forest property rights, adding governmental afforestation finances, improving forest management techniques, cultivating high-quality fast-growing tree species while providing ecological compensation for public welfare forests so that land users can benefit tangibly from forest by sustainable technological application.

(3) Government-led project with land user participation

In the dissemination model, the government provides funds, the farmers provides land and the farmers provide paid labor and the benefits are owned by the land users. The dissemination model applies to the technologies of “forestation with plastic mulches”, “seed sowing for forestation during rainy season”, “conifer-broadleaf forestation in semi-arid area”, “supplementary seed sowing plantation of degraded grassland”, “sandificated grassland forest shelterbelt “and “farmland forest shelterbelt” etc.

The plastic film mulched forestation technology which is demonstrated in Bahrain Right Banner, Inner Mongolia of China relies on the Beijing-Tianjin Sandsource Control Project, the Farmland Conversions into Revegetation Project, and the German funded forestry projects such as Germany. The SFA determines forestation tasks by unified planning so that the Forestry Department of the Inner Mongolia Autonomous Region can allocate afforestation tasks to the prefecture cities, and the Forestry Bureau of Chifeng city can allocate forestation tasks to each Banner Forestry Bureaus that will negotiate with the township forestry stations for forest farms or farmers (herdsmen) to sign the land use agreement. The Banner Forestry Bureau will purchase the tree seedlings and carry out forestation technical training in unified manner, and organize forest farms and farmers and herdsmen to do tree planting on their contracted lands with paid labor. After the afforestation, the land users or the forest farm staff will take care of the established trees and the benefits from ecological compensation and thinning goes to the land users. The mulching forestation improves the survival rate and maintenance rate of the forestation by raising the temperature and moisture, and the farmers participate in using the technology as beneficiaries by ensuring the implementation quality of the project. With the exemplary role of the project, the surrounding areas and provinces are now adopting this technology. The short-term economic benefits of the project are low, so it is necessary to increase the government subsidy in the initial implementation stage of the project.

In the dissemination of other technologies, the government offers the project finances, the provincial level departments of forestry, water resources offers supervision, and county and township people's governments organize village farmers and herdsmen to carry out the field work. Farmers and herdsmen receive labor payment by carrying out project activities. With the implementation of collective forest tenure system reform in agriculture and pastoral areas, farmers and herdsmen have acquired the land use rights forestland and ownership right of the forest.

(4) Governmental support with local participation

In this dissemination model, the government provides certain forms of support to the project while the farmers provide free labor contribution for specific implementation on their own land to help farmers solve practical problems. The costs for project maintenance are also borne by the land owner. The dissemination model is for the technologies of “saline-alkaline draining ditch”, “mechanically recovery of residual plastic film” etc. In practice, the government carried out unified management to finalize the project lands and participants, the planning design for field construction.

(5) Governmental investment with encouraged local participation

Warping dam, check dam are very effective in controlling soil and water erosion. However, due to the relatively high construction costs, these technologies are usually executed with governmental finances that drive additional enterprise investment. By publicity for raising awareness and offer of priority use right of the silted lands, the farmers are encouraged to participate by offering labor.

(6) Governmental financed project with mobilized local participation

The technology of “enclosed grassland for controlling sandification (Caokulun)” is conducted in key construction projects led and planned by the government that also provided technical services. The township government organizes construction, and the herdsmen undertake field construction operations. The grasslands contracted to households are categorized for fenced protection, and for irrigation facilities establishment on grasslands with good water and soil conditions. Such household based Caokulun project, involves planting pastures for restoring degraded vegetation, with the expenditures of the wells, greenhouses, silage shed, fences and survey and design are paid by the government and the herdsmen worked without payment. Now the "Caokulun" model has been used in development to adapt new situations. The evolved from include currently “enclosed grassland (sandland) Caokulun”, “integrated tree-shrub-grass Caokulun”, “integrated planting-livestock-processing Caokulun”, and “Caokulun equipped with facilities of water, grass, forest, fodder and machinery” etc. The initial investment is high so substantial portion of the expenditures should be covered by the dissemination department in form of incentive or project support to the herdsmen who will otherwise not use the technology.

(7) SLM scaling up with government subsidies

The government uses various subsidies to assist farmers adopt certain technologies, including the “Crop straw residues returning to farmland”, “green manure planting”, “pasture grasses mixed sowing”, “solar cooker”, “biogas digester” and “wind/solar energy” etc.

“Crop straw residues returning to farmland” is developed with the change of rural production and life style for which crop straw has no longer been used for heating and cooking as before by Chinese farmers. Instead in many places they simply burn it, which not only leads to air pollution but also unconducive to the maintenance of soil fertility. Since 1999, six Chinese ministries and commissions including the National Environmental Protection Agency etc. jointly issued the order of “Straw burning ban for comprehensive utilization” followed by related circulars and plans by local governments. By these official documents there formulated a series of subsidy policies for farmers’ adoption of the technology (e.g., 30% subsidy for expenditure of buying crop straw returning machines). With vigorous publicity the farmers are mobilized to take part in the technology training which has helped its dissemination across the country. The technology play roles in reducing air pollution, increasing the so physical and chemical properties relevant to fertility, organic matter, soil pellet structure, thermo-moisture and air permeability. However, there are still some technical defects such as incidence of weeds, diseases and pests in the coming year. The nitrogen will also be consumed due to straw decomposition with excessive transports on soil surface. Therefore, further research is needed on the technology.

