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CLIMATIC CHANGES AND THEIR IMPACT ON AGRICULTURAL PRODUCTION IN THE LOESS PLATEAU OF CHINA

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Based on the abundant data and information of the Loess Plateau, China, the spatial and temporal changes of climatic factors and their impact on agricultural production have been studied. It is found that different areas had different restrictive factors to agriculture, and different factors had different changes. So agricultural production should be arranged according to local climatic conditions. For example, the crop planting should be arranged in the south-east plateau where precipitation is more than 400mm and aridity is lower than 2.0, while the land where no water for irrigation and precipitation $300mm can only be used for developing the extensive animal husbandry.

The Loess Plateau is located in central China (100°54' - 114°33'E, 33°43' - 41°16'N) with its domain reaching Taihang Mountains to the east, Riyue Mountains to the west, Yinshan Mountains to the north and Oinling Mountains to the south. It is a special and unique area with most of its land covered with deep locss, Its geographical area is about 627,983.52 km^2, accounting for 6.54% of the whole area of China (GISLP, CAS, 1991).

For a long time, here is a farming-grazing mixed region, and planting and animal husbandry change frequently. During the past lOO's years, although planting and grazing fluctuated back and forth frequently, the general tendency was planting replacing animal husbandry step by step. As a result, the land degradation soil erosion and eco-environment deterioration became more and more serious. In some regions the ecological environment become very fragile and easily to be damaged but difficult to be restored. So it is very important for us to arrange the agriculture production according to regional and temporal climatic change regulations and characteristics of the plateau.

CLIMATIC CHANGES OF THE LOESS PLATEAU

The locss plateau covers a large gcographical area and most of it belongs to the northwestern border of monsoon climate zone of eastern China according to Chinese Climatic Classification. In general, the climate of the Loess Plateau ranges from subhumid region in warm temperate belt to arid region in middle temperate belt from southeast to northwest (Zhang Ruyi and Wang Qinxue, 1990). Its annual precipitation varies between 600 and 300 mm decreasing progressively from southeast to northwest, and annual mean temperature ranges form 14°C through 6°C. Except for the precipitation and temperature, all the other climatic factors including both favorable and restrictive factors to agriculture change spatially and timely in the plateau. The favourable factors include the rich sunlight, warm temperature, large diurnal range of temperature and long growing period while the unfavorable conditions refer to the shortage of rainfall, drought, dusty wind, rainstorm, frost and hailfall and so on.

1. Favorable Factors to Agriculture:

1.1 Sunlight resource: According to the distribution of the annual total amount of solar radiation and the radiations during the temperature ~ 0° C and ~ 10° C respectively, the light resource in the Loess Plateau to be found is comparatively abundant. The annual total amount of solar radiation changes from 5.0×10^9 J/m^2 in the southeastern part of the Plateau to 6.3×10^9 J/m^2 in the northwestern part which is greater than that of other areas in China except for the Xinjiang Uygur Autonomous Region (5.5×10^9 J/m^2 - 6.5×10^9 J/m^2) and Qinghai-Xizang Plateau (5.5×10^9 J/m^2 - 8.0×10^9 J/m^2).

The solar radiation during the temperature ~ 0° C which is closely related with the cool-loving plants ranges from 4.0×10^9 J/m^2 in the south to 4.Rx10')J/m^2 in the north. It is much greater than that in the Northeastern China (3.0x10'J/m^2 - 4.0×10^9 J/m^2) where the period of temperature ~ 0° C is just equal to that of the Loess Plateau. The solar radiation in the period of the temperature ~ 10° C closely related with the warm-loving plants ranges from 2.7×10^9 J/m^2 to 3.4×10^9 J/m^2. These values are obviously greater than that of the North China Plain (1.5×10^9 J/m^2 - 3.4×10^9 J/m^2) where the latitude is the same as the Loess Plateau.

The light resource in the Loess Plateau, as above mentioned, is very abundant and increasing from southeast to northwest. It can create good conditions for the photosynthesis of green plant and the high photosynthesis potential of production.

1.2 Temperature, diurnal range and growing period

1.2.1 Spatial changes of temperature: The annual mean temperature in the Loess Plateau ranges from 6.0° C in the middle-western part to 14.0° C in the southeastern part, and the annual mean lowest temperature ranges from _2.0° C through 9.0° C and the warmest month (July) temperature from 18° C to 26° C. The accumulated temperature of ~ 0° C ranges from 2600° C to 5900° C and of ~ 10° C from 1900° C to 4500° C.

