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

# Situation Analysis Report of Agriculture Production and Climate Change in Henan Province

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# 1 Introduction

## 1.1 Background

Henan Province is located in the middle and lower reaches of the Yellow River, South of the North China Plain and the Eastern end of the Qinling Mountains range. Situated between 110°21′-116°39′ east longitude and 31°23′-36°23′ north latitude, it is high in the west and low in the east. It is surrounded by four mountain ranges, the Taihang, Funiu, Tongbai and Dabie, which stand in its north, west and south. In its middle and eastern parts there is a vast fluvial plain created by the Yellow, Huaihe and Haihe rivers. It has an area of 167,000 square kilometers, accounting for 1.74% of the national total. Amongst, mountainous area is about 44,000 square kilometers, accounting for 26.6% of the provincial total. Hills cover around 30,000 square kilometers, taking up 17.7% of the total. Plains cover around 93,000 square kilometers, 55.7% of the provincial total. Mountainous and hilly areas take up 44.3% of the total.

Directly under the jurisdiction of the provincial government, there are 18 cities and prefectures which govern 158 counties and districts, and 1,892 towns. By the end of 2006, the province had a population of 98.20 million. Amongst, rural residents totaled 66.31 in number, accounting for 68% of the total.

Henan is a large agricultural province, whose output of grain, cotton and oil rank among the top in China. It is an important base of quality agricultural products. According to the terrain and topography, and also the resemblance in crop distribution and tillage system, the province can be divided into 8 agricultural zones, i.e. the Taihang Mountains, piedmont plain in the north, plains in the east and north, Huaibei Plain, Huainan hilly areas, Nanyang Basin, mountainous areas in the west, and yellow and hilly areas in the west. By irrigation facilities and other agricultural conditions, the province can be divided into four zones, i.e. high-yield irrigation zone in the north, supplement irrigation zone in the middle, rainfed zone in the south and arid zone in the west.

Edible wheat of Henan has been successfully exported, indicating that a significant improvement has been in the agricultural production of the province, the wheat produced in the province can compete in the international market and make due contribution to alleviate the stressed supply of grain in China. However, as a superior crop-planting region in China, Henan still has many technical problems that affect the sustainable development of grain production. Firstly, no new progress has been made in high-yield irrigation zone and technologies. The palingenesis for super-high-yield integration technological achievements is very poor. Secondly, there is a disparity in regional output increase of summer and autumn crops. The technology content in grain production is poor and economic returns from grain production are low. Thirdly, the pressure of inadequate water resource and increasing agricultural demand of water is not technically solved. While constantly increasing the grain production ability, we must attach importance to maintaining the farmland, increase soil fertility, and mitigate the multifold pressure based on the protection of soil, water and biological resources. We should closely combine the guaranty of grain security, increase of farmers' income and protection of ecological security, and strengthen the research on strategies for environment-friendly ecological agriculture. This is of great strategic and practical significance to improve the grain production in Henan, boost the construction of a relatively well-off society in rural areas, revitalize the province, and boost the grain production in China.

## 1.2 General description of the study area

According to the difference in temperature, moisture and topography which affect the climate, Henan can be divided into 7 climate zones, i.e. Huainan, Nanyang Basin, Huaibei Plain, Northeastern and Taihang Mountainous Region, Western Hilly Region and Western Mountainous Region.

**Table 1 Climate Zones of Henan Province**

| Name | Scope | Climate conditions | Grain production | Main meteorological problems |
|---|---|---|---|---|
| Huainan | Huainan and part of Huaibin, Xixian and Zhengyang | The annual average temperature is higher than 15℃, annual precipitation more than 900mm, frost-free period 220 days and active accumulated temperature (≥ 10℃) more than 4,800℃ | Double cropping of rice and wheat | Much rain in spring, making wheat prone to waterlogging, and low temperature in winter |
| Nanyang Basin | Other counties in Nanyang except Nanzhao and Fangcheng | The annual average temperature is higher than 15℃, annual precipitation more than 700mm, frost-free period 220 days and 230 days in the southwestern part, and active accumulated temperature (≥ 10℃) more than 4,800℃ | Double cropping of rice and wheat | Frequent drought/flood in summer, especially severe drought in middle and late August |
| Huaibei Plain | Zhoukou, Zhumadian and Linying, Yancheng and Wuyang counties of Xuchang | The annual average temperature is 14-15℃, annual precipitation 800mm, frost-free period 210-220 days and active accumulated temperature (≥ 10℃) more than 4,700℃ | Rotation cropping of rice and wheat | Frequent waterlogging in summer, normally 4-5 times every ten years. |
| Northeastern | Puyang, Shangqiu, north to Qixian and Weishi of Kaifeng, and east to Yanjin and Wuzhi of Xinxiang | The annual average temperature is 13-14℃, annual precipitation 600-700mm, frost-free period 210-220 days and active accumulated temperature (≥ 10℃) 4,400-4,600℃ | Double cropping, long-stalk and waterlogging-tolerant crops in autumn | Frequent spring drought, and sand-drift, one waterlogging in summer and autumn every two years |
| Taihang Mountainous Region | Linxian of Anyang and west to Wuzhi of Xinxiang | The annual average temperature is 13-14℃, annual precipitation 600-700mm, frost-free period less than 200 days and active accumulated temperature (≥ 10℃) less than 4,300℃ | Single cropping in high-latitude and cold mountainous areas | Severe water and soil loss |
| Western Hilly Region | Areas below 500 meters above sea level south of the Yellow River and West of the Beijing-Guangzhou Railway | The annual average temperature is 12-13℃, annual precipitation less than 600mm, frost-free period 190 days and active accumulated temperature (≥ 10℃) 4,400-4,600℃ | Double cropping in plain areas and triple cropping in two years in hilly areas | Severe drought in middle and late August, and water and soil loss |
| Western Mountainous Region | Luanchuang of Luoyang, and Mianchi and Lushi counties of Sanmenxia | The annual average temperature is less than 10℃, annual precipitation 700-800mm, frost-free period 180 days and active accumulated temperature (≥ 10℃) less than 4,000℃ | Double cropping of wheat and miscellaneous grain crops | Protracted rain in summer and autumn |

This project mainly studies the west of Henan Province which is classified into semi-humid area in terms of agro-ecology, and can represent the semi-humid areas in western and northern Henan Province, Fenwei Plain and Low Coastal Plan in Northern China. The terrain is mostly low and hilly, where the soil is cinnamon and yellow, and the soil fertility is low (content of organic substance is around 1%). In terms of climate conditions, the light and heat resources are adequate, rainfall is unevenly distributed, and seasonal drought is distinctive. The main crops in this area include wheat in winter, maize in summer, sweet potato in spring and miscellaneous grain crops in autumn. There is a large disparity in the inter-annual grain output. The cropping system includes one harvest, three harvests in two years and double harvest. It is an important dry farming area in China, which covers a total of 791.2hm2 of farmland, accounting for about 8.15% of the national total farmland, and supports a population of 81.456 million.

The project consists of three demonstration areas which represent three agro-ecological areas respectively. Yao'ao represents low hilly areas, Songzhuang represents supplement irrigation areas and Niuzhuang represents yellow soil hilly areas.

# 2 Agricultural situation in the Yellow River Basin

## *2.1 Middle region - Henan*

### 2.1.1 Production and cropping systems

Henan is one of the cradles of China's agriculture. The development of agriculture in this province plays an important role in China. Since the founding of the People's Republic of China, especially the Third Plenary Session of the 11$^{th}$ Central Committee of the Communist Party of China, much progress has been made in agricultural and rural economy, the status of agricultural economy as foundation in national economy has been consolidated, and people's living standards further improved.

The light, temperature, water and soil resources in Henan are suitable for many crops. As one of the major agricultural product bases in China, the province teems with wheat, maize, rice, cotton, sesame, peanut, flue-cured tobacco and many other local products.

Crops in Henan can be roughly classified into grain crops, cash crops and other crops. The grain crops consist of summer and autumn grain crops. The summer grain crops mainly include wheat, barley and pea. The autumn grain crops mainly include maize, rice, soybean, sweet potato, mung bean and millet. Many of the grain crops in the province play a pivotal role in China. The proportion between summer and autumn grains was roughly 4:6 after the founding of the People's Republic of China, 5:5 after 1979 and 6:4 in some years.

Grain production in Henan has experienced a complicated development course which can be roughly divided into 7 stages.

The period between 1949 and 1958 was a time when grain production in the province witnessed a resilient rise. In 1949, the total provincial grain output was only 7.135 million tons, the unit yield 690kg/ha, and per capital grain possession 171kg. In 1952, the total grain output reached 10.07 million tons, representing a growth of 41.1%, and an average year-on-year growth of 12.2%.

Between 1959 and 1966, grain production in Henan reported a stagnation and decline. In 1962, the grain production plummeted to the lowest level and after that began to recover. In 1966, the total grain output nearly reached the level of 1955.

**Table2 The sown area of grain crops and cash crops and their proportion during 1978-2000 in Henan province Unit: $10^4$ Mu**

| Year | Total sown area | sown area of grain crops | sown area of cash crops | Proportion of grains crops and cash crops |
|---|---|---|---|---|
| 1978 | 16450.05 | 13684.95 | 2362.01 | 83.2：16.8 |
| 1991 | 18002.84 | 13560.68 | 4367.67 | 73.3：24.7 |
| 1992 | 17904.45 | 13207.05 | 4628.25 | 73.8：26.2 |
| 1993 | 18102.00 | 13453.50 | 4951.50 | 74.3：25.7 |
| 1994 | 18131.60 | 13216.35 | 4762.49 | 72.9：27.1 |
| 1995 | 18205.23 | 13214.96 | 4825.02 | 72.6：27.4 |
| 1996 | 18386.12 | 13448.00 | 4796.31 | 73.1：26.9 |
| 1997 | 18415.11 | 13319.81 | 4949.32 | 72.3：27.7 |
| 1998 | 18850.58 | 13652.97 | 5058.62 | 72.4：27.6 |
| 2000 | 18989.85 | 13544.40 | 6160.95 | 68.7：31.3 |

Between 1967 and 1978, grain production in Henan began to grow. The total grain output increased from 13.82 billion kilograms to 20.98 billion kilograms, which represented an annual growth of 8.9%.