“Green manure planting “is usually practiced in projects led by government by organizing and guiding farmers to cultivate green manure. The project publicity would improve farmers' fertilization awareness by holding farmer field schools, on-site exchange meetings with distributed publicity readings and CD-ROMs to increase the enthusiasm of farmers in using organic fertilizers. At the same time, the project may subsidize farmers' purchase of seeds and rhizobia. Through raising the awareness of farmers and herders regarding the green manure function on fertility, the integration of conservation and utilization, alternative fertilizer use, as well as demonstration of improvement of soil organic matter and aggregate structure after the cultivation of green manure, and the increase in crop yield, farmers gradually adopted this technology. At present, with the government advancement of structural reforms on the supply side of agriculture, the agricultural restructuring and the transformation of production means, the promotion of agricultural quality and benefits have become the consensus of the whole society. More farmers especially the new-generation agricultural management entities are increasingly aware of the importance of fertility, cost-effectiveness and development of green manure. Green manure cultivation has a broad market prospect in China.

“Pasture grasses mixed sowing” ecological application is mainly supported by government investment with local counterpart fund. The project provides finances for grass seeds, field construction and pest/disease control and the herdsmen invest by their labor. The project has good role in improving forage quality. However, if there is no project support, the herdsmen will not adopt the technology. With the project dissemination role, large contractors and enterprises are not gradually applying for national special funds for building mixed grass seeds sowing pastureland.

“Biogas digester” and “wind/solar energy” technological application are subsidized and encouraged by the government. As these new technologies bring convenience to the life of farmers and herdsmen for improved living standards, they became welcome easily among farmers and herdsmen.

4.2.2 Government driven SLM scaling up

（1）Government-lead project with stakeholder participation

Under this dissemination model, the government provides land, concessional loan and technical training for enterprises and farmers to contract the land and to invest for technological application. The dissemination model applies to the technology" farmland ridge shrub + tableland economic forest" adopted in Gansu Province. In Gansu, the production was initially implemented wholly by the government with paid labor from the local people and the planted economic forest belonged to the state. Due to inappropriate tending little output were produced, so the government provided concessional loans, preferential policies and tax-exempt production management to enterprises to improve the situation. Consequently, the enterprises invested in the management of the shrubs and tableland economic forests with good results. Specifically, the government provides each land user with loan not more than 1 million yuan with training of relevant policies and technologies to the horticultural enterprises and local farmers who as land contractors shall resolve such resources as tree seedlings and tractors. The free use of forestation-suitable barren hilly lands with long contracting period and expectation of fruitful return fortifies the wishes of fruit companies to venture to invest. This technology has been extended widely in the loess gully regions of Gansu.

(2) Government mandatory measures

In order to protect and nurture resources for improved ecological condition, and in accordance with relevant laws and regulations and actual local situation, the government adopted mandatory measures for application of certain technologies. For example, in Wuqi County of Shaanxi province, the "mountain closure with grazing ban" was adopted with the livestock for penned keeping. Shaanxi province by its responsibilities and tasks allocation to lower level governments, carried out the design and planning. The herdsmen household that implemented the standard technology as scheduled received incentives for with related technological dissemination achieve built. The technology is very effective in protecting forest and grass vegetation, so has been nationally extended. However, due to the low awareness of ecological protection, it is hard to avoid theft grazing, which indicates the importance of strengthened education to farmers regarding importance of soil and water erosion and sustainable land management. In addition, investment should be expanded with formulated subsidy policies in place, and livestock husbandry experts should be organized to conduct free training to farmers on livestock pen construction, silage feed etc. At the same time, it is necessary to strengthen the closure for rehabilitation inspection mechanism. Livestock husbandry is the important income source of farmers in mountainous areas, so scientific planning, stagewise categorized implementation of grazing ban are necessary. This will not only benefit the development of forestry, but also avoid some conflicts in the process of implementation to sustainably benefit the farmers and herders with win-win in forestry and animal husbandry.

4.2.3 Project-driven SLM scaling up

(1) Enterprise led technology application

The enterprise initiates the technology application for governmental approval and support, such as the “Sandy area poplar pulpwood raw material forest “project in Ningxia. The project was started by the Ningxia Mingli Paper Company with the approval of the People's Government of Ningxia Hui Autonomous Region and the State Development Planning Commission. The project funds are mainly bank borrowing by the Company with subsidiary finances for the state for forestation and water conservancy facilities construction. Three application models are available for project participation namely the enterprise independent operation, shareholding cooperative operation, company plus farmers. Specifically the Company established its own pulpwood forestation base; The shareholding forestation base company was formed by cooperation of the state-owned farms or joint-venture township(village) enterprises for shareholding mechanism based production management; The “company plus farmer” model means the low-yield farmland was reconstructed for forestation by the farmers to supply in priority based on prior contract the harvested wood to the Company. Due to the policy restriction of the afforestation base, this model is no longer implemented locally.

