

Situation analysis Report of Climatic Change in Shandong Province

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1 Introduction

1.1 Background

In the last hundred years the global climate is getting warmer, leading to a major change in temperature, rainfall precipitation and evaporation both in spatial and time distribution. As a result, the agricultural production is affected in the availability of moisture to crops, change in length of growing periods, reduced output, change in cropping patterns and crop allocation, thus increasing the instability of agricultural production. Due to the regional differences of climate changes and the differences in the local economic development characteristics and in the people's recognition of climate change, climate change has different impacts on the agricultural production in various regions in China.

Shandong, located at the lower reach of the Yellow River, is an important economic and agricultural province with a large population, with its agricultural production, especially the grain production, directly related to the social stability and sustainable development. Agriculture is one of the main sectors with a climate-fragile ecological system. Changes in climate will bring a remarkable impact on the agricultural production.

Shandong lies in a complex monsoon climate region, where the atmospheric circulation system is complex, with winter controlled by strong Mongolia cold anticyclones, summer affected by the Indian low pressure and western Pacific subtropical high pressure, and spring and autumn in the winter-summer circulation conversion period. In addition, the summer monsoon is instable, making metrological disasters easy to occur frequently in this region.

With an increasing warmer climate, the agricultural disasters in the province tend to increase in frequency and have caused economic losses of different degrees. Moreover, the warming climate has intensified the fragile water resource supply and affected agricultural conditions, cropping systems, crop species allocation and crop outputs, forcing Shandong's agricultural production to face a huge challenge.

Therefore, studying the effect of climate change on agriculture is very essential to finding a coping strategy for reducing the unfavorable impacts of global climate change to the utmost so as to enable a global sustained development. The paper presents briefly the climate change, influential factors, agricultural production's vulnerability to climate change as well as the impacts of agricultural practices on the environment in Shandong. It also makes a

preliminary discussion on measures for coping with climate change, aiming to provide meaningful references for disaster prevention and mitigation, the sustained development of agriculture and the mitigation of the impact of climate change in Yellow River Basin on the agriculture in Shandong Province.

1.2 General description of the study area

1.2.1 Overview of geography and population

Shandong is located in a coastal region in east China and at the lower reach of the Yellow River, roughly at north latitude of 34°22'52" to 38°15'02" and east longitudinal 114°19'53" to 122°43'. It borders with Hebei, Henan, Anhui and Jiangsu. The geomorphologic pattern of the province is: (1) Center, south and east Shandong are mountainous and hilly areas; (2) West and north Shandong are part of the northwest Shandong plains formed by the alluviation of the Yellow River, which is part of East China Great Plains.

The Yellow River delta is at an elevation of 2-10m and at the lowest part of inland Shandong (Fig. 1). The landforms in Shandong are complex, consisting of 9 basic geomorphic types, namely middle mountain, low mountain, hill, mesa, basin, pediment plain, Yellow River alluvial fan, Yellow River plains and Yellow River delta. Shandong Province has a total area of 157,800 square kilometers (amounting to 1.6% of the national total and ranking the 19th in China), with the mountainous and hilly areas amounting to 37.45% and the plains to 62.55%. By the end of 2005, Shandong had 17 prefecture-level cities (Fig. 2) and 140 county-level administrative units (49 districts under city administration, 31 cities and 60 counties). Shandong also has a large population, ranking the second in China. In 2007, its total population was 93.46 million, including a rural population of 59.09 million, which amounted to 63.1% of the total, a proportion far higher than that of the agricultural labor population in China's whole labor population, which was 51%.

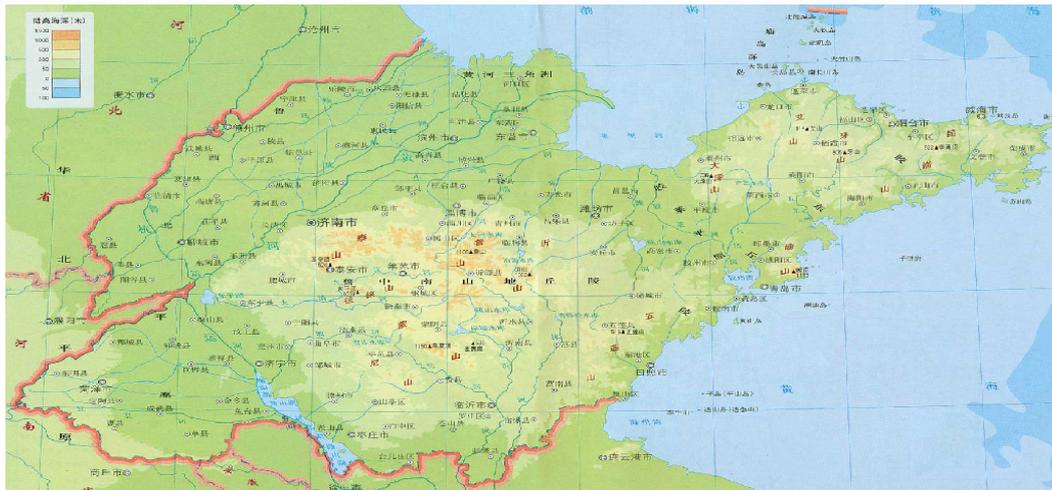


Fig.1 Shandong geomorphological map



Fig.2 Shandong administrative area chart

1.2.2 Climate

The climate in Shandong belongs to the warm temperate monsoon climate, which is moderate. It is characterized by concentrated precipitation, rainfall and heat in the same season, short springs and autumns and long winters and summers. The annual average temperature is 11-14°C, increasing from the coastal area in the northeast to the inland southwest, with that those in the Jiadong Peninsula and Yellow River delta below 12°C and that in southwest Shandong above 14°C. The province has an average of annual light hours of 2290-2890h, an annual frostless period of 173-250d, which increases from the coastal area in the northeast to the southwest, and an annual average rainfall precipitation of 550-950mm,

which decreases from the southeast to the northwest. The rainfall precipitation is not balanced in a year and mostly occurs in summer, with the rainfall in July to August amounting to 60-70% of the yearly total.

The climate in Shandong varies in different regions due to the impact of geological environment factors such as the difference in landforms and sea-land distribution. In the principle of combining the comprehensive factors with the leading factors, and serving the production practice and regional integrity, the province is divided into 5 climate zones and 15 climate subzones (Table 1).

In addition, Shandong is a region where climate disasters occur frequently, with drought, flood, wind and hail affecting most on agricultural production. Compared with adjacent provinces, Shandong has some particularities in its climate. Firstly, its spring temperature is higher than that in north Jiangsu on its south; and though summer monsoon invasion is not as strong as that in Jiangsu, the rainfall in the central south Shandong is higher than in north Jiangsu due to the landform effect; secondly, the northwest Shandong, though in the rainfall shadow zone, has a server drought even than the south Hebei; and thirdly, its number of sunlight hours and heat resource are higher than those in most regions in north China, which is 2300~2900h depending on the regions in Shandong, 200~400h more than that of Jiangsu ((2100~2500h).

1.2.3 Vegetation situation

Shandong lies in the warm temperate zone and has vegetation of forest distribution region type. The virgin forest no longer exists due to the impact of long-term human activities, and the present vegetation is of secondary type or artificial cultivation type. Due to Shandong's unique geographical position and geological history, the flora in the region is evidently characterized by rich plant species, complex and diversified plantage components and ancient origin. In China's vegetative regionalization, Shandong belongs to deciduous broad-leaved forest zone in the temperate zone of warm temperate zone. The boundary of two subzones of the northern and the southern deciduous oak forests in warm temperate zone right passes the center of Shandong, which runs westwards from the north Jiaolai River mouth in east Jiaodong, via the north edge of mountainous and hilly region in central south Shandong to near Jinan, and then crosses the Yellow River to the west provincial boundary via the south of Liaocheng. This boundary line divides Shandong into two parts: the northern

subzone and the southern subzone of deciduous oak forests in warm temperate zone (Table 2).

The vegetation in Shandong can be classified into 10 types, namely coniferous forest, broad-leaved deciduous forest, bamboo grove, brushwood, shrub, meadow, marsh, psammophilous vegetation, halophytic vegetation and aquatic vegetation. The plant

China Climate Change Partnership Framework - Enhanced strategies for climate-proofed and environmentally sound agricultural production in the Yellow River Basin (C-PESAP)

Table1 Characteristics of climate district in Shandong Province (From Shandong Province Network)								
Code	Climatic region	Code	Climate district	Average annual temperature	Non-frost time(Day)	Sunshine hours	Annual precipitation	Major disaster
I	South of shandong	I 1	South of shandong plain moist warm climate district	13-14°C	215-225	2400	About 900	Heavy waterlogging, more rainstorm
		I 2	Shudong hill humid moderation climate district	About 12°C	210-230	2500	About 920	more rainstorm
II	Southwest Shandong	II 1	Southwest of Shandong plain sub-humid warm climate district	13-14°C	220-230	2400-2600	600-700	Heavy waterlogging, drought-prone
		II 2	Yanhu sub-humid warm climate district	13-14°C	About 220	2300-2600	700-900	Heavy waterlogging, more rainstorm
III	Central of shandong	III1	South Central Shandong mountainous region sub-humid warm climate district	12-13°C	About 210	2400-2600	700-900	Heavy drought, more hails
		III2	Niyi hill sub-humid warm climate district	About 13°C	About 210	2450-2650	700-900	Heavy drought, first frost early, last frost late
IV	North of shandong	IV1	North of shandong coastal semi-arid warm cool climate distric	About 12°C	About 210	2700-2800	600-650	Strong winds, more hails
		IV2	North of shandong plain semi-arid warm cool climate distric	12-13°C	210-220	2700-2800	550-650	More arid wind, drought-prone, middle waterlogging
		IV3	North of shandong plain semi-arid warm cool climate distric	About 13°C	About 210	2600-2700	500-600	Heavy drought, middle waterlogging
		IV4	Xiaoqing river semi-arid warm climate distric	About 13°C	About 210	2500-2600	600-700	Waterlogging-prone, middle drought
V	East of shandong	V 1	Peninsula east end moist warm cold climate district	About 11-12°C	200-240	2500-2600	800-900	More gales, low temperature
		V 2	Southeast peninsula moist warm cold climate district	11-12°C	210-220	2400-2600	800-900	More gales and rainstorms
		V 3	Middle peninsula sub-humid warm cold climate district	11-12°C	200-220	2650	700-800	First frost early, last frost late
		V 4	North peninsula sub-humid warm cool climate district	11-12°C	220-240	2600-2800	650-750	More gales and hails
		V 5	Jiaolai plain sub-humid warm cool climate district	About 12°C	About 210	2500-2700	700-850	Heavy waterlogging

Table2 Shandong vegetation regionalization system (From Shandong Province Network)

Region	Sub-region	Vegetation area	Vegetation plot
(IIIi) Warm temperate deciduous broad-lea ved forest zone	(III ia) North warm temperate zone deciduous oak tree forest sub-region	IV (III ia-3) North of shandong Plain vegetation area	West north of shandong bei plain vegetation plot IV 1 [III ia -3(1)] North of shandong coastal plain vegetation plot IV 2 [III ia -3(2)]
	(III ib) South warm temperate zone deciduous oak tree forest sub-region	I (III ib-1) East of Shandong mountainous hill vegetation area	Jiaodong hill contains Northeast ingredient vegetation plot I 1 [III ib -1(1)] East south of shandong hills contains the southern ingredient vegetation plot I 2 [III ib -1(2)]
		II (III ib-2) Central and south of shandong mountainous hill vegetation area	Jiwei plain vegetation plot II 1 [III ib -2(1)] Central of shandong mountainous hill vegetation plot II 2 [III ib -2(2)] South of shandong mountainous hill vegetation plot II 3 [III ib -2(3)] Yishu plain vegetation plot II 4 [III ib -2(4)] Wensi plain vegetation plot II 5 [III ib -2(5)]
		III (III ib-3) West of shandong plain vegetation area	Lakeside marsh land vegetation plot III 1 [III ib -3(1)] Southwest Shandong plain vegetation plot III 2 [III ib -3(2)]

zoning is very evident due to the effect of hydrothermal conditions. The plant species in east Shandong that has good hydrothermal conditions are the richest, and become less in central south Shandong, even less in west Shandong and the least in north Shandong.

1.2.4 Water Resources situation

Shandong faces the sea on the east. It has complex terrain, concentrated rainfall, and developed rivers, with more than 5000 rivers being over 5 km long, including 1552 rivers longer than 10km, and more than 70 main streams and primary tributaries. Its main rivers include the Yellow River, Huaihe River, Haihe River, Xiaoqing River and Shandong Peninsula water system, and its average river-net density is 0.24km/km². The main lakes in Shandong include Nansi Lake, Dongping Lake, Baiyun Lake, Qingsha Lake, Mada Lake, etc, of which, Dongping Lake is the flood detention and storage regulating reservoir on the lower reach of the Yellow River that has a total reservoir area of 627km² and a flood control capacity of 1.194 billion cubic meters.

However, the contradiction between water supply and demand in Shandong is very serious, which is exhibited by insufficient total water resource and low water resource per capita and per mu of land. Its average annual total water resource is 30.5 billion m³, amounting to only 1.09% of the national total, and water resource per capita is 330m³, only 14% of the national average figure, ranking the third to the last place in China.

1.2.5 Socio-economic situation

Shandong is a large coastal economic province in east China. Its economy has been in high speed growth since the eighties, with both the growth rate and economic aggregate ranking in the front in China. According to the preliminary accounting of 2007 Shandong national economy and social development statistics bulletin (Fig.3), its GDP was 2.6 trillion yuan, ranking the second in China, about 20 billion yuan more than that of Jiansu which was the third. The added value of the primary industry was 250.91 billion yuan; that of the secondary industry 1477.34 billion yuan, of which the industrial added value was 1341.12 billion yuan; that of tertiary industry 860.52 billion yuan; and the ratio of the three industries was 9.7: 57.1: 33.2.

The employment and reemployment has kept a steady growth. In 2007, 1.101 million urban residents got employed and 15.56 million farmers got jobs in urban areas, including

7.78 million laborers who got urban employment through job training. The regional economic development has been accelerated, the implementation of the development strategy of “one body with two wings” has started and the construction of Yellow River Delta efficient ecological economic zone (north wing) and south Shandong economic zone (south wing) has got under way. The marine economy is developing in full swing and the total output of the marine industry in 2007 was 367.52 billion yuan, a year-on-year growth of 22.4%. However, there are still many difficulties and problems in the economic and social development in Shandong, which mainly include striking economic structural contradiction, lagged development of service industry, too high resource environment load, still arduous tasks of energy consumption reduction and environment protection, high employment and re-employment pressure, unbalanced development of urban and rural regions, insufficient social security capability, etc.

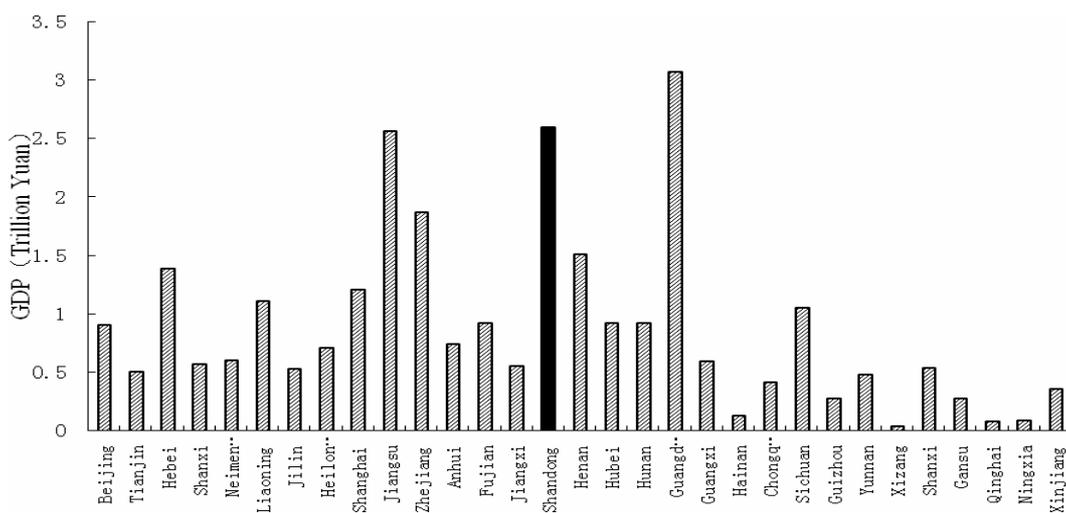


Fig3. 2007 GDP of some cities in China

2 Agricultural situation in the Yellow River Lower region – Shandong

2.1 Production and cropping systems

Shandong has a complete line of crop production, covering grain crops of wheat, maize, and other rainfed minor cereals and paddy, cash crops of cotton, peanut, sesame, tobacco and hemp, vegetables, temperate zone fruits, tea and special flowers. Since the founding of the P.R.China, with the population growth, the material level improvement, the demand of industry and foreign trade on the agricultural products, the increase of farmland input and the spreading of new agricultural technology, Shandong has carried out stepwise the reform of cropping system and the regulation of crop structure, which have been further speed up since the eighties. As a result, the proportion of grain crops in the arable land and the total cultivation area has been gradually reduced while the area for cash crops, and vegetables has been on increase.

2.1.1 Main crops, production and cropping areas

The main crops in Shandong include grain crops of wheat and maize, and cash crops of peanut and cotton. The sowing area for grain crops has been on continuous decrease. During 1931-1936 before the war of resistance against Japan and in 1949, the sowing area for grain crops accounted for about 90% of the total crop sowing area; in 1990, it was 74.9%; and during the eight years of 2000-2007, that on average was 62.9%. Though there has been variation in different historical periods, the integral structure with only a small proportion of crops other than grains has been remained unchanged, which is characterized by taking the grain crops as the main and considering also the cash crops.

2.1.1.1 Wheat and corn are the main food crops

With respect to the sowing areas for wheat and maize, that for wheat amounted to one third of the total for grain crops while that for maize was less than 10% in the thirties before the war of resistance against Japan and in the early period of the fifties; during the fifties to the seventies, that for wheat was about 37%, which had changed little, and that for maize was about 14%, an increase of nearly 50%; in the eighties, that for wheat and that for maize were 47% and 27% respectively, with that for maize keeping a steady rapid growth; From the nineties, that for wheat exceeded 50% while that for maize kept at 30%-38% (Table 3).

With respect to the production level, before the founding of the P.R. China, as the farmland was mainly used in way of triple-cropping in two years, the multi-cropping index of farmland was 140%. The wheat and maize production was characterized by small sowing area, low productivity and not high per mu yield, with the per mu yield of wheat and maize being only 615kg/hm² and 930 kg/Hm² in 1949. Since the founding of the P.R. China, with the progress in technology and the input increase, the per mu yield has greatly increased. The per-mu yield of wheat in 2007 was increased by nine times over 1949. In addition, with the temperature rise, the multi-cropping index has also increased. Through the arable land and wheat sowing area have been reduced yearly, the unit area yield has had a tendency of increase. The development of wheat production after the founding of the P. R. China can be roughly divided into five phases:

(1) Phase of steady recovery and development of area and per-mu yield before 1952: the land reform greatly aroused the farmers' initiative and the promotion of agricultural technology achieved a preliminary development. At the end of the phase, the wheat area increased by more than 0.33 million ha and the per-ha yield by 210 kg compared to those in 1949, equivalent to the level in the abundant years before the war of resistance against Japan.

(2) Phase of gradual reduction of area, slow growth of per-mu yield and hovering of total output during 1953-1970: The arable land area was continuously reduced, the multi-cropping index rose slowly, and the wheat area was reduced to 3.4 million ha in the "Third Five-Year Plan" period from 4 million ha in the "First Five-Year Plan" period. Though wheat breeding and cultivation technology achieved a great progress, the per-mu

yield grew little due to the restriction of the rural economic system and the slow growth of agricultural input. The total wheat output was reduced to below 200 Mt in 1961 and 1962 due to the “sequel” of “Great Leap Forward” campaign and natural disasters, which was gradually recovered after 1963.

(3) Phase of area hovering, and rapid increase of per-mu yield and total output during 1971-1982: The growth of the multi-cropping index was offset by the decrease of arable land area, and the wheat area was kept between 50 ~ 58 million mu. The newly improved seeds were put into use in production, the irrigation works and farmland basic construction projects in the campaign of “Agriculture emulating Dazhai” played their role, the production capacity of chemical fertilizers had a substantial increase and the contract system with remuneration linked to output for farmland was implemented in a full swing. All these factors promoted the growth of wheat per-mu yield. In the end of the phase, its per-mu yield was over 160kg and its total output exceeded 8 billion kg.

(4) Phase of area rally, continuous increase of per-mu yield and total output doubling during 1983 and 1999: Shandong took the development of wheat product as the major task in making the grain production to step on a new stage and made great efforts to promote intercropping and expand the wheat land area. As a result, the cropping index of farmland rose violently; the farmers’ initiative in increasing the input was excited by the contract system with remuneration linked to output; the updating of crop species was accelerated; the fine sowing and semi-fine sowing technologies were gradually spread and the formulated fertilization was widely adopted. These technical factors were rapidly converted into productivity.

(5) Phase of area and total output decrease and hovering, and per-mu yield rally since the beginning of the 21st century: The arable land area has decreased, with the wheat land area reduced by nearly 0.6 million ha. With the economic development and the regulation of cropping structure, it is very difficult to stabilize the wheat land area due to the low economic benefit of wheat and the reduced farmers’ initiative. In recent years, Shandong Restricted by drought, frost and salinized land, the wheat output in Shandong has been low and instable. However, with the implementation of policies beneficial to farmers and the spreading of fine species and high-yield fine-quality cultivation technology, the unit yield of wheat has somewhat increased after the reduction.