From 1979 to 1983, grain production in the province registered a continuous growth. The total provincial grain output grew from 21.35 billion kilograms to 29.04 kilograms, up 8% year on year.

Between 1984 and 1988, grain output in the province lingered for the first time since the reform and opening up drive was kicked off in 1978.

The period between 1989 and 1999 reported a rapid growth in grain production of the province since 1978. The total output rose from 26.63 million tons in 1988 to 42.53 million tons in 1999, representing a record high 9% year-on-year growth. In 1999, the average unit yield in the province stood at 313kg, doubling the level in 1978, 49.8% higher than the level in 1983. The per capita grain possession reached 455kg, 52% higher than the level 1978, and 12.3% higher than the national average at the same time. The technological level of grain production in the province was significantly improved.

Between 2000 and the present, agriculture in the province undergoes a comprehensive restructuring. In terms of grain production, focus is put on the improvement of grain quality and returns while at the same time the grain productivity is stabilized and increased. Moreover, the planting sector is restructured, breed and quality structure and regional distribution adjusted. High-efficiency crops are vigorously developed, and a new pattern of the planting sector featuring rational distribution, optimized structure, high quality and sound economic returns is preliminarily put in place. Some problems, including that there is a structural surplus of grain production and that the output is increased but farmers' income is not increased, are basically solved.

In the new era, agriculture in Henan made much progress, and took on new characteristics: significant increase in agricultural productivity, dramatic improvement in quantity and quality of grain and rapid development in non-agricultural sectors. In 2001, the output of township businesses in the province rose by RMB28.9 billion, accounting for 10.5% of the newly-added output of agriculture and resulting in an annual growth of RMB200 in net per capita income of farmers.

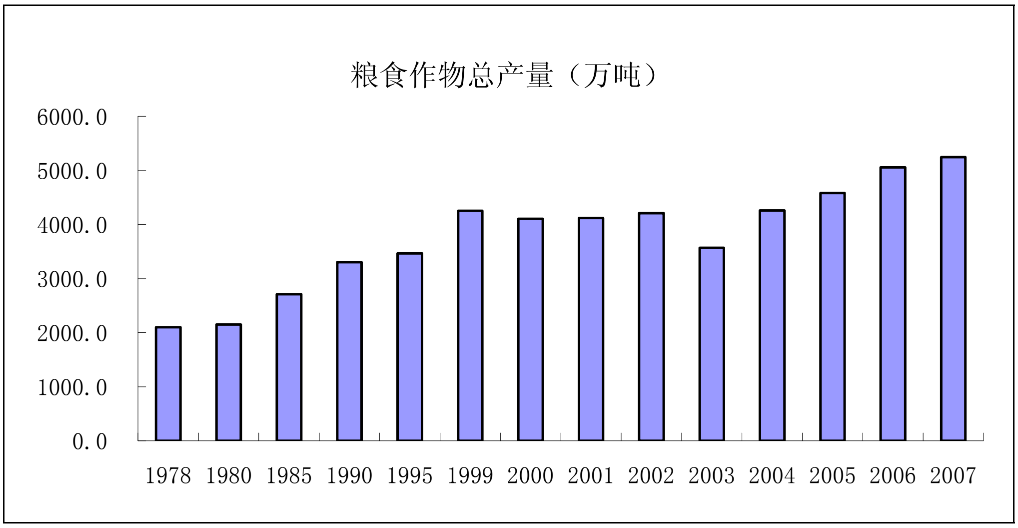


**Fig 1 Total grain production in Henan province (Unit: ten thousand Ton)**

### 2.1.1.1 Main crops, production and cropping areas

As one of the most important grain producing provinces in China, Henan has a variety of crops and complicated planting modes. Its research on and application of cultivation techniques is among the most advanced in China. Double cropping of wheat and summer maize is the major planting mode in the province. The area and total output of the two crops and also the commodity grain provided each year rank among the top in China. After 1999, like other parts of China, Henan also witnessed a continuous reduction in farmland area, grain planting area, grain output and per capita grain possession, which dropped to the lowest level in 2003. In this context, the CPC Central Committee and the State Council attached great importance to grain production, and issued a series of preferential policies for agriculture and farmers. From 2004, grain production embarked on a resilient recovery journey. In recent 5 years, the area of wheat in the province has maintained a stable growth to 78 million mu in 2007 and the total output of wheat has remained around 20 billion kilograms.

As the second grain crop in Henan, maize has registered a continuous rise in its sown area. The total output of maize in the province accounts for more than 10% of the national total, and unit yield is also higher than the national average.

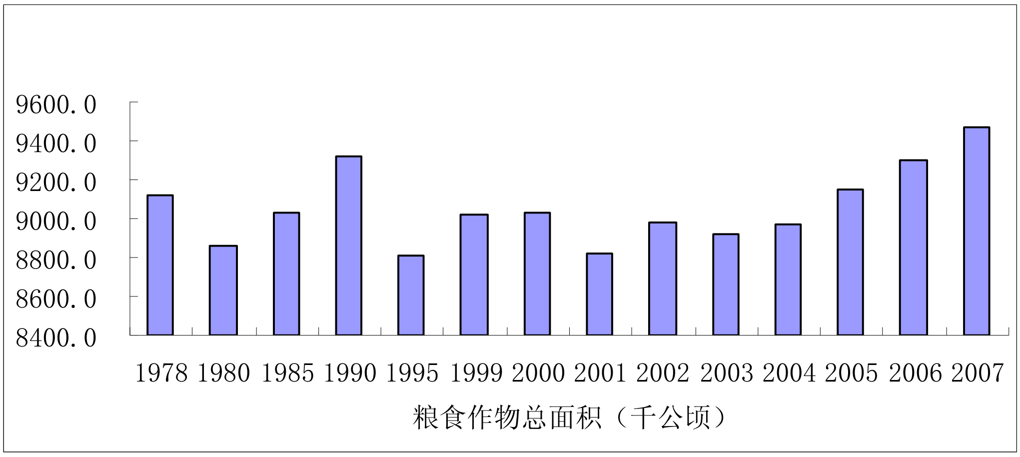


**Fig 2 Sown area of grain crops in Henan province (Unit: thousand hectare)**

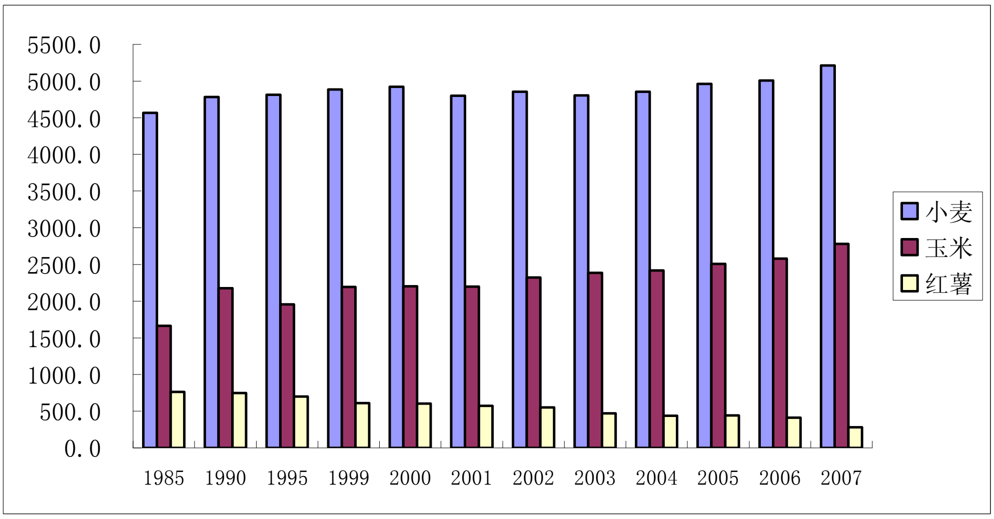


**Fig 3 Sown area of Wheat (blue), Maize (red) and Sweet Potato (yellow) in Henan province (Unit: thousand hectare)**

### 2.1.1.2 Status and potential of less common crops

Located at the transitional area from sub-tropical climate to warm temperate climate, Henan boasts complicated ecotypes and high ecological diversity. It plants most crops. The sown area of maize in the province rises continuously, and the sown area of sweet potato declines while that of rice remains relatively stable. Other oil and cash crops, fruits, vegetables and tobacco also have a certain status in the province.

**Table 3 Sown area and yield per unit of different crops in Henan province in 2007**

| | area (thousand ha.) | Yield per unit (kg/ha.) |
|---|---|---|
| rice | 600.0 | 7275.0 |
| soybean | 468.8 | 1813.0 |
| rape | 356.4 | 2410.0 |
| peanut | 947.8 | 3942.0 |
| Sugar cane | 3.0 | 54840.0 |
| fruits | 448.5 | 663.5 |
| vegetable | 1688.4 | 6235.5 |
| cotton | 700.0 | 1071.0 |
| Tobacco | 102.3 | 2339.0 |

#### 2.1.1.3 Cultivation systems and practices

In terms of planting system, the province mainly adopts double cropping, and also single cropping and triple cropping in two years.

The major planting systems include:

Double cropping: winter wheat -summer maize, or winter wheat-miscellaneous grain crops.

Single cropping: Dry-land wheat (summer fallow after the wheat is harvested). Spring sweet potato (winter and spring fallow after the harvest).

Triple cropping in two years: winter wheat-summer maize-winter wheat-summer fallow.

