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Integrated farming systems in China

(an overview)

LI WENHUA

1993

CONTENT

Foreword and acknowledgements

It is a great honour and privilege for me to have been invited as a guest professor and to spend ten months at the Geobotanical Institute of the ETH in the beautiful city of Zurich, Switzerland.
After eight years coordinating work in the field of natural resources and environmental studies in China, I received this unusual opportunity to pause and freshen up my knowledge in a quiet environment and to exchange knowledge with experienced colleagues in the field of ecology and forestry studies.

I would like to take this opportunity to express my sincere thanks to Prof. E. Landolt for his kind invitation and generous support in my work and for his great interest in participating in my lectures during my stay at the ETH. I also wish to thank him for his strong encouragement in preparing this paper and for providing me with the necessary conditions. Without his support and encouragement this paper would not have been completed.
My special gratitude goes also to Prof. F. Klötzli. He went to great efforts in arranging my visit. I wish this book to symbolize our friendship and mutual interest in ecological studies. I will never forget the efficient scientific assistant and administrative support given by Dr. Regula Müller, Mrs Susy Dreyer, Mr René Graf, Mrs Anita Hegi and many others.
I wish to extend my thanks to Mrs April Siegwolf, who has spent so much time for editing my poor English draft, and Mrs Anny Honegger for the layout. Last but not the least, I should like to express my great appreciation to Mrs Monika Adam for assisting me in the field work in the Swiss forests, in typing and in drawing some of the figures by computer.

Integrated farming is an old practice in many countries of the world. In recent years, many scientists in China as well as abroad have expressed increasingly great interest in this system and have been engaged in its further development. They have made significant progress. Unfortunately, very little information from China is so far available to the scientists and practitioners working in this field. This paper is intended to give a general overview of the integrated farming systems which have been successfully practiced in China. Due to the limitation of time and the constraints of my personal speciality, I should not expect too much for this paper at this stage. I should be very satisfied if this paper lays down a framework for the further improvement and supplement of more up-dated information.
It is my sincere hope that the integrated farming system should be a contribution in approaching the ultimate goal of sustainable development in rural areas in general, and in developing countries in particular.

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.

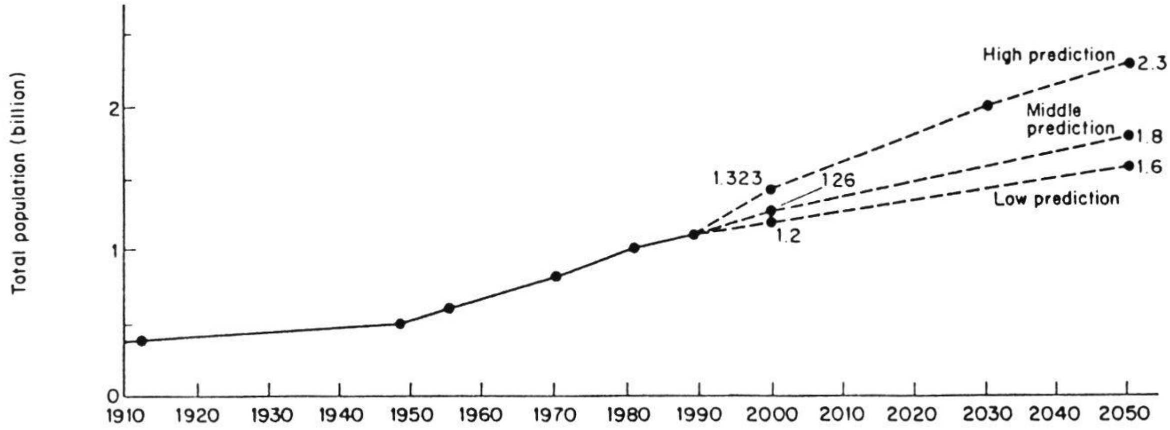

Fig. 1. The trend of population growth in China. (CAI Yunlong 1990).

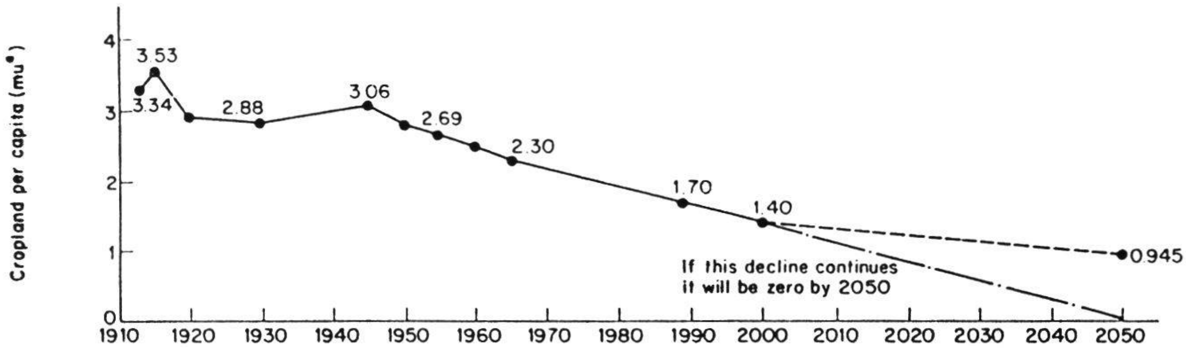

Fig. 2. Crop land area per capita in China. (CAI Yunlong 1990).

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 shortsighted 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.

2. DEFINITION AND CHARACTERISTIC FEATURES OF INTEGRATED FARMING SYSTEMS IN CHINA

2.1. Concept and definition of integrated farming systems in China

Despite the fact that integrated farming system (ecological farming, ecological agricultural engineering, etc.) is widely recognized by both natural and social scientists in China, there is no commonly approved definition for this term. Some scientists suggest that the integrated farming or ecological farming system is an agro-ecosystem with a carefully designed ecosystem structure in space and time, in order to ensure sustainable development by means of regulating the relationship between its components, prolonging the food or trophic chain and multiplying the recycling of nutrients and other materials.
Others define integrated farming as a kind of agricultural engineering with the aim of constructing a sustainable, high production agricultural system, using the principles of economy and ecology to obtain optimum ecological, economic and social effects.
At the 'All-China Conference of Ecological Agriculture' held in 1987, this term was defined as a new type of integrated farming system, in which multiple agricultural production and development are guided, organized and managed in the light of ecological-economic principles and by using the system engineering approach.
Attempts to arrive at an absolute definition usually produce a result too general to be used. What we intend to do in this paper is to clarify the most important features of the system rather than just create a brief definition. What then are some essential features of this important but broad concept?

2.2. Important features of the concept

1. IF (Integrated Farming) is system oriented multicomponent agriculture. It views the farming in a holistic manner emphasizing the interactions between components. Giving the multi-biological components as its central part, integrated farming is a complex biological-social-economic system. The final goal of management is to seek for the integrated effects of the whole system, not the effects of its individual compartment. (Fig. 3).
2. IF goes beyond narrow sectorial limitations. Whenever possible it tries to combine agriculture, forestry, horticulture, animal husbandry, aquaculture, as well as other biological production, into an interconnected system.