Table 3 Sown area of wheat and corn

Time	Crops sown area ($\times 10^4$ Ha)	Wheat			Corn		
		Sown area ($\times 10^4$ Ha)	Output ($\times 10^4$ t)	Yield per unit area (kg/hm ²)	Sown area ($\times 10^4$ Ha)	Output ($\times 10^4$ t)	Yield per unit area (kg/hm ²)
1949	1097.6	358.4	221.5	615.0	94.9	88.0	930.0
1952	1170.2	392.4	320.5	825.0	99.7	122.0	1230.0
1957	1149.4	414.8	337.0	810.0	137.3	181.0	1320.0
1962	992.0	329.5	198.5	600.0	92.7	101.0	1095.0
1965	994.0	372.5	347.5	930.0	135.6	237.0	1755.0
1970	934.5	343.5	318.5	930.0	132.9	287.5	2160.0
1975	920.5	377.1	656.0	1740.0	179.9	491.0	2730.0
1978	880.8	371.4	803.5	2160.0	213.5	612.0	2865.0
1979	873.5	372.1	957.0	2580.0	213.6	730.0	3420.0
80's	807.4	381.3	1249.2	3244.5	221.4	961.7	4365.0
90's	810.7	407.5	1998.6	4910.0	258.8	1400.4	5432.2
2000-2007	690.2	343.4	1752.6	5110.5	261.8	1532.2	5970.9

Since the founding of the P. R. China, the maize planting area and per-mu yield has increased by many folds, which is an important cause for the growth rate of core production to greatly exceed that of other grain crops. The development of maize production after the founding of the P. R. China can be roughly divided into five phases:

(1) Phase of steady development of the planting area, per-mu yield and total output during 1949-1958: With the land reform and the recovery of rural economy, especially with the promotion of high-yield crops in 1956 and 1957, the maize land area was increased to over 0.4 million ha. However, due to the then very slow level of species, fertilization and cultivation, the per-mu yield gained only a small increase, which was about 20kg.

(2) Phase of the area reduction and then recovery, and the decrease, recovery and increase of per-mu yield and total output during 1959 and 1966: The destruction of agricultural productivity caused by the “Great Leap Forward” campaign and the natural disasters led to the decline of crop farming. Through the mistake correction and production recovery, the maize area in 1965 returned to over 1.33 million ha. The promotion of double cross hybrid remarkably increased the per-mu yield.

(3) Phase of maize planting area's continuous slow increase from a temperary slow

decrease, and accelerated growth of both per-mu yield and total output during 1967-1975: In this phase, the irrigation conditions of farmland were greatly improved and the chemical fertilizer production and application amount were increased by folds. The maize crossbreed was popularized, the triple cross hybrid replaced double cross hybrid, and the single cross hybrid began to be spread, with the production of hybrid seeds evidently raised.

(4) Phase of the planting area's further increase from hovering, violent rise of per-mu yield and doubling of total output during 1976-2007: With the implementation of rural economic system reform, the input on farmland increased more rapidly than ever before, the cropping structure of grain crops was further regulated, the maize single cross hybrid was spread, a number of new high-yield, anti-disease, compact-type improved seeds were put into use, the planting density was increased and the intercropping in wheat land was popularized. As a result, the maize planting area was expanded from 2.13 million ha to about 2.85 million ha, the average per-mu yield approached 425kg, and the total output was increased from 6 billion kg to 18.16 billion kg.

2.1.1.2 Cotton and peanut are the main economic crops

Cotton is an important cash crop in Shandong, whose planting area and output occupies certain position in China. In early thirties, the cotton land area and output accounted for more than one fourth of the national total. Later, Shandong's cotton position was lowered due to the war. During the period from the late thirties to prior to the founding of the new China, its cotton land area and output accounted for only about 5% of the national total. After the founding of the new China, the cotton production in Shandong was improved by fully making use of the favorable natural conditions and expanding the cotton planting area. Especially since the opening and reform, the cotton production has been developing rapidly by practicing household contract responsibility system, and implementing a series of policies encouraging the cotton planting and improving the planting technology. The recovery and development of Shandong's cotton production since the founding of the new China has experienced six phases (Fig. 4).

(1) Phase of development during 1949-1952: The party and government took a series of measures to recover and develop the cotton production, including setting up the cotton purchase organ, issuing the deposit for pre-purchasing the cotton and necessary

production and living materials, spreading the improved seeds, improving the cultivation technology and expanding the planting area. As a result, a 52% increase in cotton planting area, a 33% per-mu yield increase and a 1.09 times total output increase were obtained in 1952 over 1949.

(2) Phase of steady development during 1953-1959: Promoted by the campaign of agricultural cooperation, the cotton production achieved a steady development, with the seven-year average annual cotton planting area being 0.714 million ha, per-mu yield 16.8kg and total output 0.18 million t.

(3) Phase of reduction during 1960-1962: Due to the shortage of grains and the more stress on grains than on cotton, the three-year average annual cotton planting area was reduced by 39.9% compared to that seven years before, the per-mu yield was only 7.6 kg and the total output even decreased 36.7% compared to that in 1949.

(4) Phase of recover and hovering during 1963-1979: The cotton planting area was 6.449 million ha during 13 years, the per-mu yield was 20 kg and the total output 0.196 million t.

(5) Phase of high-speed development during 1980-1984: After the Third Plenary Session of the CCP 11th Central Committee, great efforts were made to promote the household contract responsibility system in the rural area, regulate the cropping structure, raise the cotton purchase price (which was raised for three times), work out the policy encouraging selling the cotton to the state by assigning grains and chemical fertilizer, and spread the new plant specie -Shandong No. 1Cotton. As a result, the cotton production was promoted. In 1984, the cotton planting area, per-mu yield, total output, and sales amount hit the historical record, with the cotton land area, total output, and sales amount ranking the first in China, and the raw cotton began to be exported.

(6) Phase of decline and hovering during 1985-1990: The super bumper harvest of cotton in 1984 led to a temporary overstock of cotton. Due to an incorrect recognition of the cotton supply-demand situation and a too rapid regulation, the cotton purchase price was reduced for consecutive two years. In addition, the prices of production goods such as agricultural pesticides and chemical fertilizers rose greatly and the class and price depression in cotton purchase was often seen. As a result, the economic benefit of cotton planting was reduced and the farmers' initiative for cotton planting was frustrated, rapidly leading to an undersupply from original overstock. In 1987, the great decline of cotton output in the previous two years and the high use of the inventory aroused the leaders'

attention. The cotton price was adjusted up and moreover, the climate conditions were favorable, leading to a record per-mu yield of 68 kg and total output of 1.244 billion kg. However, during 1988-1990, the total output and the per-mu yield of cotton declined yearly once again.

(7) Phase of downturn during 1991-2000: The low cotton price, low cotton planting benefit, irrational grain-cotton price ratio and the frequent natural disasters in Shandong such as drought, hail and insect damage led to a continuous decline in the cotton planting area, choking the growth of cotton production. However, due to the promotion of scientific control of plant disease and insect pests and new cotton varieties, the unit area yield showed a tendency of increase.

(8) Phase of steady growth since 2001: The cotton planting area has increased as a result of market function. In recent years, a wide price decline has been seen due to the fierce competition of farm product markets in various places. Comparatively, the benefit of cotton planting has greatly increased, with the income of per mu cotton reaching about 800 yuan, 200 yuan higher than the total income of wheat-maize intercropping. The good news of cotton export growth due to China's WTO entry has excited the farmers' initiative of cotton planting in Shandong. The scientific and technological innovation has done a great help and the technical challenges that had puzzled the cotton production for a long time have been solved in recent years. The wide spreading of Bt cotton, the great decrease of labor strength and the evident production income have led to the high enthusiasm of farmers for cotton planting. To improve the comprehensive benefit of cotton planting, intercropping modes of cotton-wheat, cotton-garlic and cotton-potato have been promoted in Shandong. A half of cotton farmland has achieved a multi-cropping index of 150%, increasing the income by a half compared to that by single cotton planting ^[1,2].

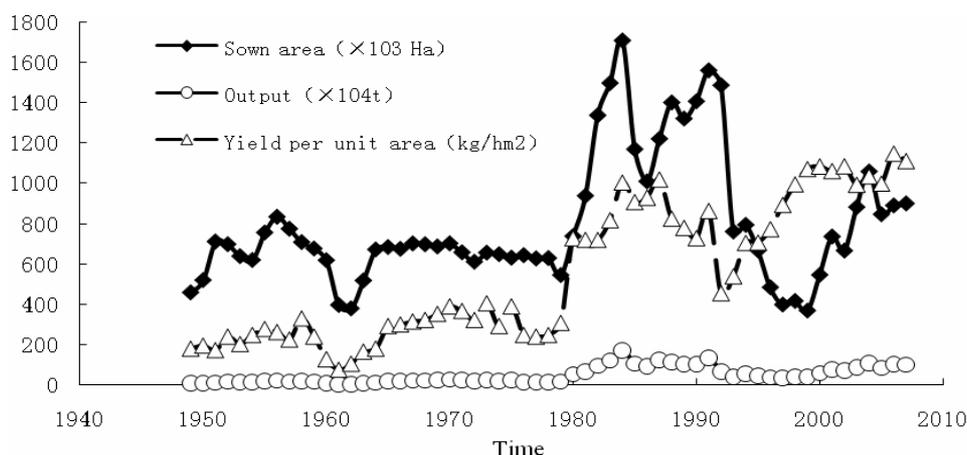


Fig.4 Shandong cotton production statistical chart

Peanut has been grown in Shandong for less than 200 years. Due to the suitable conditions for peanut planting and the advantageous export by sea in Shandong, peanut has developed rapidly and become one of the main crops in Shandong, with its planting area and output ranking the first in China. Shandong has become an important peanut export base in China. Since the founding of the new China, the peanut production in Shandong has experienced a four-phase process: development, decline, hovering and accelerated development (Fig. 5).

(1) Phase of development during 1950-1957: The then policy of grain-oil unified accounting in state purchase promoted the farmers' initiative in planting peanut by taking measures to suit the local conditions. The eight-year average annual planting area was 9.807 million mu, the per-mu yield, 96.5 kg and the total output, 805.8 million kg. The planting area and total output of peanut in 1956 created a historical record of the province in 1956.

(2) Phase of decline and hovering during 1958-1978: The policy of grain-oil unified accounting in state purchase was cancelled and the agriculture output was greatly reduced for consecutive four years starting in 1959, leading to the living difficulty of urban and rural people. Cereal production increase became an issue of first importance and the peanut production was seriously depressed, with the peanut output decreasing to the historical low level in 1960. By the end of the sixties, the peanut production was recovered somewhat after three-year regulation period. However, due to the lateral stress on making the grain output to exceed the outline-specified indexes (per-mu yield of 200 kg for

regions north of the Yellow River and 250 kg south of the Yellow River), and the index set for the regions of the Yangtze River (per-mu yield of 400 kg), cash crops did not received due importance. The peanut production hovered for a long time and was still unable to recover to the level in middle fifties during 1958-1978.

(3) Phase of accelerated development during 1979-1990: The implementation of household contract responsibility system and the up-adjustment of peanut price of state purchase aroused the initiative of farmers in planting peanut. In 1980, the total output of peanut reached 1.404 billion kg, exceeding that in 1956; in 1981, the peanut planting area broke 10 million mu; in 1985, the peanut planting area reached 13.786 million mu, the per-mu yield was 190 kg and the total output was 2.621 billion kg, with the planting area, per-mu yield and total output creating a historical record; in 1987, the per-mu yield broke 200 for the first time. The 12-year average annual planting area was 10.538 million mu, average annual per-mu yield was 166.5 kg and average annual total output was 1.755 billion kg, with the area increasing by 58.7%, the per-mu yield by more than one fold and the total output by 2.24 folds. The yield increase during this period was mainly due to the implementation of the contract responsibility system, which raised the initiative of the farmers. This is mentioned in the report. It was no wonder that the per mu yield exceeded 200 kg in 1987 as it reached 190 kg already in 1985.

(4) Phase of steady development since 1991: Due to the grain and oil price increase, the peanut production has got a high benefit, leading to a continuous growth in peanut planting area for years. The decrease of wheat sowing area in winter and the increase in spring has also left a large room for increasing the peanut sowing in spring.

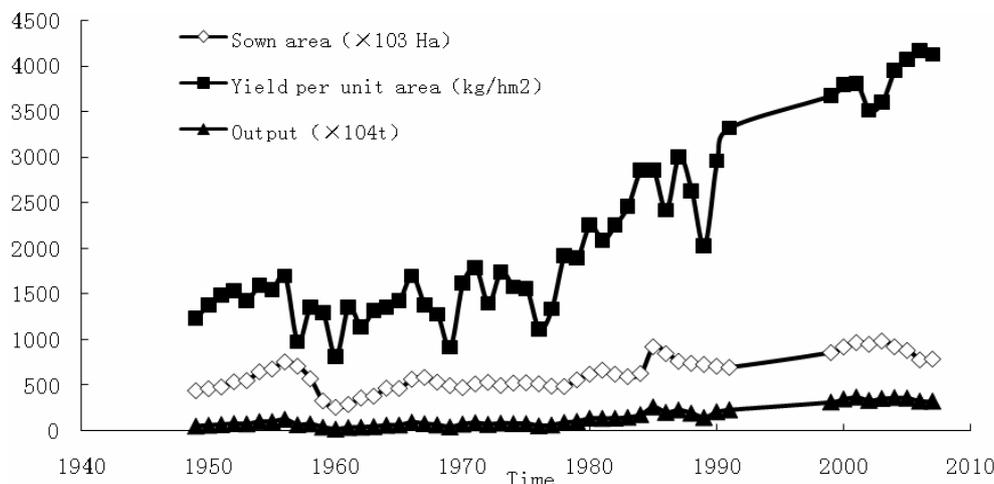


Fig.5 Shandong peanut production statistical chart

2.1.2 Status and potential of less common crops

The sowing area for other crops in Shandong has continuously increased, which increased from 0.227 million ha in 1949 to 0.43 million ha in 1990, and then to 2.019 million ha in 2007, a nearly tenfold increase. The vegetable area has increased most and its proportion has risen most rapidly (Fig. 6). During the period from the establishment of the P. R. China to the First Five-Year Plan period, the vegetable industry was at its recovery. The average vegetable cultivation area in the province was 0.186 million ha, a 39% increase than that in 1949. At the end of this phase, it reached 0.25 million ha. During the Second Five-Year Plan period to the Seventh Five-Year Plan period, it was at its steady development. In early sixties of this phase, the diet of both urban and rural people adopted a way of “low standard and using vegetables to replace grains”. The area for bulky vegetables for tiding over the lean years increased sharply, once exceeding 0.5 million ha, which returned to normal status when the living turned better. Since the nineties, the construction and implementation of Shandong “vegetable basket” projects have been carried out. Under the support of the Ministry of Agriculture and the local governments of all levels, a number of production bases for commodity vegetables have been built in the cereal producing zones that are far from the suburbs. The thriving of sunlight greenhouse and vegetable plastic sheds and the promotion of science and technology have promoted a linear growth trend of vegetable area, total output and unit area yield in Shandong. The

vegetable production in Shandong has basically realized the transfer from mainly suburban production to mainly large bases in rural areas, from mainly autumn vegetables to mainly winter and spring vegetables, and from bulky vegetables to fine vegetables. Shandong has gradually established its position as the national “large vegetable garden” by relying on its large quantity and fine quality of vegetables.

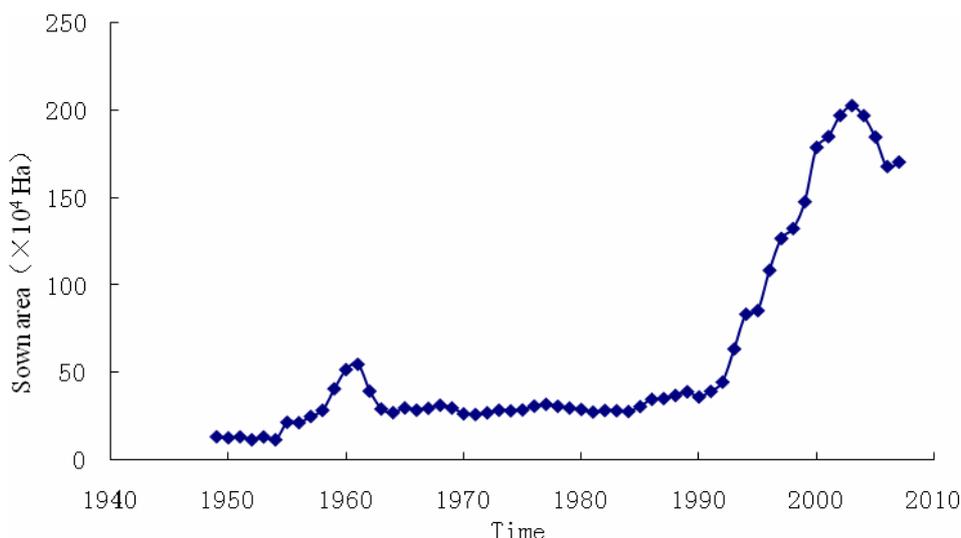


Fig.6 Vegetable sown area in Shandong

The output value of vegetables exceeded that of grains in 1999 for the first time, the vegetable industry became the largest industry of planting industry. The total output of vegetables in Shandong reached 86.35 million tons in 2008, a growth of 3.5% over the previous year. The climate warming has provided the favorable climate conditions for the development of winter plastic shred vegetables in Shandong, benefiting the increase of its output value. However, continuous temperature rise will increase the crops’ demand for water, and therefore, also increase the withdrawal of underground water. Excessive withdrawal of underground water can lead to the decline of water table to form funnel areas, aggravating the seawater encroaching in offshore regions. The temperature rise will speed up fertilizer decomposition and propagation of plant disease and insect pests, suggesting a greater input in farming. Now, the vegetable area in Shandong has basically been stabilized, the vegetable industrial structure and layout continuously optimized and the vegetable market and circulation system improved. The development of the vegetable industry integrating production, processing, transport, sales and export in Shandong has become an important way for the farmers to become rich and prosperous.

Fruits are an important component of Shandong farm production. 2004 statistics showed that the fruits were only next to grains and vegetables in terms of output value and one of the main ways for increasing farmer's income. Since the founding of new China, the fruit planting area of Shandong has had an enormous increase (Fig. 7). In 1949, the total orchard area of the province was only 22,400 ha and the total yield was only 250, 000 tons.

In order to increase the fruit production, the people's government adopted many measures such as organizing transport and sales, reducing and exempting taxes, issuing loans, organizing the investigation and study, setting up fruit technical guidance institutions and state-run fruit horticultural farms, and popularizing new technology and improved varieties of fruit tree saplings.

In 1952, the government supported the development of fruit production with apple as the main variety in old revolutionary base areas such as Xixia, Haiyang, Wuliang, Yishui and Yiyuan. In the same year, the total planting area of fruit trees reached 27,500 ha and the yield was raised to 345, 000 tons. During 1955 and 1957, the State Council, the Ministry of Agriculture and the Ministry of Forestry issued a series of guidelines and policies for developing the fruit production such as opening up new fruit orchards in mountain areas and wasteland, reducing and exempting the agricultural tax of new fruit orchards, strengthening the leadership, making an all-round planning and laying stress on both development and improvement.

Shandong Province also formulated the corresponding fruit production plan which took apple as the main variety for development, worked out the specification standard for fruit tree saplings, and assigned the state-run fruit horticultural farms the task to cultivate fine saplings. In 1957, the planting area of fruit trees was expanded to more than 61,000 ha and the total yield of fruits to 378,000 tons.

In 1958, "agricultural great leap forward" campaign was carried out and in 1959, the fruit orchard area increased by over 300,000 mu compared to 1957. In the follow-up three years of economic hard time, the land for fruits was returned to grain growing land and the area for fruit trees was shrunken. However, the reduction was only 5.2% in 1962 compared to 1959. But the total yield was reduced by half due to insufficient management of fruit orchards. Afterwards, the leadership was enhanced, the purchase price was raised, the grain requisition task for fruit orchards was reduced or exempted and the premium purchase of fruits was adjusted, leading to a gradual recovery of fruit production.

During the 70s, dwarfing rootstocks of apple trees, dwarf shoot type Hongxing and Fuji apple trees were popularized, the area of fruit orchards exceeded three million mu and the fruit output surpassed one million tons.

In the early 80s, with the implementation of the system of contracted household responsibility related to output, the farmers owned the autonomy of production. The area of fruit orchards tended to be stable, the fruit yield increased gradually and the production of fruitlets rose again.

In 1984, with the emerging of township enterprises, the fruit processing industry gained development, and the fruit tree structure and varieties were changed. The application of dwarf thick planting, hole-storage of fertilizer water, straw mulching of orchards, plastic membrane mulching and biological hormones and the development of low-yield orchards promoted the development of fruit production by science and technology.

By 1988, the area of fruit orchards exceeded 10 million mu and the total fruit yield reached 2.625 million tons. The area of apple trees accounted for 64% of the total and the apple output for 61%. The area of hawthorn trees was expanded most rapidly to over one million mu, only next to that of apple trees, and the area for grape and peach also increased greatly.

After 1988, in response to the appeal of the country to restrict the occupation of fertile grain field, the growth of the fruit area slowed down and slightly declined. The area of fruit trees in 1991 was 613, 000 ha. Shandong carried out the adjustment of internal agricultural structure and took the development of vegetable and fruit production as the main task in its adjustment of agricultural structure.

After 1992, the area for fruit trees was expanded quickly and in 1996, it had a 56.8% increase compared to 1991, with the total yield doubled. Afterwards, the area of fruit trees declined continuously and in 2007, it was reduced by 31.5% compared to 1996. However, the total fruit yield rose perpendicularly, exceeded 10 million tons in 2003 and reached 13.339 million tons, a growth of 58.1% compared to 1996. The reasons were three: (1) the adjustment of farm production structure. Around 1994, the planting areas for fruits and for vegetables were basically equal but in 2007, the planting area for vegetables reached 2.2 million ha, three times that for fruit planting; (2) the continuous decline of fruit prices, which bruised the fruit farmers' initiative; (3) the result of market competition.

Geographically, the fruit production of Shandong has no evident position superiority. In terms of apply production, the natural advantage of Shaanxi and Gansu is better compared

to Shandong. Their development in recent years has formed an enormous competition pressure on the fruit production and sales of Shandong.

2.1.3 Cultivation systems and practices

The farming system include the cropping pattern (crop allocation, intercropping, rotating cropping and multi-cropping), soil cultivation system, fertilization system, irrigation system and disease-pest-weed prevention and control system.

