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1. CHALLENGE AND OPPORTUNITIES

1.1. China's crucial problems in agriculture development

There are different ways of developing in agriculture. One approach to increasing productivity of cropland over the past several decades is the so-called "high-input agriculture" or "petroleum agriculture". This increased productivity has required the use of a wide range of physical, biological and chemical inputs, including irrigation, tractors, fertilizers, pesticides, the breeding of high-yield varieties, and the development of fast-growing cultivars that allow double and even triple-cropping. This "high-input" agriculture will be a useful approach to increasing food production in the future as well.
But high-input agriculture has a number of serious drawbacks. For one thing, it is expensive and requires a large consumption of ore energy. It is considered that if the agriculture production and diet level of developed countries (e.g. the U.S.A.) is adopted among five billion people in the world, then 5000 to 6000 billion litres of petroleum would be consumed annually and the petroleum verified to date would be used up within only thirteen years. In addition, many developing countries which have no petroleum resources suffer a great deal from energy shortage.
Another drawback is that it requires a high degree of expertise and farmer training. Perhaps most limiting, over a long term, high-input agriculture can lead to fearsome ecological problems, including the salinization and waterlogging of soils and the poisoning of non-target species (including humans) by pesticides. (World Resources Institute and International Institute for Environment and Development 1986).
China is a country with escalating population pressure, limited natural resources, rural poverty, environmental degradation and small possibility for implementation of high input agricultural systems.
Although China ranks third in the world in total land area, only 65% (6.27 million km^2) of this land can be used for agriculture, forestry, grazing, fishery and human habitation. The remaining area including the Gobi desert, glaciers, rock mountains and frigid wilderness, is not suitable for the development of agriculture (Table 1).
Population is probably the greatest problem in the development of China. According to statistics in 1990, there are 1.14 billion people crowded onto 9.6 million km^2 of land. Presently the amount of cultivated land per capita is merely 0.12 ha. It is an arduous task to feed 20% of the world's population

Table 1. Land resources in China.

Category	Area (1'000 km^2)	%
Arable land	994	10.4
Orchard	34	0.3
Closed forest	1219	12.7
Open forest	156	1.6
Shrub	296	3.1
Grassland	2857	29.8
Suitable for cultivation		
for arable land	333	3.5
for forest	779	10.3
Wetland and swamp	110	1.1
Desertified land	170	1.8
Shrub desert	600	6.3
Gobi desert	150	1.6
Cold high mountain desert	560	5.8
Rock mountain	460	4.8
Glacier and snow covered	50	0.5
Beach	20	0.2
Inland water surface	270	2.8
Total	9600	100.0

with only 7% of its total arable land. It continues to shrink, on an average of some 520,000 ha/year. The most serious loss of crop land, however, is taking place in the eastern coastal areas where the cultivated land per capita is less than 0.067 ha. If this decline continues, another 7.5 million ha of cropland will have disappeared by the end of this century. As the population of China will probably reach 1.26 billion by that time, the arable land per capita will therefore be only 1.4 mu (1 mu = 1/15 ha) or 0.094 ha (Figs. 1 and 2).

An increase in high-yield crops and multiple cropping, along with a decrease in organic manure applications, has led to a decrease in soil fertility. The average organic matter content of farmland soil in China is less than 1.5% with 10 million ha lower than 0.7%. Of the total farmland, 59.1% is deficient in available phosphorus and 22.9% in potassium. The proportion of highly productive farmland has decreased from nearly 1/3 to 1/5.