(2) Industry guided technological application

Based on the principles of sustainable development and optimization of ecological management, and in accordance with the local conditions of resources, location and phenology etc., local featured industries are promoted by land use industrial development based on the ecosystem characteristics for economic and ecological development. Industries are the foundation of economic development, so the industry based economic development helps benefit farmers. The technologies for the dissemination include “licorice cultivation”, “Salix psmmophila coppice planting” and “grape planting”.

“Licorice planting in Ningxia”. In order to disseminate the technology, the government issued a series of policies to consolidate project finances such as the concessional agriculture loans. At the county level, the licorice demonstration zone is established with the operations by enterprises or large-area planting household. At the same time, the government provides free seedlings for the households and farmers to set up at the township level 20 thousand-mu demonstration parks. And each administrative village suitable for licorice cultivation also establishes demonstration sites with a number of licorice plantation technology demonstration households for extending the planting scale. In terms of technological support, the government departments cooperated with the research institutes to resolve technical problems of high-yield cultivation, pest management, deep processing of products etc. The county science and technology bureau sent technology commissioners to planting sites to offer consultation to farmers by holding training courses and site-learning demonstrations. At the same time, the government makes efforts to nurture the developments of distribution companies, medicinal processing companies and specialized cooperatives of Chinese herbal medicines with brokers engaged in related marketing services. As the result, one licorice market was established in Yanchi County with satisfactory sales and job opportunities for the local people. With the development of social economy and the "brand strategy "of Ningxia, "Yanchi licorice" was certified and registered as a source production area trade mark. With the efforts of environmental monitoring, product quality control and vigorous advertisement, the Yanchi licorice industry, licorice history, and licorice culture became well-known products with high market recognition. In recent years, with the in-depth research development of licorice medicine, the market demand for licorice has been increasing and the market prospects have become even wider.

"Salix psmmophila coppice planting" Inner Mongolia. The Salix psmmophila processing enterprises are supported to boom the market demand and stimulate farmers in planting cultivation.

"Grape planting in Ningxia". The local grape planting base and wineries are established and source production trade mark was approved for protection upon application. At the same time, the Helan Mountain Grape Culture Town has been conceived for approval to develop winery with attracted domestic and foreign investments which further promotes the grape plantation.

(3) Key project driven SLM scaling up

The dissemination of certain technologies, such as "aerial seeding for sandification control" has requirements beyond the capacity of common farmers for independent implementation. These technologies are generally implemented through key projects. The demonstration area of the technology is located at the Dalate Banner of Inner Mongolia. In practice, following the issuance of project assignment from the State Forestry Administration, the Autonomous Region will break down the assigned task each Banner Forestry Bureaus who shall carry out planning design of the area and technical implementation procedures. Generally the use rights of the aerially seeded lands belong to farmers and herdsmen, but due to the poor fertility, low utilization rate, and remote location, the farmers and herders welcome national investment for and would sign agreements with township governments for aerial seedling. The cost of aerial seeding for vegetation recovery is paid by the government with the tending management performed by the farmers and herdsmen. Future land ecological compensation and coppice revenues accrue to the farmers and herdsmen, so their participation enthusiasm is very high.

4.2.4 Participation of the social forces

(1) Non-governmental organization

Many non-governmental organizations and enterprises in China are engaged in public welfare activities such as environmental protection. For example, the Chinese Women's Development Foundation has carried out the charity project "Mother's Water Cellars" since 2001 which focuses on helping the people in western China especially the women get rid of poverty and backwardness for severe water shortages; The Alipay's "Ant forest" project promotes Carbon Green Life by energy saving , emissions reduction for accumulating "green energy "for forestation in the Alex Desert of Inner Mongolia. This model has high environmental protection significance in mobilizing the general public for environmental actions by carbon trade. In addition, some individual companies or non-profit organizations projects have carried out a number of forestation projects to control land degradation.

(2) Sustainable charity with commercialized sandification control

With the government's policy support, the company can make public welfare investment in form of industrial development with market based participation by farmers and herdsmen. This dissemination model promotes desert economic development with the environmental charity to achieve win-wins of "ecology, economy and people's livelihood". At present, the Yili Group Corporate has adopted the model in Inner Mongolia. The Cooperate started by sandification control in Kubuqi Desert and became successful in sand-controlling related industrial development shifting the ecological restoration from a public welfare activity to the industrial service activity.

4.2.5 Technological demonstration

Scientific research achievements are disseminated to promote land degradation and sand industrial development. For example, "Haloxylon ammodendron inoculated with Cistanche deserticola technology" was initially a governmental research project" Study on the Comprehensive Supporting Technology for Artificial Inoculation of Cistanche in Arid Desert Area in Alex" in Inner Mongolia. After three years of research, a set of artificial inoculation techniques and cultivation models which innovatively resolved the technical constrains of artificial inoculation of Cistanche deserticola. This technical achievement was assessed as a domestic leading technology, upon the trial use in the local Sandification Control Station. Due to the high herbal medicinal value of Cistanche, the farmers, herdsmen and enterprises have requested to adopt the technology. At present, there are many Cistanche industrial production bases in China.