The present crop allocation of Shandong is characterized in that: (1) as the province follows a principle of taking cereals as the main agricultural product while considering cash crops, the other crops takes a rather small portion; (2) in terms of either the area composition or the output composition, the autumn grains and summer grains take an equal important position; (3) the summer grains and the autumn grains take wheat and maize as the main respectively, with the other grain crops such as sorghum, millet and soybean having only a small sowing area; (4) the cash crop structure tends to be monoculture, forming a cotton-oil structure where the cotton has the priority; and of the oil crops, peanut is given the priority to; and (5) of the other crops, the vegetable has the highest proportion in sowing area.

Up to the early thirties in the 20th century, two-year three-cropping had been the main cropping system, with its area accounting for about two thirds of the arable land area. Since the seventies, a transition to two harvests in one year has been gradually carried out. In the eighties, the area used for one-year two-harvest system was expanded rapidly, with its area amounting to over 48% of the total arable land in 1990 and to over 55% in the 21st century. The large-scale application of intercropping and multi-cropping characterized by large area, many crop varieties and various modes has effectively adjusted the contradiction between crops in land and time needed, and also alleviated the contradiction caused by vast population and limited farmland and the struggle between grains and cash crops for land use. The increased fertilizer input, the improved mechanical level, the changed planting system and Due to the climate warming and the change of cropping system, the multi-cropping index of farmland in Shandong has continuously increased from 140% in the fifties in 20th century to 147% in the following thirty years, to about 160% in the nineties and about 170% in the 21st century.

In terms of soil tillage system, the province has intensified the promotion of

protective tillage. The core of protective tillage is to carry out no tillage or less tillage of farmland as much as possible. The crop stalk and stubble mulch is used to protect the land surface, and the supporting agricultural cultivation technology is adopted to protect the soil natural function and land output capacity. According to the statistics, the number of the counties (cities, districts) which are demonstrative ones in promoting protective tillage in 2006 in Shandong was 102 and increased by 72 over 2005. The number of the demonstrative bases for protective tillage of various levels was over 1100, the protective tillage machinery was more than 1600 units, a more than one fold year-on-year increase. In the recent three years, the governments at all levels have remarkably increased the support to agriculture, rural areas and farmers. The implementation of the state subsidy policy for purchasing farm machinery and the use of various farm support funds have reduced the farmers' load, stimulated farmers' enthusiasm in buying and applying farm machinery, which has now been purchased by farmers themselves

Great efforts have been made to develop the farmland water conservancy so as to improve the farmland irrigation conditions. In 2007, the number of completed electro-mechanical wells reached 0.9546 million, a 1.3 times increase compared to that in 1978; the mechanical power for drainage and irrigation was 20.593 million kW, a 2.4 times increase over 1978; the effective irrigated farmland in the province was 48.4 million ha, amounting to 76.5% of the arable land area, an increase of 16 percentage points over 1978.

Flood irrigation is a traditional mode of irrigation in the province, and its low water utilization rate may lead to water resource waste. For Shandong, a province with insufficient total water resource, it is of particular importance to practice a water-saving irrigation.

The water-saving irrigation started early in the province and has developed rapidly in recent years. In 2007, the farmland area adopting various types of water-saving irrigation reached 20.20 million ha, accounted for 26.91% of the provincial total. Greatly alleviating the impacts of drought and flood disasters.

Various modes and methods of water-saving irrigation have been adopted to suit different places according to the different climates, water resource conditions and economic development conditions in the middle, south and west regions and Jiaodong of the province.

Three main development lines of water-saving irrigation have been formed, including

that for the eastern region of the province which is composed of sprinkler irrigation, sprinkler spraying and drip irrigation for plastic shed vegetables, economic forest and orchards, that for the central region which adopts low-pressure piping irrigation for field crops, and that for the western region which includes water-saving transformation and paddy water-saving irrigation for the Yellow River irrigation region.

The water saving technologies for dry farming mainly includes engineering water saving measures, agronomic water saving measures, management water saving measures and supplementary irrigation water saving measures.

The engineering water saving measures include anti-seepage of water transport channel, low-pressure pipe transport of water and sprinkler irrigation; the agronomic water saving measures include furrow cropping, plastic membrane mulching, stubble mulching and breeding of drought-tolerant varieties; the management water saving technology stresses on the combination of space and time; and the supplementary irrigation water saving measures mainly include the water saving utilization of out-region water resource and water resource for regulating and storage.

With the climate warming, the winter has become evidently warmer, leading to a heavier occurrence of plant diseases and insect pests and further an evident increase of the use of pesticides which are mainly chemicals.

Since the beginning of 21st century, the annual average pesticide consumption has been 0.1583 million t, with that of unit area being 14.47kg/hm². In 2007, the pesticide consumption was 0.1657 million t, an 18.1% increase over 2000. The temperature rise led to an accelerated release of chemical fertilizers, and further to an increase in the consumption of chemical fertilizers in order to satisfy the crop demand on fertilizer. During 2000 and 2007, the total amount of agriculture-use chemical fertilizers and the consumption of NPK fertilizers increased yearly. Of them, the nitrogen fertilizer consumption remained high.

In 2007, the application rate of nitrogen fertilizer per unit area was as high as 466.54kg/hm², a 27.1% increase over 2000. In recent years, with the popularization of the scientific fertilization concept, the area of orchards, vegetable gardens and fields using organic fertilizers has increased. The ratio of crop stalk/ stubble returned to the farmland has been raised. In 2007, the comprehensive utilization rates of the stalk and stubble of wheat and maize in the province were 64% and 87%, of which the mechanized rates amounted to 53% and 85.6% respectively.

In addition, the climate warming, the delay of high temperature period and the harvest of summer maize in a proper later time are beneficial to an efficient utilization of limited light heat resource, increase of grain weight and improvement of unit yield. The proper delayed sowing of winter wheat is favorable to its steady growth and safe overwintering. Therefore, since the autumn harvesting and sowing in 2008, a major regulation has been made on the agricultural cropping system, and the technology of proper delayed harvesting of summer maize and the proper delayed sowing of wheat has been promoted in all places, which is called “dual delay” technology for short.

2.2 Socio-economic aspects

2.2.1 Crop prices, income and profitability

Since 2007, the prices of some farm products such as maize, wheat and vegetables have shown a tendency of rising, those of pork, poultry eggs and edible oil have risen greatly. According to statistics, the price indexes of cereals, oils, meat, poultry and its products, eggs and fresh vegetables were up by 8.1%, 21.9%, 34.7%, 20.8% and 13.4% on a year-on-year basis respectively. The continuous rise of farm products has raised the farmers’ production initiative, and the income from selling farm products has seen a great increase. However, at the same time, the prices of agricultural inputs such as urea, diesel and plastic sheeting for farming use have greatly risen. The real income increase from the price rise of farm products has been substantially offset, leading to only a small change in the profit of farm products. It was reported that by the end of 2006, a cereal bumper harvest was achieved in Shandong and the grain price was up. The rise of grain prices was, on the one side, related to the increase of international grain prices due to the general output reduction in the global main grain producing countries except China; and on the other side, related to the unfavorable macro grain regulation which was influenced by the domestic policy of protecting farmers’ interests and also to the domestic seasonal demand increase, though China achieved remarkable output increase. However, the main profit was detained in the circulation link, with only a little benefit left for farmers.

2.2.2 Agricultural credit and non-agricultural income

Shandong Rural Credit Cooperatives is composed of 134 county-level cooperatives. By 2008, the balance of deposits broke 400 billion yuan and the balance of loans hit 300 billion yuan. Rural Credit Cooperatives has simplified the loan handling formalities and granted preference to farmer loans.

At the end of 2006, the additional agricultural income of Shandong Rural Credit Cooperatives amounted to more than 95% that of the financial institutions in the province, displaying an outstanding role in supporting the local economy development.

The provincial government was the first to carry out the pilot test of policy agricultural insurance for wheat, maize, plastic shed vegetables in Zhangqiu and Shouguang^[3].

The insurance plan was to insure 50,000 mu vegetable greenhouses. All winter warming greenhouses and the vegetables planted in the greenhouses could be covered by the subject scope of this insurance. The insured liabilities were: (1) fire hazard and flying object falling;(2) greenhouse damage and destruction caused by violent storm, tornado, snow disaster, hails and ice and the vegetable freezing to death due to the greenhouse damage and destruction caused therefrom; (3) theft and robbery of the motor of roller shutters and greenhouse mulching membrane.

The insurance period was six months from 0:00 the day after the insurance was purchased to 24:00 of the termination day. The pilot test period was from November 20, 2006 to April 20, 2007. The insured amounts were classified according to the main materials of greenhouse, and determined in reference to the local market prices, with the market price as the upper limit. The premium was 100 yuan/mu, of which 40yuan was from the government as subsidy and 60yuan was paid by the farmer. The fund for the insurance premium subsidy was supported by the provincial, city and county finances on a 3:3:4 prorated basis.

The insurance premium subsidy for Shouguang city by the province and Weifang was made in the principle of “subsidy to actually insured amount and settlement at fixed period” and was allocated quarterly or yearly according to the actual insurance underwriting. Shouguang Municipal government paid the subsidy from its own finance prior to the subsidy settlement.

To answer the call of “intensifying the state’s support to and protection of agriculture”, the province has further expanded the pilot test scope, added insurance varieties and increased the financial supportive fund. In 2007, the pilot test points of policy agricultural insurance covered 25 counties and 10 varieties; and in 2008, the number of counties covered reached 60, actively protecting the farming.

During 2000-2007, the farmers’ income in the province kept a rapid increase. Shandong implemented several policies for strengthening agriculture and benefiting farmers such as reducing and exempting agricultural taxes, setting up the system of direct subsidies to grain sellers and increasing the input in farm infrastructure, greatly increasing farmers’ confidence and enthusiasm in grain production. Since 2004, the agriculture-involved reforms have been further deepened with the reform of taxes and charges as the breakthrough, the accumulated effects of a series of policies for increasing farmers’ income have been liberated in a concentrated manner, a big break of farmers’ income increase has appeared and the farmers’ income has kept a two-digit growth.

In 2007, the average pure income per rural resident reached 4985.3 yuan, an 87.5% increase over 2000 (Table 4). With the development of agricultural economy, the farmers have an increasingly wide income channel. The non-agricultural income has taken an increasingly greater proportion, which reached 2202.7 yuan per capita in 2005, amounting to 56% of the total income and exceeding the agricultural income for the first time, and rose to 58.4% of the total income in 2007. The labor force shift characterized by large scale, high speed and improved quality is an important source for income increase of farmers. In 2007, the wage income in the average per-capita pure income was 1950.8 yuan, a 1.3 fold increase compared to 850.6 yuan in 2000. What’s more, with the gradual increase in the economic strength of farmer households, the assets income and transfer income have increased rapidly by 1.5 folds and 1.6 folds over 2000 respectively, increasing the non-agricultural income of farmers to a certain extent.

Table 4 Per capita net income of rural inhabitant Unit: Yuan/person

(From Statistical Yearbook of Shandong Province)

Years	Annual net income	Agricultural net income	Non-agricultural net income			
			Salary income	Household management	Property income	Transferability income
2000	2659.2	1274.3	850.6	402.6	57.8	73.9
2005	3930.5	1727.9	1437.6	530.2	102.8	132.1
2006	4368.3	1825.0	1671.5	584.8	127.6	159.4
2007	4985.3	2074.8	1950.8	625.7	144.3	189.7

2.2.3 Contribution of agriculture, food transformation industries and food trade to GDP

Since the beginning of 21st century, Shandong's gross output value of agriculture has kept a steady sustained growth. It broke 300 billion yuan in 2003, 400 billion yuan in 2006 and in 2007, got a 1.1 fold increase over 2000. At the same time of agricultural growth, industry and other trades have made greater progress, making the proportion of agriculture in Shandong GDP to have a decrease tendency, which reduced from 26.9% in 2000 to 18.4% in 2007, an eight-year average annual reduction of 1.1 percentage points.

Since the late eighties in 20th century, the processing trade in Shandong has experienced a rapid development and gained a significant progress. The export volume of its processing trade has risen year on year and exhibited a good steady development, which increased by 3.4% in the eight years from 2000 to 2007. Its proportion in the provincial GDP has also kept a steady rise, which increased by 4.3 percentage points in 2007 over 2000. The rapid development of processing trade has displayed an important role in the social and economical development of Shandong.

2.2.4 Food consumption and degree of self-sufficiency

In the eighties of 20th century, the largest expense of rural residents was on foods, which remained the same in the nineties, with its proportion in the total expense somewhat reduced. Since the beginning of 21st century, the proportion of food expense has seen a rapid decrease of 13.1 percentage points over the last phase. In 2007, the living expense per rural resident was 3144 yuan containing 1191 yuan on food, and the Engle's

coefficient was 37.9%, a decrease of 1.9 percentage points on a year-on-year basis. It indicates that the proportion of food expense in living expense has decreased and the farmers are able to spend more of their income on large household electric appliances, children's education and social insurance. The proportion of the staple food expense in the food expense has also reduced, which was reduced by 50 percentage points in 2007 compared to that in 1978. The expense on non-staple foods has rapidly increased, which has increased by 20.6 percentage points over the 30 years, and the expense on nutrient meat, poultry, eggs and aquatic products has also increased. The proportion of the expense on outdoor diet in the total food expense has increased by about 1.2 percentage points.

By 1999, the cereals had been in a situation where the output was greater than the consumption in Shandong. Since 2000, there has been a great change in grain surplus and shortage pattern against a great decrease of grain output and continuous growth of grain consumption. During 2000- 2004, the average annual grain shortage was nearly 5 million t and the rate of self-sufficiency in 2004 was only 85.8%.

In terms of the factors for grain consumption growth, the annual growth of ration was -4.56%, a reduction of 4.48 percentage points in the growth compared to that during 1990 and 2000; the annual growth of grain for feed was 5.0%, a growth of 2.3 percentage points compared to that during 1990 and 2000, showing an evident growth trend. It was the main cause for the growth of grain consumption and the grain shortage.

The implementation of policies benefiting the farmers such as the reduction and exemption of agricultural taxes and charges, the establishment of direct grain subsidies, and the increased input on agricultural infrastructure has excited the farmers' confidence and enthusiasm in cereal production.

The grain output increased in 2005. The grain consumption then decreased due to the great decline of feed consumption under the impact of bird flu and the depression of some grain processing enterprises. With the grain output increase and the consumption decrease, a basic balance between output and consumption was found. It should be no problem for Shandong to realize a more than self-sufficient grain output based on self-production and self-consumption. However, in a fully opened grain market, the uncertainty of grain circulation decides the instability of grain self-sufficiency. In addition, Shandong is a large fodder consumption province.

2.3 Partners and stakeholder institutions

2.3.1 Characteristics of farming communities: education, age structure, and gender distribution of labour

2.3.1.1 Education of farming communities

The cultural quality of the rural population in Shandong has been continuously improved. In 1985, the illiteracy or semi-illiteracy rate of the rural population in the province was as high as 25.5%, which was reduced by 50% in 1995, again by 50% in 2000 and to 4.8% in 2007 (Fig. 7). Meanwhile, the proportion of the rural population with an education background of junior middle school, senior middle school, technical secondary school, and college or above has been continuously raised, which amounted to 38.84% of the total population with education background in 1985 and to 78.5% in 2007. Though the illiteracy rate was greatly reduced and the ratio of high education background of technical secondary school and college or above somewhat rose, the proportion was very small and only 5.9% of the total rural population with education background. Now the rural population with an education background of junior middle school still takes a main proportion (57.3% of the total educated rural population), suggesting that the farmers' level of education can still be improved.

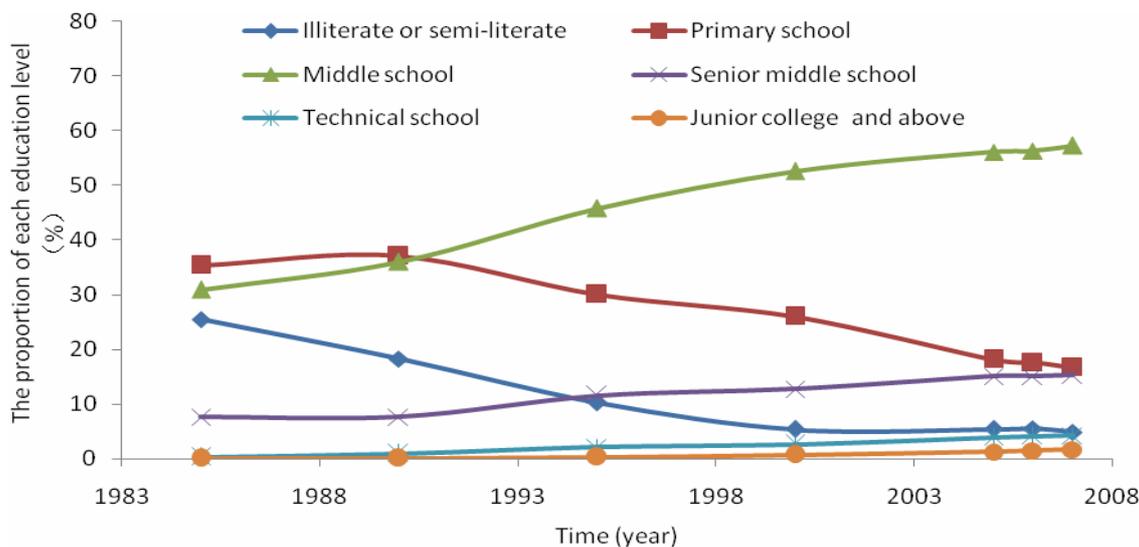


Fig. 7 Level of education of rural population in Shandong province

2.3.1.2 Age structure of farming communities

Population structure will have not only an important impact on the type, speed and trend of the future population development but also some impacts on the future social and economic development. With the population growth, the age structure of the population of the province has had an important change. It is found from the population age structure over the years (Table 5) that in recent nearly five decades, the population age structure of the province has undergone several up-and-down changes. The first census made in 1953 showed a population age structure of “early adult period” type; the second census in 1964, a typical “youth period” type; the third census in 1982, once again an “early adult period” type; the fourth census in 1990, a “middle adult period” type; in 1994, a formation of “aged period” type; the fifth census in 2000, a typical “aged period” type; in 2005, the population aged 0-14 took a proportion of 15.85%, indicating an accelerated aging. The aging of farmers can lead to insufficient labor input and low farm production efficiency, and influence the spreading of farm science and technology, industrial structure adjustment and land transfer rationality.

Table 5 Population age structure over the years in Shandong Province

Year	Proportion of Population of 0-14 years in total population (%)	Proportion of Population of 65 aged and above in total population (%)	Ratio of population of aged 65 and above to 0-14 years (%)	Median age (year-old)
1953	36.4	6.3	17.3	23.2
1964	40.9	4.5	11.0	19.9
1982	31.0	5.6	18.1	24.5
1990	26.6	6.2	23.3	26.4
2000	20.83	8.12	38.98	
2005	15.85	9.93	62.6	
2007	15.1	10.2	67.5	

2.3.1.3 Gender distribution of labour

With respect to the population status of a society, the sex structure is directly related to other population structures including the population distribution, migration and employment structure. Influenced by the aging speed, population migration direction and composition, the population sex ratio of the province has its clear features:

(1) The sex ratio has risen and then fallen, and is lower than the national average level (Table 6). The sex ratio in the fifth census of Shandong Province evidently decreased, which was related to that the immigrated female population from other provinces due to marriage or employment was more than out-migrated male population of this province due to entering a higher school, employment or joining the army, and also related to an effective population control.

Table 6 Contrast of sex ratio between Shandong and nation in five population census after the founding

	1953	1964	1982	1990	2000
Sex ratio in Shandong	98.97	101.13	102.88	103.46	102.50
National sex ratio	105.99	105.46	106.30	106.60	106.74

(2) The sex ratio of children group population is on the high side. Compared the data of the fifth census in 2000 with that of the fourth census in 1990, the sex ratios of the age groups of 0-14 year-old children rose remarkably except the 0-2 age group which decreased slightly. The total sex ratio rose from 109.81 to 111.63, with the 9 year-old group as high as 116.92^[6], at the peak position.

(3) The population sex ratio has an evident regional difference. According to the fifth census data, of the 17 prefecture-level cities in the province in 2000, Liaocheng, Qingdao, Weihai and Bingzhou had the lowest sex ratios, which were not higher than 101, and Jining, Linyi and Dongying had the highest sex ratios, which were above 104, and varied between 100.37-104.33, with an extreme difference of 3.96^[7].

In the rural area of Shandong, especially in the southwest and northwest regions with relatively backward economy, the farmers' economic income and social security is weak, and the farmers are worried about their aging problem and have strong concept of bringing up sons to support parents in their old age and carrying out the family line. Therefore, the sex ratio of the agricultural population of the province is high. In 2004, the sex ratio of registered population was 101.69 and that for above 15-age unmarried population was as high as 130.78, 3.5 and 20 higher than that of urban population, respectively. Theoretically, a higher sex ratio means more male people and sufficient labor force for farm production. Actually, due to the aging and transfer of rural laborers, a high sex ratio does not necessarily mean more laborers in farm production. Of the laborers transferred from rural areas in the province, young male rural laborers are the main force of migrant workers in cities. In 2000, male population accounted for 65.8%, with the 18-40-age group taking up a proportion of 72.1% and 18-30 age group taking up the greatest proportion. In 2006, male laborers accounted for 67.9%, with the below-40 age group taking up a proportion of 79%, mainly between 21-30 years old (35.7%).

2.3.2 Farmer associations and interest groups

Farmers' professional association is a production operation mode with autonomous operational decision policy, which connects the small-size production of every family with the ever changing large market and combines the scattered production operation into one economic benefit union so as to resist jointly the impact of market tide, improve the

farmers' ability to resist risks and increase the farmers' income. Now, farmers' professional associations are rapidly developing in many regions in Shandong. An operation mode of "farmer family +association +market" has been set up, which takes processing industry as the carrier and association as the base to help farmers build rich families. By the end of 2007, there were 24619 farmers' professional cooperative economic organizations of various types, involving 3.49 million participants of farmer households and connecting 4.3 million farmer families. Shandong Academy of Agricultural Sciences has been in close collaboration with agro-technical stations and farmers' technical associations of all levels by way of base drive, joint popularization, academy-local institution cooperation and sending science and technology to rural areas. The academy has converted 90% of its scientific and technological achievements into practical use. In December 2008, Shandong Spark Science &Technology information service hotline 12396 was open, which was sponsored by Shandong Science and Technology Dept. and undertaken by Shandong Academy of Agricultural Sciences. Presently, a convenient, efficient Shandong Spark Science &Technology information service hotline 12396 has been preliminarily set up, which takes the provincial information service center as the core , 10 municipal information service centers as the backbone force, and basic township service stations as the basis to form an all-direction network. It aims to actively promote an integral development of rural informatization.

