CLIMATE CHANGE AND ITS IMPACTS ON ECO-ENVIRONMENT AND AGRICULTURE IN THE WEST OF NORTHEAST CHINA

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ABSTRACT:

Based on the literatures and investigation, response characteristics of global change in western Jilin province, its impacts on eco-environment and agriculture are analyzed. The study and prediction of climate change trend, close combination of GIS spatial analysis function and calamitous climate forecast is proposed, and spatial decision support system of climatic disaster is established, in order to rationally allocate water and soil resource and promote scientific process of western ecological restoration construction and land consolidation.

1. INTRODUCTION

Including Heilongjiang, Jilin, Liaoning and some parts of eastern Inner Mongolia, the western region of northeast China is located in 42°□50° N□117°□125° E, with total area of 320,000 km^2. It lies in the East Asian temperate monsoon climate area. Affected by solar radiation and monsoon climate, climate of different seasons change obviously: dry windy weather and temperature rose rapidly in spring, hot and rainy weather in summer, sunny weather and temperature decrease rapidly in fall and cold dry weather in winter. Affected by the global climate change, the precipitation has decreased markedly, while temperature and aridity index has increased in recent decades. The aridity index in this region is generally over 1.2, but in Horqin Sandy land where mean annual precipitation is less than 350 mm, the aridity index reach up to 1.5-1.8 and the surface water loss is 90-200 mm (Figure 1), showing a warmer and dryer climate change trend (Li Enze, 2001; Lian yi et al. 2001.). In recent 20 years, precipitation in Cherim League reduced by about 50mm while precipitation in Songnen sandy land reduced by 120.3mm. In recent 40 years, precipitation in Baicheng Municipality decreased obviously: precipitation of this area in late 1990's reduced about 100mm, compared with that in early 1990's. 120~140 days/ wind speed is over sand rising speed each year in this region, and in spring, the average number of days when the wind speed is greater than eight level is 13.9, while the number in Shuangliao is even as much as 33.7(Lian yi, et al. 2001). This region belongs to typical semi-arid and sub-humid arid climate zone. It is a typical agro-pastoral transitional zone, and also an eco-environmental fragile area.

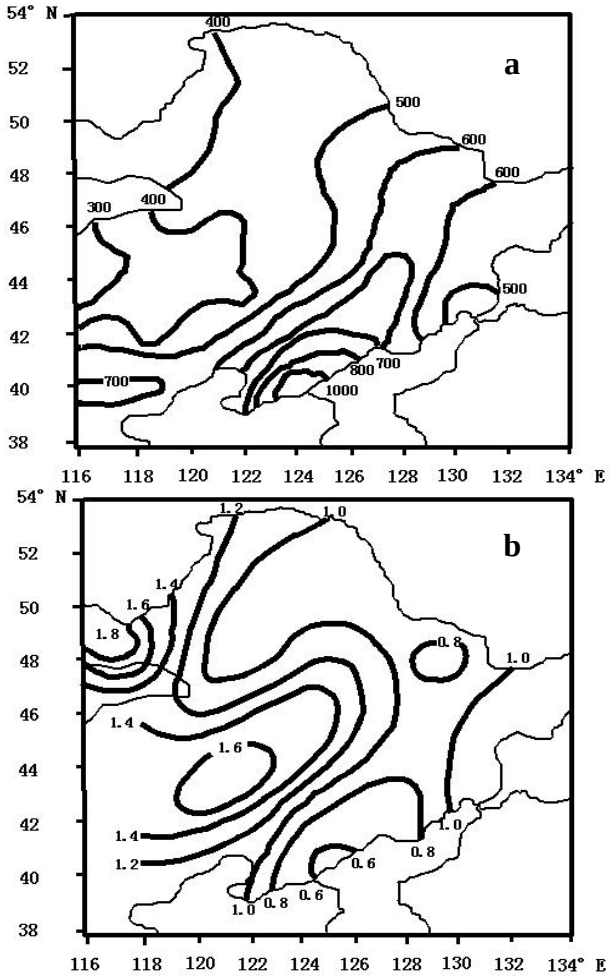

Figure 1. Distribution of Average Precipitation (a) and Aridity Index from May to September (b) in the Northeast of China