Some of the village cottage industries which have an immediate link with the system are also becoming a component of the system.

3. Increase in primary and corresponding secondary productivity is a key indicator in judging the successfulness of the system. This goal is to be reached mainly by multiplying the composition and structure of the system in space and time; by rising the converting effects, by increasing the recycling of nutrients within the system and, through the intensive management, using the surplus labour in the rural areas rather than relying on high input from outside the system.
4. The system is expected to meet the economic needs of the farming community by providing multiple products. It is expected to overcome or mitigate the risks of monoculture, particularly those of irregular rainfall, market fluctuations, pest outbreaks, insufficient weeding and high fertilizer costs. The IF system is expected to have more flexibility in distributing work loads over the course of a year, allowing farmers to earn additional income in their village's small processing industries. The IF system should combine short-term with mid-term and long-term goals, introducing better varieties and crops with higher economic value.

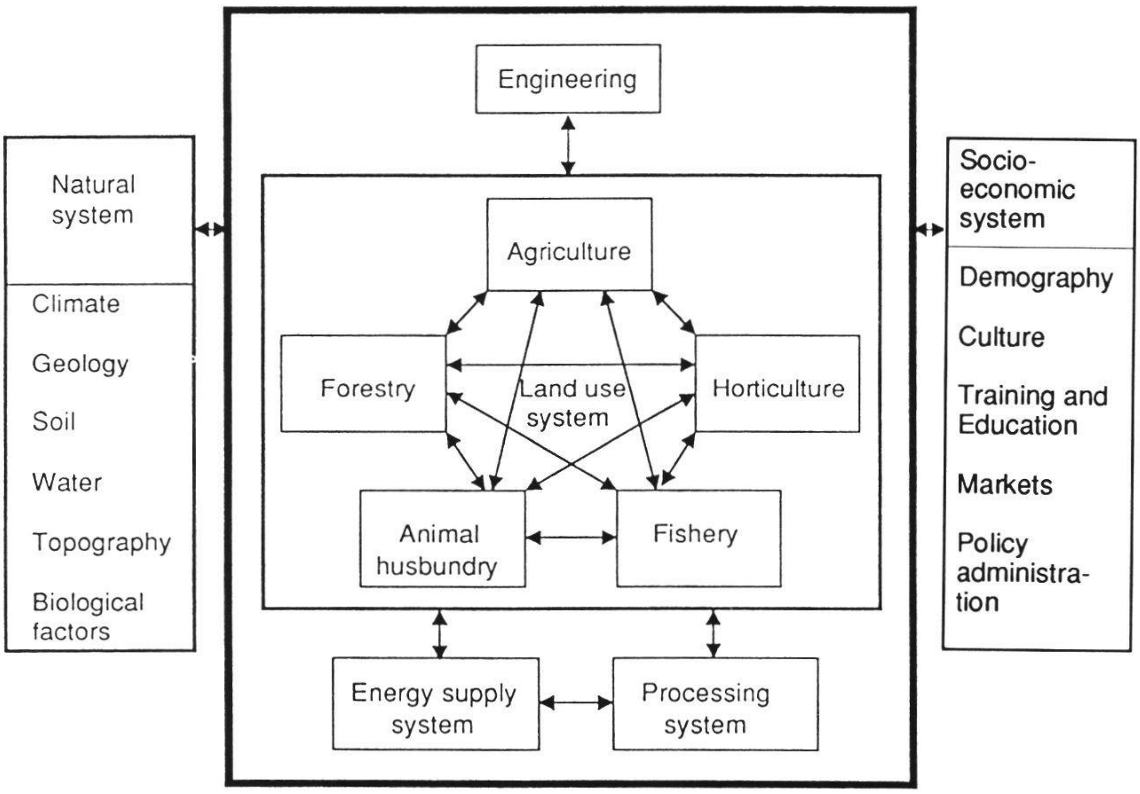

Fig. 3. Diagram of the structure of an integrated farming system.

5. IF's high ecological value, allowing multiple use, is achieved through recycling organic materials under the philosophy that by-products (waste) from the use of one resource must, whenever possible, become an input into another use of resources. IF is trying to use renewable energy and apply energy-saving techniques to complement the inadequate conventional energy. IF pays great attention to using organic fertilizers and biological pest control. Chemical input, while not excluded, is limited to a certain extent.
6. Although incentive is necessary, integrated farming tends to develop a mechanism, which can help the farmers to develop their economy on a self-reliant basis.
7. The IF concept can be used in different hierarchies, from the homegarden to farmland, watersheds of the regional and national levels if these areas are designated as integrated units for implementation.
8. The ultimate goal for the development of the integrated farming system is to achieve integrated ecological, economic and social effects, or in other words, to implement the concept of sustainable development in the rural area.
9. Research for integrated farming should be of a cross disciplinary character with interdisciplinary experts in participation.
10. For the implementation of IF, particularly in medium and macro-scale integrated farming, it is necessary to have the cooperation not only of the scientists and technicians but also of the farmers and related decision makers.

One can readily see that the integrated farming system bears similarities to many existing concepts, such as 'Agroforestry', 'Ecological Farming', 'Alternative Farming', 'Holistic Agriculture' etc. We do not intend to give a detailed review of the similarities and differences between these terms in this report. What we wish to emphasize is that integrated farming is generally understood in China in a wider sense. For example, woody species in most combinations are an important component of the integrated farming system. However, inclusion of woody species is not a prerequisite for the definition of an integrated farming system, if several non-woody species are deliberately managed in more than one component within one system.

Furthermore, integrated farming is treated as a physiological socio-economic system in which the off-farm production activities are also treated as elements of this system.

3. GUIDING THOUGHTS FOR THE IMPLEMENTATION OF INTEGRATED FARMING SYSTEMS IN CHINA

3.1. Sustainable development concept

Almost three decades have passed since the American biologist Rachel Carson published her book 'The Silent Spring'. She captured the imagination of the public with the graphic picture she drew of a world in which, as a result of the indiscriminate use of pesticides, the song of the birds at spring time would be lost for ever. Suddenly there was a new awareness that natural resources are not unlimited, and nature is no bottomless pit for pollutants and man generated wastes. The research of the Club of Rome and findings of the IGBP have shown us limitations of primary productivity and the potential limits of growth in the future. No matter how many different ideas have been expressed about these works, they have played an important role waking up the world's people. They were asleep in a deep dream of triumph in conquering nature. The people have since started to rethink the cost they have paid for their 'victory' and to seek a way to regulate the relationship between man, resources, environment and development.

Two important events are particularly worth mentioning here: the launching of UNESCO's Man and Biosphere Program in 1971, and the United Nations Conference on the Human Environment, held in Stockholm in 1972. Both programs laid emphasis on the vital feature of man's role in the ecosystem, and promoted the further improvement of rational utilization of natural resources and better environmental management through the efforts of different channels using multidisciplinary approaches.