Let's take Zhangqiu City as example. In May 1997, Wanxincun Chinese Onion Association in Zaoyun Country, Zhangqiu City was established, with the members increasing from several tens of families in 1997 to more than 1600 families in 2002. in 1999, Luxiang Leek Association in Zhangqiu City was set up, which connects with farmers to build a stable industrial chain characterized by " sharing both benefits and risks" , which carries out a standardized management of "contracts + files" over planting households, and implements a system of "joint households and joint guarantee" to realize a mutual supervision between planting households. In addition, a dairy corporative was set up in Gaoguanzhai Township where there is developed dairy industry. It organizes the technical training of the members in fodder proportioning, epidemic prevention, breeding management and milk cow breeding, and the systematical learning with practice. Now, the milk cow inventory has reached 17,000 and 11 milk cow intensive breeding subzones have been formed, realizing a centralized breeding, silage fodder, scientific breeding and

on-order sales. Dairy cow breeding has become the primary industry for income increase and becoming rich in this township. By the end of 2006, the number of the additional farmers' associations in Zhangqiu was 18, with the total number being 198. Of them, seven associations have been determined as Jinan City-level farmers' professional cooperative organizations, with the business scope covering planting, breeding, processing, circulating, etc., which have attracted and connected with more than 50,000 farmer households, involving a sales of 0.53 million t farm products and a total annual business income of 300 million yuan. The thriving development of farmers' associations has had an increasingly greater impact on farmers, and however, the number of such farmers' associations as "Wanxin" and "Luxiang" that operate in a standard way and have strong driving force is still too small and there are still some restrictions in the production operation intensification degree, fund, technology, information and concept. They remain to be further improved. Shandong Academy of Agricultural Sciences, which is the undertaker of this project, can provide the technology and information lacked by farmers associations. It can cooperate with local farmers associations by way of training, sending science and technology to the rural areas and setting up demonstration bases, and pass on the technology and information of scientific farming (such as soil testing and formulated fertilization, returning stalks to the field, water-saving irrigation, utilizing organic waste substances as fertilizer and comprehensive prevention and control of diseases and insect pests) to vast farmers through farmers associations.

2.3.3 Research organisations, extension services, NDRC and other governmental institutions

Shandong provincial research institutions include the three main scientific research institutes, namely, Shandong Academy of Agricultural Sciences, Shandong Academy of Sciences and Shandong Academy of Medical Sciences, and 101 related scientific research institutions such as Shandong Research Institute of Water Conservancy and Shandong Institute of Environmental Sciences, with 36 units of technical development type and 65 units of social benefits. Shandong Academy of Agricultural Sciences, as a main participant of Agriculture, has its research fields covering more than 50 disciplines needed by the agricultural development in Shandong and the regions of Huanghe River and Haihe River, including cereal and cash crops, fruit trees, vegetables, poultry eggs, sericulture, soil and fertilizers, plant protection, inspection, agricultural application of atomic energy,

agricultural microbiology, agricultural biotechnology, information, etc.

Shandong Academy of Agricultural Sciences has been in close collaboration with agro-technical stations and farmers' technical associations of all levels by way of base drive, joint popularization, academy-local institution cooperation and sending science and technology to rural areas. The academy has converted 90% of its scientific and technological achievements into practical use. In December 2008, Shandong Spark Science & Technology information service hotline 12396 was open, which was sponsored by Shandong Science and Technology Dept. and undertaken by Shandong Academy of Agricultural Sciences. Presently, a convenient, efficient Shandong Spark Science & Technology information service hotline 12396 has been preliminarily set up, which takes the provincial information service center as the core, 10 municipal information service centers as the backbone force, and basic township service stations as the basis to form an all-direction network. It aims to actively promote an integral development of rural informatization.

As a large agricultural province, Shandong has given top priority to spreading the agricultural technical achievements and new type practical technology so as to promote a sustained agricultural growth and farmers' continuous income increase. Shandong Department of Agriculture has set up the general station for spreading agricultural technology and there are such stations in 17 cities of prefecture-level, in 91 county-level cities and counties and in towns and townships, forming a province-wide network for spreading agricultural technology. In order to make a full use of the resource superiority in media publicity, export technology and professional service of Shandong Agricultural Technological Association, build a perfect network for agricultural technology promotion, training, demonstration, application and marketing service, continuously enhance the capability of technical spreading and demonstrative application, speed up the application of new agricultural technologies and products, provide a rapid efficient technology-product integration service characterized by "one station", rely on advanced practical technology, hi-tech products and networking service function, reduce the circulation links of agricultural means and the agricultural production cost, promote the development of modern agriculture industrialization, improve the agricultural production level and promote the farmers' income increase, Shandong Agricultural Technological Association Technology Promotion Center was set up on December 23, 2006, which

provides the service in the training, application promotion and product marketing of new agricultural technology. Meanwhile, 15 regional technical promotion service stations in the 17 prefecture-level cities of the province were also formally established, with 1000 special technicians in 1700 towns and townships of the province. A demonstrative household of technological application will be set in each administrative village of the province for carrying out the pilot demonstration and promoting new agricultural technology and products.

The provincial government organs involved in climate change include Shandong Metrological Bureau, Shandong Department of Agriculture, Shandong Department of Water Conservancy and Shandong Administration of Environment Protection and the corresponding sectors in all administrative levels. Shandong Rules of Metrological Disaster Prevention was formally implemented in 2005 and an automatic weather station monitoring net covering the whole province has been preliminarily formed. Now, the province has a comprehensive observation capacity of climate system. The provincial metrological sector has 4 national reference metrological stations, 19 national basic weather stations, 100 national general weather stations, 18 basic station of agricultural metrology, 60 soil moisture observation stations and 7 automatic soil moisture observation stations. The metrological sector has strengthened the construction of research and capability of climate change, carried out the wind energy resource investigation, the third agricultural climate zoning, and accomplished the research projects such as “Relationship between Subtropical Monsoon and Summer Rainfall in Shandong” and “Study on the Effect of Climate Change on the Cropping System in East China”, and preliminarily built a metrological information service. It has also conducted, together with the agricultural and water conservancy sectors, the research projects of the effect of climate change on the agricultural production, the grain security, and the coping measures; the effect of global climate warming on the farmland ecological system function and elementary productivity; the extreme climate events faced by the agricultural production such as drought, flood and hail, especially the natural risks of drought in consecutive areas for consecutive years; the scope and degree of the influence of global climate warming on crop disease and insect pests, especially the possibility of earlier and expansive explosion of overwinter disease and insects; and the effect of climate warming on the main grain production capacity and fluctuation in Shandong.

2.3.4 Non-governmental organizations

Various kinds of civil organizations have been developing rapidly in many rural regions in Shandong. Those that are registered can be classified into two types. One type is the rural private non-enterprises units sponsored and run by farmers such as scientific research institutions and health stations. By the end of 2005, Shandong had registered 43 private non-enterprise technical organizations, 134 health organizations and 4236 education organizations under towns and townships. The other type is economic type social organizations majoring in providing service of production, sales and technical promotion of agriculture, forestry, animal husbandry and fishery. Now, there are 16,000 agricultural professional technical associations of various types and 6393 rural economic associations registered in Shandong, with 4.94 million farmer members, 5288 full-time employees, 70.39 million yuan registered capital, 185 million yuan fixed assets and annual income of 3.13 billion yuan. In Weifang City, Shandong, there are over 1600 rural economic associations sponsored by farmers and registered with the administrative sectors, which are mainly distributed in townships and villages, covering nearly 80% villages. Agricultural professional economic associations organize the farmer households, enterprises and cooperative organizations majoring in the production and circulation of the same kind of farm product, and are displaying an important role in transmitting technological information, conversion of scientific and technological achievements, promotion of advanced practical technology and new achievements and varieties, market exploitation and maintenance of economic order. They have become the most widely distributed, most vital and most functional non-government organizations in the rural area in Shandong. However, due to the restriction of thinking, policy and cost, the rural civil organizations are in an unperfected development environment, unable to display a full role and still at their primary development stage.

3 Projections of climate change factors and other drivers of change

3.1 Climate change scenarios for the YRB

The scientific research indicates that in recent hundred years, the global climate is experiencing a remarkable change characterized mainly by becoming warmer. The third report of IPCC ^[8] pointed out that the global near-ground temperature has been on rise since 1861 and the global temperature rose by $0.6\pm 0.2^{\circ}\text{C}$ in the 20th century, most remarkable in its nineties. With respect to precipitation, the rainfall precipitation in the medium-high latitude area in the northern hemisphere increased by 0.5%-1% every ten years in the 20th century. Under a general background of global warming, the temperature in Shandong continues to rise and the climate is becoming warmer, which is generally in accord with the global climate change trend and also exhibits its own regional characteristics ^[9, 10].

3.1.1 Temperature change ^[11]

During the sixties and nineties in the 20th century, the average annual temperature in Shandong was 12.51°C , 12.81°C , 12.86°C and 13.46°C respectively. It is clearly seen that there has been an evident warming trend during recent nearly 40 years, with the biggest temperature rise of 0.60°C during the eighties and nineties, about two times the average value in the four decades. The average annual temperature change every ten years tends to be 0.302°C , which has continued since the beginning of 21st century, with the 8-year average annual temperature as high as 13.9°C .

The temperature change in recent five decades in Shandong is characterized by cold climate in the early period and warm climate in the late period, with the dividing point at 1986. That is, the cold period was from 1961 to 1986 and the warm period began in 1987 ^[12]. The average annual temperature during 1987-2004 was 0.8°C higher than that during 1961-1986. Shandong has a complex topography and the space distribution of warming is not the same at different regions, with the highest temperature rise occurring in the central

and north part of Shandong and Jiaolai River basin, where the average annual temperature rise was 1.0-1.5°C, the lowest rise in some areas in south Shandong, which was below 0.6°C, and a temperature rise of 0.6-1.0°C in other areas.

Climate warming in Shandong is most evident in winter, when the average temperature rise is 1.4°C, 2.2°C and 1.2°C respectively in January, February and December, with the highest rise in February (Table 7). The temperature rise tendency rate of winter is most evident in four seasons, which is about 1.8 times of the annual average temperature rise of the same period, that of summer is the smallest, only 3.3 % that of winter. Shandong saw 18 warm winters from 1986 to 2006.

Table 7 Margin of the monthly average temperature, maximum temperature and minimum temperature between 1987-2008 and 1961-1986 in Shandong Province

Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
Average	1.4	2.2	1.0	0.9	0.1	0.1	0.5	0.1	0.9	0.5	0.4	1.2	0.8
Maximum	0.5	2.2	0.5	0.7	-0.4	-0.3	0.4	0.0	1.0	0.5	0.2	0.8	0.5
Minimum	2.0	2.3	1.4	1.4	0.7	0.6	0.6	0.2	1.0	0.7	0.5	1.5	1.1

3.1.2 Changes of the highest temperature

In recent five decades, the number of high temperature days first decreased and then increased, which was high during the fifties to sixties in last century, comparatively low during the seventies and eighties and has increased since the nineties. With the increase in the number of high temperature days, the highest temperature rose. The annual highest temperature in Shandong during 1987-2004 was 0.5°C higher than that during 1961-1986 (Table 10), a rise below the annual average rise of temperature. The rise in the highest temperature was the greatest in winter months (from December to February), which was 1.2 °C, that in spring (from March to May) was the second and that in summer (from June to August) was little. The average annual lowest temperature in Shandong during 1987-2004 was 1.1°C higher than that during 1961-1986 (Table 10), a rise higher than the average annual rise of temperature. The rise in the lowest temperature was the greatest in January, February, March and December, which was 2.0°C, 2.3°C, 1.4°C and 1.5°C respectively, that during April to November was 0.2°C-1.1°C, which was higher than the rise in the highest temperature of the same period, indicating the rise of average

temperature was mainly due to that of lowest temperature.

3.1.3 Change of accumulated temperature

3.1.3.1 Changes of average daily temperature $\geq 0\text{ }^{\circ}\text{C}$ and $\geq 10\text{ }^{\circ}\text{C}$ accumulated temperature

The period when the average daily temperature is stable and higher than 0°C is proper for cropping, and the period with a stable and higher than 10°C average daily temperature is proper for the active growth of overwinter crops, for the sowing and growth of thermophilic crops and for starting the sowing of such thermophilic crops as cotton, maize and peanut. The heat resource during the cropping period in Shandong has evidently increased. The active accumulated temperature in the period when the daily average temperature was $\geq 0^{\circ}\text{C}$ during 1987-2004 was 182°C higher than that during 1961-1986, and the active accumulated temperature in the period when the daily average temperature was $\geq 10^{\circ}\text{C}$ during 1987-2008 was $139\text{ }^{\circ}\text{C}$ higher on average than that during 1961-1986.

It is a basic indicator reflecting the total heat of crop growth period and used to assess the land capacity for multiple cropping;

3.1.3.2 Changes of average daily temperature $<0^{\circ}\text{C}$ accumulated temperature

The accumulated negative temperature during the period when the average daily temperature is $<0^{\circ}\text{C}$ is a composite temperature index for assessing the crop overwintering conditions. The negative accumulated temperature, the duration and the extreme lowest temperature are the basic conditions for evaluating crop overwintering capability. Its absolute value shows a tendency of decrease in Shandong. It was -217°C on average during the sixties in the 20th century, -183°C in the seventies, -170°C in the eighties, -102°C in the nineties and -104°C during 2001-2004.

3.1.3.3 Changes of frost-free period

Frost-free period is an important index for assessing the heat resource ^[13], which is the number of continuous days from the final frost day to the initial frost day, and is generally represented by the number of the days of a period starting from the initial day to the final day when the lowest temperature of ground is above 0°C and may also be approximately represented by the consecutive period when the lowest temperature (thermoscreen) is greater than 2°C. Due to the climate warming, the average initial frost day in recent five decades in Shandong has shown a tendency of delay, 0.2 day each year; the average final frost day has had a tendency to shift to an earlier day, 0.3 day each year; the average frost-free period has had a tendency to increase, it was 204 days on average in the sixties, 206 days in the seventies, 209 days in the eighties, 216 days in the nineties and 226 days during 2001-2004, indicating an increase of 5 days every ten years.

3.1.4 Changes of precipitation

The rainfall precipitation in a wet year may be several times that of the a dry year, and the distribution of rainfall precipitation is non-uniform among seasons, with the rainfall precipitation in summer (from June to August) accounting for about 60% of the yearly total. In recent five decades, the average rainfall precipitation in Shandong has exhibited a downward trend, and the tendency rate is 31.7mm decrease every ten years, with difference in different periods, seasons and space. The average annual rainfall precipitation was 729mm, 704mm, 599mm and 649mm respectively during the sixties to the nineties, and was 679.9mm during 2001-2008. It can be seen that the annual rainfall precipitation had the greatest decrease in the eighties and rallied somewhat in the nineties. The increase and decrease tendencies of annual rainfall precipitation in Shandong in recent five decades corresponded to the wet period and dry period respectively. 1961-1964, 1970-1975 and 1986-1995 were wet periods and 1965-1969, 1976-1985 and the years after 1995 were dry periods, with the dry period amounted to 2/3 of the total time.

In terms of the time-related change in precipitation, the average rainfall precipitation in spring, summer and autumn tends to decline, with that in summer most evident and the second being that in autumn. The average rainfall precipitation in winter on the whole tends to have a slight increase. The decrease of rainfall precipitation in three seasons especially in summer has made the average annual rainfall precipitation in Shandong in recent five decades to have a tendency of decrease on the whole.

The space distribution of the rainfall precipitation in four seasons is as such: (1) the space distribution of spring rainfall precipitation is basically parallel to the latitude, exhibiting a progressive increase tendency from north to south and from west to east; (2) the space distribution of summer rainfall precipitation is similar to that of spring but has some differences.

Its rainfall precipitation distribution has a progressive increase tendency from northwest to southeast and from northeast to southwest, with the rainfall precipitation in the northwestern region being the lowest; (3) the space distribution of autumn rainfall precipitation has a progressive increase tendency from northwest to southeast and from west Shandong to east Shandong, with the highest rainfall precipitation in coastal southeast region and the lowest in the northwest plains; and (4) the winter rainfall precipitation decreases evidently, with the constant value lines concentrated in northwest and northeast Shandong and those in central south Shandong being sparse. Its space distribution has a tendency to decrease from northwest and southeast Shandong.

3.1.5 The prediction of temperature and precipitation in Shandong

The short-term climate forecast business system of the province adopts 17 representative stations (Dezhou, Huimin, Linqing, Liaocheng, Binzhou, Yanzhou, Heze, Jining, Zibo, Jinan, Tai'An, Linyi, Yantai, Laiyang, Qingdao and Weifang). The mean value of these stations is used as that for the province, and the temperature and rainfall precipitation forecast of the province is made by three methods, namely orthogonalization mean generating function model, differential mean generating function model, and variance cycle analysis model, with year as the calculation period, annual mean value for temperature, annual accumulated value for rainfall precipitation and rainfall precipitation and temperature as the data types. The sampling time is 52 years from 1951 to 2002, the forecast is made for a period from 2003 to 2050, and the calculation step length is 48 years.

3.1.5.1 The prediction of average temperature in whole province

It can be seen from Fig. 8 that the fitting result of the average annual temperature values of the province calculated by orthogonalization mean generating function model is not very good, and the low temperature extreme value in 1967 and the high temperature extreme value for 1998 are forecasted on a wrong side. The fitting result for the values for years after 1990 is rather poor: though the curve shape is somewhat real-like, the values are far different. The curve of the forecast results seems an oscillation distribution around the mean value, which does not accord with the forecasted tendency of global and nation-wide temperature rise.



Fig.8 The predictive curve of annual average temperature in whole province by the model of mean generating function of orthogonalization

When the variance cycle analysis model is used to forecast the average annual temperature, the cycle can not be found when the reliability coefficient is 0.01~0.15. It is clear the cycle of the average annual temperature of the province cannot be found by variance cycle analysis model.

The results of average annual temperature forecasted by differential mean generating function model are shown in Fig. 9. The fitting results are good especially for the high temperature of these years. Though the low temperature extreme value of 1985 is reversed, those for other years are good. The curve of forecast results is an oscillating curve exhibiting a rising trend, indicating the temperature will increase in the future, which

accords with the forecasted global and nation-wide temperature rise. Therefore, the forecasted results by differential mean generating function model are adopted. It is forecasted that the average annual temperature of the province in the future 50 years will take a rising oscillation distribution mode, the mean value, highest value and lowest value of average annual temperature of the province will rise and the number of high temperature days will also increase. Air temperature rise helps increase the planting area of thermophilic crops and the temperature rise in winter will provide favorable climate conditions for the development of greenhouse vegetables in winter. Researcher Ma Shinming holds that, when the air temperature keeps rising and no effective measures are taken, the production capacity of crop farming will decrease and the decrease will be mainly exhibited in wheat, corn and rice production.