The annual mean diurnal range of temperature ranges from 14° C in the north to 12° C in the south. The duration of temperature ~ 0° C ranges from 200 days in the west to 300 days in the southeast and of temperature ~ 10° C from 100 to 220 days.

Comparing to the North China Plain, which has the same latitude with the Loess Plateau, the mean temperature of July in the plateau is 0.7° C-2.0° C lower, the duration of temperature ~ 0° C is 13 - 26 days longer and ~ 10° C is 0-() days longer, and the daily range of temperature is 0.5 - 1.5° C higher. All these characteristics are beneficial to the growing of cool-loving crops.

1.2.2. Temporal changes of temperature: According of the fluctuation of temperature in recent century, four high- temperature stages and three low-temperature stages can be found. The first remarkable high temperature stage occurred in 1920s. In the early 1930s temperature began to decrease and formed the first low-temperature stage. Then it gradually rised and by the middle of 1940s developed the second high temperature stage. In the end of 1940s, it turned to decrease, and till the middle of 1950s developed a little bit long low-temperature stage. After then, it began to rise slowly, and by the middle of 1960s to decrease. From the early 1970s, it also began to rise and developed the second pluvial stage from middle 1970s to early 1980s and finally went down remarkably in 1980s. In the southern part (Xi'an), it was waving near the average value from the middle 1930s, then increased constantly in 1940s and developed a pluvial period till the end of 1950s. In 1060s the precipitation also fluctuated around the mean value and by the end of 1970s it was going down to the lowest point. After then it turned to rise and till the middle and end of 1980s began to drop again. In the southwestern part (Linxia), it was decreased slowly from the middle 1940s, then increased slowly from the middle and cnd of 1950s, after then it fluctuated around the average value and finally tended to decrease slightly in 1980s. Due to the small amplitude of precipitation changes, it was difficult to divide its pluvial periods in thc southern and southwestern part s of the Loess Plateau.

To sum up, the inter annual change of precipitation of the Locss Plateau w:is very great, and its general tendency was going down gradually. According to st at isticc (Wang Ling and Wang Qinxue *et al.* F)92), the annual mean precipitation of 19805 was 30 - 80mm less than that of 1%05 in most part of the plateau. Some areas such as Changzhi, Yangquan and Wutanshan of Shaanxi province and Wuqi in Shanxi Province the decrease even reached 93.3mm. 9O.6mm, 116mm and 102.3mm respectively. That is why the drought and desertification in these area became more and more serious in recent 10 - 20 years.

2.2 Drought and dusty wind: In the Loess Plateau, there are many kinds of severe weather such as drought, dusty wind, storm rainfall, frost, hailfall damage and so on, in which drought and dusty wind cause the most serious harm to agriculture. Due to small precipiation, great evaporation (lOOOmm in the southeast to 700mm in the west), high aridity (1.5 in the south to 4.0 or more in the northwest) and serious shortage of soil moisture (400mm in the southeast and southwest, 300mm in the middle south and 700-900mm in the northwest), the drought and dusty wind frequently and severely affect the seed-time and germination of crops seeding in spring such as paddy, maize, Chinese sorghum and millet.

Shi Shangwcn *et al.* (1988) analysed the data of rainfall variability of 50 meteorological stations in the plateau from 1957 to 1,)~(). They found that drought often occurred in spring, summer and autumn in till; Locss Plateau, especially in spring and early summer it was very severe in middle-southern part of the plateau. In autumn, drought was relatively slight in the whole pl.ucau. Statistics also verified that there were 16 years out of 24 (1957 • 19S0) in which at least there was one month occurring drought" occupied ()7'jL, 10 out of 24 in which there were 2 months occurring drought, occupied 42%, and 4 out of 24 in which 3 months occurring drought, occupied 17%. In 1965, there were 5 months occurring drought which caused serious damage to crops. Power Spectral Analysis verified that there were 3, 10, 22 and 32 years almost-periods exacting In the cvoluation of drought in the Locss Plateau.