For quite a long period, however, the ecologist and the people in the development department went their separate ways. It seems that development and conservation are incompatible. The contradiction between environment and development is that 'the environment is frequently placed in jeopardy by development'. It seems that if you want to have development, you must take the risks of environmental damage.

This situation did not improve until the concept of sustainable development was created. This concept has received increasing recognition from the public of different countries of the world.

The term 'Sustainable development' came into wide-spread use after the 1972 Stockholm UN Conference on the Environment, attended by 116 nations. Since then, more applications of environmentally sound development have taken place in the world. Especially two publications brought the concept of sustainable development to the attention of the whole world; the publication of the 'World Conservation Strategy' (1980) by IUCN, UNEP and WWF in collaboration with FAO and UNESCO, and the very influential Report, 'Our Common Future', prepared by the World Commission for Environment and Development (WCED 1983), an urgent call to address environmental issues by the UN General Assembly.

According to the WCED report, 'Our Common Future', sustainable development is a process of change in which the exploitation of resources, the direction of environment, the orientation of technical development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations (1987). The WCED report defines sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (1987). The assumption of sustainable development is that humans have the ability to make development sustainable.

Environmental management is only recently being seen less as a road-block to economic development than as a necessary prerequisite for it. The time has come for a marriage of economy and ecology, so that governments and the people can take responsibility for the policies that cause damage. That conservation and sustainable development are interdependent can be illustrated by the plight of the rural poor. The dependence of rural communities on living resources is direct and immediate. For the 500 million people who are malnourished, or the 1500 million people whose only fuel is wood, dung or crop wastes, or the almost 800 million people with an income of $50 or less a year - for all these people conservation is the only thing between them and at best abject misery, at worst death. Unhappily, people on the margins of survival are compelled by their poverty to destroy the few resources available to them. The vicious circle by which poverty causes ecological degradation leading to more poverty can be broken only by development.

The sustainable concept should be functioning not only as a guiding thought and declaration used in policy statements but should also play the role of an operating concept or planning strategy in the management of earth resources.

Some leading ecologists have adopted a more pragmatic approach, stating that these problems may be resolved if approached in a more comprehensive manner. ODUM (1989) urges that a more holistic way of thinking and action must be adopted to reduce regional stresses. He advocates a unified approach to the management of a region through cooperative planning by agronomy, forestry and industry.

Similarly, there is an increasing interest in bringing together the more basic and applied aspects in environmental sciences. Other authors in the same series point to the false dichotomy between ecology and agriculture sciences and to the successful converging of ecologists and agricultural scientists within agro-ecosystem science.
The integrated farming system is but one approach toward transforming the idea of sustainable development from a concept into reality. Whenever we design an integrated farming system we must keep in mind that conservation can be integrated with development by means of anticipatory environmental policies, coordinating mechanisms which ensure that a cross-sectorial integrated approach is used in solving the challenges we are now facing.

3.2. Integrated approach

Two features characterize our time. The first is that the present scope and rate of change and man's ability to effect change are unprecedented in the history of human kind. Second is the interconnectedness between countries and different departments. During recent years, the state of the world resources base and environment has continued to deteriorate, despite efforts to improve the situation. The failure thus far to successfully meet these challenges can be explained by the institutional deadlock prevalent in nearly all countries. Most institutions and sciences are organized along sectorial lines, making it difficult to deal with problems requiring a holistic approach.
The integrated farming system is not merely a combination of different crops/animals in space or time, it is also not merely a land use system, but rather a kind of integrated rural development pattern. So the integrated farming system is not an activity of any individual sector or discipline in its right. Along with creating integrated measures for its proper management, a cross-sectorial cooperation and a multidisciplinary effort under consideration of biophysical, socio-economic, cultural and political aspects is necessary to better understand the system's behaviour, its response to the biophysical environment and its resilience under various environmental stress factors.

3.3. Economic-ecological principles

The designation and implementation of integrated farming systems should be based on ecological principles.
Many concepts play important roles in the understanding and development of

integrated farming systems. These are, to mention only a few, the ecosystem, community, energy flow, materials cycling, niche, succession, competition, food nets, species diversity, ecological adaptation, conservation of resources, ecosystem fragility, density dependent regulation, limiting factors, maximum sustained yield and carrying capacity, etc. According to the concept of the ecosystem, living organisms and their non-living environment are inseparably interrelated to each other. The biotic community in a given area interacts with the physical environment, so that a flow of energy leads to a clearly defined biotic structure and a cycle of materials between living and non-living parts. The productivity and structure, decomposition and succession, the cybernetic nature and the stability of ecosystems not only exist in natural ecosystems but also govern the development of man-made ecosystems such as our integrated farming systems.

The flow of energy and cycling of material are the basic interactions inherent in the ecosystems. Some incoming solar energy is transformed and upgraded in quality by the community (that is, converted into organic matter, a more concentrated form of energy than sunlight), but most of it is degraded and passes through and out of the system as low quality energy. Energy can be stored and then 'fed back' or exported, but it can not be reused. In contracts to energy, matter, including water and vital nutrients (carbon, nitrogen, phosphorus etc.) can be used over and over again. Food chains are another important concept for the implementation of integrated farming. According to the two laws of thermodynamics, energy inflow balances the outflow and each energy transfer is accompanied by a dispersion of energy into unavailable heat (i.e. respiration). Secondary productivity tends to be about 10% at successive trophic levels, although efficiency may be higher, say 20%, at the carnivore levels. The unavailable part of energy consists of two parts. One part is used in the grazing food chain and loses a great deal in the form of transpiration. At the same time a large amount of energy enters directly into the detritus food chain and participates in the biogeographical cycle without any economic effect.

Biogeochemical cycles are recycling pathways through which the chemical elements, including all the elements of protoplasm, tend to circulate in the biosphere in characteristic paths from environment to organisms and back to the environment. These more or less circular paths are known as biogeochemical cycles. The movement of the elements and inorganic compounds that are essential to life can be conveniently designated as nutrient cycles.

Although the flow of energy and cycling of materials exist both in natural and man-made ecosystems, basic features of this process differ greatly between them. One distinct characteristic of the material and energy flow in man-made agricultural ecosystems is that a relatively high proportion of the produce is transferred to outside of the systems. In order to keep system sustainable, supplementary input of materials and energy should be provided through soil improvement measures, crop cultivation technologies, insect and pest protection measures and production processing measures. These subsidies come either from biological sources or from fossil energy. Thus in an integrated farming system, where the main purpose is the realization of sustainable development under environmental improvement and sustainable high productivity, the input of auxiliary energy is not refused. On the other hand, though energy can not be reused, we can regulate this process through the careful design of the composition and structure of the system as well as through the selection of appropriate agricultural techniques so as to obtain optimum economic efficiency, while sustaining a positive ecological balance.