3.1.5.2 The prediction of annual precipitation in whole province

The three models are also used to forecast the future rainfall precipitation trend of Shandong (Figs. 10, 11, 12). It can be seen that the fitting results for annual precipitation of the province are very good by both orthogonalization mean generating function model and differential mean generating function model, and the fitting result of variance cycle analysis model is poorer, which has found a 20- year cycle and an 8-year cycle. In other words, the annual precipitation of the province has a 20- year cycle and an 8-year cycle. The results forecasted by orthogonalization mean generating function model and differential mean generating function model exhibit a near-mean value oscillating distribution while those by variance cycle analysis model exhibit an oscillating curve with a tendency of decline, indicating that the future precipitation will decrease. As the fitting result of orthogonalization mean generating function model is poorer, the forecast results of differential mean generating function model are adopted, which forecasts that the average annual precipitation of the province in the future 50 years will take a descending oscillation distribution mode

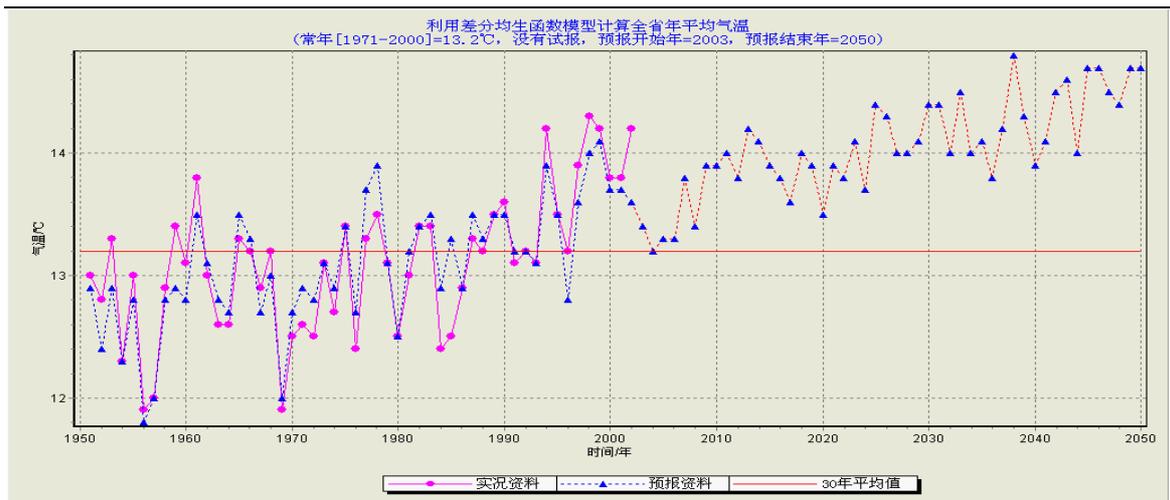


Fig.9 The predictive curve of annual average temperature in whole province by the model of difference means generating function

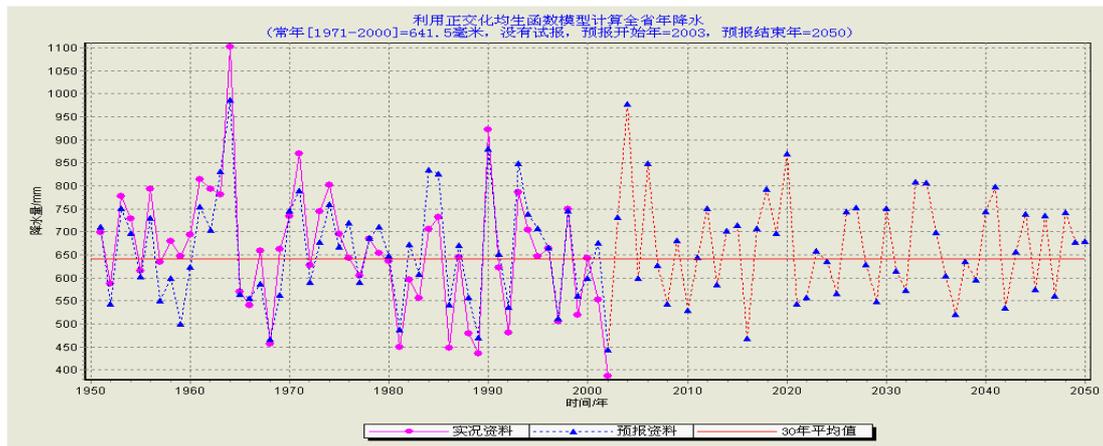


Fig.10 The predictive curve of annual precipitation in whole province by the model of mean generating function of orthogonalization

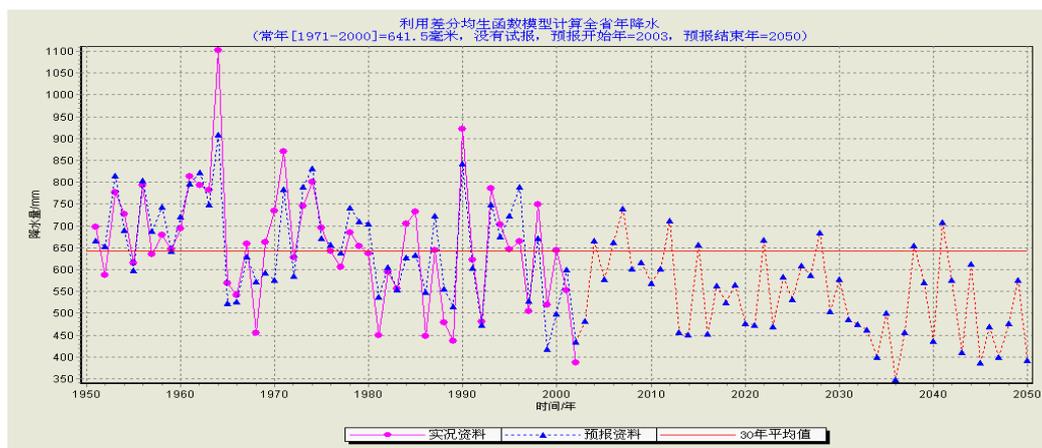


Fig.11 The predictive curve of annual precipitation in whole province by the model of difference means generating function



Fig.12 The predictive curve of annual precipitation in whole province by analysis model of variance cycle

3.2 Scenarios of other drivers of change

3.2.1 Demographic growth, migration and urbanisation

The population of the province will keep a growth (Fig. 13). The total permanent population at the end of 2007 was 93.67 million, a 4.1% increase over the data of the fifth census, indicating an average annual increase of 0.6%. The growth of population will inevitably increase the demand on grains and other products. However, the aging of population and urbanization will be sure to influence the demand on grains. First, the aging will directly reduce the grain consumption; and second, urbanization will reduce the ration consumption while increasing the feed grains, suggesting an increase of grain demand.

With the accelerated national economic development of Shandong, the rural labor force shift has increases gradually in both size and speed. The proportion of the rural non-agricultural labor force in the total rural labor force rose from 31.62% in 2004 to 42% in 2004. The rural labor force shift of the province is characterized by the following ^[14].

(1) The stability of shifted labor force has increased. In recent few years, the proportion of the returned labor force in the shifting process has decreased year by year. The investigation on the fixed observation points in 25 villages of 17 cities shows that, in 2004, of the 2900 rural laborers that went out for employment, 1544 found stable jobs, an 8.2% year-on-year increase, and 100 laborers that didn't find a job, 13 persons fewer than last year.

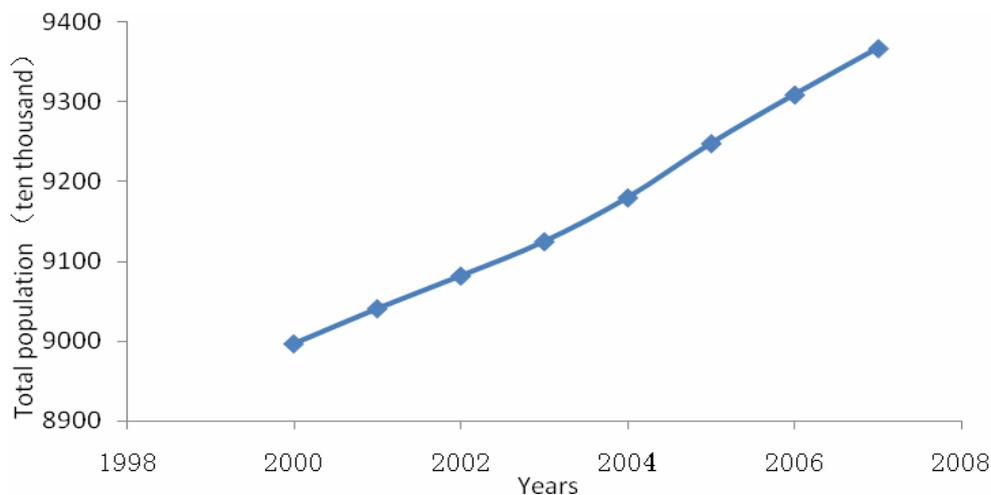


Fig.13 Population growth of Shandong province in 2000-2007

(2) Young male rural laborers are the main force in outside employment. Of the shifting rural laborers, male people accounted for 65.8%, with 18-40 year group amounting to 72.1% and the 18-30 year group being the largest group in 2000; and in 2006, male people accounted for 67.9%, with the below 40-year group amounting to 79% and the 21-30 year group being the largest group(35.7%).

(3) The education level of the rural shifted laborers of the province has been raised. In 2002, the shifted laborers that received professional training amounted for 25.9% and in 2004, 30.7%, a year-on-year increase of 5.6%, with those receiving high middle school education amounting to 21.3%, an increase of 0.9%.

(4) Finding a job within the province is still the main way for shifted rural laborers. As a large population province, Shandong has exported only 2 million laborers and 43,600 laborers to other places in China and to foreign countries respectively. In 2006, of the laborers shifted, those finding a job outside the local township but within the local country amounted to 38.0%; those finding a job outside the local country but within the local city, 19.1%; those finding a job outside the local city but within the province, 25.9%; and those finding a job outside the province, 17.0%.

The industrial structure of population can reflect such major issues of socioeconomic development as the regional laborer quality, sci-technical development level and labor productivity and also reflect the conditions of laborer shift. It can be seen from the industrial structure of population of Shandong that, in recent three decades, the proportion

of the population in primary industry has shown a tendency of decline, which has dropped by about 50%, while that for the secondary and tertiary industrial has a tendency of rise, especially that for the tertiary which has risen steadily by 2.4 folds, indicating the employment structure of the province is under continuous optimization (Table 8). Since the beginning of the 21st century, the industrial structure of population of the province has been transferred from the traditional type to development type. By the end of 2007, the population in the primary, secondary and tertiary industries amounted to 37.3%, 32.7% and 30.0% of the total respectively. The transformation of the population employment structure has promoted the transfer of the economic structure towards non-agriculture direction, indicating from one side the continuous shift of rural laborers.

Table 8 Industrial structure of population in Shandong Province from 1980 to 2007 (%)

Age	1980	1985	1990	1995	2000	2005	2006	2007
Primary industry	78.9	68.5	64.0	54.4	53.1	40.2	39.1	37.3
Secondary industry	12.3	19.8	22.8	25.1	23.6	30.5	31.4	32.7
Tertiary industry	8.9	11.7	13.2	20.5	23.3	29.3	29.5	30.0

Shandong ranks the second in population in China and is also one of the provinces (autonomous regions) where the urban and rural economy and urbanization have developed the fastest since the reform and opening. With the implementation of China's coastal development strategy and the deepening of rural reform, Shandong economy has developed very rapidly and its rural industry has achieved an unexpected development, greatly promoting the urbanization of rural population and the improvement of urban modernization level. According to the statistics, in 1982, the urban population of Shandong amounted to only 19.07% of the total. By the fifth census in 2000, the urbanization rate of the province had reached 38.15%. The proportion of urban population had rose by 19.08 percentage points in the 18 years, an average annual increase of 1.06%. Since the beginning of the new century, Shandong's socio-economy has been developing rapidly and the urbanization has also been accelerated.

Since 2000, the urbanization of Shandong has entered its accelerated development phase, which is characterized by increasingly higher level and speed. In 2001, the urbanization rate of the province was 39.2%, and in 2007, it was 46.75%, a rise of 7.55 percentage points in only short six years, and an annual increase of 1.26% on average,

with both the development level and speed creating the record. However, during 2005 and 2007, the population urbanization raised by only 1.5, 1.1 and 0.65 percentage points respectively on a year-on-year basis, indicating a slowdown growth.

In terms of space distribution, the urbanization in Shandong has a remarkable regional difference, mainly in the difference of urban modernization level, with that in the east coastal regions and regions along Jiaodong-Jinan railway line higher than that in central and west Shandong. On the whole, the urbanization of the province takes a stair-shape distribution with high east and low west. It is generally classified into five levels: (1) Qingdao; (2) Weihai, Jinan, Dongying and Yantai; (3) Zibo, Rizhao, Laiwu, Weifang and Tai' An; (4) Linyi, Jining, Bingzhou, Zaozhuang, Liaocheng and Dezhou; (5) Heze.

Reviewing the development history of Shandong urbanization, the economic development level, industrialization, administrative strength and investment have been the main power for the urbanization of the province. High-speed stable economic development level, modern rapid industrialization, rational and perfect administration and large sum of investment have all greatly promoted the rapid but steady development of Shandong urbanization.

3.2.2 Economic development and industrialisation

Since 1991, Shandong economic aggregate has been keeping a growth rate of over 10% and realized a two-digit growth for consecutive 17 years. The average annual growth during 2003-2007 was 14.6%, 4.0 percentage points higher than that of the country. The annual average growth rates for the primary, secondary and tertiary industries were 5.3%, 17.3% and 13.4% respectively, 0.8, 4.9 and 3.0 percentage points higher than those of the country respectively; the GDP growth of Shandong was 13.4%, 15.3%, 15.2%, 14.8% and 14.3%, and the growth rate tended to fall after 2004, with the fluctuation around about one percentage point and still in a steady but rapid growth scope. The tendency of a too rapid economic growth was preliminarily curbed and the economic development was turned from a rapid growth to a steady rapid growth. Since the beginning of the 21st century, Shandong has realized a jump in economic aggregate and ranking. In 2002, it realized a GDP exceeding one trillion yuan, becoming the third province in China to exceed one

trillion yuan; in 2004, its economic aggregate exceeded 1.5 trillion yuan, ranking the second in the country. In 2006, its economic aggregate and its urban and rural resident deposit exceeded 2 trillion yuan and one trillion yuan respectively and in 2007, 2588.77 billion yuan and 1143.81 billion yuan respectively. Per capita GDP stepped over consecutive two stairs in 2004 and 2005, from the ninth place to the seventh place in the country; in 2005, it exceeded 2 trillion yuan and reached 2772.3 trillion yuan in 2007, converted to US\$3646 billion on annual average exchange rate, marching towards the average level of the world middle income countries. The five-year economic aggregate and per capita GDP were increased by 1.5 and 1.4 times and the urban and rural resident deposits, by 1.0 time. The proportion of its economic aggregate in the country total rose from 8.5% in 2002 to 10.5% in 2007. However, the rapid economic development must not be at the cost of our existence environment. In recent two years, though the province has gained some achievements in energy conservation, and pollution and discharge reduction, it still lags behind some front-ranking provinces in these respects. Its sulfur dioxide and COD emission is still higher than that of Jiangsu, Zhejiang and Guangdong, which is mainly related to its high proportion of heavy and chemical industries involving high energy consumption and high pollution. Therefore, priority should be given to speeding up the regulation and optimization of industrial structure and the change of economic development mode in the future socio-economic development.

Since the reform and opening, Shandong industrialization has developed rather rapidly. The average annual industrial added value was increased at rate of 24.84% during the five years from 2000 to 2005 and reached 1155.6 billion yuan in 2006. Generally speaking, when the industrialization develops to a certain level, it will tend to transfer from taking the processing industry as the main to taking the industry of labor subject and labor means as the lead, making the heavy industry more prominent. The output value of heavy industry takes a high proportion in the total output value of Shandong (Fig. 14). Except during 1961-1964 when the rate of heavy industry declined rapidly due to the regulation of industrial structure, it has had a rising tendency. Its proportion rose from 9.84% in 1949 to 65.07% in 2007, with an average annual growth rate of 0.95%. Especially since the reform and opening, the proportion of heavy industry has been in a rapid steady phase, with a rise of 14 percentage points in 2007 over 2001, an average annual growth as high as 2%. The added value of heavy industry has taken a very large proportion in the total of the province and exhibited a tendency of growing with time. It

increased from 60.17% in 2000 to 65.36% in 2005, with the annual growth in 2005 being 3.995 times that in 2000.

Shandong Province lies in the hinterland of north China plain and at the south end of Bohai Bay. It possesses a long golden coastal line, several fine ports and rich mineral resources such as petroleum, coal and iron ore. It borders on Shanxi, a large province of energy and heavy industry. Its rich mineral resources and special geological position provide a reliable guarantee for its development of heavy industry. The continuous deepening of the reform and opening and the gradual maturation of market economy have also provided solid technology, equipment and fund guarantee for its development mode of heavy industry in Shandong.

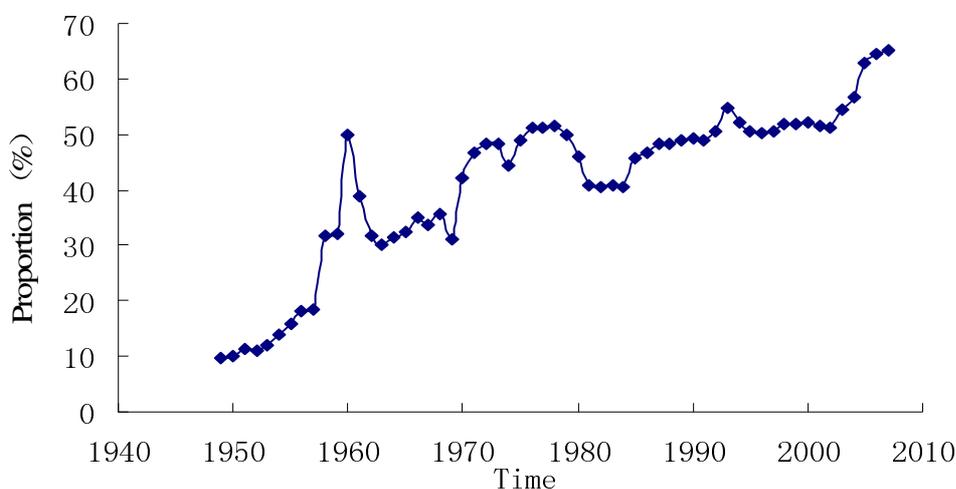


Fig.14 Proportion of heavy industry output value in Shandong total industrial output value

3.2.3 Changes of land use and land cover

The land utilization in Shandong can be classified into eight broad categories of first class, namely, arable land, garden land, forest land, grassland, land for urban and rural population centers, factories and mines, land for transportation, waters and unexploited land. Compared with that in 1984, the land use structure in 2005 had certain change (Table 9).

The change mainly lies in the following aspects:

(1) Land is used mainly for agriculture. In 2005, the used land amounted to 89.06% of the total land, and the unused land was mainly wild grass ground, mudflat and salinized land, with the reserve land resource rather limited. Of the used land, the agricultural-use

land was dominant and accounted for 73.65% of the total, a rise of nearly 10 percentage points over 1984. The land used for construction amounted to 15.42%.

(2) The agriculture-used land was mainly for cultivation, which somewhat decreased.

The arable land in the province was widely distributed in plains, mountain front inclined land, valleys and hill slopes, with the arable land rates of different landforms widely different. The proportion of the arable land area was 7 percentage points lower than that in 1984, and the increase of the land for construction was the main cause. In addition, it was also caused by the salinization of arable land due to sea water encroachment and storm surges, side penetration of the Yellow River, river erosion and caving of coal mining and occupation by mining.

The ratio of the arable land to the sum of garden land, forest land, grass land and land for other agricultural purposes was 1.88:1 against 0.23:1 of the country value of the same period. Though the grass land area was reduced by 71.4%, the garden land proportion increased by 2.5 times, making the sum of the area of garden land, forest land and grass land to rise.

The garden land was mainly used for orchards, which amounted to 95% of the total garden land area and distributed mainly in Jiaodong Peninsula, next in central south Shandong and also in Yellow River flood plain and Yellow River delta in small amount. The increase of garden land area in the recent years was mainly due to the impact of commodity economy, market economy and comparison of economic benefits.

The land cultivation rate in 2005 was 47.85%, higher than that of the country total by 35.35 percentage points, ranking the first in the country.

(3) The land used for non-agriculture purpose was mainly for rural residence points and rural roads, with the land for residence centers and for factories and mines growing rapidly, which had grown 47% in the 20 years. (4) The land used for water conservancy facilities amounted to 1.59% of the occupied land, a 7-time difference compared to that in 1984, which was due to the different statistics methods. In 1984, the waters area included river beds, lakes, reservoirs and their subsidiary facilities (dyke, etc.), and other water conservancy engineering structures and mudflat, while in 2005, the waters area referred to only the land for water conservancy facilities.

Table 9 Change of land use structure in Shandong Province 1984-2005 (unit: $\times 10^3\text{hm}^2$)

Land use type	1984		1994		2005	
	Area	%	Area	%	Area	%
Arable land	8533.0	54.45	8016.1	51.00	7518.9	47.85
Garden land	293.1	1.87	908.2	5.78	1020.7	6.50
Wood land	1360.5	8.68	1276.2	8.12	1351.6	8.60
Grass land	120.7	0.77	75.1	0.48	34.1	0.22
Residential and industrial land	1365.8	8.72	1733.4	11.03	2011.0	12.80
Traffic land	453.0	2.89	430.0	2.74	161.3	1.03
Water land	1715.0	10.94	1649.5	10.49	250.1	1.59
Unused land	1830.6	11.68	1630.7	10.37	1718.3	10.94

4 Vulnerability of agricultural ecosystems and production to potential impacts of climate change and other drivers of change

4.1 Changes in cropping periods

With the climate becoming warmer, the crops grow more rapidly and the growth period is generally shortened, leading to the reduction of substance accumulation and seed output. Hao Yunli and Wang Jianyuan pointed out in their report that if the rice grows at 6-31°N place, its yield will reduce by 10-20% for a 1-2°C temperature rise. The higher the latitude, the more serious the impact will be. With the shortening of crop growth period, the three harvests in two years (partial spring maize) was replaced by two harvests in one year^[16] and the cotton planting system adopted various modes such as intermittent cropping intercropping, multi-cropping and rotational cropping^[17], evidently raising the multi-cropping index. The multi-cropping index was 1.53, 1.63, 1.65, 1.71 in the sixties, seventies, eighties and nineties respectively and was 1.69 during 2001-2004. The climate warming has also impacted the crop harvesting and sowing periods. The sowing of winter wheat was postponed by 8-12 days compared to that in common years. The direct-sown maize's varieties were transferred from middle-early ones to middle-late ones, which were mainly Shandong No. 13 maize (96-day growth period) and No.14 maize (100-day growth period) in 1990; Shandong No. 10 maize (100-day growth period) in 1995 and Yedan No 13 (110-day growth period) in 1997.

4.2 Occurrence of floods and droughts

Shandong lies in monsoon climate zone and the unstable monsoon can lead to a greatly varied precipitation in a year and along several years. The drought and flood thus caused are the main natural disasters in the province and also the disaster that causes the heaviest loss among many natural disasters, with an affected area amounting to 60%-80% of the total disaster-affected area.

The average annual land area affected by drought and flood in the province accounts for 28% of the total arable land area, with the drought affected area amounting to 17% and

the flood-affected area, 11%^[18,19]. The drought and flood disasters in the province are of evident seasonal nature.

The drought disaster mainly occurs in spring or summer and often in consecutive spring and summer, causing huge loss to the agriculture. For example, in 2002, a most serious drought in recent hundred years occurred, and the average rainfall precipitation of the province was only 396.9mm, a 43.3% decrease compared to the average annual value, which affected 3.71 million ha in the province, with 1.23 million ha seriously affected and 0.3million ha having no harvest at all, leading to a direct economic loss to over 10 billion yuan.

The flood disasters mainly occur in summer and autumn, with the highest occurrence frequency in summer and the second highest in autumn. For example, during September 25 to October 12, 2007, a rarely seen long- consecutive time rainy weather occurred, bringing a higher precipitation, lower sunlight, and lower average temperature than common years, which seriously affected the autumn harvesting and sowing. The continuous rainy weather led to the decreased quality of maize due to mildew, deterioration and germination, resulting in a direct economic loss of 64.32 million yuan. Drought and flood occur very frequently in Shandong and they are seen almost every year. Continuous drought and flood events occur from time to time.

The events of drought in consecutive years in recent five decades occurred in the years of 1965-1968, 1972-1973, 1977-1983, 1986-1989 and 1999-2002, and the events of flood in consecutive years occurred in the years of 1960-1964, 1970-1971 and 2003-2004.