V Scaling up strategies of sustainable land management technologies in China

5.1 Goals

The Chinese government starting from its “ecological civilization construction” blueprint has incorporated land degradation control into the national sustainable development overall strategy, for comprehensive and continuous advancement of land degradation prevention to strengthen ecological protection and restoration, improve environmental management, fortify ecological safety protection mechanism, and enhance national ecological well-being. China's land degradation prevention and control objectives are formulated for promulgation by the State Council and its relevant government departments in forms of master plans concerning land degradation (and land degradation zero-growth) including the “national territorial land plan outlines, “national sandification prevention and control plan”, “national forest management plan”, “national soil and water conservation plan”, “national plan for grassland protection, construction and utilization”, “wetland protection and restoration regulations”, “action plan for soil pollution prevention” , “national farmland protection plan”, “zero-growth action plan for chemical fertilizer and pesticide use”, “ecological protection red lines” etc. These plans as starting points and baselines supervises the construction of safe, harmonious, green, sharing and sustainable ecological condition and living environment, and the construction of a beautiful China with friendly environment, ecological harmony, territorial and food security to contribute to sustainable development of the mankind.

Sustainable land management implementation and dissemination are the basic measures for achieving the overall objective of ecological civilization and land degradation control in China. The incorporation of sustainable land management measures into the overall development strategy of national ecological civilization construction and sustainable development, allows the sectoral departments take sustainable land management measures in fields of legality, policy, projects, science and technology and finances. The sustainable land management measures of Chinas take as basic means the UN sustainable development goals in 2030 regarding land degradation zero growth in combination with the synergy execution of the UN desertification convention, the UN climate change convention, the Paris Agreement and the UN convention of biological diversity etc. In local land management planning of China, sustainable land management measures is also taken as basic measures for development.

5.2 Challenges for adoption of sustainable land management measures

5.2.1 Long-term complexity of adoption of SLM measures

The special historical, physical geography and socioeconomic conditions have determined that land degradation control in China is long-term, arduous and complicated undertaking. Due to specific historical reasons and the large population, land degradation is one of the most prominent ecological problems in China. Land degradation in China has diverse types, wide distribution, huge acreage, severe damage complicated causes. With the fragile natural ecosystems and frequent disasters in most regions, land degradation control faces immense challenges. Sustainable land management measures must adapt to Chinese complicated diverse land degradation types for which and it is difficult to choose the appropriate sustainable land management model.

5.2.2 Shortage of finances and inputs

There is still a large gap between actual input and demanded input for land degradation prevention and control, and between control processes and planned targets of national ecological construction. Over a period of time, the general investment for combating land degradation remained at relatively low level resulting in extensive management in some regions without significant control achievements or with difficulty in maintaining the treatment achievements. With the increasing difficulty of treatment and the rise of treatment cost, the resources input have been on rise. Inadequate inputs led to slow progress in treatment, growing gap between the requirement for land degradation control and national ecological construction for a comprehensive well-off society.

5.2.3 Conflicts between existent institutional mechanism and the demand for accelerating the treatment

The management of land degradation involves many sector and departments, for which the coordination and cooperation should be strengthened. Currently the coordination mechanism between departments, regions and projects has not yet been fully formed, with the key stakeholders undetermined, the resources distribution in imbalance. Each sectoral department tends to emphasize its own authoritative interests neglecting effective cooperation with other department. Absence of joint force is not conducive to the smooth development of land degradation prevention and control. In addition, The linkages between existent laws and regulations do not facilitate the advancement of the prevention and control of land degradation. There are still phenomena of neglecting the lawfulness, instrict observation of laws and lack of enforcement to illegality.

5.2.4 Pressures of ecological protection and resources utilization

There are conflicts between land degradation, resource constraints and development utilization. China has entered a period of relatively rapid economic development for which the demand for resources has increased. With the economic growth, the social requirement to the living environment became higher, resulting in both socioeconomic opportunities and pressures for land degradation control. The rich resources of coal, minerals and petroleum in western China is the foundation for future large-scale economic construction, so it is of both high significance and a great challenge to coordinate for a balance among resources use, economic development and ecological protection for sustainable land management for multiple benefits.

5.2.5 Huge gap between the actuality and development targets

At present, sustainable land management measures are based on the accumulated lessons and experiences of ecological construction, land degradation prevention technologies, construction models in China over the past decades. Some technology models have applicability and dissemination values while other has no longer to adapt to the changed socioeconomic development requirements. In particular, China has entered the middle to late stage of the industrialization process, the rural labor force has been shifted to the urban resulting in severe shortage of rural labor and quick rise in labor prices. Various industries such as the building industry occupy land resources resulting in rises of land prices. Traditional agriculture, forestry is facing high competition of new types of industries. All these make the long practiced land management models and technologies no longer workable.

5.2.6 Scientific and technological strength incompatible with ecological construction and land degradation control

The current collection of hundreds of models and cases reflects mainly traditional land management practices and many recent scientific and technological achievements utilized. To give full play to the role of science and technology in the land degradation management, it is imperative to strengthen the scientific and technological scaling up of sustainable land management models to meet the field requirements of land degradation control and ecological construction in new era.