In terms of tillage system, mechanized operation dominates in the province. As of the end of 2007, the total power of agricultural machinery reached 87.187 million kw. There were 149,400 medium/large tractors, 313,400 supportive agricultural machines, 3.2397 million small tractors and 6.0231 million supportive agricultural machines. Combine harvesters numbered 93,200, drainage and irrigation machines totaled 1.5461 million. Power consumption in rural areas reached 22.343 billion kw/h. The area cultivated by machine reached 6.058 million hectares, accounting for 84.1% of the total farmland in the province. The area sown by machine was 6.564 million hectares, accounting for 46.6% of the total sown area. The area harvested by machine stood at 5.419 million hectares, taking up 38.5% of the total sown area.

### 2.1.2 Socio-economic aspects

#### 2.1.2.1 Crop prices, income and profitability

In 2006, the provincial total grain output reached 50.55 million tons (the first place in China). Amongst, the output of wheat totaled 28.2269 million tons (the first place in China). The output of cotton reached 0.83 million tons, oil plants 4.7992 million tons, including 3.6748 million tons of peanuts, 0.8474 million tons of rapeseed and 0.2598 million tons of sesame. The total output of vegetables reached 64.00 million tons and fruits 14.1381 million tons. Moreover, Henan is also an important base of livestock products. In 2006, the output of meat products totaled 7.3723 million tons, poultry eggs 4.0082 million tons and milk 1.5407 million tons. The total power of agricultural machinery in the province reached 83.0913 million kw. There were 3.2235 million medium/large tractors. In 2006, the added value of farming, animal husbandry and fishery sectors reached RMB 204.99 billion. The net per capita income of farmers reached RMB3,261.03.

#### 2.1.2.2 Agricultural credit and non-agricultural income

The province boasts a well-established system and process of rural credit cooperative institutions. The total rural deposits reached RMB0.26 billion and rural loans RMB1.29 billion. The deposits at rural credit cooperatives reached RMB2.33 billion, and loans RMB1.72 billion. The average cash income per capital was RMB4,109.4. Amongst, the agricultural income reached RMB 2,100.1 and non-agricultural revenue RMB2,009.3, accounting for nearly 50% of the total.

#### 2.1.2.3 Contribution of agriculture, food transformation industries and food trade to GDP

In 2007, the GNP of Henan reached RMB15.01 billion. Amongst, the primary industry contributed RMB0.22 billion, accounting for 14.8% of the provincial total. The gross product of farming, animal husbandry, fishery and service sectors reached RMB49.50million.

#### 2.1.2.4 Food consumption and degree of self-sufficiency

The per capita consumption of urban residents mainly concentrated on flour (149.3kg/person/year) and fresh fruits (64.8kg/person/year). Rural residents consumed 206.0kg of unprocessed food grains per person in the year. Amongst, the consumption of wheat was 162.3kg/person/year and that of vegetable and vegetable products reached 102.1kg/person/year.

Henan can contribute around 15 billion kilograms of unprocessed food grains and finished products each year while meeting its own grain demand.

### 2.1.3 Partners and stakeholder institutions

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

Due to its unique economic and geographical advantages, Henan has historically been one of the highly-populated centers in China. It now has a population of 98.69 million. Amongst, rural residents total 64.80 million, and rural laborers reach 47.45 million including 25.54 million male and 22.61 million female laborers. By sector, 29.10 million people are engaged in agricultural production. The net income per capita of rural residents is RMB3,852.

The province boasts adequate rural laborer resources, which present the following distinctive characteristics:

Since the reform and opening up, due to the development of agricultural production and rural economy, the transfer of rural laborers to the secondary and tertiary industries was accelerated. Since 1995, more than 3 million rural laborers have been transferring out each year.

Rural laborers mainly concentrate in Nanyang, Shangqiu, Xinyang, Zhoukou and Zhumadian in the south. According to the statistics in 2001, rural laborers in these areas accounted for more than half of the provincial total.

Quality of rural laborers has been significantly improved. The proportion of people that are illiterate, semi-illiterate and only receive primary school education every one hundred rural laborers is 11.8% lower than the national average. The proportion of rural laborers who receive junior high school education, senior high school and above education is 9.9% and 19.7% higher than the national average respectively. Among the rural laborers who have transferred to other sectors, those who receive junior high school and above education account for 87.9%.

#### 2.1.3.2 Farmer associations and interest groups

Currently, in the province, there are 1,892 towns, 47,533 villagers' committees and 1,217 agricultural legal entities.

#### 2.1.3.3 Research organisations, extension services, NDRC and other governmental institutions

There is a well-established agricultural research and technology extension team in the province. The government departments concerning agriculture include the department of agriculture, department of water conservancy, bureau of animal husbandry, department of grain, department of land resources, department of environmental protection and bureau of agricultural machinery management. The research institutions include the academy of agricultural sciences, academy of aquatic sciences, and academy of forestry sciences. Organizations for agricultural technology extension include the provincial extension stations of agricultural, agricultural machinery, water conservancy, forestry, water and soil maintenance, soil and fertilizer, and botany protection technologies. City/county-level agricultural authorities are complete with professional technology extension departments in related areas.

Agricultural research organizations mainly include the Henan Institute of Agricultural Science, and also 18 city-level and 31 county-level research institutes, which carry out research on nearly all agricultural areas, including selection and cultivation of new crop breeds, soil and fertilizer, botany protection, agricultural economy management, high-yield cultivation, flower and gardening. The research on selection and cultivation of new wheat and maize breeds and high-yield cultivation technologies rank among the advanced in China.

In 2000, the provincial agricultural technology demonstration and extension system was further improved. There were 6,687 agricultural technology service organizations which vigorously promoted the transfer of technological achievements into productivity.

The government departments concerning agricultural technology extension include the department of agriculture, department of forestry, department of water conservancy, bureau of agricultural machinery, bureau of animal husbandry and bureau of tobacco which are complete with the extension stations for agricultural, agricultural machinery, water conservancy, forestry, water and soil maintenance, soil and fertilizer, and botany protection technologies.

#### 2.1.3.4 Non-governmental organisations

In recent years, NGOs have been growing rapidly, which cover most agricultural areas, including organizations of breeding experts and intermediary services.

# 3 Projections of climate change factors and other drivers of change

## 3.1 Climate change scenarios for the YRB

On the one hand, the climate gets warm, precipitation drops and drought gets worse, further exacerbating the shortage of water resource and the disparity between water supply and demand. On the other hand, as the temperature rises, the tendency that the growth period starts early is quite obvious.

Since the 1990's, natural rainfall has been generally declining. Take Luoyang as example. Changes in rainfall between 1961 and 2006 presented a regular fluctuation, with the annual average being 613.9 mm. The annual precipitation has been falling by 2.5538 mm/year, higher than the national average in 40 years which stands at 1.269 mm/year. The annual rainfall distribution is quite uneven, with the maximum being 1,035.4 mm and the minimum being 315.2mm. In recent ten years, the decline in precipitation has been deteriorating. The annual average rainfall in 37 years between 1971 and 2007 was 597.4mm. Since 1992, the annual average rainfall has dropped to 537.0mm. In recent 10 years, the annual average rainfall has fallen to 528.9mm. 2003 was a special year in terms of rainfall.

The rainfall is not only declining, but also unevenly distributed. 70% of the rainfall is concentrated in June-September. More than 60% of the rainfall is in the mountainous areas in the south, and the rainfall in agricultural areas is quite limited.

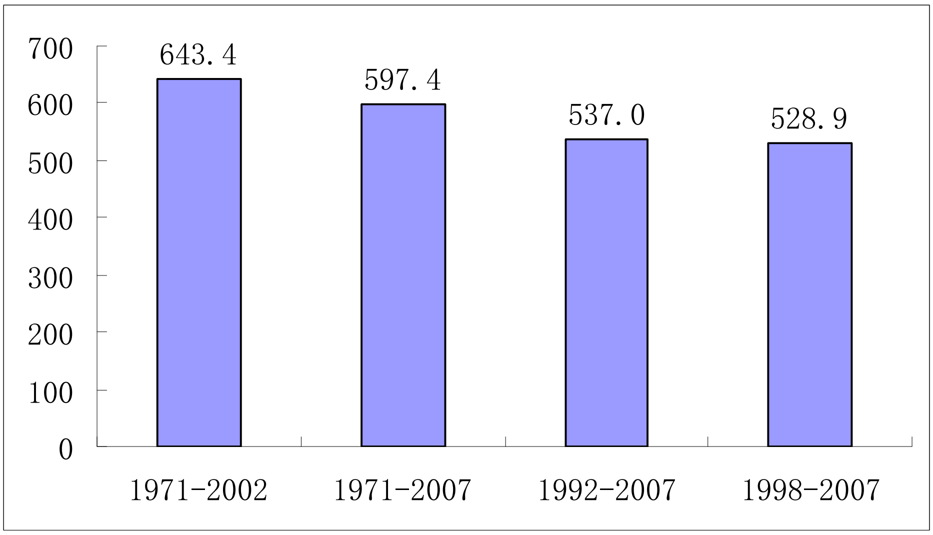


**Fig 4  Rainfall in Luoyang from 1971 to 2007 (mm)**

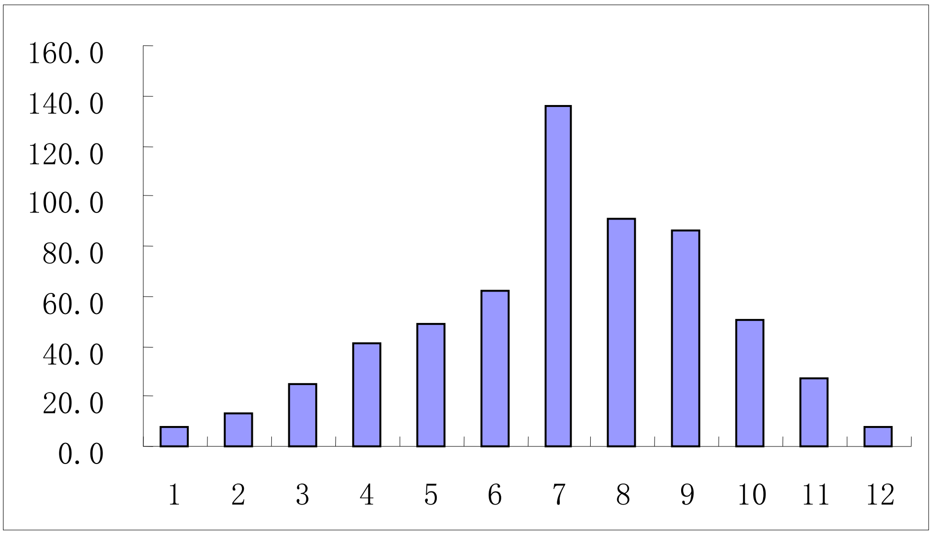


**Fig 5 Distribution of rainfall in Luoyang (1972-2007, mm）**

## *3.2 Scenarios of other drivers of change*

### 3.2.1 Demographic growth, migration and urbanisation

The population growth of Henan is decelerating. Since 2003, the population has been growing by 500,000 each year. In 2007, the birth rate was 1.13‰, mortality rate 0.63‰ and the natural growth rate 0.49‰.