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In recent a hundred years, the eco-environment in the west part of northeast China has been encountered an unprecedented serious damage because of the double effects of natural and human factors. Horqin Grassland, Songnen Grassland and Hulunbeier Grassland, which are famous for high yield per unit area and high quality of palatability, are the three best pastoral areas in the 10 major pastoral areas of China. Due to the warming and drying climate change and the irrational use of grassland, degradation, desertification and salinization of large areas of grassland are caused, which thus leads to rapid expansion of desertification. According to the current study, land desertification in the west of northeast China is increasing at the rate of 1.4%. Currently, desertification area of Horqin sandy land and Songnen sandy land has been reached to 72,000 km^2（Qiu, 2008; Qiu et al., 2005; Lian et al., 2001 ）.

According to current study, multiple factors lead to the formation of the desertification of the west of northeast China. Material source is the first factor. The west of Song-Liao Plain has deposited 70~100m loose sediments, espatially in the west Liao River Plain the thickness of loose sediments is 180m.The ground of Song-Liao Plain is composed of fine sand, which provide adequate sand source for desertification(Lian yi et al., 2001). Climate change is the second factor. In recent decades, warming and drying trend of climate is obvious and continental climate increases markedly, which is one of the nature factors of desertification. Human activity is another factor. For example, 40% grasslands become severely degraded grasslands because overgrazing and severe damage of vegetation. Besides, irrational use of water recourse is another human factor. For example, the construction of large reservoirs and other projects in the upper reaches of the rivers cuts off the runoff of the middle and downriver, and causes riverbed exposing and spring filled with sand.

In conclusion, adequate sand source, arid climate and excessive damage due to human factors are all causes of desertification in the west of northeast China. The western region of Jilin province is located in the southwest of Songnen Plain, including plains between 123°09′~124°22′E, 44°57′~45°46′N. It is composed of Baicheng and Songyuan Municipalities that including 10 counties, with total population of 4.716 million and total land area of 49,850 km^2. It is a complex system, including farmlands, forest, grassland and wetlands. Cultivated land area is 1.9 million hm^2, accounting for 38.1% of the total land area; Grassland area is 986,400 hm^2, accounting for 19.8% of the total land area; Forest area is 706,700 hm^2, accounting for 14.2 of the total land area; Water area, including wetlands area, is 455,800 hm^2, accounting for 9.1% of the total area. The topography is higher in the northwest, lower in the middle and slightly elevated in the middle south. It belongs to semi-arid and semi-humid continental monsoon climate zone, with altitude of 180-600m, average annual temperature of 4.5□, annual sunshine hours of 2915.3h, annual rainfall of 300-400mm and annual evapotranspiration of 1500-1900mm. This region is also a major agro-pastoral transitional zone and an area sensitive to global change. In recent decades, the eco-environment of the region has been seriously deteriorated because of the double effects of natural and human factors, mainly manifested in degradation of large areas of grassland, desertification and salinization of soil, spread of desertification and shrinkage of wetlands（Hou, 2006; Huang et al., 1996; Li, 2001; Qiu et al., 2005; Zhou et al., 2002).