The concept of limiting factors is valuable because it gives the ecologist an 'entering wedge' into the study of complex situations. Environmental relations of organisms are apt to be complex, but fortunately all possible factors are not equally important in a given situation or for a given organism. So primary attention should be given to those which are 'operationally significant' to the organism continuously during its life cycle. When we make an environmental impact statement or make an agroforestry designation, it is not to make long, uncritical lists of possible 'factors', but rather to achieve these more significant objectives: 1) to discover, by observation, analysis and experiment, which factors are 'operationally significant' and 2) to determine how these factors affect the individual, population, or community, as the case may be. In this manner, the effect of disturbances or proposed environmental alterations can be predicted with reasonable accuracy.

Ecosystems are rich in information networks comprising physical and chemical communication flows that connect all parts and steer or regulate the system as a whole. Accordingly, ecosystems can be considered cybernetic (from kybernetes = pilot or governor) in nature, but control functions are internal and diffuse rather than external and specified as in human engineered cybernetic devices. Redundancy - more than one species or component capable of performing a given function - also enhances stability. The degree to which stability is achieved varies widely, depending on the rigour of the environment as well as on the efficiency of internal controls. The stability actually achieved by a specific ecosystem depends not only on its evolutionary history and on the efficiency of its internal controls, but also on the input of the environment and perhaps also on its complexity. Functional complexity seems to enhance stability, but cause-and-effect relationships between complexity and stability are little understood. Some suggested that a diversity of species should enhance the stability of the biotic community, but species diversity per se has not proven to be strongly correlated with stability. However, the theory of redundancy or congenetaxis suggests that a moderate diversity of species, each capable of performing key functions, should contribute to controlled responses.

For the development of an integrated farming system, the economic and social conditions must be taken into consideration. Reviving growth is one of the most important tasks of the successful development of any farming system in rural areas of developing countries, because that is where links between economic growth, the alleviation of poverty and environmental conditions operate most directly. This can be reached through 1. rapid rise in incomes; 2. reduction of risks in agricultural production; and 3. combination of long term target with short term and medium term benefits. The ecological farming system can provide different products to satisfy the needs of farmers for not only conventional crops but also sawwood, firewood, posts, poles, fruit, fodder, vegetables, medical products etc., so that farmers do not need to buy these products or transport them from far away. Many perennial crops are "standing capital" that can provide produce over a long period and insure against emergencies in case of immediate cash need. On the other hand, the long-term investment for the establishment of perennial crops may be considerably reduced by the short-term income from annual crops during the early stages of tree growth. In integrated farming systems dependency and catastrophes associated with monocultures are overcome or mitigated. There is more flexibility in the distribution of the work load over the course of the year. Well designed successful schemes of integrated farming allow higher productivity by means of associating the most desirable plant and animal species in space and time, at the same time allowing a gradual change from destructive land use practices towards more stable and ecologically sound system.

4. SUCCESSFUL EXAMPLES OF INTEGRATED FARMING PRACTICES IN CHINA

Before successful examples of the implementation of integrated farming practices in China can be related, it is necessary to briefly review the classification of this complex system. The classification of integrated farming systems in China is far from being a completed task. Although the combination of components is the most commonly used criterion for the nomenclature of the systems, it can not provide a logical way of grouping all varieties belonging to different categories. The complexities of integrated farming itself imply that a single criteria classification scheme is inadequate. Therefore, it is suggested that integrated farming systems can be tentatively categorized according to the following sets of criteria:

1. Based on space scale of the system:
   Integrated farming systems come in all sizes according to which a unit can be distinguished into:

   - Micro-scale (as in home gardens)
   - Medium-scale (as agroforestry practiced on small farms)
   - Macro-scale (implementation of integrated farming in a watershed or establishment of a shelterbelt system on the regional and national level)

2. Based on the combination of components:
   In integrated farming, there are at least four basic production systems, agriculture (including horticulture and medicinal plant cultivation), forestry, animal husbandry and aquaculture. The combination and interaction of these components comprise different types of integrated farming systems. According to this criteria the following types can be distinguished:

   - Agro-silvicultural system
   - Silvo-pastoral system
   - Aqua-pastoral system
   - Agro-aquacultural system
   - Agro-silvo-aquacultural system
   - Agro-silvo-pastoral system
   - Silvo-aqua-pastoral system
   - Agro-aqua-pastoral system
   - Agro-silvo-aqua-pastoral system

3. Base on arrangement in space:

   - Evenly mixed type can be further subdivided into densely or sparsely mixed types

- Unevenly mixed type can be further subdivided into mosaic, alley cropping, hedge cropping, shelterbelts, etc.

4. Based on arrangement in time:
According to the arrangement of components in time, the following types can be classified:

Coincident, concomitant, intermittent, overlapping, separate, interpolated

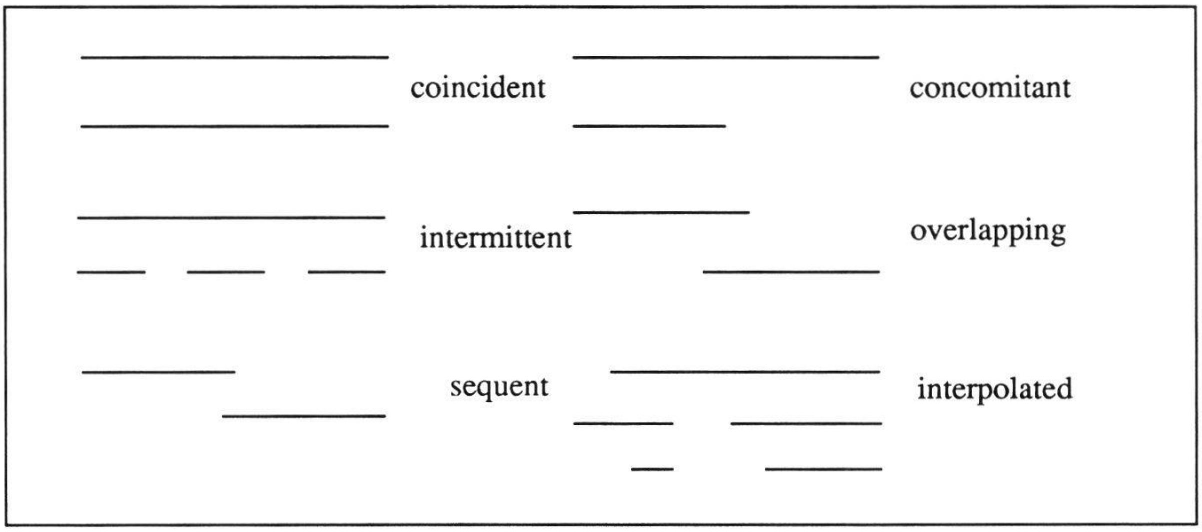

Fig. 4. Scheme of temporal arrangement of components. (NAIR 1989).

5. Based on management system:

- Multiple agricultural system
- Agriculture/industry interaction system
- Agriculture/industry/commercial interaction system

Theoretically,any variation of system combinations is possible, although only a few are widely used and successful. In this chapter, it is not intended to present a systematical review covering all existing integrated farming system types, but rather to introduce a few which are most widely distributed and demonstrate the most satisfying effects, from sociological, economical and ecological points of view.