The final water conservancy project of Xiaolangdi Hub Water Conservancy Project in the middle reaches of the Yellow River involves some migrants. The Xiaolangdi Reservoir causes climate changes in Mengjin County and Jiyuan City, which is conducive to agricultural production.

The pace of urbanization is accelerated. Zhengzhou-Kaifeng integration is basically finished. The city cluster with Zhengzhou and Luoyang as the first and second centers has initially taken shape. The construction of small towns is full swing and significant progress is made.

### 3.2.2 Economic development and industrialisation

The economic growth of Henan is among the top in China. The industrialization is accelerated and mechanization in agriculture has reached a high level.

### 3.2.3 Changes of land use and land cover

In general, drought and other disasters are frequent in the province. Drought and water shortage has been a factor that hinders agricultural production. Moreover, natural and human production activities, especially the predatory operation in traditional agricultural production, destruction of forest and wasteland opening up, excessive reclamation and depasturage, result in the worsening loss of water and soil, degradation and desertification of land resources, which in turn leads to deteriorating ecological environment, low and unstable agricultural output, and severely affects the sustainable development of agricultural development. The development conditions vary greatly from region to region. Due to complicated topography, transitional climate, hydrology and soil factors, the regional distribution of land resources in the province is distinctively different. Three quarters of farmland is concentrated in plains which take up 55.7% of the area of the province. In contrast, hilly areas which account for 44.3% of the total provincial area have only one quarter of the farmland. The conditions for development of land resources also vary significantly from region to region. Boasting sound combination of water, heat and land conditions, the Huang-Huai-Hai Plain in the east and the middle and southwest of Nanyang Basin are the main farming areas in the province, where irrigable land and paddy field are concentrated, and development conditions are excellent. The hilly areas in the west and the rim areas of Nanyang Basin have poorer water and land conditions. In particular, water resource is severely inadequate in most areas. This part is the major dry farming area in the province, where it is difficult to develop the land resources, and return on input is low, making this area suitable to develop forestry and fruit businesses. The sub-tropical humid hilly areas in the south have good water and heat conditions, huge potential of land development, and sound conditions for sub-tropical forestry and fruit businesses.

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

For Henan, the impact of temperature and rainfall on grain production is relatively larger. Meteorological factors mainly affect wheat yield in three critical periods, i.e. December, February and May. Sunshine duration has a relatively smaller impact on grain production, mostly a small negative impact on wheat and a small positive impact on maize, with the fluctuation being quite small. For most time, rainfall has a positive impact on wheat production and a small impact on maize output. Except for Luoyang and Sanmenxia, rainfall is not a factor that restricts the increase of maize yield in Henan. Temperature has a positive impact on wheat production in plain areas before the New Year’s Day, with the peak value in the first half of December, and a negative impact after the New Year’s Day before April, with the peak value around March. In the mountainous areas in Western Henan, temperature has a positive impact almost at all periods. Temperature has a major negative impact on maize production around the beginning of August. Temperature rise causes severe misplacement of breed application, irrational crop distribution and serious frost damage. This problem is especially serious with wheat. The agricultural production becomes more unstable. Growth of crops starts early, making the frost damage in spring more severe. Farmers do not select the breeds according to the land and ecological conditions, but according to the market trend. Therefore, due to inadequate technology extension, farmers plant spring breeds as winter breeds, and breeds for irrigation area as breeds for dry land. According to the statistics of breed management department, breeds of spring wheat account for over 30% of that in dry land. However, the sown area of drought-resistant breeds takes up less than 30% of the total sown area. Consequently, the sowing period starts early, frost damage deteriorates, and disaster resistance gets weak, leading to widespread drop in yield.

## 4.1 Changes in cropping periods

Due to climate change, the temperature rises. As a result, crops begin to grow at an earlier time, and the temperature and sunshine are sufficient for double cropping. The negative impacts include earlier sowing, excessive growth before winter, common and serious low-temperature and frost damage in spring. Moreover, maize is harvested at an earlier time. There is a gap of 30-40 days before wheat is sown, resulting in a waste of temperature and sunshine resources. There is a huge gap in the potential for output increase.

The growth periods of winter wheat in Henan, from turning green to getting mature, especially the jointing period, start early. In contrast, the growth periods of summer maize, especially maturation, get postponed. In terms of intervals of growth periods, the interval between sowing and winter periods gets longer for winter wheat, and the interval between the wintering and jointing periods continues to get shorter, the interval between jointing and milky periods gets longer and the interval between milky and maturity periods significantly gets shorter. There is a shortening tendency in the complete growth period of winter wheat. For summer maize, the intervals between sowing and three-leaf, and between silk and maturity periods get longer, and the intervals between three-leaf and silk periods get shorter. In general, the total growth period gets longer.

## 4.2 Occurrence of floods and droughts

Henan is prone to various natural disasters, especially drought and waterlogging, which affects the stable and sustainable development of agricultural production to a certain degree.

Flood is the most severe in the east and south of the province. In 601 years between 1300 and 1900, severe waterlogging occurred 69 times, once every 8-9 years on average. Waterlogging occurred 7 times between 1949 and 1979, once every 4-5 years on average. In 2003, 4.828 million hectares of farmland suffered floods, accounting for 67% of the farmland of the province which stood at 7.187 million hectares.

Drought occurs in Henan mainly because there is a significant disparity in seasonal and inter-annual precipitation. Spring drought, early and hot summer droughts and autumn drought are frequent. Amongst, the spring drought is the most frequent, which is getting increasingly severe.

Drought mainly occurs in the dry-farming land in the west of the province, where it occurs once about every 12.4 years. Major drought (the rainfall drops by over 70%) occurs once every 58 years. In 500 years between 1470 and 1978, there were 46-49 dry and light dry years in every one hundred years, waterlogging occurred in 11-14 years every century, while the rainfall was normal in 37-43 years. In dry years, 63% of the drought occurred in spring and early summer, 35% occurred in hot summer and autumn. Drought in middle and late August, which causes the most damage to maize production, occurred once about every 3 years. According to the statistics since the 1950's, the minimum natural rainfall during the growth period of summer maize was only 160mm. The lowest rainfall between late July and early August stood at 14.8mm. Obviously, when such drought happened, the harvest of maize would be extremely low. Severe drought occurred in 1995, 1999 and 2001, affecting 90% of the farmland.