5.2.7 Current SLM models unfit for the new normal of Chinese economic development

Chinese economy has progressed from the stage of pursuit of speed to that of pursuit of quality and benefits for which there have been and new dissemination models of eco-tourism, forest promotion of health, desert park etc. that combines ecological conservation, industrial utilization and regional development. The current sustainable land management models have not included these forest new models so awaiting improvements in meeting the latest trends of economic construction and ecological restoration.

5.2.8 Land management measures imcompliance with global sustainable development

To address impacts of climate change the most serious environmental and development challenge for mankind, most countries have put forward corresponding actions and measures. Climate change brings new challenges to land degradation management because climate change has been the key stress factor of the global ecosystems. Climate change leads to incidences of extreme weather and climatic events, unbalanced distribution of water resources, continuous droughts and floods causing decline of land productivity, soil and water erosion and thereafter deterioration of the fragile ecosystem and land degradation. To this end the additive effect of climate change and human irrational production activities will form new and more severe challenges to land degradation management.

As basic tools for land degradation management, sustainable land management measures have to overcome numerous challenges to achieve synergies of benefits.

5.3 Opportunities for extending sustainable land management measures

5.3.1 China makes blueprints of the Ecological Civilization construction goals

The strategic ecological civilization construction has provided an unprecedented historical opportunity for the prevention and control of land degradation. China has included the construction of ecological civilization into the “five-in-one” overall blueprint along with the economic construction, political construction, cultural construction and social construction. The basic principle of "Priorities in conservation and protection, with the natural restoration as main measure “and the ideologies of “respecting nature, conforming to nature, and protecting nature”, the “green development, cyclical development, and low-carbon development” have be promoted to restore the natural ecosystems. Pollution control will be conducted by strictly following the promulgated eco-environmental ecological red lines and by implementing the comprehensive prevention and control measures of desertification, rocky desertification, soil and water erosion to improve the ecological condition for coordinated sustainable development of resources and socioeconomics.

5.3.2 Reforms provides regulatory assurance of land degradation management

The restructuring of the ecological civilization system is an important part of the overall deepening of reforms. To build up a beautiful China with the ecological civilization, regulatory assurances and institutional mechanisms should be promoted for development of the national territorial space, the conservation of resources, and the protection of the ecological condition, for the harmony of man and nature in new pattern and new era. The future ecological protection and land control of China will adopt the strictest source protection system, damage compensation system, and accountability system for improved environmental governance and ecological restoration. At present, China has carried out the in-depth institutional reform by following the principle of "one type of affairs is responsibly managed by one department" based on the unified management of resource utilization, protection, and supervision. In the future, the management of land degradation will be conducted by one department that will facilitate the coordination of the line agencies and departments.

5.3.3 Economic development provides material basis for sustainable land management

The rapid and steady economic development and the comprehensive improvement of national strength have provided material basis for the prevention and control of land degradation by enabling the higher priority on policy making of sustainable ecological protection. The financial investment has continued to increase, and the vitality of non-public sector in resources allocation has come to be demonstrated. Advances in science and technological innovations in equipment have also injected new vigorous support for ecological protection and land degradation.

5.3.4 UN goal furthers international cooperation in land degradation control.

The UN Sustainable Development Summit successfully held in September 2015 adopted the UN sustainable development agenda in 2030 blueprinting the global development direction and the international cooperation in next 15 years. Implementation of the UN sustainable development agenda in 2030 is the core part of international development and inclusion of the objective of zero-growth land degradation into the UN agenda 2030 reflects the international community's high priority for land degradation. With this favorable conditions for international cooperation in land degradation control, the Chinese government has acted actively and in September 2016 the Chinese Premier Li Keqiang hosted at the UN headquarters in New York the discussion meeting "sustainable development goal: work together to transform our world-China's position" to announce " Agenda of China for implementing the UN sustainable development goals in 2030.

5.3.5 Rising ecological awareness and higher requirements for the ecological condition

In recent decades, China has achieved remarkable achievements in economic construction. With the improvement of people's living standards and quality of life, the whole national is paying increased attention to the problems of ecological condition and the awareness of environmental protection has been increasingly improved with higher demand for ecologically friendly living and working environment. Accelerating the pace of environmental construction and land degradation prevention and control, building beautiful China, and improving the ecological quality have become national consensus and eager expectation of the people, and the related performance is a key indicator of achieving the grand goal of "overall well-better-off society".

5.4 Strategies and methods for extending sustainable land management measures

China has now established the government-led desertification and land degradation combating system regarding policies and legality, project operation, management mechanism, technological support, personnel training and monitoring, and early warning system. The main strategy of extending sustainable land management measures in China is to incorporate the scaling up of sustainable land management measures into the national system of land degradation control based on the overall situation of ecological and economic construction in China to strengthen the role and positioning of sustainable land management measures in the national strategies.