4.1. Homestead gardens

Home gardens, as a kind of integrated farming system on a micro-scale level, can be found on every continent of the world. It is particularly common in the tropical region of Southeast Asia, the South Pacific and in the lowlands of South Asia. For example, Java's home gardens are often quoted as a good example in this respect. In East and Central America, there are various forms of home gardens, like Chagga home gardens, Nyabisindu systems, etc. In West Africa compound farming is another example. In the American tropics, homestead gardens are very common in thickly populated areas. Even in Mediterranean countries the home garden system in the oasis is also very common.
China has a long history in the development of homestead economy. Production from the homeyard has become an important part of the self-sufficient rural economy and an important part of the income of the rural poor. Chinese homestead gardens are characterized by numerous relatively small individual areas, intensive management and great varieties of patterns. In recent years, scientists have started to study this special micro ecosystem. A special book entitled 'The Homeyard Economy in China', was published by Prof. YING ZHENG MING (1990). The importance and principles of home gardening, a general survey of the existing patterns of home gardens in China, the input/output analysis and some technologies used in the home garden system were reviewed in this book.
We have mentioned the high population and increase of growth rate in China. Another thing, which is often ignored is the growth rate of the family. In China, due to the implementation of the family planning, the size of the family is decreasing, from 5.21 persons per family in 1949 to 4.48 persons in 1982. On the other hand, the number of families has been increasing at a growth rate of about 3% per year which, in comparison with the growth rate of the general population, is much higher. In the rural areas, once there is an individual, a small piece of land is allotted for to the construction of a house and some homestead production activities. At present, China has a total of 180 million families in the rural areas. The size of the land distributed to each family depends on the size of the family and the region. In general, it averages 0.3 mu or about 0.02 ha per household. In China the total area of homestead gardens consists 3.6 million mu or 6-16% of China's total arable land or twice the arable land of the Zhejiang Province.
It is interesting to note that though farmyards occupy a certain amount of land, decreasing the total arable land, the total production has not decreased.

This is due to integrated production and intensive management. For example, according to the survey of 30 households in the Shijiazhang area of the Hebai Province in 1983, the total privately owned land in homeyards is about 21 mu. Out of this area 3.98 mu are used for construction sites, 17.27 mu are used for other purposes other than agriculture, the area used for home garden production accounts for only 4.28 mu. But the total income from this limited area can reach as high as 30,584 yuan RMB, e.g. 7139 yuan per mu, about 20 times higher in comparison with the income from land with conventional cultivation (300 yuan per mu). Of the total area occupied by households, the average income per mu can still reach 1774 yuan, e.g. 5.92 times more than from conventional high yield culture land.

A homestead is an operational unit in which a number of trees and crops vegetables are grown in conjunction with fruit trees, livestock, poultry and/or fish, mainly for the farmer's sustenance.

Although sometimes home gardens appear to be a random mixture of trees, shrubs and herbs, a certain general pattern does seem to exist. The components are very intimately mixed in horizontal and vertical strata, as well as in time. Complex interactions exist between the soil, plants and other components and their environment in the plots around the house.

A home garden in China consists of a number of tree and fruit species and provides both productive and protective functions.

Among these, poplar, willow elms, *Sophora* and varieties of fruit trees like apple, pear, peach, date palms, *Ailantus* as well as vineyards, are common in northern China. In the subtropical region the litzhii, rangon, *Eryobotrya*, melia, orange and bamboo are the most common woody species. In the tropical region the mango, palm, banana, jack fruit, papaya, tamarindus and some tropical fruit trees are widely planted on homesteads.

On the ground level, a wide variety of vegetables, medicinal herbaceous plants and flowers are common species cultivated on homesteads.

Most farm families raise a variety of animals, such as cows, buffaloes, bullocks, pigs, sheep, rabbits, chickens, ducks and geese. In the low-lying regions of southern China and on the marshlands of northern China and in the coastal areas, aquaculture and mariculture is extensively practiced on homesteads adjoining canals, paddy fields and ponds. Sometimes earthworms and eels or other marketable aquatic animals are also involved in the systems.

Different animals have different energy and matter conversion rates. According to the study of Prof. Han chuungru et al. the ecological effects (output biological energy/input fodder energy) is about 15%. Out of the total output en-

Table 2. Energy and matter conversion rates of different animals.
*1 = mechanical holding, *2 = householding, *3 = average of different animals in response to their weights

		Bull	Cow	Sheep	Pig	Chicken *1	Chicken *2	Duck	Rabbit	Average *3
Output energy in biomass / Input energy of fodder		0.06	0.11	0.11	0.24	0.15	0.12	0.08	0.08	0.15
Output energy in edible part / Input energy of fodder		0.034	0.10	0.06	0.19	0.14	0.11	0.08	0.05	0.11
Output energy in manure / Total output energy (%)		73	74	72	66	59	68	81	82	70
N	Biological conversion rate (%)	11	21	24	27	22	18	21	17	17.70
	Return to soil rate (%)	48	45	45	53	31	36	33	45	45.52
P	Biological conversion rate (%)	11	14	22	12	23	19	27	9	14.63
	Return to soil rate (%)	88	76	71	76	54	63	55	61	77.33
K	Biological conversion rate (%)	2	13	5	15	6	5	4	5	6.01
	Return to soil rate (%)	80	59	74	82	73	85	86	77	77.99
Organic matter return to field (%)		32	38	19	43	20	36	25	32	32

ergy, the energy contained in manure consists of 60-80%. The conversion rate of N, P, K differs between animals. In general, the conversion rate of nitrogen is higher (17-18%) than P (14-15%) and K (5-6%). It has been calculated that for the increase of 1 kg of edible protein, 102.01 kg of fodder is necessary (Table 2).

A typical homestead with a multitude of crops presents a multi-level canopy configuration, particularly in tropical areas. The leaf canopies of the components are arranged in such a way that they occupy different vertical layers, the highest level having foliage tolerant of strong light with high transpiration demands and the lower-level components having foliage requiring or tolerating shade and high humidity. Many cash land medicinal plants are also permanent components of homestead gardens.

The components on the homestead are also selected according to the necessity of providing material for a cottage industry and sideline handicraft productions. For example, in the subtropical provinces of southern China, bamboo is planted around the family dwellings to provide material for weaving different bamboo products.

The implementation of biogas is also an important aspect in making up for the shortage of rural energy. It also strengthens the chain of nutrient cycling within the system.

Homestead gardens have a number of merits:

1. The multitude of crop species and animals on the homesteads helps to satisfy the needs of the farmers on the subsistence economy basis.
2. The mixed feature of the home gardens leads to substantial improvements of the physical and biological characteristics of the soil and environment.
3. The immediacy of human involvement and the full utilization of human waste can reduce the pollution of the environment.
4. The convenient location of the home gardens provides the possibility to effectively utilize the family labour. Much work can be accomplished during time free of field work. The old men and the women can also participate without wasting much time getting to the garden plots.
5. The ratio between input and output is higher than that of conventional work in the field.
6. A special microclimate is created within the homestead garden systems.