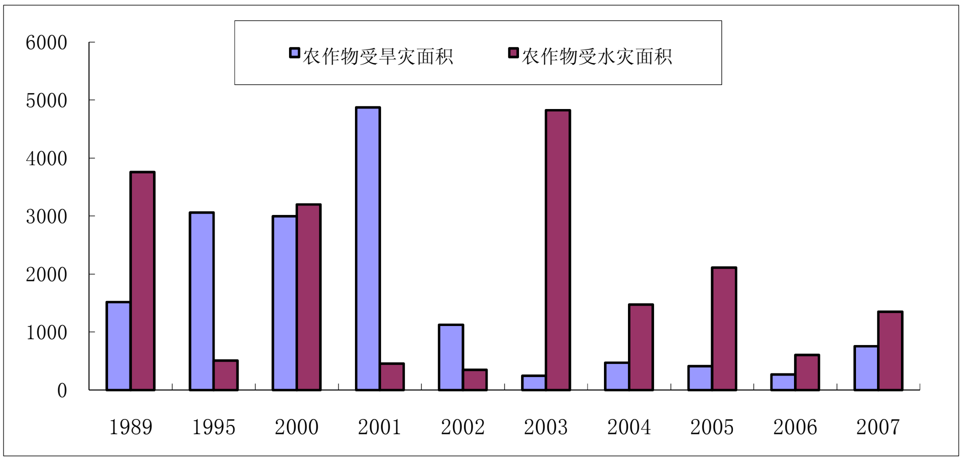


**Fig 6 Crop area of affected by drought (blue) and flood (red) in Henan province (thousand hectare)**

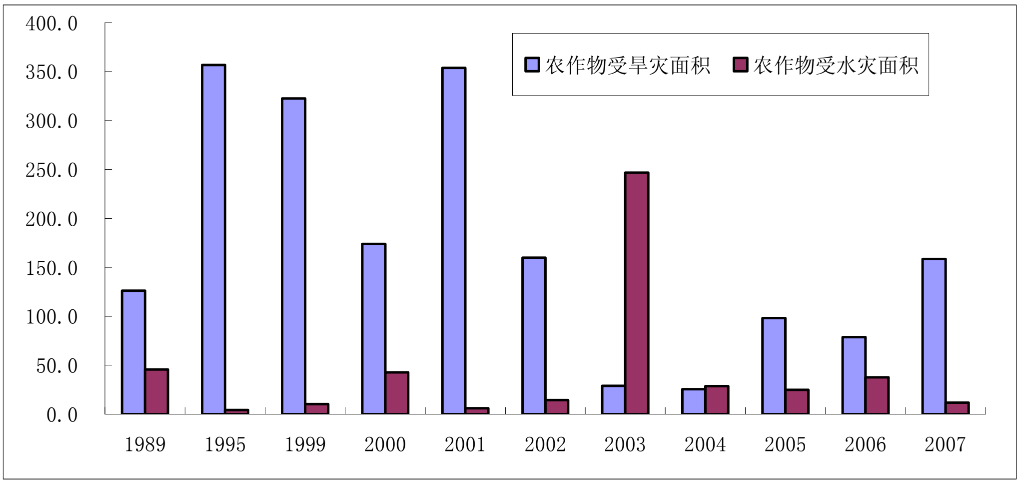


**Fig 7 Crop area of affected by drought (blue) and flood (red) in Luoyang City (thousand hectare)**

## *4.3 Decline in runoff and water availability*

Henan boasts excellent natural resource conditions. It is located in the transitional area from sub-tropical zone to warm temperate zone. The climate has the characteristics of both zones. The province has a warm climate and four distinctive seasons. The south of the province is controlled by north sub-tropical humid climate, abounds with sunshine, heat and rainfall. The annual precipitation is 800-1,200mm, and declines from the south to the north. The north of the province is controlled by warm temperature semi-humid climate, where the annual precipitation is 600-800mm, and declines from the east to the west. The frost-free period is 190-230 days, sunshine duration as long as 1,740-2,310 hours. Farmland in the province totals 7.926 million hectares, ranking the third in China. There are four water systems in Henan, namely the systems of the Yellow River, the Huaihe River, the Haihe River and the Hanshui River, with over 1,500 branch rivers flowing inside the province. The province is rich in water resources, with the annual total amount of water resources being 43 billion cubic meters. The per capita possession of water resources is 570 cubic meters. But the water resources available for each mu of farmland reach only 39.5 cubic meters, one sixth of the national average. In terms of land development, by the end of 2007, farmland resources in the province totaled 7.926 million hectares and the actual farmland covered 7.201 million hectares. The per capita farmland area is lower than the national average.

## 4.4 Loss of soil fertility and desertification

Due to climate, topography, hydrology and other natural conditions, and also the long history of agricultural production, Henan has a large variety of soils. The major soil types include yellow brown soil, brown soil, cinnamon soil, flovo-aquic soil, sajong black soil, saline-alkali soil and rice paddy soil. Clay, sandy, loamy, sandy and clay, and gravel land account for 47.1%, 19.9%, 15.1%, 14.0% and 3.9% of the total farmland respectively.

The fluvo-aquic soil area is the most widely distributed in Henan. It includes sandy soil, alluvial soil and blended soil. In these areas, due to the long history of farming, the soil generally lacks organic substance, and has low natural fertility. Because of the leakage of water and fertilizer, the land in these areas requires much irrigation and fertilization.

Sajong black soil is mainly distributed in the Huaibei Plain south of the Shahe and Yinghe rivers and the along the banks of the Tanghe and Baihe rivers in Nanyang Basin. In these areas, soil is high in viscidity, low in physical performance of moisture, and poor in drainage performance. It is often insulated by sajong at the bottom. However, the content of organic substance is high, presenting much fertility potential.

The major soil in Henan is brown soil, which is mainly distributed in the yellow hilly areas and low hilly areas in the west. In these areas, the soil has much fertility, but the loss of water and soil is severe. Therefore, moisture maintenance measures need to be taken for such soil.

## 4.5 Salinisation of soils and aquifers

Saline-alkali land covers an area of 0.79855 million hectares in Henan. After decades of arduous treatment, much progress has been made. By 2000, 0.6823 million hectares of saline-alkali land had been treated, accounting for 85.4% of the total saline-alkali land in the province.

## 4.6 Effects of other environmental impact factors

In general, due to its geographical location, Henan boasts distinctive climate conditions and excellent natural conditions. It has a long history of agriculture. However, there are also many conspicuous natural conditions adverse to agriculture, including frequent drought, waterlogging, dry-hot wind, hail, low temperature and protracted rain. The level of economic development has a major impact on agricultural production. The developed and relatively developed areas boast better agricultural conditions besides rich mineral resources. These areas are located in piedmont plains, where the soil is fertile, surface and underground water abounds, conditions for drainage and irrigation are good, and it is easier to fight against drought and waterlogging. Therefore, these areas are favorable for agricultural development. Less developed areas are mostly located in the plains in the south and southeast of the province. Although the soil there is thick and terrain is flat, land there is prone to natural disasters. In parts of the plains in the southeast, because the land is low-lying, water can't be smoothly drained, making the land prone to floods. Agriculture in these areas is mostly traditional, which is less resistant to natural disasters. The impact of natural conditions on the regional economy is far greater than that in developed regions. The preferential investment policies issued by the central and provincial governments affect the economic development in different regions, and further affect the overall economic development in rural areas. Since the founding of the People's Republic of China, the government investment in industry in the province totaled tens of billon, accounting for over 60% of the total capital investment in the province. The investment is mostly used in the west of the province. Other moderately developed regions around the developed regions have also been listed as key investment destinations by the central and provincial governments in history. In contrast, the less developed regions received little central and provincial investment in the past five decades.

## *4.7 Estimated overall impact on crop production*

Drought and waterlogging often lead to a significant reduction in grain output. Normally, the drought causes a reduction of 20%-30% in grain output, and severe drought reduces the grain output by 50%-60% and even causes total harvest failure. 2007 suffered severe drought, when the total annual precipitation was only 370.2mm, 62% of the normal level, and down 227.2mm over the normal rainfall. Moreover, the rainfall that year was quite unevenly distributed. There was only 59.2mm in August and September, only 33% of the normal level. Drought continued in February and March of 2008, when the rainfall was only 11.3mm, 19% of the normal level. As a result, the grain output of dry land dropped significantly in 2008, and the area of total harvest failure totaled 100,000mu.

# 5 Assessing the impacts of agriculture on the environment

## *5.1 GHG emissions and carbon sequestration*

The greenhouse emissions from agricultural production mainly come from the utilization of crop stalks. Due to the economic development in rural areas, stalks are no longer the primary fuel. The comprehensive utilization of stalks is rather backward, stalks are excessive and cropping index is increased. Farmers have to burn the stalks on the spot at time of harvest rush. This not only causes air pollution, but also severely wastes the precious resources. Currently, the output of stalks in China reaches around 650 million tons each year. Only more than 100 million tons are returned to the farm, and the land to which stalks are returned only accounts for one third of the total. In Henan, nearly half of the stalks are burned. Stalks are the source of carbon recycled in soil, which can also fix carbon. The irrational utilization of stalks will emit a large quantity of greenhouse gases and leads to the soil infertility.

## *5.2 Over-exploitation of water resources*

The moisture of farmland is imbalanced, and the water needed by crops is insufficient. The annual precipitation is inadequate and unevenly distributed. There is a severe gap between natural rainfall and water needed by crops. In terms of time distribution, 70% of the rainfall concentrates in June-September. In terms of spatial distribution, 60% of the rainfall is in the mountainous areas in the south. The assurance rate of rainfall between 450 and 520mm is

≥80%. The rainfall is excessive in one quarter but inadequate in two quarters. The rainfall in the growth period of wheat can only meet the demand in a few years. Drought for maize often occurs in different growth periods in different years. The deficit of rainfall can be up to 95.6%. The rainfall satisfaction rate for summer maize is 19.72 percentage points higher than that for wheat. The rainfall satisfaction rate for winter wheat is 51.18% on average. The highest rate is 78.23% during the seedling period, and the lowest rate is 21.10% during the greening period. The rainfall satisfaction rate for summer maize is 70.9% on average. The highest level is 110.6% from the jointing to heading period, and the lowest rate is 55.0% during the seedling period.

The forced and excessive extraction of water resources is quite common. Water conservation is not well implemented. Currently, the utilization rate of surface water in Henan is more than 30%. The amount of utilized shallow ground water accounts for over 60% of the exploitable quantity. The level of water utilization is far higher than the national average.

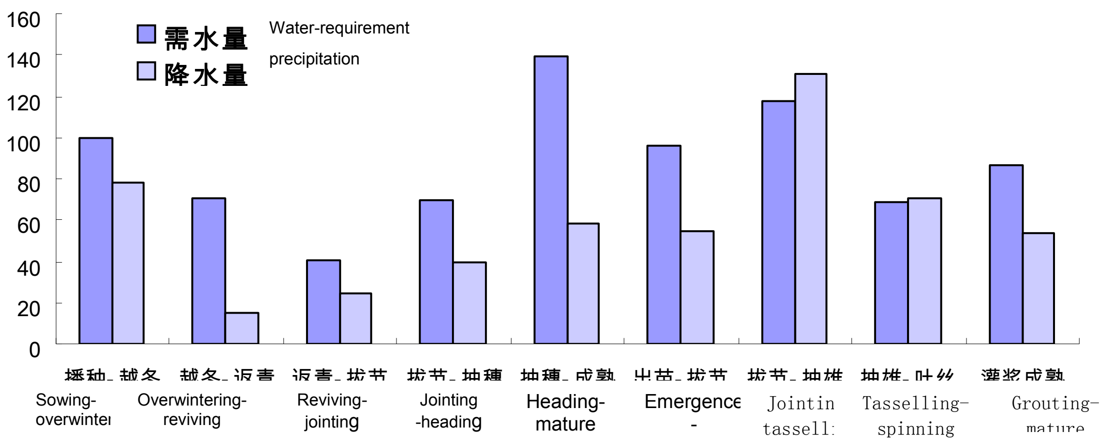


**Fig 8  Precipitation and water requirement in growth stage of wheat-maize (1992~1995)**

## *5.3  Pollution of soil, water and food*

Due to the continuous socio-economic development and accelerated urbanization, the loss of water and soil is quite serious. Each year, the newly-added water and soil loss area is around 50,000 hectares. In the yellow hilly areas in the west, around 30,000 hectares of farmland is lost due to gully erosion each year. Farmland runoff and water/soil loss are important carriers of pollutants. Experiments show that mud and sand in runoff can contain or absorb a large quantity of nutrients, including organic substance, metal, ammonium ions, phosphate and other carriers of toxic substance. As a result of industrial "three wastes pollution" and abuse of chemicals in agriculture, the quantity of water and land resources in the province decline, and the physical and chemical performances of soil drop. Over the years, to pursue high yield in agriculture, a large quantity of nitrogenous and phosphate fertilizer was applied. According to the survey of the soil fertility station of Henan Province, only one third of the nutrients in the chemical fertilizer applied by farmers are absorbed by crops, one third goes into water and the rest one third remains in the soil. As a result, the content of nitrogen and phosphor is excessive in soil in many areas. In addition to damaging the water body and reduce the quality of agricultural products as they flow with the rainwater, the nutrients also cause many human diseases. Therefore, it brooks no delay to solve the imbalance of nutrients for crops. The quality of water used for agriculture deteriorates rapidly.