2_1 Rainstorm: Just same as the distribution of precipitation, the mean occurring times of rainstorm in the Loess Plateau decreased progressively from south to north, namely -~ 0.35 in the northwestern zone, 0.35 - 0.91 in the middle zone and 1-2 in the southeastern zone. In the whole plateau, the rainstorm was timely concentrated on summer (June - September) when the summer monsoon was prevailing and spatially concentrated on the mountainous region in the southeastern area. It was more and heavier on windward than on leeward in the mountains (Shi Shangwen *et al., 1990).*

The Loess Plateau, because of soft soil structure, few and scattered vegetation, strong wind as well as heavy rainstorm, indeed suffered from the severest soil erosion even in the world, especially in the middle part where except for natural reasons, human activities such as irrational reclamation and over grazing further aggravated the soil erosion.

2.4 Frost: The Locss Plateau located inland, its relief (800 - 2500 meters a.s.l.) was high and land form was very complicated. From late spring to early summer or from late summer to early autumn, as the cold air mass intrude this area, in addition to the addition cooling at night, the temperature often dropped suddenly and occurred frost.. First frost might cause the damage of growing crops, and second frost could kill large area of seedings.

Due to the increase of latitude and altitude, the first frost occurred earlier in the north than in the south, and a bit earlier in the west than in the east.. For example, the heavy first frost ($0' C) occurred in the middle of November in the south, and in the middle of September in the north, the difference was some 60 days, and it occurred on 16, October at Minghe in the west and on 18, October at Changzhi in the cast, the difference was only 2 days. On the contrary, the second frost ended earlier in the south than in the north. the heavy second frost ($0' C) could last to the middle of March in the southern part and to the middle of May in the northern part, the difference was about 60 days, but the difference between cast and west was only 3 days or so.

2.5 Hailfall: Hailfall was another kind of local severe weather.. Although it occurring in small area or short duration, yet its falling force was very strong and its density was great, so its damage was often serious. In the Loess Plateau, hails often occurred in June to August when the wheat and barley was just in the period from heading to yellow maturity and beans (legumes) from flowering to milking.

According to statistics of data from 1958 to 19R5 of 97 meteorological stations «(jISLP, CAS, 1l)()1), the distribution of hailfalls had characteristics as follows:

Obvious local variation: Where there was more rain, there was more hailfall, There were more hail days in the mountains and plateaus than that in the vallies and basins, and more in moisture areas than in dry regions. Such as in Daban and Laji mountains of Qinghai Province, the hail days averaged more than 10 in a year; in the east of Qilian mountains and the Gannan Plateau of Gansu Province about 3-6 days; in the Daqung Mountains of Inner-mongolia 4-6 days; in the Wutan Mountains of Shaanxi Province 10 days or more. These are heavy hailfall areas. But in other areas, the days occurring hailfall averaged 2-3.

Large lnterannuul variation: The maximum was about 3-13 times of the mrumum, as in Hualong of Qinghai Province, the maximum hail days were 18 and the minimum 6 days, and in Yongdeng of Gansu Province, the maximum was 13 days and the minimum only 1 days.

Great concentrated degree: Hailfall often occurred during March to October, especially concentrated in summer (June to August). The days of hailfall in summer approximately occupied 50% in the plateau and even could reach 70% in some areas such as Jiyuan and Huzhu counties, Liupan and Wutan Mountains.

Obvious diurnal variation: The hailfall often occurred in the afternoon to the middle night.

To make a comprchensive survey, the climate of the Locss Plateau changes regionally colder and drier from southeast to northwest and timely warmer and drier in recent decades.

IMPACTS OF CLIMATE CHANGES ON THE AGRICULTURAL PRODUCTION

Because of large geographic area and complicated climate types of the Loess Plateau, the different local conditions should be considered when discussing the impact of climatic changes on agricultural production. For example, in northwest part of the plateau, where belongs to the arid province in temperate belt, crops can not be planted without irrigation in spite of rich light and moderate heat resources. The shortage of moisture, drought, dusty wind and frost are the main restrictive factors to agriculture. Except for small area as Yellow river vallics can develop irrigational planting, the other vast areas can only be used for extensive animal husbandry. In the middle part of the plateau, where belongs to semi-arid province in the temperate belt, planting and animal husbandry are mixed together for a long time. Due to obvious transitional and sensitive climatic characteristics, here is also called "transitional belt" where the eco-environment is very fragile. In the relative pluvial period, large areas of grass land in this belt was rcclarnated for planting, but when in dry years the rcclarnated land had to be left uncultivated. Meanwhile, the decrease of grass land also caused serious overgrazing. As a result, severe soil erosion and desertification occurred in many places of this belt. For these reasons, agriculture in this belt had obvious fluctuational features, so we called it "wave agricuh urc" which is closely dependent with the change of precipitation. The southeast part of the plateau, which belongs to subhurnid province in the warm temperate belt, is the major grain production base in the Loess Plateau. Due to small variation of the climate, agricultural production in this area arc developed sustainably and stably.