5.4.1 Strategy for extending SLM measures

5.4.1.1 National legal system to assure implementation of SLM

China has established its legal and policy system for prevention and control of desertification and land degradation including the "sandification prevention and control law", "soil and water conservation law", "forest law", "environmental protection law", "grassland law" and " land management Law", "land contracting law", "water pollution prevention and control law", and "the law of preventing and controlling atmospheric pollution". The governments at all levels have meanwhile promulgated a series of regulations regarding prevention and control of land degradation, such as "Carrying capacity balance management methods of grass and livestock", "Farmland conversions into revegetation", "Wetland conservation management" and "Nature reserve regulations" which have guaranteed the implementation of degraded land sustainable management measures. To actualize the fundamental function of these laws, regulations for sustainable land management, firstly, the law enforcement should be strengthened. Secondly, the counterpart or supplementary laws and regulations regarding land degradation (e.g., the "Regulations of sandification prevention and control"); Thirdly, the relevant management system of vegetation protection in degraded areas should be strengthen for effective tending maintenance of the treatment achievements. The grassland contracting management system should be furthered by enforcing the requirements of grass-livestock capacity balance, grazing ban, rest grazing and rotational grazing to prevent additional overgrazing damages to the restored grassland. Active implementation of the stringent water resources management system should be actualized by rational water allocation of the upper, middle, and downstreams for water was in production, life and natural ecology. The water-saving irrigation and water-saving technologies should be emphasized for the degraded lands with strengthened feasibility study and planning regarding degraded land. The management responsibilities of sandification land and degraded land such as those located along the railways lines, highways, rivers and ditches as well as around towns, villages, factories, mines and reservoirs, with the local county government's supervision to related construction entities. Fourthly, law enforcement should be fortified by cracking down such illegal activities as indiscriminate grazing, mining and illegal land acquisition that harm vegetation and wildlife resources of the degraded lands. Fifthly, institutional capacity of the law enforcement team should be enhanced with improved supervision mechanism for law enforcement in strict, fair and civilized manner. Sixthly, by using modern media, the publicity and dissemination of law and regulations should be improved to upgrade the legal awareness of the cadres and the general public.

5.4.1.2. Strengthened leadership, coordination and institution building

Full play will be given to the institutional advantages of the Chinese government. By using the opportunities of the state institutional reform, unified leadership and nationwide coordination are expected for the land degradation combating. Each local government shall have overall responsibility for the prevention and control of land degradation in its respective jurisdictions, for which land degradation management plan will be formulated in line with the upper level administration's plan. The prevention and control of land degradation shall be incorporated into the local long-term socioeconomic development plan. Comprehensive accountability assessment system and performance targets responsibility system will be set up for land degradation management, with the treatment tasks assigned level by level for implementation. Awards and penalties will be imposed the assessment results to ensure the smooth implementation of prevention and control of land degradation work.

5.4.1.3 Key projects to promote scaling up of sustainable land management

China will further add inputs to the series of national forestry ecological projects related with land degradation management, including the "Sandification prevention and control project", "Farmland conversions into revegetation project", "Three-north shelterbelt protection forest construction project", "Natural forest protection project", "Wetland conservation project", "Soil and water conservation project", "Beijing-Tianjin sand source control project", "Grassland construction and pastureland restoration project", "Farmland protection project", "farmland restoration project", "soil pollution prevention and control project" etc. At the local government level, treatment projects are encouraged by creating conditions for the private sector and individuals to participate. By these means, the desertification treatment project system with the triple roles of national key projects, regional or local projects, and individual entity projects could be formed to comprehensively promote sustainable land management.

5.4.1.4 Progress in science and technology to assist sustainable land management

Inputs should be continuously added to land degradation research, education, training and discipline construction to enhance capability of scientific and innovation and technological scaling up. Basic researches and disciplines of land degradation should be enhanced with the scientific researches targeted more accurately at key technical constrains in project implementation. The land degradation research and technological scaling up system should be established with a batch of demonstration zones and demonstration sites in a planned systematic manner. Systematical summaries should be made to identify a batch of land degradation prevention and control technologies and management models, to introduce a batch of highly resistant plant varieties suitable for growth in different types of degradation lands to ensure the application of land degradation prevention and scientific research achievements. The monitoring, statistical analysis of the sandification dynamics of the entire country should be strengthen by using modern information technology for improved monitoring level to serve the scientific decision-making. Technical training for grassroots technicians and farmers and herdsmen should be prioritized so that the general public can master the basic knowledge and basic skills of land degradation prevention and control.

5.4.1.5 Capacity building for sustainable land management

Increased support should be given for the implementation of compulsory education in the desertification areas to improve the overall education level of local population. The training of various types of desertification-combating technological personnel should be enhanced and on-the-job refresh training and study should be encouraged. Preferential policies should be put forward to attract talented people, managerial talents and technical personnel to work in the desertification areas. The infrastructure construction and work conditions in the desertification area should be improved with the transportation, communication capabilities, basic scientific research facilities as priorities for full play of the role of the talents. International cooperation and domestic cross-regional cooperation should be conducted to promote two-way flow of the intelligence.