On the other hand there are some constraints in homestead garden system. Not all farmers have the knowledge to organize the different components in a proper manner. This leads to a reduction of yields in the individual understory crops. In the humid tropical and subtropical areas, a high plant density on homesteads can cause the fungi diseases, especially during the rainy seasons. Sometimes, the faulty utilization of wastes causes pollution.

4.2. Rotation and Intercropping System

Rotation and intercropping systems are widely practiced in different countries of the world. In China, due to diversified physiographical conditions and a long history of practical experience, hundreds of varieties of rotation and intercropping systems have been developed. A few of them are listed below.
Crop rotation systems:

- Legume → sorghum → millet/spring wheat → Maize
- Lucerne → cotton → maize → wheat
- Lucerne → wheat → maize
- Cotton → maize → winter wheat
- Maize → fallow → winter wheat
- Spring crops → winter wheat → summer crops
- Cotton (3 years) → spring maize → winter wheat → sweet potato
- Tobacco → winter wheat → maize → winter wheat → sweet potato
- Rice (3-5 years) → soybean
- Green manure crop of rice → rape → double cropping rice → wheat → double cropping

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Table 3 (p. 31). Summary of crop handling.
(RUDDLE and ZHONG 1988).

- Planting and harvesting months (Mo) numbered consecutively from January to December (1-12)
- Planting location (Loc.): E - Elephant grass dike, G - private plot, M - Mulberry dike (MS - Mulberry shed), P - pond perimeter, R - roadside, S - sugar cane dike, V - vegetable dike, W - water body

Btw. - intervals between rows in m
In. - intervals of individual plants in cm
I.D. No. - interplanting date with number of species
(a) - trellised
(b) - also known as *moagua*
(c) - harvested 50 days after planting
(d) - interplanting rare
(e) - broadcast, not deliberately spaced
(f) - harvested 40 days after planting
(g) - harvested 50-60 days after planting
(h) - leaf mustard is planted both in summer and winter. The former is planted 6-9 and harvested 80 days later. Plants are spaced 10 cm apart in the planting rows. Winterplanting is done 10-3 and also harvested 80 days later. Plants are spaced 40 cm apart in the planting rows.
(i) - also known as *dabacai*
(j) - also known as *hongluobo*
(k) - also grown in rice fields
(l) - a wide range of interplants is used; mostly cultivated around perimeters of dikes and along roadsides
(m) - the main planting months 6-9 and 9-10; generally planted throughout the year.
(n) - harvested throughout the year
(o) - planted throughout the year

Table 3. Summary of crop handling.

I.D.No.	Botanical identification	English name	Chinese name	Planting Mo.	Planting Loc.	Spacing In.	Spacing Btw.	Harvest Mo.	Interplants (I.D. No.)
Cucurbits									
1	*Benincasa hispida*	Wax gourd	donggua (a)	1-3, 9	V	80	3	4-8/9	14, 18
2	*Benincasa hispida* var.*chich-qua*	Hairy squash	jiegua (a, b)	1-3	V	20-25	3	4-5	14
3	*Cucumis sativus*	Cucumber	huanggua	1	V	10-15	2	3	14
4	*Cucumis melo* var.*conomon*	White melon	baigna	3-8	V	10	2	4-9 (c)	14
5	*Luffa acutangula*	Sponge gourd	sigua (a)	1-3, 9	V	20-25	3	1-8/9	14
6	*Momordica charantia*	Bitter cucumber	gugua	1-3, 9	V	10-15	2	4-6	14, 18
7	*Solanum melongena*	Eggplant	qiegua	12-1	V	50	1	3-4	14, 18
Leafy green									
8	*Allium tuberosum*	Chinese leek	jiucai	1-12	V	20	0.2	1-12	14 (d)
9	*Amaranthus gangeticus*	Chinese spinach	xiancai	1-4	V	(e)	(e)	(f)	none
10	*Beta vulgaris*	Beetroot	jundacai	12-3	V	35	0.3	2-5/6	none
11	*Brassica alboglabra*	Cabbage mustard	jielan	9-3	V	20	0.2	(g)	none
12	*Brassica chinensis*	Chinese cabbage	baicai	9-3	V	20	0.2	11-5	none
13	*Brassica juncea*	Leaf mustard	jiecai	(h)	V	(h)	0.2	(h)	none
14	*Brassica parachinensis*	Flowering cabbage	caixin	1-12	V	20	0.2	1-12	s.above/below
15	*Brassica pekinensis*	Beijing cabbage	shaocaì (i)	8-1	V	30	0.3	11-4	14, 44
16	*Brassica oleracea* var.*capitata*	Cabbage	yecai	7/8, 3	PV	40	0.4	10/11, 6	none
17	*Ipomoea reptans*	Water spinach	tongeai	3-10	V	20	0.2	?	none
18	*Lactuca sativa*	Lettuce	shengcai	9-3	V	20	0.2	11-5	1, 6, 7
19	*Spinacia oleracea*	Spinach	bocai	?	V	20	0.2	?	none
Peas and beans									
20	*Glycine max*	Soybean	Imangdon	3-6	SMV	25	0.3	5-8	39, 41
21	*Glycine soja*	Soybean	baidon	3-6	SMV	25	0.3	5-8	39, 41
22	*Phaseolus angularis*	Adzuki bran	hongdom	3-6	SMV	25	0.3	5-8	39, 41
23	*Phaseolus aureus*	Mung bean	ludon	3-6	SMV	25	0.3	5-8	39, 41
24	*Pisum sativum*	Garden pea	wandou	10-2	V	10-15	2.0	12-4	14
25	*Vigna cylindrica*	Catjang	meidou	3-6	SMV	25	0.3	5-8	39, 41
26	*Vigna sinensis*	Green cowpea	qingdoujiao (a)	1-8	V	10-15	2.0	3-11	14 (d)
27	*Vigna sinensis*	White cowpea	baidoujiao	1-8	V	10-15	2.0	3-11	14
Root crops									
28	*Colocasia esculenta*	Taro	yutou	3	EPS	-	-	7-9	41
29	*Daucus carota*	Carrot	huluobo (j)	11-2	V	-	-	1-4	none
30	*Ipomoea batatas*	Sweet potato	fanshu	7-8	PVR	20	2.0	12-1	none
31	*Pachyrhizus erosus*	Yam bean	shage	1-3	V	20	1.0	6-8	none
32	*Raphanus sativus*	Radish	luono	8-3	MV	-	-	11-6	39
Miscellaneous food crops									
33	*Arachis hypogea*	Peanut	huasheng	2	V	15	0.2	7	none
34	*Heleocharis tuberosa*	Water chestnut	mati	8	V (k)	?	?	10-1	none
35	*Nelumbo nucifera*	Lotus root	lian'ou	2-3	W	-	-	8	none
36	*Sagittaria sagittifolia*	Arrowroot	cigu	11, 8	VW	?	?	5-6, 12-1	none
37	*Zea mays*	Maize	yumi	2, 6	PRV	45	0.4	5, 9	none
Commercial crops									
38	*Agaricus campestris*	Meadow mushroom	mogu	11	MS	-	-	1	none
39	*Morus atropurpurea*	Mulberry	sang	1-2	MD	12	0.6	5-11	s. above
40	*Musa paradisica*	Plaintain	xiangjiao	1-8	EPR	2-300	2.5	10-8	(l)
41	*Musa sapientum*	Banana	dajiao	1-8	EPR	2-300	2.5	10-8	(l)
42	*Saccharum officinarum*	Sugar cane	ganzhe	2	S	30	1.3	2-3	s. above
Livestock feed									
43	*Eichhornia crassipes*	Water Hyacinth	jiashuixian	(m)	W	-	-	(n)	none
44	*Pennisetum purpureum*	Napier grass	xiangcao	2	GPRE	20	0.2	(n)	none
45	*Pistia stratiotes*	Water lettuce	shuifulian	(o)	W	-	-	(n)	none