Most of the 1,500 rivers in the province are polluted. The water quality of these rivers is mostly lower than Grade IV of national standards. As a result of pollution, the usable water resources are declining by more than 1 billion cubic meters year by year, exacerbating the shortage of water resources for agriculture. The area of land that is directly irrigated with raw sewage reaches 45,480 hectares and the area of land which is irrigated with surface water lower than Grade-V standard is 67,036 hectares. The long-term irrigation with polluted water has caused severe agricultural pollution. The application of mulch film also causes pollution. Mulch film accumulates in soil and does not degrade or decay for a long time. This will lower the permeability of soil, hampers the transportation of moisture, severely affect the growth of crops and mechanized operation. Moreover, the accidents in which livestock get sick and die because of the mistaken intake of plastic film residue occur each year. As a result of plastic film residue in the soil, the seedling ability becomes worse, the seedling period is postponed, the disease resistance and yield drop. Each year, more than 300t of mulch film is used in Luoyang city. The residual quantity of mulch content in the plow layer is up to 52.5kg /(hm2·a). If the land is covered with mulch film for six years in a row, the residual quantity can be up to 300kg /hm2, resulting in severe "white pollution". The serious pollution makes it difficult to carry out clean production and meet the demand of "green and environment-friendly" products. According to the information provided by the provincial department of agriculture, the contents of heavy metals and pesticide residue in grain, vegetables, fruits and animal products exceed the standard in some places, making it difficult to export them to the international markets. In some counties where the water pollution is serious, the pollution not only hinders the restructuring of local agricultural production, but also escalates the social conflicts and affects the social stability in rural areas.

## *5.4 Loss of biodiversity and natural ecosystems*

The awareness of land resource protection is still rather low and the farmland is misused. According to statistics, the total area of farmland in the province has dropped from 9.062 million hectares in 1954 (when the area of farmland was the largest in history) to 6.834 million hectares in 1998 at a rate of 50,600 hectares each year. The per capita farmland has dropped from 0.205 hectare in 1954 to 0.074 hectare in 1998. The forced and excessive extraction of water resources is quite common, and water conservation is not well implemented. Currently, the utilization rate of water resources in the province is up to 30%, and the rate between utilized shallow ground water and the exploitable quantity is up to 60%. The utilization level of water resources in the province is far higher than the national average. The utilization of ground water in the mountainous areas in the north is up to 95%, giving rise to 8,000Km$^2$ of shallow water funnel area. The level of ground water gets increasingly low in many areas in the west of the province. If this extraction mode continues for a long time, such water resources will get exhausted, and the stratum structure will be destroyed, jeopardizing the buildings on the ground and giving rise to severe consequences. In some regions, forest resources are severely destroyed. The cultivation of mushroom and other edible fungus in some cities in the mountainous areas poses a devastating destruction to roburs. According to a survey carried out in 1998, among the provincial annual consumption of forest resources, broad-leaved trees account for 80.75% of the total. Amongst, roburs are the mostly consumed trees, whose annul consumption is up to 1.8183 million m$^2$, accounting for 46.48% of the total. According to the two provincial surveys of forest resources in 1988 and 1998, the total area of oak trees rose slightly in the ten years, but the total standing volume witnessed an obvious declining tendency. Moreover, the phenomenon of irregular clear-cutting still exists, which is very serious in some places. According to the check in 1998, 112,500 hectares of forest were destroyed and converted into farmland. There were 422 cases of severe forest destruction, which destroyed 10,100 hectares of forest. In addition, shelter belts are destroyed in some plain areas, giving rise to new desertification. A survey conducted in 1988 showed that the area of mobile and semi-fixed dunes stood at 3,600 hectares, which increased to 29,000 hectares in 1993, 41,000 hectares in 1995 and 53,000 hectares in 1998, increasing by more than 15 times in ten years. All these have affected the bio-diversity and caused the loss of ecological functions.

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

## 6.1 National policies and initiatives

As a large agricultural province, Henan is one of the major winter wheat and summer maize growing regions in China. Its total grain output exceeded 50 billion kilograms in two successive years, hit a record high for 4 years in a row, and ranked the first in China for 8 successive years, making outstanding contribution to China's food security. In recent years, climate changes posed a certain impact on agricultural production, especially the grain production. In this context, the provincial CPC committee and government of Henan has unveiled a series of preferential policies for agriculture to cope with the impact of climate changes on agricultural production, including policies on agricultural subsidy, environmental protection, resource protection and utilization and water-saving agriculture. Moreover, a plan for dry-land agriculture has been specially prepared.

According to the Plan for Key Medium Irrigation Areas and the Census of Medium/Small Irrigation Areas which were prepared and issued in 2003, 211 medium irrigation areas whose size is from 10,000 to 300,000 mu need to be renovated, requiring a total investment of RMB2.4 billion. The Plan for Supportive Water-saving Facilities in Large Irrigation Areas (2009-2020) prepared in 2008 planned a total investment of RMB20.4 billion.

In 2008, the provincial CPC committee and government issued the Outline Plan for the Construction of Core Grain-producing Areas in Henan for the National Strategic Grain Project, proposing to take effective measures to increase the annual grain output from the current 50 billion kilograms to 65 billion kilograms and build the province into an important grain production base in China. The detailed measures include to cover the 75 million mu of the total 108 million mu of farmland into the core grain production areas, increase the cropping index, and increase the sown area of grain to 150 million mu each year; stabilize the sown area, increase the unit yield, consolidate the output of summer grain, lay stress on summer grain, optimize the structure and increase the returns, further consolidate and improve the yield of 25 million mu of land whose unit yield is up to 1 ton, and stabilize the unit yield to 1,000 kilograms; develop 25 million mu of medium-yield farmland into high and stable-yield land to increase the unit yield to 900 kilograms; convert 25 million mu of low-yield land into stable-yield land to increase the unit yield to 800 kilograms so as to ensure 650 billion kilograms of grain output by 2020.

In 2009, the provincial CPC committee and government issued the Opinions on the Implementation of Measures to Consolidate the Construction of Agricultural Infrastructure, Further Develop the Agriculture and Increase the Income of Farmers as the No. 1 document, deciding to further increase the direct subsidy to farmers, agricultural materials, sows and cows, agricultural machines, formula fertilization by soil testing and training for transferred laborers, incorporate "Super Rice" into the subsidy scope of fine breeds, and increase the subsidy to farmers to over RMB6 billion this year. Governments at various levels plan to invest more than RMB50 billion in improving agriculture, production and living conditions in rural areas. The total provincial agricultural investment is set to rise by 15%, and the increase in central fixed assets investments for rural areas will be increased, and the appropriation of government revenues from land assignment used in rural construction is planned to be higher than the previous year. The newly-added revenue from farmland occupation tax will mainly be used for the agriculture, farmers and the countryside, and stress will be laid on water conservancy for farmland, overall agricultural development and construction of infrastructure in rural areas.

## *6.2 Yellow River Basin and selected focus areas*

### 6.2.1 Human capacity and awareness

Government officials only have some concept ideas on climate change. Professional technical personnel have a stronger conception. In contrast, the knowledge of ordinary farmers on climate change is quite limited. According to surveys, 74.2% of the farmers think that there are changes in climate, but only 19.2% of them know the reasons.

The cognition of farmers on climate change is mainly limited to temperature rise (saying that it gets hotter and hotter) and the decline in the number of torrential rain (saying that heavy rain and rainstorm becomes less frequent).

The idea of farmers on the impact of climate change on agricultural production is mainly that the growth periods of wheat starts early (saying that wheat gets ripe earlier). They are evenly divided on whether drought occurs more frequently, but their knowledge of the impact of drought on agricultural production is inconsistent. 54.6% of the farmers think that the impact of drought does not get more severe.

### 6.2.2 Adaptation processes

Henan is an important agricultural cradle and a major grain producing province in China. Normally, the area of farmland whose unit yield declines due to drought is up to 50 million mu. In years of severe drought, the grain output is reduced by several million tons. The dry farming land in the province involves 12 cites, 48 counties/districts and 670 towns, covering an area of 35,200 square kilometers, accounting for 45.9% of the total land and 36.7% of the farmland in the province, and affecting 38.9% of the provincial population. The utilization rate of crop stubbles is less than 30%, and the rate of stalks returned to farmland is less than 10%. The province mainly applies single technologies to cope with the climate change. In particular, it has made many outstanding achievements in the research on and application of drought fighting and water saving technologies. But agricultural plantation is the result when environmental resources, economic development and technology are closely combined. With the social and technological advance, to maximize the utilization of natural resources is the major direction of agricultural technology research in many other countries. In this regard, Henan has many problems, including inadequate research force, inconspicuous dominant technologies and imperfect application result.