5.4.1.6 Monitoring supervision assessment for adoption of SLM measures

The land degradation prevention project monitoring and evaluation system should be established by formulating feasible assessment indicator system and technical specifications for scientific analysis and assessment of the quality, effectiveness and tasks completion of the project implementation. The plan implementation supervision system with clear responsibility and high rationality should also be formed to further the accountability of land degradation management at all levels of governments, for all related departments.

5.4.2 Recommendations for extending the SLM measures

5.4.2.1 Integrate the scaling up with national and regional industrial development strategies

According to the "the 13th five-year plan for national economic and social development of China", "National ecological protection and construction plan" and the "National sandification prevention and control plan", Chinas has large and wide distribution and diverse types of land degradation, which lays good material foundation for the development of sand industries. By rational development utilization of regional resources and the featured industries means an impetus for economic development, an income source of farmers and herdsmen, and an important force to drive ecological construction in the sand region. The desertification areas of western China with their local advantageous resources for protective utilization mechanisms, can carry out specialized planting, livestock and processing industries and sand tourism wherever the local conditions permits. By implementation of intensive management new economic growth spin-offs can be cultivated. High technology can also be used for industrial development by adapting to the local planting cultivation, breeding, deep processing, renewable energy and sand landscape tourism. Sustainable land management measures should be specified by referring to the local industrial development plans.

5.4.2.2 Extend SLM in combination with national poverty eradication strategies

China has determined that by 2020 the 50 million rural poor under the current poverty line standard and all impoverished regional counties all be lifted from poverty for the “all-round well-off society”. Targeted poverty alleviation and ecological construction are priorities for Chinese government in future years or the future decade. The arid areas are localities with fragile ecological condition, infertile lands, concentrated poverty-stricken populations and key areas of land degradation is management. Sustainable land management is not only the basic method to prevent and control land degradation, increase land productivity and food production, but also a solution to increase the income of local farmers. By incorporating the dissemination of sustainable land management measures into national poverty alleviation strategies and priority areas of national poverty alleviation strategies, related national policy, funding and technical supports can be obtained to accelerate the scaling up implementation efforts.

5.4.2.3 Extend SLM in line with national promulgations and plans

The scaling up of sustainable land management measures, as a fundamental requirement, should follow laws of the nature with attention to the natural regeneration function of the ecosystem for improved workability and sustainability. According to the requirements of the "National plan of main functional zones" and the "13th five-year plan for national economic and social development" regarding the ecological security strategic framework of "two shelters and three belts", the spatial distribution characteristics of land sandification combating of China has been determined in "national sandification prevention and control plan (2011-2020)”. With comprehensive consideration to the severity of damage, construction capability etc., the general distribution of sandification prevention and control is determined in accordance with the conditions of landform, hydrological condition, climate, land sandification status and location, existing problems, the natural conditions, the expected ecological and socioeconomic functions. By considering the similarity of treatment directions and the need of relative geographical contiguity, the sandification land of China is divided into five major types (sandification management, soil and water conservation, grassland management etc.) and 15 sub-types for determination of the treatment measures according to site conditions, for targeted comprehensive prevention and control with adaptable sustainable land management measures.

5.4.2.4 Integrate the scaling up with national climatic change strategic actions

By referring to the global climate change government trends, the carbon storage capacity and carbon sequestration capacity of the land should be increased in arid ecosystems to mitigate and adapt to climate change impacts. Greenhouse gas emissions from agriculture, forestry and land-use change account for 1/4 of global GHG emission exceeding the emission from transportation and building. The IPCC's fifth assessment report pointed out that afforestation, reforestation, and forest management are the most effective measures to reduce emission and add carbon sinks. Afforestation, reforestation and vegetation recovery are the main practices of sustainable land management, so land carbon sequestration capacity and carbon storage capacity should be taken as basic indicators and main objectives for sustainable land management measures dissemination. In accordance with "China national program for combating climate change", actions should be taken for forestry and land management by adding soil carbon as a performance indicator for the projects of "sandification prevention and control", "Farmland conversions for revegetation", "shelterbelt construction", "restoration of degraded forestland" etc.to improve the overall capability to mitigate climate change impact, to promoted integrated management of land degradation, land use and climate governance for combating desertification.

5.4.2.5 Promote SLM scaling up by establishing sustainable industrial system

By full use of the advantages in light, heat, wind, vast land resources, unique animal and plant resources, such agricultural industries with more light, less water, high technology ,and the pollution-free, high-return deep-processing industries of agricultural products, and the eco-tour industries should be developed. By irrational use of the animal and plant resources in desertification areas and by introducing and cultivate lead enterprises, the dissemination models of" company plus farmer, factory plus production base" could be adopted. Establishment of cross-regional, cross-sectoral industrial conglomerates for industrialized operations of sand industries to speed up farmers better-off out of poverty and dissemination of sustainable land management measures.

5.4.2.6 Use market economy incentives and mechanisms for scaling up

China has now established its government-led market-oriented resources allocation system. The accelerating industrialization, increasing transfer of rural labor, prominent labor shortages have jointly led to increased labor prices，which is added with rising or fluctuating prices for land and planting stocks, the land management project implementation costs have tended to rise. The land degradation management and other ecological restoration projects have been implemented with the participation of the government and public-private partnership, with the bidding arrangements for large-scale social afforestation projects. The national ecological construction project is undergoing reforms in terms of project management, financing, and governance models. The pressure for project performance assessment requires the selection of the best land management model. Only the land management models with both economic benefits and competitive strength of products in market deserve practical dissemination.