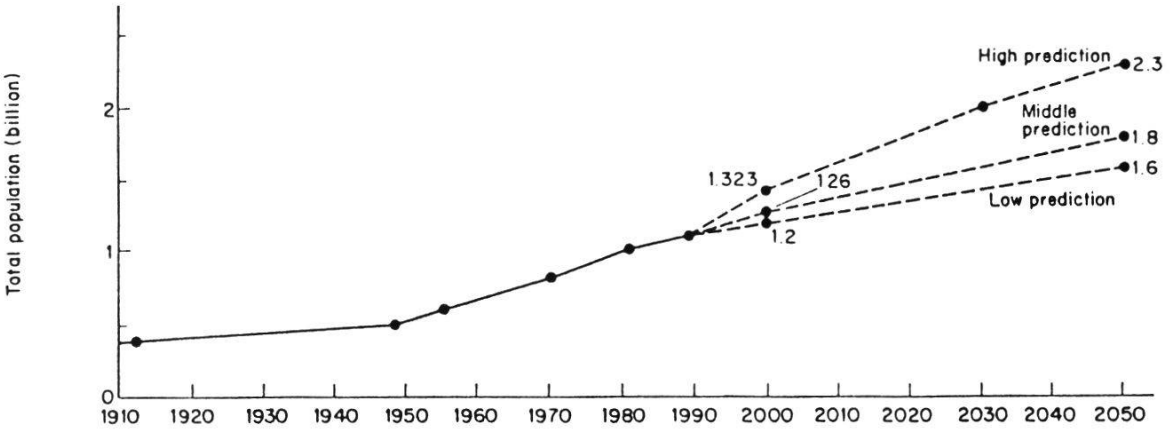

Fig. 1. The trend of population growth in China. (CAI Yunlong 1990).

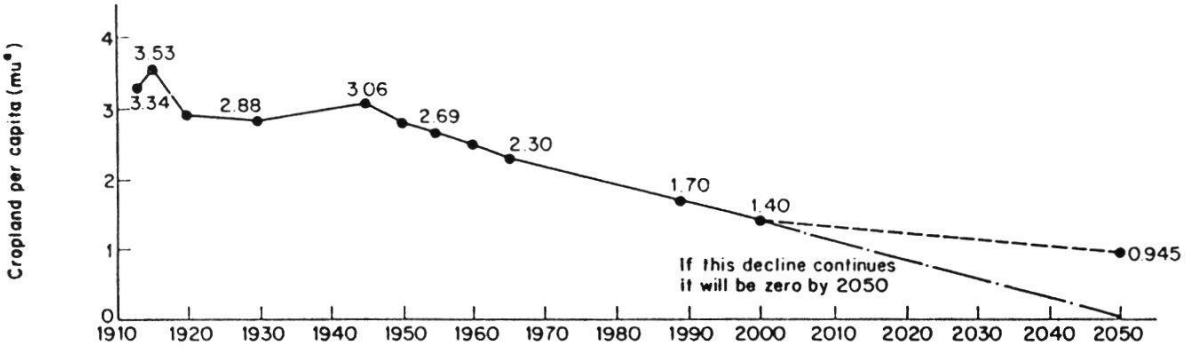

Fig. 2. Crop land area per capita in China. (CAI Yunlong 1990).

Pollution is another of China's agricultural problems. Annual average fertilizer application is 208 kg/ha, twice more than the world average. Eighty per cent of the applied fertilizer is nitrogen which has led to a poor ratio of NPK and has caused an increasing risk of N loss and pollution. The pesticide polluted area for the whole of China totals 13 million ha. Along with high-input agriculture, urban and industrial wastes have caused serious pollution, decreasing food-grain production by 5 million tons. An estimate shows that 50% of the ground water in the North China Great Plains was polluted (GUO SHUTAIN and HAN CHUNRU 1988).

On the other hand, China is in shortage of potentially arable land. It is estimated that only 333'000 km^2 of land, or 3.5% of the total land is suitable for cultivation. This means there is very little potential for further development of agriculture by expanding the cultivated area.

All this indicates that conventional agricultural development has been unsuccessful in solving the problems under the current conditions and infrastructure

of China. It is a necessity to find a development model for an ecologically sound and economically feasible approach adapted to to the specific conditions of China.

Old China has left us with little forest and a poor base for forestry. Owing to the rapid growth of population, coupled with the development of agriculture and industry, the exploitation of forest resources has accelerated, leading to a series disasters and dangerous trends.

Forests in China cover a total area of 115 million ha with 9.2 billion m^3 of growing stock. Although ranking sixth in the world, the forest area amounts to only 0.1 ha per capita, 18% of the world's average. The growing stock per capita is about 8 m^3 or 13% of the world's average. Some 9 million m^3 of wood are imported annually, and rural householders have suffered acute fuel shortages.

Distribution of forests is uneven. In general, the forests of China are mostly concentrated in mountain and hilly areas of N.E., S.W. and S. China. In vast areas of the Northern Plains and the lower reaches of the Yantze and Yellow Rivers, which are densely populated and economically developed, forest resources are very poor and the rural people are suffering acute shortages of timber, fodder and fuel.