2. CLIMATE CHANGE ANALYZING

2.1 Temperature Change

The western region of Jilin lies in the higher latitude of China and is one of the regions affected most obviously by global warming. Since 1990's, this region is changing to a warmer and dryer climate. Figure 2 is the time series from 1961 to 2004 of average temperature from May to September in Jilin province. It can be seen from figure 2 that the average temperature of plant growing season is a significant linear upward trend. The figure also shows that the linear trend line of early 1980's has risen to the positive anomaly region of average temperature, especially after the mid-1990's, the temperature is continuously high, while the average temperature of 45°N in the Northern Hemisphere shows a linear downtrend, and shows a significant increasing high-temperature trend, but is still lower than the high temperature of early 1950's (Lian Yi, 2007). Figure 3 is the time series from 1953 to 2000 and its log fitting trend of the anomaly percentage of annual average temperature of Baicheng and Songyuan. The figure shows a significant upward trend, and that the middle 1970's is the dividing line of positive and negative anomaly log fitting curve. The figure also shows that the rates of annual average temperature split in 1990's are all positive, which indicates that 1990's is a period when the temperature increased most obviously (Qiu, 2008; Lian, 2007). In recent 50 years, the temperature of Changling county increased by 0.4□ every 10 years, particularly 1990's ,the temperature in which increased by 0.6^0 every 10 years, is a period when the temperature increased fastest, and the temperature in 1990's is 1.4^0 higher than that in 1950's, and is 0.8^0 higher than that in 1949. These all indicate that the warming rate of Changling is higher than the average rate of the whole country and the northeast of China in the past 40 years. The temperature of plains in the centre and the west of Jilin province increased more obviously than that of the east (Han, 2007).

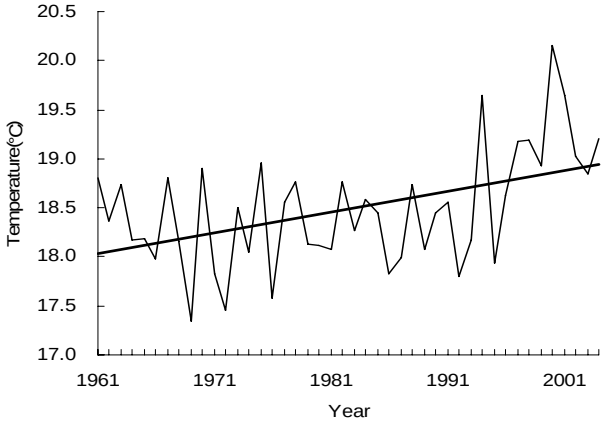

Figure 2. Time Series from 1961 to 2001 of Average Temperature from May to September of Jilin Province

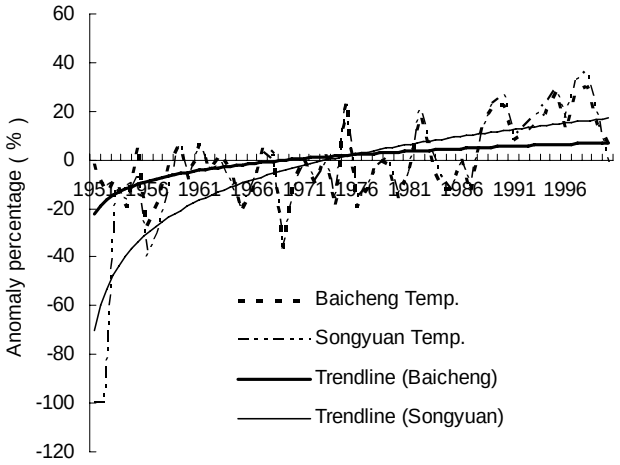

Figure 3. Time Series and its Log-Fitting Trend of the Anomaly Percentage of Annual Average Temperature of Baicheng and Songyuan

2.2 Precipitation Change

Figure 4 is the linear trend rate distribution of annual precipitation from 1961 to 2000 in the northeast of China. It can be seen from figure 4 that the east of 120°E, the south of 45°N in the west of the northeast, including the west of Jilin province (43°-46°N, 122°-124°E), Zhe League of Inner Mongolia, the south of Xinan League, major grain producing areas in central Songliao plain in Jilin province (43°-46°N□124°-126°E) and major regions of Changbai Mountain in the central south of Jilin province except of the east of 128°E in Yanbian, are all areas where the precipitation shows a linear negative trend. These areas together with Liaoning province are composed of areas where precipitation linear trend shows a significant declining trend in the central-west and central-south of the northeast.