At present, the technologies applied in Henan to cope with the impact of climate change on agriculture mainly include:

Screening, appraisal and application of drought-resistant and water-saving breeds: select drought-resistant and water-saving breeds to improve the moisture utilization efficiency according to the moisture sensitivity of different breeds.

Mechanized furrow sowing for winter wheat: It is dry and moisture content in soil low when winter wheat is sown. This technology can improve the sowing quality of winter wheat in dry-farming areas.

Soil moisture-determined re-sowing, surface covering technology for summer maize: It is dry and moisture content in soil low when summer maize is sown. This technology can improve the sowing quality of summer maize in dry-farming areas.

Omni-directional sub-soiling: By sub-soiling and returning stalks to the land, the sub-soiling technology can improve the till and physical properties of soil, increase the water storage and moisture preservation, and also the utilization rate of natural rainfall so as to effectively mitigate the impact of drought in dry-farming areas.

Mechanized no/less-tillage and cover: This technology can improve the rainfall storage rate in years of normal precipitation, slight drought and serious drought. The effect is extremely obvious in dry years. The output of maize can be increased by up to 14.93%. Due to this technology, the soil has a high moisture content to enhance the photosynthesis of wheat in later growth period, increase the content of organic substance and activity of microorganisms in soil, and improve the soil fertility.

Furrow sowing on side of film mulch for wheat in dry land: This technology can solve the problem of low moisture content in soil when winter wheat is sown and improve the water utilization efficiency.

### 6.2.3 Measures for reducing unsustainable land use

The crop stalk utilization and conservation tillage technologies have been applied to a large area. However, the growth is rather slow, and the guaranty system is not well established. Therefore, the demonstration and extension should be intensified.

We should implement the Plan for the Construction of an Ecological Province, kick off 8 provincial ecological projects and 4 industrial projects. In addition, we should make breakthroughs in shelter belts, suburb forests, forestation of towns and villages, ecological corridor network and ecological energy source forestry. Moreover, we should invest RMB6.13 billion for 5.08 million mu of forestation, and1.60 million mu forest cultivation and renovation. Furthermore, we should increase the area of ecological corridor by 552,000 mu, and build 16 ecological counties.

We should carry out the “Seeds Project” to accelerate the construction of fine crop breeds cultivation bases and increase the coverage of find crop breeds to over 98%, speed up the implementation of the “Soil Fertilization Project”, and continue to provide technical service of formula fertilization by soil testing for farmers. In addition, we should increase the area of land that adopts formula fertilization by soil testing to over 55 million mu. Moreover, we should continue to carry out the “Science and Technology Project for High Yield of Food Crops”, strive to solve the key problems that hamper the significant increase in unit grain yield, and put in place a high-yield technology system accommodating to various ecotypes. Furthermore, we should continue to implement the “Plant Protection Project”, build various professional protection teams, establish and improve a warning and control system for major disease and pest disaster to handle more than 90% of the emergency disease and pest incidents.

# 7 Potential C-PESAP strategies, adaptation and implementation scenarios and cost/benefit estimates

## *7.1 Human capacity and awareness*

### 7.1.1 Potential strategies

Governments at various levels should well increase the public awareness as an important measure to cope with the climate change. The awareness of decision makers of governments, enterprises and institutions at various levels should be further increased, and a team of cadres that have a strong sense of climate change should be established. The force of all walks of life should be mobilized for the publicity of policies on climate change to increase the public awareness.

Based on the poor public knowledge of climate change and the difference in individual cognition, government departments should intensify the publicity of and training on knowledge relating to climate change to create an atmosphere involving government departments, agricultural technology personnel and farmers to cope with the climate change, strengthen the screening and appraisal of technology, lay stress on the application of integrated technology, consolidate the demonstration and extension of technologies so as to enhance the public cognition.

We should formulate a 3-5 year publicity and training plan to increase the knowledge and awareness of the general public.

The government should put in place a well-established training and follow-up service system for the training of professional techniques for farmers. It should also appropriate special funds, hammer out appropriate measures, and integrate technologies to adapt to and cope with climate change into the training programs of farmers.

In addition, the government should combine the policies to cope with climate change and other related policies. It should also set up special research projects or break up related contents into related major research projects. In addition, it should carry out systematic and complete research on the technology to predict and analyze climate change, impact of climate change on agricultural production, screening, appraisal and integration of technologies to cope with climate change, and intensify the experiment and demonstration.

### 7.1.2 Implementation scenarios

By 2010, we should make universal the knowledge of climate change, improve the awareness and atmosphere to adapt to and cope with climate change in the whole society. By 2015, we should preliminarily establish an organization and management system to cope with the climate change. We should also implement and intensify the “Sunshine Project”, “Rain and Dew Program”, “Spark Program” and employment program for rural laborers, further increase the subsidy, integrate the training resources and expand the training scale. Moreover, we should encourage training institutions to improve the training for transferred farmers. Besides, we should train 1.2 million transferred farmers this year, lay stress on the training of new farmers, organize and carry out various training and certification projects for farmers, cultivate a large batch of talents that can meet the demand in rural areas.

### 7.1.3 Cost-benefit estimates

For the development of rural economy, to cope with the climate change, the most important measure is to significantly increase the agricultural investment. Due to the difference in ecological conditions and socio-economic development, different regions should lay stress on different aspects. But in general, this is a long-term task that involves all the social and economic management departments. As long as we enhance the publicity, intensify the knowledge of leaderships of local governments, formulate appropriate strategies for different government departments, improve the application of technologies, intensify the guidance on training, increase the awareness of general public on climate change and related technologies, there will be no problem to increase the investment.

We should make universal the new rural cooperative medical system, raise the subsidy, and increase central and local subsidy to each farmer from RMB40 to 80. We should also perfect the rural medical assistance system, strengthen the medical assistance management and improve the medical assistance. Besides, we should accelerate the establishment of public healthcare service system, medical service system, medical security system and drug supply guaranty system that cover all the farmers in the province to provide safe, effective, convenient and low-cost medical and health service for farmers. Moreover, we should intensify the construction of health service networks at the county, town and village levels, and advance the construction and renovation of 100 county-level hospitals, traditional Chinese medicine hospitals and women and children care hospitals. Furthermore, we should build 8,000 standard village infirmaries and complete the construction of infirmaries in all the administrative villages within 3 years.

We should improve the system of allowance for low-incomers in rural areas to increase the allowance for each eligible person to no less than RMB40 each month. We should also expand the allowance coverage and incorporate all the poverty-stricken population that meets the requirements into the coverage. Besides, we should earnestly carry out the five-guarantee subsistence work in rural areas, put in place the funds for the five-guarantee subsistence, provide subsistence for eligible people in accordance with stipulated standard, and issue the pension through social security channels. Moreover, we should continue to strengthen the construction of homes of respect for the aged and increase the rate of collective service for eligible people to 40%.

## *7.2 Adaptation processes*

### 7.2.1 Potential strategies

In general, we should, based on the conditions of large population and limited farmland and the current grain production, provide classified guidance, stabilize the sown area, increase the unit yield, optimize the structure and increase the return. In light of the current conditions and problems in different regions, we should screen and integrate production technologies suitable for the sustainable development in different regions.

We should also vigorously carry out sustainable, ecological, organic and urban agricultural strategies.

### 7.2.2 Adaptation scenarios

#### 1. Start with crop distribution and adjust the plantation structure

We should optimize the regional distribution of agriculture, facilitate the concentration of superior agricultural products to dominant regions to form agricultural product belts and increase the agricultural productivity. Besides, we should increase the plantation of cash crops and fodder crops to promote the transition to a ternary structure composing of grain crops, fodder crops and cash crops. We should also adjust the planting system, develop multiple cropping systems and increase the cropping index.

In irrigation areas, we should consolidate the summer grain and lay stress on autumn grain. Besides, we should give prominence to high yield, quality, efficiency, environment-friendliness and safety to improve the overall grain productivity. We should also start with drought-resistant and water-saving breeds in dry areas, appropriately arrange the wheat and maize breeds and increase the production potential of natural resources for high-efficiency utilization of limited resources. Moreover, we should focus on wheat, pay attention to maize and arrange “early-maturity and early-maturity breeds” in hilly and dry areas. Furthermore, we should focus on maize, pay attention to wheat breeds and arrange “early-maturity and middle-maturity breeds” in dry plain areas.

### 2. Start with breed distribution and intensify the screening and application of fine breeds

We should cultivate new animal and plant breeds that boast high yield potential, excellent quality, outstanding resistance and adaptability. We should also improve the distribution of crops and breeds, cultivate and select adversity-resistant breeds that are drought, waterlogging, temperature and pest-resistant.

In terms of breed distribution, we should highlight the principle of classified management. We should also appropriately arrange the breed distribution in light of the natural and ecological conditions in the northern high-yield irrigation area, central supplement irrigation area, southern rainfed area and western dry area. Besides, we should select moderately drought-resistant wheat breeds in the dry area, and highlight drought, cold, dry-hot wind, pest and adversity resistance features. In irrigation areas, we should give prominence to high-yield and water-saving breeds. For maize, we should select middle-late-maturity maize breeds which boast much potential for high yield, prolong the growth period of maize so as to make full use of the light and heat resources and bring into play the production potential of natural resources before the wheat is sown.

To cope with the trend of winter wheat breeds becoming spring breeds, we should gradually increase the proportion of semi-winter breeds. In central and northern parts of the province, we should adjust the proportion of semi-winter breeds and spring breeds to be 60%-70% and 30%-40% respectively. In the dry-farming areas in the west, semi-winter should prevail.