It has been estimated that with the increase of population and the development of economy, the demands for timber and other forests products double every 30 years. In order to maintain a sustainable development of forest resources, the annual consumption should not exceed the annual natural increment. At present, the annual stock increment is about 300 million m^3, while annual forest consumption is 400 million m^3, i.e. 100 million m^3 is over-exploited every year.

The major timber production comes from clearing the mature and over-mature virgin forests. Although, due to the increase of young plantations, the forest area remains more or less the same, the growing stock and the quality of timber have been degraded significantly. If current trends remain unchanged, the growing stock is predicted to decrease steadily from 9.2 billion m^3 to 7.4 billion m^3 by the year 2000, and the the mature and over-mature forest resources will be exhausted by 2010. The exploitation will have to return to the middle-aged forest stands. Then the forest area will decrease drastically. With the growing stock constantly in decline, the stand quality and age structure will steadily deteriorate.

In past years, much attention has been paid to regeneration and afforestation in areas where virgin forests had been distributed. Since these forests are

mostly located in remote areas, the government-owned forest enterprises must provide employment, hospitals, schools, transportation and maintenance, as well as many other services - all on a dwindling resource base. So the cost for forest regeneration is very high and the government is in no position to provide the necessary investment to cover the expenses needed for afforestation projects in these areas. And, because these areas are mostly located in the cool temperate or subalpine belt, the rotation period for the next harvest is long and accessibility is low. So, not giving up the effort for regeneration in remote areas, we must develop another mechanism, which will attract the interest of small householders to join the afforestation campaign in easily accessible areas by using integrated land use systems to solve timber and fuel shortage problems.

Although China has about 287 million ha of natural grasslands, the major source of meat, eggs and milk are from forage, produced on croplands. More than 90% of the meat supply is from the eastern agricultural regions while the natural grasslands are located in semiarid-arid areas of western China with a low carrying capacity and degraded environment.

Moreover, overpopulation goes always along with poverty. The big progresses of the national economy during the recent decades have not been enough to narrow the gap between China and the developed countries. According to a World Bank report the per capita gross national product of China in 1991 was 325 US$, which ranked 23rd from the bottom among 119 surveyed countries.

As correctly emphasized in the report of the World Commission on Environment and Development, Our Common Future, 'Poverty is not only an evil in itself, but sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life. A world in which poverty is endemic will always be prone to ecological and other catastrophes' (World Commission on Environment and Development 1987).

The escalating needs of soaring numbers have driven people to take a short-sighted approach when exploiting natural resources. The toll of this approach has now become glaringly apparent: a long list of consequences, including soil erosion, desertification, pollution, ecosystem degradation and destruction and extinction of species and varieties etc. has become increasingly dangerous, which in turn is influencing the speed and process of development. We have become more and more aware that development and conservation are becoming ever more interwoven into a seamless net of causes and effects and only an integrated approach, which combines development with conservation,

can harmonize short-term profit with long-term goals. And only the combination of outside incentive with the farmer's own spirit of self-reliance can solve the country's dilemma in economical development in general, and in agriculture in particular.

1.2. The necessity and validity for the development of integrated farming systems

On the other hand, China has its own special merits for implementing low- input agriculture by using the integrated approaches. These include:

1.2.1. The traditional integrated philosophical thoughts for understanding the world in general, and the agricultural production in particular

The traditional integrated philosophical thoughts for understanding the world in general, and the agricultural production in particular: As to agriculture, our ancestors have long regarded the organism, environment and human being as entities. And using the 'san Cai' theory to explain the relationship between 'the Heaven', 'the earth' and 'human being'. The theory of 'ying yong' has been widely used in agriculture to reflect the relationship between different components of the agricultural system. Many excellent ideas in this aspect were recorded in some earliest outstanding works on agriculture. For example, the four essays in Lü Shi Chun Qui (Master Lü's Spring and Autumn Annals) namely, 'Shang Nong' ('lay stress on agriculture'), 'Ren Di' ('Capacity of soil'), 'Bian Tu' ('Work the ground') and Shen Shi ('Fitness of the Season'), which was completed in 239 B.C., can be claimed as China's earliest agricultural treatises. These essays are not independent specialized writings on agriculture. Yet together, they form a complete set of treatises with deep system opinion.