In 2001, Shandong Science and Technology Association proposed countermeasures for preventing and controlling drought and flood disasters during the Tenth Five-Year Plan period. The following measures could be used to reduce the draught and flood-caused loss in the province: (1) greatly strengthening the construction of water projects; (2) carrying out the study of non-engineering measures for flood prevention and draught resistance and doing well the related work, such as enhancing the monitoring and forecast of draught and flood disasters and the study of countermeasures; (3) strengthening water resource protection, doing well soil and water conservation and improving ecological environment to alleviate drought and flood disasters; (4) carrying out afforestation to improve the climate;(5) spreading water & energy saving irrigation technology such as trickle irrigation, sprinkler irrigation and under-mulch irrigation; (6) transforming the tillage and cultivation technology, such as ridge and ditch planting to improve the utilization rate of

natural precipitation and light and heat sources; (7) adopting draught-resisting and flood preventing farming technical measures such as deep tillage for moisture storage, intertillage for moisture preservation, compaction for moisture increase, applying more organic fertilizer and returning stalks to the field; (8) popularizing physicochemical agro-technical measures, such as using biotechnology and atomic energy radiation to develop and cultivate new varieties with drought resistance and flood tolerance and using plastic film mulching and chemical draught resisting agent; and (9) enhancing the study of remedial measures after draught and flood disasters and popularizing the effective technical methods so as to reduce the draught or flood-caused loss^[21].

4.3 Decline in runoff and water availability

Shandong is one of the provinces with greatest water-shortage in China and its per capita water resource is only 14% of the country value, ranking the third place to the last. In recent several decades especially recent two decades, the climate change and the great increase of human economic activity have led to a reduced available water resource.

In terms of climate factors, temperature change's impact on water resource mainly includes the increased evaporation amount and intensity due to temperature rise. Either in way of water surface evaporation, soil surface evaporation, leaf surface evaporation or phreatic water evaporation, temperature rise will increase the water consumption, leading to the decrease in available water resource amount^[20].

Water surface evaporation is mainly affected by meteorological factors while the other three modes of evaporation are also related to such factors as soil water supply capacity, crop physiological conditions and the depth underground water table in addition to meteorological factors. When the other conditions are the same, temperature rise is the most affecting factor, and is one of the main causes for reduced available water resource.

At the end of the 20th century, the temperature in the province gradually rose and high temperature and drought often occurred together. High temperature intensified the drought, increasing the farmland demand on water (the gradually raising total grain output and unit area yield and continuously expanding irrigable land area); and high temperature also induced an increased urban living water consumption, increasing the urban water supply load and intensifying the supply-demand contradiction of water resource.

Available water resource generally refers to the regenerable surface water resource and underground water resource, and in the final analysis, they are complemented by atmospheric precipitation.

Therefore, the water resource in a region depends on the atmospheric precipitation. The average precipitation in the province in recent five decades on the whole exhibits a remarkable downward tendency, and the tendency rate is 31.7mm every ten years, with the changing state of average precipitation different in decades, seasons and space. In terms of decades, the average annual precipitation during the sixth to ninth decades were 729mm, 704mm, 599mm and 649mm respectively and that of 2001-2008 was 679.9mm.

It can be seen that the annual precipitation was reduced the most during the eighties and rallied somewhat during the nineties, but was still 50mm less than that in the sixties. In terms of the time change of seasonal precipitation, the average precipitation of spring, summer and autumn exhibits a downward tendency, with the largest decrease in summer and that in autumn being the second, while that of winter has somewhat an upward tendency on the whole.

The precipitation of three seasons out of four exhibits a downward tendency, especially that of summer, which has evidently decreased, making the average annual precipitation in Shandong in recent five decades to have a downward tendency on the whole.

In terms of the space distribution of the precipitation in the four seasons, (1) the space distribution of spring precipitation is basically parallel to the latitude, with an increasing tendency from north to south and from west to east; (2) the special distribution of rainfall in summer is similar to that in spring, with some disparity. The rainfall increases from the northwest to the southeast and from the northeast to the southwest. The northwest still sees the lowest precipitation; (3) the rainfall in autumn increases from the northwest to the southeast and from Western Shandong to Eastern Shandong. Amongst, the coastal areas in the southeast see the highest precipitation while the plain areas in the northwest report the lowest rainfall; (4) the rainfall drops significantly in winter. The contour lines in Northwestern and Northeastern Shandong are denser, while the contour lines in Central and Southern Shandong are sparser. In terms of special distribution, the rainfall declines from the northwest to the southeast. In recent years, the drop in rainfall and the uneven time and special distribution leads to the lack of available water resources in Shandong Province.

In addition, the continuous decline of underground water level due to excessive extraction will directly affect the flow of surface water and the supply to underground water. This is also the major human reason for the reduction in available water resources in Shandong Province. For example, influenced by less rainfall and larger underwater withdrawal, the average burial depth of underground water in Liaocheng City, Shandong was 6.8m in 2007, a year-on-year decrease of 70cm compared to the previous year, and the underwater reserve was reduced by 240 million cubic meters.

The 2006 statistics of Shandong Department of Water Resources showed that the shallow underground water withdrawal in the plain terrain of the province was 7.113 billion cubic meters, a year-on-year increase of 192 million cubic meters. The underground water reserve in the plain terrain of the province was reduced by 1.444 billion cubic meters at the year ending compared to that at the year beginning. Compared to that in 1980, it had an accumulated decrease of 5.706 billion cubic meters.

4.4 Loss of soil fertility and desertification

The climate warming will accelerate the microbiological decomposition of soil organic substance, leading to the reduction of its content in soil, which can change the soil water balance, structure and nutrition conditions, causing the reduction of soil fertility. Moreover, the salinization of soil can also deteriorate soil physical behavior, weaken its microbial activity, slow down the release of available nutrients and reduce the organic substance, leading to the reduction of soil fertility.

Since ancient times, Shandong has been one of the provinces suffering from serious wind-borne sand disasters, which are formed by several rout changes and bursts of the Yellow River, river flood, coastal sea wind and sea tide, and mainly distributed in northwest Shandong and Yellow River flood plain at its lower reaches, involving 27 counties (urban districts) under 6 cities. The statistics shows that there are still more than 6300 villages in Shandong that are under the threat of wind-borne sand and nearly 64million mu arable land that are affected by erosion and desertification of different degrees.

4.5 Salinisation of soils and aquifers

The salinized soil in Shandong is classified into coastal and inland types, and is mainly distributed in Yellow River fluvial plains and deltas in northwest and southwest Shandong, with the area amounting to 3.8% of the total. There is a larger proportion of area under the threat and impact of salinization, which occurs in spring. Presently, of the 8.1 million mu unused land in Yellow River Delta, 2.7 million mu land is saline and alkaline land. In the Yellow River Delta region in Shandong, the saline and alkaline land increases yearly by more than 6000 ha, making a large amount of land lie waste.

The main cause for the occurrence and development of soil salinization in Shandong is the high water table, which makes the soluble salts in the underground water and soil rise via the soil capillarity to ground surface and gradually accumulate.

The farmland in the regions of the cities along the Yellow River in Shandong such as Heze, Liaocheng, Bingzhou, Dongying and Jinan is mainly of irrigable type and is the main Yellow River irrigating regions, where the underground shallow water is at a great depth, and the deep underground water has a high mineralization. In case of the interruption of the Yellow River water flow, the farmland cannot be irrigated by Yellow River-diverted water, which is worsen by climate warming that leads to a reduced precipitation and increased evaporation. Now, the shallow underground water will rise along soil capillary and bring the salts to the soil surface, causing the soil salinization and further increasing the area of soil salinization.

Sea water intrusion can also cause the soil salinization in the involved regions. According to 1995 statistics, the coastal seawater encroached area in Shandong was about 974 square kilometers. At the acceptance evaluation meeting of the project of “ 1000t/d antiosmosis seawater desalinization and engineering technology development” in 2001, an expert pointed out that, with the development of agriculture and industry, the excessive-withdrawal of underground water in China was serious, which had led to seawater encroachment and soil salinization. Only in Shandong alone, around 500 square kilometers fertile field had been salinized in more than 10 cities and counties. For example, in Laizhouwan region in Shandong, the climate warming has caused a reduced precipitation in a non-uniform seasonal distribution and a strong evaporation. Therefore, the zero flow of the rivers in this region is frequently seen, which has led to the lowering of underground water table, the continuously expansion of underground water hopper area,

the increase of the level difference of seawater and underground water, and the acceleration of the seawater intrusion, finally causing the soil salinization of the encroached region. The salinized soil in Laizhouwan region is basically parallel to the coastline, with the salinization degree increasing in the direction from the inland to the sea.

The climate warming causes the rise of sea level rise, and further promotes the expansion of salinized soil to the inland area. A serious land salinization and swamping will be caused by sea water encroaching and a serious degradation of the soil of coastal and adjacent inland regions will occur.

4.6 Effects of other environmental impact factors

Soil is a large carbon warehouse. The wide application of chemical fertilizers and the climate warming accelerate the transformation of the organic carbon in soil, and increase the emission of greenhouse gases such as CO₂, N₂O and CH₄ to the atmosphere, which in turn help the temperature rise. Climate is also an important factor driving the change of land utilization mode. The zero flow of the Yellow River due to climate warming and precipitation reduction has impacted the land use pattern in regions around Yellow River delta to different degrees. In case of serious zero flow of the Yellow River, the pure reed wetland and the *Suaeda glauca* community of saline land at the low river course are made to expand over a large area. The reduction of the water from the Yellow River leads to the lowering of the underground water level on both river sides, and a large area of overflow land and unutilized land are reclaimed into farmland, leading a tendency of farmland area increase. The serious insufficient fresh water resource in the years with serious flow cutoff leads to a sharp decline in the Yellow River course areas and a great shrinkage of the breeding farms and mudflat areas around the Yellow River. The frequent over-year change of the water from the Yellow River leads to the corresponding change in underground water level and soil salinity of the areas along the Yellow River, the continuous mutual transformation among the Chinese tamarisk forest, reed community and reed- *Suaeda glauca* community, and the continuous change of the land areas for different uses, thus affecting the stability of delta wetland ecological system.

4.7 Estimated overall impact on crop production

Climate warming and abnormal warm winter are easy to bring a “late spring coldness” weather, which has remarkable impact on the crop normal growth and crop harvest. For example, a sustained high temperature after wheat sowing, in addition to much rainfall before and after the wheat sowing, will lead to a very serious “winter flourishing” of some wheat fields, which will cause a vain growth, too high distribution density, too much nutrient consumption of wheat seedlings, bringing a serious impact on the normal reviving and elongation. All this will lead to the yield reduction of the main crops and the grain output variation in most regions of the province.

The climate warming has increased the frequency of extreme climate events and natural disasters in the province, which has caused an annual direct economic loss of several tens of billion yuan, amounting to 3/4 of the GDP of the province. All this has increased the instability of the agricultural production in the province and seriously affected the grain security of the province.

On the other side, to suit the change of production conditions due to climate warming, the agricultural cost and investment will greatly increase, and the demand on production means such as water, fertilizer, pesticide and herbicide will gradually increase. (1) The climate warming increases the water demand of agriculture and also greatly increase the land area needing irrigation; (2) the climate warming will accelerate the microbial decomposition of the organic matter of soil, leading to a reduced content of soil organic matter; the drought soil restricts the accumulation and decomposition of the root biomass capable of supplementing the soil organic matter, suggesting a more fertilizer application for satisfying the crop need; (3) the climate warming provides superior conditions for the larva overwintering and weed growth. Therefore, climate warming may intensify the disease and insect pests and weed spreading. All this means that climate warming will increase the application of pesticides and herbicides, greatly increasing the agricultural production cost.

5 Assessing the impacts of agriculture on the environment

In recent years, the excessive agricultural development behaviors such as destroying forest or burning grass for land reclamation and the excessive application of chemical fertilizers and pesticides brought about by the development of intensive agriculture has seriously damage the ecological environment in Shandong, greatly reduced vegetation and water area, intensified the water-soil loss, expanded the land desertification, deteriorated the environment quality and threatened the sustainable development of agriculture, making people to pay greater attention to the protection of ecological environment and the sustainable development of agriculture.

5.1 GHG emissions and carbon sequestration

Agriculture is an important source of greenhouse gases. The organic matter in soil is decomposed by microbe and released in form of CO₂ into the atmosphere. CH₄ is produced by fermentation in farmland immersed in water for long time and half of the global N₂O comes from soil nitrification and denitrification processes. The production of greenhouse gases in agricultural ecological system is a complex process and any minor change of a factor of the conditions of climate, vegetation, soil quality and farmland management may change the production and emission of CO₂, CH₄ or N₂O.

The simulation results of 1990 statistic data made by Li Changshen et al ^[21] with the internationally used biogeochemical model DNDC (Denitrification-decomposition) show that China's agricultural ecological system emits 95 million t C/a of CO₂, 9.2 million t C/a of CH₄ and 1.3 million t N/a of N₂O. Shandong has a farmland area of about 8.5×10⁴km² and an annual CO₂ emission involving about 1.95 million t C, CH₄ emission involving 0.055million t C, and N₂O emission involving 0.038million t N.

As the greenhouse gases of CO₂, CH₄ and N₂O have different warming effects, their impacts on the global warming are different. We use the global warming potential (GWP) to express their combined effect. The calculation shows that the GWP value of Chinese farmland in 1990 was 344~2102 million t CO₂ equivalent, with the middle value being 1222.55 million t CO₂ equivalent. Of the three greenhouse gases, N₂O emission has the

largest contribution to the GWP value of Chinese farmland, amounting to 50% of the total; CO₂ emission is the second, 29%; and CH₄ has the least contribution, only amounting to 21% of the total.

The ten provinces that have the largest contribution to the national GWP include Heilongjiang, Inner Mongolia, Jilin, Sichuan, Jiangsu, Liaoning, Jiangxi, Anhui, Xinjiang and Guangxi. Shandong ranks the 15th in this respect, and its GWP value is about 0.25~53.88 million t CO₂ equivalent, with the middle value being 27.06 million t CO₂ equivalent. Of the three greenhouse gases, N₂O emission has the largest contribution to the GWP value of the farmland in Shandong, amounting to 68% of the total, far greater than the sum of the other two; CO₂ emission is the second, 26%; and CH₄ has the least contribution, only amounting to 3% of the total. This is mainly due to the cropping structure of Shandong that has a rather large proportion of vegetable planting area, which is the main source of N₂O emission. The small CH₄ emission is contributed to its small irrigable land area.

The simulation result shows that the C loss of the farmland in Shandong is very serious. This is mainly because that Shandong lies in north China plain, and has a long history of agricultural production. The farmland has been long utilized, leading to gradual reduction of the soil organic matter content. In addition, the ratio of stubble and stalk returned to soil is rather low and as a result, the organic C of the soil of large area farmland has reduced to a low level. In this case, if the input of organic matter to the farmland can be increased, the sequestration of farmland for atmospheric CO₂ will increase sharply so as to make a remarkable contribution to the mitigation of global greenhouse effect. Increasing the ratio of stalks or animal manure to soil will not only turn the C balance of the farmland in Shandong from loss to surplus but also evidently raise the N mineralization rate of soil itself. Its N yield can also greatly reduce the use of chemical fertilizer.

5.2 Over-exploitation of water resources

The analysis of the hydrological data for the period of 1956-2000 shows that the average annual total water resource of Shandong was 30.582 billion m³, amounting to only 1.1% of the national total. The per capita water resource amount was only 344 m³, less than 1/6 of the national value. Even if the Yellow River water diversion index of 7 billion

m³ was considered, the per capita water resource amount of the province was only 456m³. In terms of the international recognized Malin Falkenmark's water-stress index, the per capita value of the province is still far lower than the critical value of 1000m³ necessary for maintaining a sustained socioeconomic development of a region, and therefore, Shandong belongs to regions with serious resource water-stress. It is especially important to carry out a rational analysis and assessment of the exploitation and utilization status of water resource in Shandong Province.

The prediction based on the economic development speed specified in Shandong's Eleventh Five-Year Plan shows that, by 2010, the province will need water resource of 31.1 billion m³ per annum. However, the available water resource will be only 27.8 billion m³ and even if the 1.3 billion m³ from water transfer from south to north is added, and there will be still a shortage of 2.0 billion m³. The fact that the marginal benefit of water used for agriculture is lower than that of water used for industry has inevitably led to the phenomenon of "agricultural water resource's converting into non-agricultural use". The further reduction in the proportion of the water used for agriculture and rural living has correspondingly intensified the shortage of agricultural water resource. For example, the proportion of the water used for farmland irrigation in the total water consumption reduced to 64.59% in 2004 from 76.27% in 1987, less than the national average 67.6% of the same period. So, it is not optimistic about the supply-demand situation of agricultural water resource.

5.3 Pollution of soil, water and food

5.3.1 Soil pollution

In modern agricultural production, with the productivity development and sci-technical progress, the application of chemical fertilizers and pesticides has really improved the level of agricultural production. However, their application seems a double edged sword. At the same time of raising the agricultural output, it can cause serious pollution to the land which is the carrier of agricultural production, destroy the soil structure, reduce the organic matter in soil, and harden the soil, leading to the reduction in both soil fertility and land productivity.

Presently, in the protective cultivation in Shandong, to pursue simply a high yield,

some people use too much chemical fertilizer, 2-5 times more than practically needed, with the residual nutrients and inorganic substance enriched in soil and water. If things go on in this way, it may lead to a secondary salinization of soil, acidification, high N₂O emissions and contamination of vegetables with nitrates if excessive amounts of organic and inorganic fertilizers are used.

5.3.2 Water pollution

The excessive application of nitrogen fertilizer will lead to the nitrate enrichment in soil and nitrate movement to the underground aquifer and further the over-standard content of nitrate in water body, which occurs in the concentrated region of protective cultivation. The eutrophication of the surface water body in some regions occurs, with livestock and poultry manure and rotten crop stalks accounting for 70% of the nutrient source, and with only a small amount of nitrogen fertilizer not adsorbed going into lakes with surface runoff. This is largely caused by excessive application of nitrogen fertilizer and water-soil loss. Phosphorus is the main influencing factor of water eutrophication, whose occurrence is closely related with the phosphorous loss of farmland soil. The available data indicate that the contribution of the non-point source phosphorus of the farmland in Tai Lake basin to the water phosphorus is as high as 19%. The phosphorus of farmland soil migrates to ground surface or underground water mainly by way of surface runoff and seepage. The seepage of soil phosphorus is mainly influenced by the level of soil phosphorus. Lu Rukuan et al. held that 50~70 mg/kg Olsen-P in soil was roughly a critical index for non-point source phosphorus to pollute water source by way of seepage. A common character of the soil of vegetable field is that phosphorus accumulates to a great amount, which, in case of heavy rainfall or irrigation, will be very apt to move to water body with surface runoff or downward seepage, leading to water eutrophication. Therefore, the pollution caused by the high non-point source phosphorus of the soil of vegetable field should arouse the concern of people.

According to the statistics of the river water pollution based on 2001-2004 “Bulletin of Shandong Water Resource” [22], the river water quality exhibited a tendency of deterioration. The water quality above Class A that had basically lost the water-body function took the largest proportion, over 66%, and it had a tendency of yearly increase. Water quality of Class I took almost a zero proportion; the water quality of Class III

suitable for drinking took a low proportion of 1.3%-9.05%; the water quality of Class V mainly suitable for agricultural use had a proportion smaller than that of Class IV for industrial use, indicating a shortage of water with a quality suitable for agriculture. Moreover, the production mode widely adopted in the province in which chemical fertilizers and pesticides are used in excessive amounts has led to the eutrophication of water body. With the accelerated intensification of agriculture and animal husbandry, the crop stalks and livestock and poultry manure not utilized are discharged into the water body, polluting the rivers, sea and even the underground water resource.

5.3.3 Food contamination

The pollution of chemical fertilizers on farm products is mainly on fruits and vegetables, which is mainly in way of nitrogen pollution. The excessive application of nitrogen fertilizer can lead to the quality reduction of farm products and the potential hazard to human and livestock health. Extensive research shows that applying a large amount of nitrogen in orchards and vegetable gardens can lead to a high content of nitrate nitrogen in soil, and the nitrogen element in various forms is transformed into nitrate and adsorbed by vegetable and fruits. The 81.2% nitrate intake by human comes from vegetables in which nitrate is easy to enrich. Therefore, the pollution of nitrate from vegetables is the most serious. The investigation shows that the nitrate in the root, stem and leaf type vegetables in Linyi, Shandong, exceeds the standard by nearly 12 times and the spot inspection of 25 kinds of vegetables made in Qingdao City found a 100% detectable rate, with the overstandard rate as high as 84%.

In recent years, to control plant disease and insect pests, chemical pesticides have been used in large amount, which has well controlled the pests endangering the crop growth but also produced some long-term potential negative impacts. The increase of pesticide residual will cause pollution of environment and endanger the human health. China's annual pesticide application amount ranks the first in the world while its pesticide utilization rate is 20-30% lower than that in developed countries. The investigation conducted by the related sector shows that half of the pesticides used in the province are high poisonous ones and chemical pesticide residual is widely seen in agricultural products. The rate of pesticide residual in grain crops such as wheat and maize is as high as 10-20%, 5-10% higher than the normal standard, and that in fruits and vegetables is

even higher, reaching 28-36%. Take Shouguang Cit which is a typical producer of vegetables by establishment-vegetable field as example. The pesticides used are various and mainly classified into insecticides and germicides. The insecticides are mainly of organic phosphorus type (such as omethoate, phoxim and methyl 16.5) and pyrethroid insecticides (such as cypermethrin and deltamethrin), accounting to 51.5% and 11.1%, respectively. The germicides are of more varieties, with mixed germicides (such as , and sandofan), imidazole type (such as triadimefon and carbendazim) and substituted benzene type (such as chorothanlonil and Topstn-methyl) more used, which account for 16.8%, 10.9% and 11.3%, respectively.

5.4 Loss of biodiversity and natural ecosystems

Modern agricultural production uses chemical fertilizers, machinery and petroleum as the technical means, power and energy for agricultural cultivation, which takes crop cultivation as the center, the single populative structure as the system functional unit and the realization of economic output as the final goal. Its ecological characteristics repel the biodiversity, reduce the interspecies competition and sacrifice the environment for gaining a temporary high yield. Therefore, the growth of agricultural productivity is realized at the cost of many values of ecological system. From the systematic viewpoint of biodiversity, the agricultural system is becoming one producing only one or two species to a great extent and therefore, is changing the rural landscape and reducing the biodiversity. Agriculture is one of the main driving forces for the biodiversity loss.