### 3. Popularize the application of technologies to cope with climate change, screen and select technologies suitable for different ecotypes, and vigorously demonstrate and promote such technologies

**Key technologies for irrigation areas:** screening and application of water-saving breeds, postponing of wheat sowing, postponing of maize harvest, quantitative water-saving irrigation, cultivation of high-yield farmland and disaster control and alleviation technologies.

**Key technologies for dry-farming areas:** screening, appraisal and application of drought-resistant breeds, mechanized furrow sowing of winter wheat, soil moisture-determined re-sowing, superficial covering technology for summer maize，furrow sowing on side of film mulch for wheat in dry land and rain water collection and moisture preservation in dry-farming areas.

### 4. Start with disaster control and alleviation, strengthen the research on and demonstration of disaster control and alleviation technologies to improve the overall grain productivity and minimize the loss caused by disasters

Currently, disaster control and alleviation technologies mainly include: establishment and application of disaster forecast and warning system, adaptive plantation, prediction and forecast of disease, pest and weed, real-time monitoring and forecast of soil moisture conditions and integration of disaster alleviation technologies.

### 7.2.3 Cost-benefit estimates

We should actively leverage government funding, preferential taxation and economic stimulus policies to increase the input of technological work on climate change. In addition, through government policy and financial guidance, we should raise social funds through different channels to increase the input of technological research on climate change. Besides, we should make use of the bilateral and multilateral funds from foreign governments and international organizations to finance the scientific research and technological development in the area of climate change.

We should make relevant policies to guide and intensify technology innovation, demonstration and extension. We should also put in place and improve a subsidy mechanism for fine breeds, agricultural machines (including small/medium agricultural machines). In addition, we should reduce the overall energy consumption of added value of agriculture by 20% and give full play to the role of meteorology in serving agricultural production. Moreover, we should establish and improve a rural defense system for natural disasters. Furthermore, we should lay stress on the implementation of “Cloud Water Resource Development Project”, and continue to carry out conservation tillage projects.

We should actively facilitate the standard construction for wholesale markets of agricultural products and further expand the pilots of “Double-market Project”. The supply and marketing cooperatives should accelerate the organizational and operation innovation and build an operating network for agricultural products to promote the construction of modern circulation networks in rural areas. We should also encourage business, postal, medical and health and cultural enterprises to develop modern logistics in rural areas. In addition, we should continue to implement the Market Project of "Ten Thousand Villages and Thousand Towns” and invest RMB60 million this year to build more than 10,000 chain supermarkets in rural areas to cover more than two thirds of the administrative villages in the province.

## *7.3 Measures for reducing unsustainable land use*

### 7.3.1 Potential strategies

#### 1. Implement the strategy of recycling agriculture and build a resource-conserving society

To develop a recycling agriculture is not only a new idea and strategy for the development of rural areas, but also a new pattern of growth. Recycling agriculture is a mode of agricultural development centering on high-efficiency and recycling utilization of resources and featuring low consumption, low emission and high efficiency on the principles of “waste reduction, reuse and recycling”. Compared with the traditional agricultural development which relies on “mass production, consumption and disuse”, this pattern represents a fundamental transition. We should gradually establish a legal, policy, innovation, government management, stimulus and restrictive system for the development of recycling agriculture to lower the production consumption of agricultural resources, improve the overall efficiency of resource utilization, lower the waste from agricultural production, and increase the return on input in agriculture.

#### 2. Implement the strategy of conservation tillage and build an environment-friendly society

The study of conservation tillage dates back to the 1940’s. From 1988, it was called protective tillage method. As this tillage method is conducive to soil protection, it is also called protective farming. In 1987, Mannering defined the conservation tillage as a system which maintains at least 30 percent surface residue cover after planting, reduces the water and soil loss and increases the farmland output. In 1993, Cai Dianxiong, a research fellow with the Chinese Academy of Agricultural Sciences pointed out that the conservation tillage refers to a farming or planting system which maintains the surface organic residue cover rate to be over 30% and controls the soil erosion to be less than 50%. It is a sustainable mode of agricultural production which intends minimize the human damage to soil system, aims to maintain a relatively high yield with less energy and material input, bring higher profits for unit input and help ecological production. In 2002, the Ministry of Agriculture formally defined the conservation tillage as "an advance agricultural tillage technology which adopts no or less tillage for farmland and covers crop stalks on ground surface to reduce wind erosion, increase soil fertility and drought resistance". It mainly consists of four technologies, i.e. no-tillage fertilization and sowing, stubble management, prevention and control of weed, disease and pest, sub-soiling and surface tillage. Amongst, sub-soiling to break the plough layer is the foundation for conservation tillage. The selection of cost-effective no-tillage sower for no-tillage fertilization and sowing operation is the core technology of and way to conservation tillage. As of 2008, conservation tillage has been applied to more than 1 million of farmland in 72 counties of the province.

We should introduce the biologically benign recycling laws in nature into the socio-economic system, carry out ecological construction in counties and cities with conditions, make the plan, analyze the current conditions of resources and define the long-term development goals. In light of the local conditions, we should adjust the industrial structure, restore the service function of ecological environment and work at the human living environment, build a system of ecological industry and culture, optimize layout of urban functions and landscaping structure, and build green communities and ecologically-advanced villages. We should also improve the quality of human living environment, carry out ecological civilization, boost environmental protection in production, circulation and consumption, advance the transition in pattern of economic growth and traditional way of living, and facilitate the construction of a resource-conserving and environment-friendly society.

### 3. Implement the strategy of organic agriculture and achieve high-efficiency and sustainable utilization of natural resources

The concept of organic culture was first raised in France and Switzerland in the 1920's. From the 1980's, as some national and international organic standards were made, some developed countries began to pay attention to organic agriculture and encourage farmers to transfer from conventional to organic agricultural production. It was not until then that the concept of organic agriculture was widely accepted. Organic agriculture is an agricultural production system which completely or basically does not use synthetic fertilizer, pesticide, production regulators and feed additives for livestock and poultry. In this system, the application of crop rotation, crop stalks, livestock and poultry manure, crops of bean family, green manure, organic waste outside farms and biological disease and pest prevention and control methods is maximized to keep the productivity and tilth of soil so as to provide nutrients for crops and prevent diseases, pests and weeds.

In China, organic agriculture started to develop in the 1980's. In 1984, China Agricultural University began the research on and development of ecological agriculture and organic food. In 1988, Nanjing Institute of Environmental Science started the research on organic food and became a member of International Federation of Organic Agriculture Movements. In October of 1994, the State Environmental Protection Administration set up an organic food development center. Since then, organic food embarked on a journey of standardized development in China. In 1990, the organic tea developed by Zhejiang Tea Import & Export Corp was exported to the Netherlands for the first time. In 1994, organic soybean developed in Liaoning was exported to Japan. After that, many organic food production bases were set up in China. Organic agriculture registered a rapid growth in the Northeast, and remote and mountainous areas in Yunan and Jiangxi provinces. In recent years, many trade companies have cooperated with organic food production bases to develop many new products, such as organic beans, peanuts, tea, sunflower seeds and honey. In general, the production of organic food in China has just begun to grow. The scale is small and most of the production is oriented to the international market. However, there are many favorable conditions and promising prospects for the development of organic agriculture in China.

### 7.3.2 Implementation scenarios

We should focus on the assembly and integration of various mature technologies, vigorously advance green and organic agriculture for sustainable development, and build an ecological environment featuring optimized structure, reasonable distribution and significantly-increased vegetation coverage rate. In addition, we should construct 7,912 square kilometers of national and provincial eco-function reserves, plant 200,000 hectares of ecological commonweal forest in the middle and lower reaches of the Yangtze River, return 370,000 hectares of farmland into forest and grassland, preserve 900,000 hectares of forest, treat 600,000 hectares of land of water and soil loss and rehabilitate the ecological environment for 500,000 hectares. Moreover, we should set up 22 wetland reserves, return 10,000 hectares of farmland into swamp (hirst), restore 10,000 hectares of habitat for wild animals and establish 20 demonstration zones for sustainable utilization of wetland. We should also increase the number of natural reserves to 50, and the area to 850,000 hectares. Besides, we should plant 3,300 hectares of sand-break forest and treat 260,000 hectares of sandy land.

### 7.3.3 Cost-benefit estimates

We should increase the subsidy for farmers to RMB6 billion, accelerate the construction of cultivation bases of fine crop breeds and increase the coverage rate of major fine crop breeds to over 98%, and the area of formula fertilization by soil testing to more than 55 million mu. We should also concentrate 70% of the agricultural development funds to support the core grain production zones in 24 counties, renovate 1.80 million mu of middle/low-yield farmland and construct high-standard farmland. Moreover, we should invest RMB6.13 billion to build 5.08 mu of forest, cultivate and renovate 1.60 million mu of forest, add 552,000 mu of ecological corridor and build 16 forestry ecological counties.

We should, through wholesale or sub-loan, solve the problem of inadequate funds for some rural credit cooperatives and new rural financial institutions. In addition, we should advance the pilot of rural cooperative banks, attract and encourage domestic and foreign strategic investors to invest in rural credit cooperatives, and build some county-level rural credit cooperatives into rural cooperative banks. Moreover, we should actively and steadily carry out the pilot of new rural financial institutions such as village/township banks and strive to build 1-2 new rural financial institutions. On top of that, we should guide various financial institutions to launch business in rural areas. Besides, we should actively foster small-sum credit organizations, encourage the development credit loans and co-guarantee loans, advance innovation in guarantee in rural areas, expand the scope of valid securities, explore a rural credit guarantee mechanism in which the governments render support, enterprises and rural financial institutions take an active part. Furthermore, we should actively carry out the pilot of agricultural insurance, improve the operating mechanism and development pattern of policy-oriented agricultural insurance, gradually expand the pilot, establish and improve agricultural re-insurance systems, and put in place a risk transfer and share mechanism for agricultural catastrophe.