5.4.2.7 Establish diversified investment mechanism for financing the scaling up

China is establishing a diversified investment mechanism. Despite the financial resources from the central and local governments, the financial compensation mechanism for ecosystem service functions is built such as those for ecological forests and farmland converted vegetation. In some areas the local governments attempt to attract corporates and individuals' investments for ecological construction projects in forms of project revenue sharing etc. In addition, China is establishing its carbon emission trade market with forestry carbon as one component. By adding forestry resources and forestland carbon sinks, additional income can be obtained through market transactions which shall mobilize the enthusiasm of all parties in adopting sustainable land management measures.

5.4.2.8 Strengthen technological integrated innovations

Land degradation prevention and control is a comprehensive-demanding ecological management undertaking involving multi-disciplinary, multi-field technological innovation development and application. Although China has accumulated a number of land degradation prevention technologies and outcome models upon long-term technical accumulation and practical exploration with its targeted research development, some technologies and models derived from production traditions so unfit for modern forestry ecological restoration and economic development. It is necessary to further the technological innovations, tests and scaling up to serve the field applications and management.

China has now achieved numerous innovations in drought-resistant forestation, water saving, new plant varieties, solar energy, wind energy, internet technologies for application to the field production. The green product certification and dissemination systems are also established for dissemination of organic or pollution-free agricultural products for added value of the product chain. New technologies and new concepts should be introduced to ensure the sustainability of technological dissemination.

5.4.2.9 Promote SLM through international cooperation and exchanges

China has fulfilled a lot of work in international cooperation on combating desertification and land degradation. China as the pilot demonstration country of the LADA project, has executed the projects of "China-GEF integrated ecosystem management", "Sino-Germany desertification combating in northern China", "Sino-Israel research and development experiment of integrated desertification control", and Sino-EU cooperative research on impacts of climate change on agro-ecosystems and water resources in arid areas" to yield numerous technological achievements and experiences. Such cooperation platforms help introduce management lessons of international projects, strengthen regional information sharing and promote concerted observation of UN conventions of biodiversity, climate change and desertification control for even more effective sustainable land management measures.

5.5 Procedures for extending the sustainable land management measures

5.5.1 Conduct technical training and capacity Building

Personnel training of sustainable land management technology should be enhanced. In course of the sixth national inventory monitoring of desertification, training courses and seminars will be held at the provincial and regional levels regarding land sustainable technology application. Related training was conducted in cooperation with domestic project implementation of desert parks, sandy land closure for rehabilitation etc. In the Inner Mongolia Demonstration Zone, training programs will held to local governmental officials, technicians and land-use stakeholders in combination with the local desertification projects with training funds and venues arranged locally and training topics of sustainable land management techniques and dissemination models.

Publicity should enhanced regarding land degradation management technologies and practices by means of monographs publication on sustainable land management technologies, websites of SFA and local forestry departments introducing sustainable land management achievements and experiences, and new media of mobile phone etc. to brief the technologies and results of sustainable land management to local officials, farmers and land stakeholders.

5.5.2 Establish the management platform for SLM technology

The sustainable land management technical standards and models that adapt to Chinese national conditions should be developed. By referring to the standardized methods (e.g., the WOCAT-LADA), information management and communication platforms can be set up including the internet-based sustainable land management database, open to all users, to facilitate inquiry and knowledge dissemination.

5.5.3 Establish performance assessment system for SLM scaling up

The practical effects and impacts of technological application should be assessed at the landscape scale with the establishment of dynamic assessment indicators and methodologies for sustainable land management. Such assessment system should include the monitoring of the status before the scaling up and changes after the scaling up, with the physical, economic and ecological indicators of soil organic carbon, above-ground biomass, forest standing stock, agricultural products etc. The scope and intensity of future scaling up should be determined be fully considering the assessment results.

5.5.4 Establish the full-participation partnership

Land management partnership will be forged at the national, provincial and local levels for the fields of forestry, agriculture, water resources and grassland and among the government, non-public companies and individuals. Large-scale ecological restoration and afforestation projects have been implemented by non-public sector and this denotes full-participation partnership.

References

China National Committee to Implement the UNCCD. 2017.China National Report of VoluntaryLand Degradation Neutrality (LDN).

State Forestry Administration. 2014. A Bulletin of Status Quo of Desertification and Sandification in China.

China National Committee to Implement the UNCCD.2006.CHINA NATIONAL REPORT ON THE IMPLEMENTATION OF THE UNITED NATION'S CONVENTION TO COMBAT DESERTIFICATION

LADA Project Team, P. R. China. 2010. China National Level Report of Land Degradation Assessment in Drylands.

FAO. 2009. National Forest Monitoring and Assessment– Meeting Evolving Needs. Expert Consultation 26-28 November 2008, Rome Italy. Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAO-WOCAT. 2011. Questionnaire for Mapping Land Degradation and Sustainable Land Management (QM) v2, Rome, Italy.