The simplification tendency of farmland plants will inevitably lead to that in the variety composition and structure of other biotic communities of farmland. In this case, the natural enemy of pests under the influence of pest simplification will also have a tendency of simplification. Especially, natural enemies will have an even stronger selectivity on their hosts (pests), not on the pest type but also on the specific growth stage of pests.

The natural enemies will not exist if there is shortage of pests or pests at the special growth stage. As a result, the biological chain of farmland ecological system will collapse, which will inevitably destruct the balance of ecological system. For example, the most

important ones of the nearly 50 natural enemies of wheat aphid commonly seen in the grain field in Shandong such as *Coccinella septempunctata*, *Propylaea japonica*, *Harmonia axyridis*, *Episyrphus balteatus*, *Ahidius gifuensis*, *Misumenops tricuspidatus* play an important role in the natural control of wheat aphid quantity during wheat grain filling period.

If the host conditions for wheat aphid deteriorate (such as the completion of wheat grain filling and grain hardening) and it is difficult to find other edible plants due to the simplification of plant communities, the wheat aphid number will inevitably decrease, and the natural enemies of wheat aphid will also decline due to the lack of hosts and are difficult to survive on such farmland.

The agricultural production activities such as human change of cropping structure, cropping system, agronomic measures and disease and insect pest control will directly or indirectly affect the biotic communities, dynamic state and diversity of farmland. Especially, the wide application of chemical pesticides will have prominent and important impacts on the diversity of biotic communities.

The research and production practice in recent years show that chemical pesticides can change in various degrees the biotic communities of farmland and their structure, and reduce the diversity of biotic communities, leading to a reduced stability of the ecological system. The direct consequence is the killing of natural enemies in large quantities, leading to pest rampancy once again.

The monitoring and research results of the pesticide resistance of cotton bollworm and cotton aphid in the cotton producing region in west Shandong show that, in the middle late eighties, the rampancy of these pests in this region was related to the growth of their resistance to pesticides. For example, in 1985, the resistance of the local secondary generation of cotton bollworm came into the sudden increase period, with a year-over-year resistance increase reaching 22.8 times, and 544.9 times in 1992.

The sudden increase of the pesticide resistance of these pests had a direct relation with the then application of chemical pesticides characterized by large area, large amount, simplification and high frequency. The area for which chemical control was used amounted to over 90% of the total control area. The dosage of pesticides in 1981 was 1800ml per hectare; in 1988, 18000ml per hectare; and in 1992, 30000ml per hectare, with the dosage increasing by 15.93 times in the eleven years. The abused application of

pesticides will directly kill not only the natural enemies but also some neutral insects, leading to a superimposed impact on the specie number and structure of predator natural enemies.

6 Status and gaps of adaptation to climate change and the reduction of unsustainable land use

6.1 Policies and initiatives

Shandong is a large agricultural province in China. The climate change in recent years has had a certain impact on the development of its superior agriculture. The governmental sectors of various levels have been adopting measures to coping with the impact of climate change on agriculture, including formulating related agricultural policies, granting agricultural subsidies, conducting agricultural training and promoting agricultural insurance.

6.1.1 Agriculture policy and subsidy

In 2005, Shandong Department of Agriculture issued “Opinions on Building Economized Agriculture”, made specific deployment in regulating and optimizing the agricultural structure, reducing the input of agriculture-use chemicals and utilizing the agricultural residue as resource, promote the building of economized agriculture, raise the utilization rate and efficiency of agricultural resources and promote the sustained development of agriculture. In 2006, to build an economized agriculture, Shandong Department of Agriculture provided free technical service for formulated fertilization based on soil testing and issued 5 million fertilization suggestion cards, involving an area of 25 million mu, and realizing a total cost saving of 650 million yuan.

The formulation and implementation of related policies can help raise the utilization rate of chemical fertilizers and waste farm products, and reduce the emission of greenhouse gases or harmful gases caused by the intensive application of chemical fertilizers and the discharge or burning of waste farm products. Moreover, efforts should be made to establish and improve the system of law, regulations and policies for adapting the agricultural field to the climate change, enhancing the construction of agricultural infrastructure, popularizing crop strains with strong stress resistance and modern farm production technology so as to improve the adaptability of farm production to the climate change.

In 2009, Shandong has arranged a provincial level budgetary fund of 17.57 billion yuan for supporting the development of agricultures, rural areas and farmers, a year-on-year increase of 3.03 billion yuan and a growth of 20.8%. It has also formulated and distributed the “Opinions on the Implementation of Promoting a Stable Agricultural Development and Farmers’ Sustained Income Increase”, which puts forward 31 policy measures and grants subsidies to agricultural development such as direct subsidies to grain production, comprehensive subsidies to agriculture, subsidies to agricultural improved seeds, development of superior agriculture, construction of agricultural infrastructure and agricultural social cause development.

6.1.2 Agriculture training

In recent years, Shandong provincial and local government sectors at all levels have actively organized various kinds of agricultural and farmers’ training to improve the policy-decision ability of agricultural administrative sector and farmers’ technical level of production.

In December 2005, “Shandong Campaign of Bringing Science and Technology to the Countryside and Winter Training of Agriculture Science and technology” started formally, which made full use of modern education means and various kinds of education and training resources to communicate the agricultural policies and regulations and advanced agricultural technology, and meanwhile, organized related scientific research personnel and technical personnel to carry out education, training and technical guidance for farmers.

In September 2008, Shandong Department of Agriculture sponsored the “Meeting of Autumn Sowing and Training for Grain Industrial Projects under Modern Agricultural Production Development Fund”. At the meeting, exchange was made on the main technical measures for bumper wheat harvest and the experience and practice of high wheat output of all places in the province during 2007-2008, discussion was made on the impact of climate change on wheat production and the main coping technical measures and the main varieties under promotion, the proper sowing period and sowing amount at all places under the present climate conditions. As a result, the understanding of climate change and the capability of coping with climate change of the related local government

sectors were improved.

In December 2008, Shandong Provincial Party Organization Department and Department of Agriculture held a topic training class of modern agriculture in Jinan City to carry out the training for the related personnel of the government sectors at all levels on the domestic and foreign production status and high-yield technology of maize and wheat, and on the modern agriculture and sustained development.

6.1.3 Agricultural insurance

In 2008, Shandong was first listed as a pilot test province for policy agricultural insurance, which was carried out in altogether 60 counties (cities, districts), covering a wheat land area of 26.1673 million mu, maize land area of 13.1868 million mu and cotton land area of 6.8411 million mu.

By the end of 2008, the wheat, maize and cotton land area under insurance was 31.39 million mu, involving a total premium of 204.38 million yuan for a total insurance value of 11.49 billion yuan, with indemnity expenditure being 33.988 million yuan, effectively protecting the benefits of disaster stricken farmers.

In 2009, the province has revised and perfected some articles in the related policy agriculture insurance and the plan of pilot test implementation, and in view of the severe situation of the current price decline of farm products, difficult farmers' employment outside rural region and serious drought, the province has made efforts to open new insurance fields based on the present basis, set up new agricultural insurance kinds suitable to Shandong drought conditions and expand the scope of pilot testing.

It can be seen that the provincial government has attached great importance to agricultural insurance, and made great efforts in its system construction and perfection. However, a number of issues remain to be improved, which mainly include:

(1) Too small area covered by agricultural insurance business. Of the 14 property insurance companies in the province, only Property Insurance Company of PICC has opened the agricultural insurance business, and of its 16 branches in Shandong, only 13 has this business, with only seven of them each having premiums of over 0.1 million yuan.

(2) Insufficient security of agricultural insurance products for agricultural risks. Take Shandong Branch of Property Insurance Company of PICC for example. It has altogether

22 clauses of agricultural insurance types, but only several risk kinds such as wheat hail insurance, fire insurance and forest insurance have premium income, which accounts for about 80% of the total agricultural risk insurance, leaving very small room for farmers to select.

(3) Insufficient benefit compensation and not high initiative of all involved parties. Take Shouguang vegetable greenhouse insurance as example. Farmers, insurers and township carders are all unsatisfactory with the benefit compensation in the pilot testing. For farmers, the insurance value for a vegetable greenhouse is 6000 yuan while the building of a greenhouse will cost several tens of thousand yuan. In case of a risk claim, the compensation is very little compared to the investment, an utterly inadequate amount, which naturally depresses farmers' enthusiasm for buying insurance. The agricultural insurance pilot test involves a large area and a great amount of workload, including publicity, registration, at door premium collection and checking, but the economic subsidy for the work is only 5% of the premium, which is unable to promote the carders' initiative. The insurance companies involved can play a role of only "agency" and provide only networking, personnel and technical service of pricing, insurance checking, disaster investigation, loss determination and claim settlement, which earn only the "agency management expense" and may even have a loss.

(4) Non-identical benefit orientation. For commercial insurance companies, they select to support the agricultural insurance at no-earning or even losing conditions with an aim to raise their awareness through agricultural insurance, and widen the business channel for commercial operation goal, which runs counter to the policy insurance objective. In addition, the financial support fund is limited, and therefore, the agricultural insurance business is made hard to continue.

6.2 Yellow River Basin and selected focus areas

6.2.1 Human capacity and awareness

In 2008, Lu Yarong et al conducted a survey on farmers' understanding of climate change in Dezhou City, Shandong. Of the 296 valid questionnaire responses, 208 thought that the climate had change, amounting to 70.27% of the total. Of them, 43 knew the

causes of climate change, accounted for 20.67%; 165 didn't know about it or failed to give an answer, accounted for 79.33%; 179 thought the climate change would have an impact on agricultural production, accounted for 86.06%; and 29 thought it would not have such impact or failed to give an answer, amounting to 13.94%.

It can be seen that farmers have a not deep understanding of climate change, with nearly one third being unaware of the climate change and about 80% respondents being ignorant of the causes of climate change.

The reasons include that most of the rural residents have a low cultural level, which was, on one side, because that their education background is of middle school or even lower, and they are on old age-side and have very weak recognition, comprehension and adaptability of climate change.

The survey result shows that the recognition of climate has a tendency of reduction with age increase and of increase with higher education level, an evidence of the impact of age structure and education level on the recognition of climate change. On the other side, farmers' channel of sensing the climate change is through their own sense or TV and their concern is mostly over weather change condition, way and content.

There have been few popular scientific books, lectures and activities in relation to climate, making it difficult to raise the consciousness of rural residents of climate change. It was also found through the survey, only 48% of the respondents adopted measures to suit the climate change and the other 52% did not.

These adaptive measures were in a narrow channel and scattered, and most of them were only the selections of farmers by their own experience, with farmers obtaining the information about adaptive measures from outside being less than 40%. Even the measures adopted were those easy to control and simple for them, and those more comprehensively and deeper were not adopted by farmers.

Viewing either from the goal, reason or from behavior for adopting measures, the farmers in the province still lack the recognition of farm production-related climate and the adaptability to climate change and are not prepared for coping with the climate change.

Agricultural insurance has become an important way to cope with the climate change. However, farmers' understanding of its significance and role is not optimistic. Zhang Wei et al conducted a survey of 400 farmer households on agricultural insurance^[23] in various places in Shandong. To the question of "Have you ever heard of agricultural insurance?"

287 of 399 respondents said yes, amounting to 71.93% and 112 respondents said not, amounting to 28.07%. To the question of “How much have you known about agricultural insurance?” , one respondent said “very much”, 87 said they knew about it, 245 didn’t clear about it and 64 was fully ignorant of this, with the respondents being “not clear” and “fully ignorant” accounting for 77.83% of the total surveyed.

It can be seen that more than two thirds of the farmers have only heard of agricultural insurance and nearly fourth fifths are not clear about agricultural insurance. It should be analyzed from two sides: farmer’s self-consciousness and agricultural insurance. On the one side, the publicity of agricultural insurance is insufficient and involves not many areas.

On the other side, most young people have gone out and those at home are mostly old people and women, who have a low education level and poor receptivity, which are the important reasons for a low recognition of agricultural insurance.

The farmers lack necessary understanding of the significance, role and knowledge of agricultural insurance. They are not aware that buying agricultural insurance is an effective way to transfer agricultural risks and protect their own benefits. It is found in investigating the farmers’ will for getting insured, 67.60% respondents said they would buy the insurance if the premium is low, 10.71% said they “badly need and want to buy” it and 21.69% said they would not buy it.

It can be seen that the premium is a key factor guiding the farmers’ decision. An insurance value of 1000 yuan requires a premium of forty to fifty yuan is really not a small amount to farmers that are not rich in the province. Some farmers think if I pay the premium but no disaster occurs, this will be an unnecessary expense.

Some of farmers doubt about the insurance business and consider there is misleading in publicity of the insurance companies, which affects their will to buy agricultural insurance. The survey on whether farmers have bought agricultural insurance shows that, of 389 respondents, only 17 had bought the agricultural insurance, amounting to 4.37% of the total respondents.

The insufficient supply and demand of agricultural insurance system, too high premium, not high reputation of insurance companies and too complex business procedure are the main reasons for a low proportion of farmers buying agricultural insurance. Moreover, the farmers’ weak insurance consciousness, the rate of risk occurrence and low

governmental subsidies are also important reasons.

6.2.2 Adaptation processes

The government sectors of all levels are making efforts, through the legal building of natural disaster prevention and mitigation, to further develop the agricultural insurance, enhance the construction of rural basic infrastructure and development of rural social cause, raise the farmers' enthusiasm for investment and re-production, carry out publicity of various forms such as lectures, TV, knowledge contest, and site guidance, improve their recognition and understanding of climate change.

The related scientific research entities apply for setting up and implementing projects on the modern agricultural production technology for coping with climate change, carry out an extensive research on agriculture-related pollution prevention and control, actively develop the water-saving agriculture, ecological agriculture and stereo agriculture and help farmers to master the new technology for coping with the climate change through demonstration and promotion.

The main measures for coping with climate change adopted presently include the following:

(1) Technology of soil testing and formulated fertilization: by the end of 2007, this technology had been spread to 94 counties in the province, amounting to over 80% of the total agricultural counties of the province, involving a total area of 3.3 million hm², reducing the input of chemical fertilizers by 0.15 million t, and bringing an accumulated cost reduction and efficiency increase of more than 2 billion yuan.

(2) Technology of stalk return to field: more than 90% of wheat residues and 60% maize residue are mechanically returned to fields, which can increase the organic substance content of soil, improve the soil fertility and increase the crop yield by about 15%.

(3) Technology of water-saving irrigation: Water-saving irrigation technology of various forms is adopted for 4 million hm² cultivated land in Shandong, amounting to about 60% of the provincial total, which includes mainly sprinkler irrigation, micro-irrigation and drip irrigation, and agronomic water-saving measures such as turning long furrows into short ones and wide furrows into narrow ones, low pressure piping

irrigation and anti-seepage of channel.

(4) Technology of utilizing organic wastes as fertilizer: there are now more than 100 organic fertilizer producers of various sizes in the province, producing annually more than 2 million t organic fertilizers with livestock and poultry manure, industrial organic wastes and crop stalks as the main raw materials. At the meantime, the government has enhanced the promotion of organic fertilizer application. In 2008, the government bought 0.12 million t organic fertilizers, which were distributed to the farmers in 30 counties of the province.

6.2.3 Measures for reducing unsustainable land use

The arable land in Shandong has reduced yearly since 2002, and its per capita ranks only the 27th place in the country, with a great shortage of reserve land resource. In the process of promoting the industrialization and urbanization, the contradiction between the eco-social development and land resource limitation is becoming increasingly tenser.

To well protect the arable land, the governments at all levels has implemented a strict supervision on and checking of the inventory of arable land in the administrative regions and the protective area of basic farmland, and the overall plan and annual implementation conditions of land utilization. Meanwhile, they implement the “Rules of Shandong on Protection of Basic Farmlands”, enhance the standardization of basic farmland construction, improve and complete the mechanism of the quality protection of basic farmland and promote the diversified input of basic farmland construction.

Now, there are five state-level and 12 provincial level demonstrative zones of basic farmland and 100 million mu of farmland is under the protection in the province, amounting to 87% of the total basic farmland.

Meanwhile, the related scientific research institutes have carried out researches on sustained land utilization and protective cultivation of arable land. For example, in 2007, Shandong Design and Research Institute of Environment Protection Sciences undertook the project issued by the provincial government on “Research of Shandong Land Utilization and Ecological Environment Protection”, studied the impact of the land utilization mode and space layout on the ecological environment and proposed the suggestions on measures for the environment- friendly land utilization modes and the

rational exploitation and utilization of land. In 2007, Shandong Academy of Agriculture set up a hi-tech independent innovation fund of the institute, started the implementation of the project of “Key Technology and Ecological Safety for the Obstruction and Control of Stereo Pollution of the Production Origin of Shandong Superior Farm Products for Export”, putting the agricultural stereo pollution control technology research on important agenda.

The current agronomic measures for reducing the non-sustained utilization of land in agricultural production include technology of stalk return to field, technology of water-saving irrigation, technology of soil testing and formulated fertilization, technology of utilizing organic wastes as fertilizer, technology of soil testing and formulated fertilization, and technology of comprehensive prevention and control of agricultural stereo pollution.

7 Environmentally friendly agriculture strategy to respond to climate change and the costs of implementation

7.1 People's ability and consciousness to respond to climate change

7.1.1 Potential strategies

The public consciousness of environment and global climate change has been a weak link and it is a long term arduous task for the province to raise the public consciousness of global climate change.

For common people, the climate change may lead to the change in demand on production, commodity and service markets and have direct impact on the benefits of special fields including energy transition system, structures, urban facilities, industrial and agricultural production, and tourism and construction industries, further affecting the human living environment. The increase and the impact of extreme weather events on human health have made residents migrate out. In addition, the global warming will increase the dissemination of malaria and dengue fever, which may endanger human health via various channels.

In view of the above impacts, the province will take measures to edify and guide the public's risk consciousness, enhance the publicity, education and training of climate change via modern information communication technology, encourage the public participation, and strive to create a good social atmosphere for effective coping with the climate change by popularizing the knowledge of climate change and improving the whole society's consciousness by 2010.

For example, we will run training classes on the basic scientific knowledge of climate change, analysis of its social and economic impacts, its coping policy measures, political and diplomatic situation and internal development pattern, which will play an active role in improving the consciousness of local managerial personnel on climate change. The adaptability to the climate change and the efforts to mitigate the greenhouse gas emission involve many fields of economical society. Only by organically combining the policies

coping with the climate change with other related policies can these policies become more effective. For example, the global warming and the frequent extreme weather and climate events have caused serious impact on world countries including China.

Realistically, Shandong agriculture is still a rain-fed one. To get out of the restriction of rain-fed agriculture, the main way is to greatly develop disaster-avoiding agriculture, and improve the comprehensive production capacity of agriculture so as to reduce the disaster loss to the minimum.

Firstly, we should make a deep study of the major impacts of climate change, and the measures for coping with various disasters so as to improve the ability to resist the disastrous climate events.

Secondly, we should set up the mechanism of early warning of and swift response to climate change. We should be able to make a quick response to the different level early warning of meteorology, concentrate all forces to the disaster prevention and control, and improve the participation consciousness of carders of various levels and vast farmers.

Thirdly, we should continue to enhance the construction of agricultural infrastructure, further strengthen the construction of agricultural comprehensive production capability, expand the dry farming demonstrative zone, and form the capacity of irrigation in drought and drainage in flood.

Fourthly, we should make great efforts to promote the disaster-avoiding agriculture characterized by taking facilities as the main. We should start from a good plan, select proper regions, set up the subzone size in a scientific way and then promote a scaled development.

7.1.2 After the implementation of the strategy

By 2010, we will strive to create a good social atmosphere for effective coping with the climate change by popularizing the knowledge of climate change and improving the whole society's consciousness.

We should further improve the coordination mechanism of multi-sectors-involved policy decision, set up the action mechanism of wide participation of enterprises and public mass in coping with climate change, and by 2010, establish and form an efficient

organizational structure and administrative system suitable for the future work coping with climate change.

Measures should be taken to enable the public mass to have a clear consciousness of climate change-related risks, and improve their consciousness of implementing the corresponding emergency actions. In the country-wide scope, the energy consumption per unit GDP will be reduced by about 20% compared with that in 2005, the emission of carbon dioxide will decrease correspondingly, and the proportion of the total amount of the exploitation and utilization of regenerable energies (including high capacity hydropower) in the primary energy supply structure will be raised to about 10% and the coalbed methane extraction will reach 10 billion m³.

By 2010, the forest coverage will be 20% and the carbon dioxide amount adsorbed by forest will be made to increase by 50 million t over 2005. About 90% of the typical forest ecological system and state major wild animals and plants will be protected, the area of natural conservation zone will be about 16% of the total state territory and the 0.25 million square kilometers land area will be comprehensively treated in for water and soil conservancy.

The safe energy, regenerable energy, energy saving and efficiency increase will be protected by the state policies, and the emission of greenhouse gases will be greatly reduced in the province. The promulgation and implementation of economic policies for forestation, and the returning the arable land to forest land and returning the field to grassland will ensure an effective adsorption of a great amount of carbon dioxide and the reduction in the emission need of greenhouse gases.

7.1.3 Cost analysis

Coping with climate change will require a corresponding economical and social cost payment and greatly increase the agricultural cost. The various socio-economical conditions should be comprehensively considered, including all related greenhouse gas sources, pools and storage, and proper measures covering all economic sectors. Input, or even a long-term input, has to be made in coping with the global climate change, which may be comparatively smaller than people image. According to an IPCC report, this investment will amount to about only 0.12% of the annual average GDP of a country to

check the global climate warming tendency from 2015. Viewing from this figure, Shandong will be fully financially capable to make a long-term investment in coping with the climate change.