The valuable thought on the development of agriculture based on ecological principles was involved in a series of extant Agricultural Treatises such as Fan Sheng Zhi Shu (The book of Fan Shengshi) before the Western Han Dynasty (206 B.C. to 24 A.D.), Chen Fu Nong Shu (Agricultural Treatise of Chen Fu) completed in 1149 in the Southern Song Dynasty, Wang Zhen Nong Shu (Agricultural Treatise of Wang Zhen) dating from the Yuan Dynasty (1271-1368), and Nong Zheng Quan Shu (Complete Treatise on Agriculture) compiled by Xu Guangqi (1562-1633), etc.

Among the existing Chinese classics solely devoted to agriculture, 'Qi Ming Yao Shu' is the best preserved and most comprehensive. It was written in the years 533-534. This book is not only rich in content, but is detailed and accurate. It sums up the vast amount of agriculture knowledge accumulated in China before the 6th century. The book embraces farming, forestry, animal husbandry, side-line production and fishery, based on ecological principles. For example, he summarized and studied the rotation system. First, according to the characteristics of crops, it distinguished the ones that could be rotated from those that could not. It also summed up a set of rotation methods and pointed out that the bean family is the best forerunner crop. Affirming the practice of fertilizing using crops as green manure, it remarked, 'To improve the soil, the best way is to plough down mung bean, next, lesser beans and sesame'. Qi Ming Yao Shu also summarizes interplanting and thus provides a new direction in the maximum utilization of sunshine and cultivated land to raise the yield per unit area.

The spatial and temporal interplanting system was particularly developed in horticulture. It is mentioned that mallow (*Malva verticillata* L.), which was called Kui in ancient China, can be sown from three to five times a year, indicating that vegetation was sown and harvested continually on one piece of land. Scallions or lesser beans were sown among melon-vines and coriander and green onion were grown together. Since intensive cultivation has long been a tradition for agriculture in China and the Chinese labouring people have succeeded in breeding a wealth of varieties, it is possible to organize different kinds of crops, vegetables, fruit and timber trees into a fixed cultivation system. The term 'Garden-style cultivation' or 'gardenization' is the embryo of the ecological farming system in China.

Chen Fu Nong Shu (Agricultural Treatise of Chen Fu), which was completed in 1149 in the Southern Song Dynasty (1127-1279), is a comprehensive treatise on agriculture. In spite of its small size (only 12'500 words), it is substantial in content. This ancient treatise systematically discussed land utilization for the first time. Giving priority to the agricultural techniques of the rice-growing region south of the Changjiang River, the author provides a general view of the intercropping and the preservation of soil fertility using comprehensive measures.

The long history of intensive cultivation customs combined with abundant labour resources provide unusual social and technical conditions in the development of a low input, highly intensive integrated farming system in China.

1.2.2. Rapid development and the upgrade of knowledge in integrated farming systems in recent years

Since the establishment of the People's Republic of China, agricultural research (including forestry, animal husbandry, fishery etc.) has developed rapidly. Along with the development of specific research topics such as genetic improvement, the introduction of exotic species, techniques for growing and tending fast growing and high-yielding plantations, etc., there is increasing interest for the study of the integrated farming system as a whole entity. This includes systematical surveys of existing models of integrated farming systems, the development of the ecological agricultural engineering theory, quantitative comparison of the integrated farming system with conventional agricultural systems. A few but very interesting studies have been undertaken on the energy flow and nutrient cycles of some systems. System dynamics analysis and simulation have been initiated in some occasions.

Many experimental plots and stations have been established. These sites are important bases for scientific research as well as important areas for demonstration, diffusion and extension to vast areas.