Major types of intercropping between agricultural crops:

- Green manure + cereal crops
- Maize + potato
- Maize + mushroom
- Wheat + cotton
- Cotton + rape

By rationally designing the rotation of crops, this system makes full use of solar energy and land resources, maintains a good nutrient balance, and controls damage done by disease, pests and weeds.
For example, a field in legume-rice rotation may produce 1500 kg/ha of soybeans or 6400 kg of late hybrid rice. Such harvests are much greater than those of the widespread rice-green manure type of rotation.
Another successful example is the legume-cereal-fallow root crop rotation system. This model is common in China's subtropical and tropical regions. With land usually divided into four sections for the year's crop, cultivation is rotated after each harvest in the sequence shown. This permits the soil to be replenished in alternating plots, either by lying fallow or through nitrogen fixation via legumes. Bush vegetation developing in the fallow plot and the legume plant-parts remaining after harvest serve as mulch to prepare the soil for new planting.
Cotton-wheat intercropping has been used in China since ancient times and has greatly improved in recent years. In the fallow year before sowing cotton, green manure is ploughed under, and wheat-green manure intercropping follows the next autumn. Sown cotton is covered by plastic sheeting, allowing the soil temperature to rise while the moisture is retained. As a consequence, cotton seedlings germinate earlier with a rise in the rate of germination of about 20%. This is beneficial for the control of injury caused by the cotton aphid, thus reducing the pesticide dose and saving labour. Intercropping can yield 3000 kg of wheat/ha, 10000-15000 kg of fresh, green manure and more than 750 kg of cotton.
Cotton-rape intercropping is a good example for reducing insect damage. When the cotton aphid was controlled mainly by pesticide, this led to serious damage, including the killing of the natural enemies of injurious insects. In early May, the cotton aphid's main natural enemy is the seven-point lady beetle. The propagation of this insect can be accelerated by intercropping rape with cotton. Rape being the host of the rape aphid, the latter then becomes the food of the beetle. As soon as the cotton aphid appears, the beetle shifts to cotton crops to devour the cotton aphid - permitting this pest to be maintained beneath the critical level.

Mushroom-crop as a new intercropping scheme has been successfully developed in China in recent years. There are different combinations: growing mushrooms in fields of cereal crops, with sugar cane, in orchards, etc.
Most mushrooms belong to the phaeophilic group and do not need illumination during growth. The upper layer of companion crop provides good shade, low temperature and high moisture to meet the mushroom's needs. After harvesting, the soil retains high nutrients, e.g. nitrogen and potassium, and offers a high-quality manure for cereals, sugar cane and fruit.
Intercropping systems are even more commonly used in vegetable production practices. With a long history of experience to draw from, Chinese farmers have developed hundreds of patterns in vegetable intercropping to maximize use of space and time and to sustain yield. Farmers have rich experience in arranging their farming activities according to their life forms and the agricultural calendar. Here a dyke-pond system in the Guangdong Province is introduced. Table 3 shows only the main commercial and subsistence crops grown by one production team.

4.3. Agro-silviculture system

The term, agro-silviculture system, or agroforestry in a narrower sense, is used here to encompass any combination of trees and/or shrubs with crops either spatially or sequentially. Agroforestry is an age-old practice and is extensively used not only in tropical regions but also in the subtropical and temperate regions of China. There are different patterns in different zones. For example, in northern China, the *Paulownia* + cereal crop system, date palm + cereal crop system and poplar + cereal crop system are the most popular patterns. In addition to this, black locust (*Robinia pseudoacacia*), Chinese pine (*Pinus tabulaeformis*), Mongolian scots pine (*Pinus sylvestris* var. *mongolica*), Chinese ash (*Fraxinus chinensis*), peach (*Persica davidiane*) and Arbo vitae (*Biota orientalis*) are common. In arid and semiarid land, more shrubs are introduced in this system. For example, seabuckhorn (*Hippophaë rhamnoides*), sacsaoul (*Holoxylon ammodendron*), oleaster (*Elaeagnus angustifolia*) and false indigo (*Amorpha fruticosa*) etc. are found in the agroforestry systems.
In subtropical zones, the most popular combinations are Chinese fir (*Cunninghamia lanceolata*) + cereal crops, *Metasequoia* + cereal crops, swamp cypress + cereal crops, *Alnus nepalensis* + cereal crops and *Eucalyptus* + cereal crops, etc. In tropical zones, the agro-silviculture system has become

Table 4. List of major woody perennial species as reported as components of existing agro-silviculture systems in different regions of China.
N - Northern China, NW - Northwestern China, NE - Northeastern China, S - Southern China, SE - Southeastern China, SW - Southwestern China