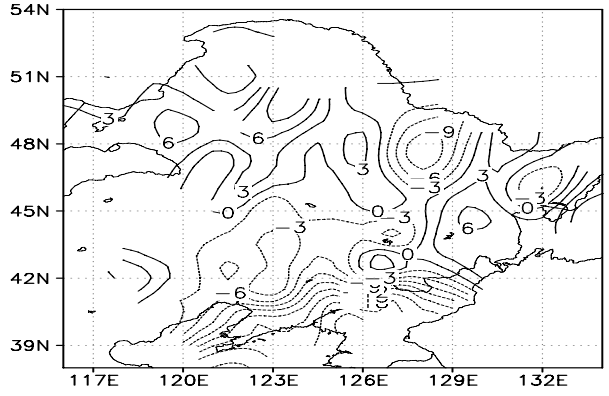

Figure 4. Linear Trend Distribution of Annual Precipitation from 1961 to 2000 in the Northeast of China (Solid line: Positive trend Contour; Dotted line: Negative Trend Contour; Unit: mm/a; Interval: 3mm/a)

Figure 5 is the time series from 1953 to 2000 and its log fitting trend of the anomaly percentage of annual average precipitation of Baicheng and Songyuan. It can be seen from figure 5 that the precipitation of the two cities all show obvious declining trend, which is just opposite with the upward trend of temperature. This shows a remark warmer and dryer trend of climate change (Qiu, 2008; Lian et al., 2003,2007; Sun et al.,2005).

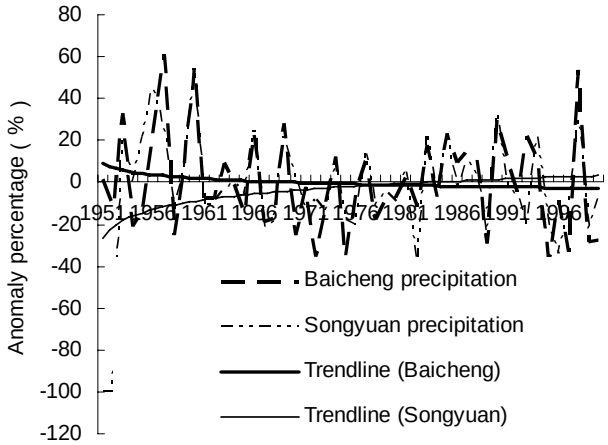

Figure 5. Time Series and its Log Fitting Trend of Annual Precipitation of Baicheng and Songyuan in the West of Jilin Province

3. IMPACTS OF CLIMATE CHANGE

3.1 Effect of Climate Change on Regional Ecological Environment

Correlative scholars have studied and pointed out that dynamical and ecological characteristics of transition zone belong to boundary area between great- scale climatic zones which has strong climatic element gradient, thus it has instability and it also is a fragile ecological environment zone, some places are remarkable regions of desertification development. According to the RS survey of desertification status of land cover by land satellites and the corresponding analysis of the regional climatic background change, since 1980's, specially in mid-to late1990's, western of Northeast China has been an area which has large relative variability of precipitation and a sensitive zone of precipitation change. Climate changes mostly to be warmer and drier, which is more prominent especially in the middle zone of the western Northeast China□44-48°N□,while the desertification of land cover in the middle zone is obviously developing along the longitude. It indicates that drought and desertification of the climate change generate "syntony"(Lian et al., 2003; Shen et al.,2000). These two points precisely are the regional responding characteristics to global change in western Northeast China in 1990's and two big prominent characteristics of eco-environment drought trend.

The west region of Jilin province is located in the hinterland of the Songnen Plain, namely a large area of Jilin province in the west of the Fulongquan highlands and north of the Songliao watershed including the northeast continuation of Horqin sandy part and the southern edge of the Songnen sandy part. This area is a typical climatic transition zone and a agriculture and animal husbandry transition ecotone with undeveloped economy and fragile ecology.