7.2 Measures

7.2.1 Potential strategies

The issue of climate change has become a global politic topic and Shandong Province faces a huge pressure of the international society requirement on controlling greenhouse gas emission. In view of this, we should speed up the transformation of economic development mode and take a low-carbon economic development road so as to promote a sustainable development; be cautious about various emission reduction plans and pay attention to maintain and secure the development rights and interests and development space; promote and enhance the mutually beneficial cooperation and exchange with the state and international related sectors ^[24] ; and intensify the provincial public consciousness of climate change and implement corresponding measures. According to the state sustainable development strategy, the province attaches great importance to the research of climate change, implements the construction for coping with climate change, enhances the education and publicity of climate change and takes the corresponding strategy and measures in fields of industry, agriculture, water conservancy and education, which are as follows.

(1) To strengthen the organization and leadership in climate change-related work: in accordance with the requirement on the full implementation of scientific outlook on development, to combine the coping with climate change with the implementation of sustainable development strategy and the acceleration of building a society of energy conservancy type and environment-friendly type, and to include it into the overall plan and regional plan of national economy and social development. To perfect the coordination mechanism of multi-sectors involved policy decision, set up the government-promoted action mechanism with wide participation of enterprises and public mass in coping with climate change, and establish and form an efficient organizational

structure and administrative system suitable for the future work of coping with climate change.

(2) To promote major technical research projects in climate change field: to enhance the policy guidance in scientific and technological work in climate change field, and encourage and support the scientific and technological innovation for coping with climate change. To strengthen the fundamental research in climate change and carry out the research in the formation mechanism of extreme weather and climate events; enhance the agriculture and ecological climate zoning against the global climate warming, study the utilization way of agricultural climate resource and agricultural productivity allocation suitable for climate change, pay attention to the cultivation of academic leaders and top talents, and gradually build a powerful contingent of climate change science and technology management, research and development.

(3) To control the emission of greenhouse gases so as to mitigate the climate change by structural optimization, energy conservation and energy structural regulation: the high-energy heavy industry takes a large proportion in the province, whose energy consumption is as high as 84% of the provincial total, while the energy-efficient new technologies takes a small proportion. To reduce the emission of greenhouse gases, great efforts should be made to regulate the industrial economic structure, enhance the elimination of the backward technologies and equipment characterized by high energy, high material and high pollution, and resolutely shut down the enterprises of 15 major categories and five new categories of small polluting enterprises. We should encourage and support the use of regenerable energies as important supplementary energies of the province by energy diversification so as to reduce the use of non-renewable energies such as petroleum and coal, and on the other side, we should enhance the energy conservation and improve the energy efficiency by structural regulation, technical transformation and enhanced management with the help of proper exciting mechanism.

(4) To conduct structural regulation and scaled operation: according to the climate change tendency and its impact on the agricultural climate resource, land productivity, cropping system and crop growth, we should energetically carry out a dynamic precise zoning of agricultural climate, and analyze the resource allocation of light, temperature and water resources and the new pattern of agricultural climatic disasters so as to provide a basis for the regulation of agricultural industrial structure.

(5) To realize a scientific and technological agriculture: with the increase in the sensitivity of agricultural environment to climate change, the demand of agriculture on science and technology will increase unprecedentedly. At the same time of adjusting the agricultural structure and cropping system, great efforts should be made to develop biological technology, introduce, cultivate and select in a planned way the crop varieties that are capable of resisting disease and pests, drought, flood, high temperature and low temperature, cultivate new livestock varieties suitable to climate change, and develop technical measures capable of disaster prevention and control, yield stability and increase and being friendly to environment.

(6) To enhance the construction of agricultural infrastructure: we should strengthen the construction of irrigation facility and the transformation of low-yield field soil, construct the field soil capable of high stable yield, and improve the agricultural capability of resisting meteorological disaster. We should stress on water saving and scientific irrigation in the construction of farmland water conservancy, develop new agricultural production processes suitable for climate change and automatic intelligent agricultural production technology, and enhance the construction of comprehensive engineering facilities for preventing and controlling natural disasters.

(7) To attach importance to education and improve the public consciousness: we should enhance the publicity, education and training of climate change through various kinds of science popularization such as lectures, TV and film, knowledge contests, arts performances, blackboard newspaper, albums of painting and site guidance so as to encourage the public participation, improve the whole society's consciousness and create a good social atmosphere for effective coping with the climate change. We should perfect the coordination mechanism of multi-sectors involved policy decision, set up the action mechanism of wide participation of enterprises and public mass in coping with climate change, and establish and form an efficient organizational structure and administrative system suitable for the future work coping with climate change.

7.2.2 Corresponding measures

The party and the government should pay great attention to and include the climate change into the issues of national security. Meanwhile, the state should formulate a great number of laws coping with climate change ^[25]. Shandong People's Government should take various measures for coping with climate change: to actively participate in climate change-related international negotiation; take a series of policy measures to alleviate the emission of greenhouse gases; work out and implement a sustainable development strategy and take coping with climate change as an important component of the sustainable development strategy; make efforts to improve energy utilization efficiency, improve the energy structure and promote the utilization of new energies and renewable energies; earnestly perform the obligations under the "UN Framework Convention on Climate Change"; conduct scientific research on climate change; and carry out the publicity and education on climate change and strengthen the public's consciousness of climate change.

Every Chinese citizen should pay great attention to the issue of coping with climate change. Firstly, we should transform the previous bad living habits, advocate the use of resource and energy in a conservancy way so as to reduce their consumption to the utmost, and improve their utilization rate. For example, the families that own cars should reduce the car use as much as possible, take an active part in the activity of using one day less the car per month, reduce the use of air conditioners and refrigerators; arrange the housing in a scientific way, object to luxury houses, use the water resource rationally, reduce the use and consumption of fossil energies such as coal, natural gas and petroleum, save grains and protect the land. Secondly, we should take an active part in the state ecological construction, such as forestation, grassland and wetland protection, and protection of sea and animals.

We will break the linkage between the energy service and the primary production; cease the forest cutting, speed up the development of low emission technology, develop the plastic fuel, energy storage and new basic facilities, use low-carbon natural gas to replace high-carbon coal, and use carbon capture and sealing-up technology.

We should implement the continued support facility construction for large irrigation areas with water-saving transformation as the center, do a good job in the projects of field

irrigation and drainage, small irrigation areas and water sources for resisting drought in non-irrigation areas; speed up the construction of rainfall collection, storage and utilization projects in hilly areas and dry areas; promote the adjustment of agricultural structure and the reform of cropping system; optimize the layout of agricultural areas, promote the concentration of superior farm products in superior production areas to form a belt of superior farm products, and improve the agricultural production capacity; select and cultivate degeneration-resistant varieties, and cultivate new fine plant and animal species with high potentiality, fine quality, prominent comprehensive resistance and wide adaptability; check the tendency of severer desertification of grassland; build artificial grassland, control the livestock carrying capacity of grassland, recover grassland vegetation, increase grassland coverage, improve its soil conservation function and prevent the further extension of desertification; enhance the research and development of new agricultural technology, and strive to achieve major progress in photosynthesis, biological nitrogen fixation, facility agriculture and precision agriculture.

We should continue to promote low-emission semi-dry cultivation technology, adopt scientific irrigation technology, research and develop fine ruminant species and scaled breeding management technology, enhance the management of animal manure, wastewater and solid wastes, and promote the methane utilization.

We should implement the measures of forestation, returning the cultivated land to forest and grassland, protecting energy forest bases and carrying out the basic construction of farmland, and should enhance the major project construction.

We will strive to add 5 million ha improved grassland, regulate 6 million ha degraded, dusterilized and salinized grassland and raise the effective utilization coefficient of agricultural irrigation water to 0.76 by 2010 by adopting the measures of enhancing the basic construction of farmland, regulating and optimizing the crop allocation, reforming the cropping system, selecting and cultivating degeneration-resistant species, and developing biological technology.

We should enhance the protection of natural forest resource, speed up the construction of major ecological protection projects such as natural reserves, set up important ecologic functional zones and promote the natural ecological restoration.

We should adopt measures to make rational exploitation and optimized allocation of water resource, perfect the new mechanism of the basic construction of farmland water

conservancy and promote water saving so as to strengthen the adaptability of water resource system to the climate change.

We should adopt measures to rationally utilize the costal line, protect coastal wetland, raise the class of seashore protective structures, and enhance the seashore monitoring and the supervision of the ecological system of littorals belt; improve the capacity of coastal regions to resist the oceanic disasters, and reduce the social impact and economic loss caused by the seal level rise to the minimum.

7.2.3 Cost analysis

Since the industrialization, human activities have caused a continuous increase in the global total emission of greenhouse gas. If further measures are not adopted, it will go on growing in the future several decades. During 1970 – 2004, the emission of main greenhouse gases rose by 70%, mainly due to the growth in population and per capita energy consumption. It is expected that the global emission of carbon dioxide in 2030 will increase by 45%-110% over 2000.

The international society holds that the earlier the effective mitigation measures are taken, the lower the economic cost and the better the mitigation effect will be ^[26]. By 2030, if the concentration of global greenhouse gases is controlled at 445ppm~710ppm (379ppm at the end of 2005), the macroscopic economic cost for global emission reduction will be controlled at below 3% of the global total GDP. If the measures are taken after 2030, a larger economic cost will have to spend. If the concentration of global greenhouse gases is controlled at below 490ppm (corresponding to an average global temperature rise of 2.0°C~2.4°C) in 2050, the macroscopic economic cost for global emission reduction will amount to 5.5 % of the global total GDP.

The policies and measures currently implemented have both advantages and disadvantages, and both the market mechanism and the government intervention are indispensable. Market mechanism such as pricing of carbon emission can effectively promote the development and utilization of low carbon products and technology. Raising the carbon price to US\$ 20~80 per ton carbon dioxide equivalent prior to 2030 and to US\$ 30~155 prior to 2050 will help control the concentration of greenhouse gases in atmosphere at about 550ppm in 2100.

7.3 Measures for reducing unsustainable land use

7.3.1 Potential strategies

The sustainable use of land refers to a kind of land utilization that can both satisfy the need of contemporary people and will not affect the mankind's future long-range demand. It has different meanings from different angles of understanding. In terms of utilization aim, a sustainable use of land refers to realizing a sustained growth and stability of land productivity; in terms of land supply-demand relation, it refers to reaching a sustained balance between land supply and demand; and in terms of human-land relation, it refers to the coordination and prosperity of land-human relation.

To maintain a sustained growth of land productivity, realize a balance between land supply and demand, and reach a coordination and prosperity of land-human relation, we should reduce the non-sustainable land utilization, and make a strategy with environment friendliness, economic feasibility and social acceptability.

Strategy 1: To maintain and improve the land resource quality, and ensure the sustainability of land production performance. In view of the fact that land degradation (including soil erosion, desertification, secondary salinization and land pollution) has seriously affected the quality of land resource and constituted a threat to the sustainability of land production capability. We will carry out the projects of returning the steep slope cultivated land to forest (grassland) and “transforming the slope land into terrace”, exploit and make green the wasteland and waste hills, improve the ground vegetation coverage; reduce the use of agricultural chemicals including agricultural pesticides and chemical fertilizers, apply biological technology for controlling disease and insect pests, plant green manure, apply organic and inorganic fertilizers in a formulated way to increase soil fertility, and enhance the transformation of low-yield products, improve the soil fertility and crop unit area yield, ensure the state grain security and eliminate the contradiction between land decrease and sustained growth of population.

Strategy 2: To keep a dynamic balance of the total land amount and alleviate the contradiction between land supply and demand. The present increasing tension contradiction between the land demand by urban production and construction and its effective supply has led to a sharp decrease of cultivated land. Therefore, we should strengthen the protection and construction of basic grain field, forest land and grassland.

In the urban production and construction, we should reduce the land occupation by tapping internal potential and practicing external economization, and develop, reclaim and regulate the land in a scientific way so as to increase the land area effectively utilized and its output rate.

Strategy 3: To realize the structural optimization of land utilization and protect the ecological environment. We should optimize the land use structure and layout from ecological benefit, economic benefit and social benefit, implement diversified operation and diversified land utilization, develop multi-functional agriculture, increase economic income, carry out the work of returning the cultivated land into forest (grassland), greening the wasteland and waste hills in weak ecological environment areas, and establish an ecological compensation mechanism for mountainous regions. The measures for supporting the above strategies include:

(I) Implementation of rural clean projects

The basic contents of rural clean projects include turning the “three wastes” into “three materials” to form “three benefits” and promoting “three cleanings” with “three savings” to realize “three livings”. That is, based on a unit of village, to promote the transformation of human and animal excreta, crop stalks and living refuse and sewage (three wastes) to fertilizer, raw material and feed (three materials) to realize economic, ecological and social benefits (three benefits); to realize clean water source, clean farmland and clean courtyard (three cleanings) by adopting a complete set of practical technology and engineering measures of water, fertilizer and energy saving (three savings) to achieve the goal of production development, plentiful living and good living ecology (three livings). Based on the experiences in pilot tests and demonstration in recent years and learning from the successful modes of rural cleaning in other provinces, the rural cleaning can be made in the following three modes ^[27] :

(1) Three-in-one type rural cleaning: in traditional agricultural areas with cropping as the lead and with an undeveloped breeding industry, the stress will be put on solving the issues of living sewage, living refuse and stalk pollution by “sewage purification, refuse and stalk compositing and property management type service”. With village as the unit, the blind drainage ditch will be built for collecting the living sewage and the purifying tank for a centralized treatment of living sewage, with the sewage treated sent for irrigation; each household will have a refuse collector for classified collection of living

refuse, which will be sent to a fermenting tank, where it is mixed with crop stalks and fermented to produce organic fertilizer; a property management type service will be adopted, with designated persons being responsible for the collection and compositing of the whole village's living refuse and the application of the resultant organic fertilizer, and a property management station will be set.

(2) Four-in-one type rural cleaning: in areas where the traditional breeding industry has a preliminary size, the stress will be put on solving the issues of living sewage, human and animal excreta, living refuse and stalk pollution by “ methane use in every household, sewage purification, refuse and stalk compositing and property management type service. With village as the unit and household as the base, the blind drainage ditch will be built for collecting the living sewage and the purifying tank of different sizes for a centralized treatment of living sewage, with the sewage treated sent for irrigation or discharged at required standard ; each household will have a refuse collector for classified collection of living refuse, and the collected living refuse and the sludge in the living sewage purifying tank will be sent to a fermenting tank, where they are mixed with crop stalks and fermented to produce organic fertilizer; a property management type service will be adopted, and people will be designated to be responsible for the collection and compositing of the whole village's living refuse, the management of organic fertilizer station and the application of organic fertilizer, the maintenance of the purifying tank of living sewage, and the discharge of methane tanks and downstream service, and a property management station will be set.

(3) Intensification type of rural cleaning: in areas with a developed breeding industry, with a breeding subarea or large and medium-sized breeding farm as unit, a factory type operation mode will be adopted. Large and medium-sized anaerobic fermentation projects and blind drainage ditches will be built. The wastewater and living sewage will be sent to the anaerobic fermenting tank, with the methane produced as living fuel and the sewage treated sent to the sewage purifying tank for a secondary treatment or use as liquid fertilizer. Meanwhile, each household will have a refuse collector for classified collection of living refuse, and the living refuse will be collected by specified personnel, who will send the collected living refuse, animal excreta and solid waste to the organic fertilizer production yard for fermentation and producing commodity organic fertilizer.

(II) Implementation of clean breeding projects

Breeding will adopt production technology with reduced pollution to reduce the production of sewage and the discharge of urinary nitrogen and phosphorous of manure. Based on the practical experience of other places, learning from the foreign manure and sewage treatment and utilization methods and combining some newest research achievements, the projects for demonstration in different areas are classified into four categories, with animal manure treatment mode as the main content and sewage treatment as the auxiliary:

(1) Methane-energy utilization type: It is suitable for pig, poultry and cow farms near to water system with strict discharge standard, high environment protection standard, and demand on energy. It is characterized by a high decontamination and purification efficiency and full utilization of energy. The excrement and sewage are treated by digestion tank or UASB (upstream anaerobic sludge blanket) technology with the methane residual used to produce organic fertilizer. The practical modes include small size, medium size and large size comprehensive utilization modes of methane.

(2) Type of comprehensive utilization of composite organic fertilizer: It is suitable for pig, poultry and cow farms in areas with rather strict discharge standard, medium environment protection standard, and not high demand on energy. It is characterized by a rather high decontamination and purification efficiency and energy consumption. Breeding will adopt production technology with reduced pollution with dry clearing-away of excrements to realize a solid-liquid separation. The solid excrement will be used to produce organic fertilizer while the sewage will be treated to meet the standard for discharge or utilization by anaerobic and aerobic technologies. The practical modes include two: producing solid composite organic fertilizer and producing solid-liquid composite organic fertilizer.

(3) Type of manure production and utilization: It is suitable for small and medium-sized breeding farms (zones), pig, poultry and cow farms in areas with medium discharge standard and environment protection standard and with the surrounding areas having a sufficient manure containing capacity. It is characterized by a medium decontamination and purification efficiency and nearby utilization of manure and sewage as fertilizer. The manure and sewage can be used at the same time to produce fertilizer. The dry clearing-away of excrements in breeding can also be adopted to realize a

solid-liquid separation. The solid excrement will be used to produce solid manure while the sewage will be treated to meet the standard for discharge or utilization by anaerobic and aerobic technologies. The practical modes include two: producing solid manure and producing solid-liquid composite manure.

(4) Type of edible fungi conversion and utilization: It is suitable for cow or sheep farms in areas with medium discharge standard and environment protection standard. It is characterized by taking using manure as resource as the guide while reducing pollution, and by high decontamination and purification efficiency, low energy consumption and large area needed for environment purification. The dry clearing-away of excrements in breeding will be adopted to realize a solid-liquid separation, with the solid manure treated by compositing, fermentation, curing and drying and used as the substrate for mushroom planting, and the sewage treated to meet the standard for discharge by anaerobic and aerobic technologies.

(III) Implementation of clean planting projects

Efforts will be made to regulate the cropping structure and optimize the cropping allocation, give priority to developing intensified vegetable planting in areas with low pollution risks and to developing leguminous plants with low manure need and outstanding environment benefits, or grain crops or cash forest in areas with high pollution risks; make a rational space allocation of cropping structure and develop strip-planting mode; and in terms of time allocation, adopt a rational rotational cropping system in accordance with the soil nutrient supply features and the crop's manure requirement so as to guarantee the environment security to the utmost.

Vegetation filter buffering belt will be built, which makes use of the complementarity of the soil nutrient adsorbing capacities of different vegetations and their interception and filtering capacities of agricultural non-point pollution to set up rational forest belts or grassland filtering belts between farmland and water body to separate them so as to effectively reduce the non-point pollutants brought about by the farmland surface and underground runoff. According to their position and function, they can be classified into wind break or shielding buffer forest belt and water-body bank buffer forest belt. The former refers to the forest belt or bush forest belt planted for preventing wind erosion and sand flying in dry or windy areas, which are mainly used for wind protection and sand fixation so as to reduce the danger of wind and sand to agriculture and environment and

protect the crop seedlings. The latter mainly refers to the various forest belts or bush forest belts along banks of rivers, lakes, streams and valleys, including also the filtering belts and buffering belts at the field side, slope foot and runoff intersection, aiming to prevent the soil nutrients, fertilizer, flowing sludge and sand, and animal manure that can effect a water body eutrophication and water quality deterioration from entering water body of river course.

(IV) Implementation of projects of returning stalks to field

Shandong is a large agricultural province and also an important grain producing area in China that has the largest stalk resource. The total outputs of wheat and corn stalks are 26.8405million t and 21.8816 million t respectively, totaling to 70.3615 million t when the stalks of other crops are added. Presently, the stalks returned to the field or utilized for other purposes amount to 60.4% of the total, with 67.3% being returned to field by mechanical way. About 46% stalks are not rationally used yet in the province, leaving a large room for further utilization.

The stalk utilization is unbalanced in the regions of the province, with high utilization rate in counties with developed edible fungi production such as Shenxian, Mouping and Wucheng, and in counties with developed breeding counties such as Shouguang County and Taian City, and the rate of stalks returned to field is high in farms, with some even reaching 100%.

7.3.2 Implementation scenarios

The implementation of the strategy will effectively alleviate the soil erosion, desertification, secondary salinization and land pollution that can cause soil degradation, reduce the proportion of low and medium-yield land, greatly raise the unit area output, effectively mitigate the contradiction between land decrease and continuous growth of population, and increase the content of soil organic substance, the soil carbon inventory and the soil fertility; balance the occupation and supplement of land for production and construction, and effectively protect forest land, grassland and cultivated land; and increase the carbon dioxide fixed by plants and soil, and decrease the carbon dioxide concentration in atmosphere.

7.3.3 Cost-benefit estimates

To cope with the climate change and realize the sustainable use of land, we should firstly implement the projects of turning the cultivated land to forest (grass) land in areas with a weak ecological environment.

By the end of 2008, 139 million mu land area was returned from cultivated land to forest land, a 2.5 million mu land area of wasteland and waste hills was afforested and a 20 million mu land area was sealed for forest cultivation.

Central financing had input an accumulated fund of more than 130 billion yuan, with each farmer involved gaining a subsidy of 3500 yuan, an important component of farmers' income. As a result, the ecological construction was promoted, the ecological environment improved and the farmers' income increased.

During 2006 to 2011, Shandong, a main source place of water and soil loss, will complete the regulation of all its cultivated slope land area of 5600 square kilometers, with all that cultivated slope land above 25 degrees being returned to forest land. Secondly, we should make soil to become fertile, improve the organic substance content of soil and increase soil carbon inventory.

Presently, 15 provinces, cities and autonomous regions have implemented the project of subsidizing the improvement of the organic substance content of soil. Shandong started the government purchase of organic fertilizer in 2008. In the first year, 30 counties involved in the project purchased 4000t each county.

By the end of October 2008, a government purchase of 41000t was completed. Thirdly, we should strengthen the transformation of medium-low yield farmland. In 2009, the financial budget of all levels including the state financing has arranged a total input of more than one billion yuan in transforming over 1.8 million mu medium-low yield farmland in Shandong.

During the "Eleventh Five-Year Plan" period, Shandong will strive to carry out the regulation of 10 million mu land including the transformation of over 9 million mu medium-low yield farmland, increase over 8 million mu land adopting water-saving irrigation, construct over 9 million mu high-standard farmland, and build over 8 million mu bases for producing various kinds of superior farm products, which will enable the province to have an added grain production capacity of 1.5 billion kg.

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