Based on the per unit grain yield (mean values of 6 crops: wheat, maize, millet, Chinese sorghum, rice and soybean) and its annual increase from 1950 to 1985, the distribution of yield and the relationship between yield and climatic recources was analysed (GISLP, CAS, 1991). It was found that the high-yield (crops yield ~ 3000 kg/ha, annual increase ~ 60 kg/yr) belt included two kinds of regions.the first where precipitation is more than 550 mm and aridity is below 2.0 such as Xinzhou, Linfen, Houma and Yuncheng Prefecture and Yangquan, Changzhi city of Shaanxi Province; Eastern and southeastern Luoyang city of Henan Province; Weinan, Xianyang and Xi,an city of Shanxi Province; Linxia Prefecture of Gansu Previncc and the

Yellow River valley of Qinghai Province. The another where precipitation is less than 300 mm, aridity is over 4.0 and the Yellow River water can be used for irrigation such as Yinchuan Plain of Ningxia Hui Autonomous Region and western Bayan Nur Meng and Wuhai city of Inner-mongolia.

The middle-yield (crops yield 750-3000 kg/ha, annual increase 30-60 kg/ha/yr) belt, where precipitation is between 350 mm and 550 mm and aridity is from 1.5 to 3.0, included Luliang Prefecture, eastern Linfen and Yuncheng Prefecture of Shaanxi Province; Sanmengxia City of Henan Province; Yuling, Yanan Prefecture, Tongchuan and Baoji city of Shanxi Province; Qinyang and Pingliang and Dingxi Prefecture and Tanshui, Lanzhou and Linxia City of Gansu Province; Haidong Prefecture of Qinghai Province and Guyuan Prefecture of Ningxia Hui Autonomous Region and western Ulanqab Meng, Ih Ju Meng, eastern Bayan Nur Meng, Hohhot and Baotou City of Inner-mongoila.

The low-yield (crops yield ~ 750 kg/ha, annual increase ~ 30 kg/ha.yr) belt, where precipitation is lower than 350 mm and aridity is about 3.0, allocated in Dongsheng county of Inner-mongolia, Tongxing and Yanchi County of Ningxia Hui Autonomous Region and so on. In these regions drought and windstrom are very serious.

According to the above mentioned, it can be seen that the crop production should be arranged in the area where precipitation is more than 400 mm and aridity is lower than 2.0, especially in the area where precipitation is greater than 500 mm. The areas, receiving precipitation ~ 300 mm should be forbidden to produce crops.

REFERENCES

Grop for Integrated Survey of the Loess Plateau, Chinese Academy of Sciences (GISLP, CAS). 1991. Comprehensive Development and Rational Distribution of Agriculture, Forestry and Animal Husbandry of the Loess Plateau. p.I. Sci. Press, Beijing, Chian.

Grop for Integrated Survey of the Loess Plateau, Chinese Academy of Sciences (GISLP, CAS). 1991. Rational Utilization of Agro-climatic Resources in the Loess Plateau. p. 1-48. Chinese Sci. & Tech. Press, Beijing, China.

Shangwen S. *et al.* 1988. Variability of Rainfall and Variation of Drought and Flood in the Loess Plateau. J. Beijing Normal Uni. Sup. 1: 67-74.

Shangwen S. *et al.* 1990. Quantitative Analysis of Drought and Rainstrom in the Loes Plateau. In. Research on the model of Integrated Development and Harnessrnent of the Loess Plateau. Sci. Press, Beijing, China. pp. 99-109.

Wang L., Q. Wang *et al.* 1993. Human Impacts on the Ecological Environment and Modern Urban Climate Change in the Loess Plateau. Chinese Geo. Sci. 3: 365-375.

Zhang, R., Q. Wang. 1990. Composite Clirntic Regionalization of the Loess Plateau. In: Region, Environment, Natural Disaster. Geo. Res. Sci. Pre., Beijing, China. pp. 67-74.