In recent decades, because of continued rainfall decline in the west region caused by global change, as well as rapid population growth, overgrazing and other natural and man-made factors, eco-

environment the west region of Jilin province degenerates seriously. The main manifestations are large-area grassland degradation, land desertification, salinization and wetlands atrophy and so on, in which grassland area is decreasing at an alarming rate, and the quality is declining. According to the statistics, the area of grassland in 1956 is more than 2 million hm^2 and fell to 1.724 million hm^2 in 1980's, to1.188 million hm^2 in 1998. During the period of more than ten years, the area of grassland has decreased by 0.536 million hm^2. Not only the area of grassland is decreasing but the quality of the grassland is declining. The forage yield has reduced from 1500-3000kg□hm^2 in the beginning of 1950's to the current 450-600kg/hm^2, and some grassland have been deprived of utilization value, while area of land salinization land has been extending greatly. In early 1980's the area of the salinized land in this area is about 1.62 million hm^2, then increases to 1.653 million hm^2 in the 1990's, and aggravating tendency of saline alkaline degree is obvious, and the proportion of the total land area the area of severe saline soil occupying has increased from 26.9% in 1958 to 40.2%.10 million mu in western Jilin province has become to desert from high-quality grasslands, as has been the alkali-saline patches basically with non-use value. The number is still increasing, and expected to reach 13 million mu by 2020 (Hou, 2006; Wang, 2007; Zhou et al., 2002).

At the same time, natural woodland, wetlands, water and other landscape components are significantly reduced, leading to rapid decline in vegetation cover, topsoil being eroded by wind so easily that alluvial sand bodies being exposed, resulting in land desertification and a source of surface sand dust storm, Land desertification expanding eastward at an annual rate of 1km. Woodlands, wetlands and water area reduction also allow the reduction of regional water storage capacity, as well as weaken the abilities of regulating river runoff and flood mitigation, exacerbating the extent of drought and flood. In 20 years from 1949 to 1969, the frequency of drought was 23.8% and waterlogging frequency was 33.3% in this area; while from 1970 to 1990, the frequency of drought was 33.3%, and waterlogging frequency was 47.6%, and the disaster intensity significantly increased; the average maximum wind speed in the western region in spring in the 1980's was 4.4m/s, the average number of sandstorm days was 5.4d / y, now, the maximum wind speed in spring is 5.6m / s, the number of sandstorm days is up to 11d/y. Thus, the dual role of natural and man-made has led to rapid deterioration of the ecological environment in the western Jilin province, affects the safety of the regional agricultural seriously (Hu et al. 2006; Qiu et al., 2008).

3.2 Effects of Climate Change on Food Production

Food production is a primary production process which under the role of artificial production management and agricultural science and technology, through photosynthesis of crops, transform the climate, soil and other natural resources into food products. From this principle, climate and soil conditions are most basic resources and environmental factors to crop growth and development, compared with relatively stable soil conditions, erratic weather conditions are main factors that affect crop's yield and quality changes.

Moisture and temperature conditions are main climatic factors that determine the crop's distribution, structure and yield, drought, flood and low-temperature conditions are common agro-climatic disasters. Latitude is comparatively high in west region of Jilin province, and climate is relatively cold, chilling damage is main meteorological disaster. According to statistics, regression relationship of crop yields and temperature from 1950 to 1975 in Jilin province, from May to September, average temperature increase one degree, the province's total grain output raised by 15%. Average yield of grain and bean in the 20th century in Jilin province hovered at l000 -2000 kg/hm^2 until the late 70s, but since 1980's it jumped into the 4000 - 5000 kg/hm^2. This change on the one hand has a relationship with agricultural production policy, on the other hand, it relates to the northeast region especially Songliao Plain whose average temperature of agriculture growing season has entered a relatively warm period since 1980's. The average yield increased to 5000 - 6000 kg/hm^2 in 1990's, but inter-annual fluctuations increased (Lian et al., 2007). Climate warming can increase the energy resources, and expand the planting area of thermophilic high-yielding crops (rice, corn), increase growing proportion of high-yielding species with longer growth period to gain a greater harvest of agricultural production. In recent years, with global warming and the continuous advancement of agricultural technology, significant changes have taken place on crop distribution in the western region of Jilin province, namely, the rapid expansion of rice's cultivation area, and the corresponding shrank of other grain-growing area (Pan Tiefu.1998). Firstly, this change due to global warming, extended frost-free period, advanced sowwing date, the original high quality rice varieties which can not grow in the western region can be promote planting; secondly, it is a result of frequent droughts which make yield of dry crop decline.