Many papers and monographs have been published to introduce the experiences and findings in this field. Among others, a monograph entitled "Ecological Agricultural Engineering in China", under the general editorship of Prof. Ma Shijun and Prof. Li Songhua (1987), give an overall review of the concept, history, principles, major types, methods of analysis and assessment, as well as the perspectives of implementation of integrated farming systems in China. Many other publications concentrate on the introduction of the structure and benefits of specific types of integrated farming systems. Although interesting facts and encouraging results have confirmed the great potential of inherent advantages in this system, most of these publications remain descriptive rather than in-depth, quantitative studies. Nevertheless, a few interesting projects have emerged in which systematical, in-depth studies were carried out. For example, the rubber/tea intercropping system, widely practiced in tropical regions, has been subjected to detailed studies by the Yunnan Institute of Ecology and the Reclamation Bureau of Hainan Province (FENG 1989). The most popular and successful model, *Paulownia* crops intercropping system, was studied by the Chinese Academy of Forestry Sciences and other local institutions. It is of particularly value to mention the work of Prof. Zhong Gonfu and his colleagues, who engaged in the study of the terrestrial/aquatic interactive system in the Zhujiang (Peal River) Delta in the Guangdong Prov-

ince since the early fifties. The monograph "Integrated agriculture/aquaculture in South China", was published in 1988. It examined the historical development, the agricultural and aquacultural components, the energy flow, the labour requirements and the household economics of the system and is the first ever, broadly based analysis of any such traditional integrated system (RUDDLE and ZHONG 1983, 1988).
Many films and video tapes have been created to introduce integrated farming projects and specific technology useful in this system. In recent years, a number of national and international symposia/workshops have been organized by the Chinese Academy of Sciences, Ministry of Agriculture and the Chinese Association of Ecology. All this provides a sound basis for further development of the integrated farming systems in China.

1.2.3. Improvement of production organization and agricultural policies

Policies play an important role in the development of integrated farming systems. Before 1987 the agricultural administrative system of China had assumed the familiar three-tier form of People's Commune, Production Brigade, and Production team. Nevertheless the household remained the smallest single unit of Chinese social organization and one in which the de facto use and management of privately owned resources, such as small homegarden plots and domestic animals, was vested.
Since December 1978 the notion of the highly collectivized and egalitarian society has progressively been repudiated. China has moved towards the creation of a mixed, national owned, marketing economy with rural reforms giving more flexibility to individual householders. This has led to decollectivization of many agricultural practices, transforming the status of the individual family as the fundamental rural economic unit from de facto to de jure.
As a consequence of these reforms, most places in rural China now practice some form of responsibility system, with land and production contracted either to individual households or to the production team. Since 1981, the Government has devoted much effort to stabilize the present ownership structure of hills and forests, allotting hillsides to peasants for their private use and setting up the forest production responsibility system through the country. Barren hills and flood land owned by the collectives have been offered partly or entirely to peasants to use privately in a way consistent with their desires and management ability. The trees and grass growing on the lots belong to the

holders, who are entitled to manage their allotments on a long-term basis. Allotments can be inherited. Young trees and half-mature trees on allotted plots may be exchanged for money. Trees of economic value, e.g. bamboo groves and shelter belts, owned by a collective can be either contracted to specialized teams or groups or to householders. The opening and development of free markets have encouraged farmers to produce diversified products.
In addition, rural cottage industries have developed rapidly. Some 1.56 million 'township enterprises' have been established, employing around 70 million workers. They are capable of processing some agricultural products.
All these reforms and policies are not only economically successful but also promote the enthusiasm of the farmers to develop a diversified integrated farming system in China.

1.2.4. Incentive from government and international collaboration

The importance of developing the low-input integrated farming system has gradually been accepted by government authorities and the necessary incentive for implementation of this approach is being practiced throughout the country. More than 200 counties are experiencing significant progress by using the integrated approach for the development of agriculture and have been titled 'Ecological Agriculture Counties'.
The need for incentives to encourage farmers to adopt integrated farming practice, particularly in the initial stage, is well recognized. The simple reasons are that farmers have little or no resources to invest in reforming their conventional mono-cultivation system into a diversified integrated system.
There are many forms of incentives in China; some are direct and others are indirect. Direct incentives include granting subsidies and providing loans to the farmers. Indirect incentives include technical assistance, tax exemption, deduction, security in land tenure, and marketing services. The goal of incentives is to encourage eventual self-reliance on the part of the farmer and the community and should fit into both short and long range plans.
Since 1978, cooperation and technical exchanges with other countries and international organizations for the development of integrated farming systems have been strengthened. UNDP, FAO, UNU, UNESCO, World Bank and WWF have developed projects for integrated farming systems. Many countries have set up joint projects with Chinese scientists to develop modes and improve technologies for this purpose.