Meanwhile, aridification is threatening the sustainable development of agriculture. Except for the soaring temperature, precipitation in this region has been lower than multi-year average value for years, which indicates a warming and drying trend of climate change. The decade since the mid-1990's was not only a time of the highest drought frequency but also a period of the most serious damage in the west of Jilin province. The statistics indicate that, drought area during the decade mentioned above was 2,017,300 hm^2 on average, disaster area was 1,286,000 hm^2, zero harvest area was 100,000hm^2, yield reduction was 2, 971,000 ton, economic crops loss was 367 million Yuan, and the extreme drought occurred in 1997, 2000, 2001, 2002 and 2004. (Hu et al., 2006).

4. DEVELOPMENT STRATEGIES

In order to curb a series of eco-environmental degradation problems caused by climate change and population growth in the western region of Jilin province, party committee and government of Jilin province put forward strategic initiatives timely about eco-province construction in 1999, grassland ecology protection, woodland, wetlands and saline-alkali land protection, desertification control, ecological grass building in the western region, and a series of ecological restoration and construction project. Eco-Office of Jilin province invested more than 6800 million yuan ecological province construction special funds on western saline-alkali land management project, relevant departments and local governments invest 100 million yuan which drive the whole society to invest 400 million yuan. Government of Jilin province implement "the western land development major

engineering" project in 2007 whose investment is as high as 6.2 billion. This major project will rebuild and perfect western three important water conservancy projects and transform saline-alkali land to cultivate rice, and strive to eliminate salinization area basically and restore vegetation. Mildly saline-alkali soil will be converted to high-quality resource on the basis of vegetation restoration; moderate region restore vegetation, 80% of which turn into available resources; vegetation be restored basically in severe region, 30% of which turn into available resources and increase cultivated land 270,000 hm^2, rice annual yield 1.65 billion kg.

High attention should be paid to climate warming induced climate disaster warning and prevention work, besides hydraulic engineering construction, land consolidation, saline-alkali soil improvement and desertification control during ecological environment protection and construction process in west region. Establish climate disaster spatial decision support system, so as to promote ecological restoration construction and land consolidation the management of scientific process actively. Therefore, recommendations and response plans are proposed as follows:

In the background of global warming, it's necessary to learn and respect the laws of nature, to insist on the principle that we should act according to circumstances and to make reasonable arrangement of farmland, grassland, pasturage and woodland. In order to prevent changing grassland to farmland and over cultivating, it's necessary to hold the faith that unifying ecology and economy, coordinating production and carrying capability, act according to local conditions and give priority to water, soil and gas under the instruction of regional difference and dominate limiting factor, and try our best to build a harmony environmental friendly society between man and nature in the western region of northeast China.

Increase the intensity of investment in ecological environment monitoring and research in western region, and promote the relevant scientific research capability of scientific and technological innovation to improve the capabilities of the scientific and technological support in the developing process of ecological environment restoration and agricultural. Promote the roles of high-new technologies vigorously such as the Remote Sensing, Geographic Information System, Global Positioning and so on in ecological environment protection and reconstruction in western Jilin province to establish different levels of dynamic monitoring and early warning systems for the ecological environment and catastrophic climate in west region, and on which basis develop application systems about ecological restoration, land consolidation planning and agriculture designation, scheme making and effects assessment, to enhance decision-making capacity on scientific management and management level of the ecological environment construction and sustainable develop agriculture and animal husbandry in west region.

Water resource is the decisive factor in the process of ecological environment's protection and restoration, industrial and agricultural and husbandry's development in the western region of Jilin province. Raising income and reducing expenditure is the fundamental way to resolve the problem of inadequate water resource in the context of climate warming and drying in the west region. The three important water project which is under construction will relieve the tense status of water utilization of industrial, agricultural and urban to some extent, and will help enhance the capacities of flood control and drought resistance. However, overall, the water resource in the western region is still scarce, and should use water scientifically, economically and efficiently, which require managing water resource scientifically in temporal and spatial configuration, implementing total amount control and quota management.

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