Species	Region of distribution	Species	Region of distribution
Acacia auriculiformis	S	*Gleditsia sinensis*	N
Acacia confusa	SW	*Glyptostrobus pensilis*	SE
Acer negundo	N	*Haloxylon ammodendron*	NW
Ailanthus altissima	N	*Haloxylon persicum*	NW
Albizzia julibrissin	N	*Hedysarum scoparium*	NW
Alnus japonica	NE	*Hibiscus tiliaceus*	N, SW
Alnus nepalensis	S	*Hippophae rhamnoides*	N,NW,SW
Amorpha fruticosa	N	*Juglans mandshurica*	NE
Anthocephalus chinensis	S	*Juglans regia*	N
Armeniaca sibirica	N, NW	*Juniperus chinensis*	N
Artocarpus heterophylus	S	*Juniperus virginiana*	S
Cajanus cajan	S	*Koelreuteria paniculata*	S
Calophyllum inophyllum	S	*Larix gmelini*	NE
Camellia oleifera	S	*Larix leptolepis*	N
Camptotheca acuminata	SW	*Larix olgensis*	NE
Caragana intermidia	NW	*Larix principis-rupprechtii*	N
Caragana korshinskii	NW	*Larix sibirica*	NE
Caragana microphylla	NW	*Lespedeza bicolor*	N, NW
Carya illinoesis	N	*Leucaena leucocephala*	S
Cassia siamea	S	*Lycium barbarum*	NW
Castanea mollisima	N, SW	*Malus prunifolia*	N, NW
Casuarina equisetifolia	S, SE	*Melia azedarach*	SE
Catalpa bungei	SW	*Metasequoia glyptostroboides*	SE
Cinnamomum camphora	S	*Morus alba*	N, S
Cocos nucifera	S	*Pandanus odoratissimus*	S
Corylus heterophylla	S	*Paulownia elongata*	N
Crataegus pinnatifida	NE	*Phellodendron amurense*	NE
Cryptomeria fortunei	N	*Picea koraiensis*	NE
Cunninghamia lanceolata	S, SW	*Pinus caribaea*	S
Dendrocalamus strictus	S	*Pinus elliottii*	S
Diospyros kaki	S	*Pinus massoniana*	SE
Duabanga grandiflora	N	*Pinus sylvestris* var *mongolica*	NE
Elaeagnus angustifolia	S	*Pinus tabulaeformis*	N
Eucalyptus citriodora	SW	*Pinus taeda*	S
Eucalyptus exserta	SW	*Pinus thunbergii*	N
Eucalyptus globulus	SW	*Pistacia chinensis*	S, SW
Eucalyptus robusta	S, SW	*Pistacia vera*	NW
Eucommia ulmoides	S	*Platanus acerifolia*	S
Evonymus bungeana	N	*Platycladus orientalis*	N
Fraxinus americana	N	*Populus alba*	NW
Fraxinus chinensis	N, NW	*Populus baichehensis*	NW
Fraxinus mandshurica	NE	*Populus berolinensis*	N
Fraxinus sogdiana	N	*Populus bolleana*	NW
Gleditsia horrida	N, NW	*Populus canadensis*	N

Table 4 (continued)

Species	Region of distribution	Species	Region of distribution
Populus cathayana	N	*Quercus mangolica*	NE
Populus euphratica	NW	*Robinia pseudacacia*	N,S,NW
Populus euramericana cf. (I-214)	N	*Salix alba*	N
Populus euramericana cf. (Sacrau 1979)	N	*Salix babylonica*	N, SW
		Salix gordejevii	NW
Populus lasiocarpa	N	*Salix mongolica*	NW
Populus nigra var. *italica*	N	*Salix matsudana*	N
Populus nigra var. *thevestina*	N	*Salix purpurea*	N
Populus nigra var. *thevestina x simonii*	N	*Sapium sebiferum*	SW
		Sophora japonica	N
Populus pekinensis	N	*Tamarix chinensis*	N, NW
Populus pseudo-simonii	N, NW	*Tamarix ramosissima*	NW
Populus simonigra	N, NW	*Taxodium assendens*	S
Populus simonii	N, NW	*Taxodium distichum*	SE
Populus simonii x nigra var. *italicax*	N	*Toona sinensis*	N
		Ulmus macrocarpa	N
Populus simopyramidalis cf. (Nanlin)	N, NW	*Ulmus laevis*	S
		Ulmus pumila	N
Populus tomentosa	N	*Xanthoceras sorbifolia*	N, NW
Prunus amygdalus	NW	*Zanthoxylum bungeanum*	S,SW,N
Prunus persica	N, NW	*Zelkova schneideriana*	SE
Pterocarya stenoptera	SW, SE	*Zizyphus jujuba*	N
Quercus acutissima	N		

highly developed. For example, the following intercropping systems can be found in Xishangbana, Yunnan Province.

Corn + *Anthocephalus chinensis*
Corn + *Alnus nepalensis*
Dry rice + *Cassia siamensis*
Dry rice + pineapple
Dry rice, corn + *Cajanus cajan*
Dry rice + *Gmelina arborea*
Dry rice, corn, soybean + *Gmelina arborea*
Dry rice + *Perilla frutescens*
Dry rice + *Pinus kesiya*
Pomelo + coffee
Rubber + tea
Rubber + *Amomum villosum*
Rubber + *Homalomens occulata*
Rubber + *Rauwolfia yunnanensis*
Tea + Yunnan camphor
Tea + *Alnus nepalensis*

Rotation of dry rice, corn, peanuts and soybeans with *Crotalaria usaramoenisis, Crotalaria junca, Crotalaria micens* and *Vigna umbellata* is also practiced.

The perennial woody legumes, *Moghania macrophylla* and *Pueraria wallichii* were tested.

The major woody perennial species reported as components of existing agro-

silvicultural systems in different regions of China are listed in Table 4. While agro-silviculture systems cater primarily to timber, fuel wood and fodder, there is also a big demand for fruit trees. These include apple, apricot, peach, plum, citrus, walnut, persimmon, mango, litchi, date palm, grape vine, etc. Another commonly practiced pattern is the interculture of crops, vegetables, flowers, rhizomatous, aromatic and medicinal herbs in the orchards. In general, fruit crops can generate 2-5 times more income than the grain crops from the same piece of land. Additional cash income from intercrops may be provided not only in the initial years but also after the orchards become productive. Though intercrops may adversely affect the growth of the fruit trees by competing for moisture and nutrients, they may also help to create favourable conditions in the rhizosphere through symbiotic microorganisms, decomposed dead roots and/or root exudates.
Here we only introduce a few of them.

4.3.1. *Paulownia*-crop intercropping system

The *Paulownia*-crop interplanting system is one of the most popular models of integrated farming and is widely practiced on the Northern Plain. According to a preliminary estimate, the area with a combination of *Paulownia* and different varieties of crops consists of more than 3 million ha, of which more than 2.5 million ha are found in Henan and Shandong Provinces.
The plains of northern China are located between 30°-40° N and 109°-122° E. The warm temperate climate of the area belongs to the subhumid continental monsoon type. In winter it is dominated by the Mongolian-Sibirian high pressure system. From October to the first part of June the prevailing dry northerly winds sweep over this region. In summer the conditions are completely reversed. A low pressure system, and warm moisture-laden southerly winds prevail. Although such reversals in the monsoon winds are noticed all over eastern monsoonal China, nowhere else is the contrast as great as on the northern plain. The soil in this area is alluvial and much of it is rather poor. Wet soils (fluvisols) develop as a result of a high water table. Tracts of saline and alkaline soils (solonchaks) are found along the coastal belt as well as in the central parts of this great plain.
Being the biggest plain, this region is the main agricultural production base in China. Unfortunately, a long list of natural disasters, sandstorms, droughts, floods, freezing and particularly the so-called dry, hot wind with speeds of over 3 m/sec., temperature of over 30°C and a relative humidity of less than

30%, often occur in this area. The production of agricultural crops, particularly wheat, the main crop of this region, is significantly influenced by these natural catastrophes. Sometimes 20-30% of the wheat production is lost as a result. At the same time, this region is one of the most highly populated areas of China. Natural vegetation has almost completely disappeared as a result of long habitation and exploitation. Timber, fuel and fodder are scarce.

Since the fifties, much attention has been given to planting trees for timber, fuel wood and windbreaks. Many species have been used for this purposes, among them, the *Paulownia* is one of the best suited.

Paulownia is an extremely fast growing and adaptable species with wide distribution in the middle and southern part of China. There are nine species of *Paulownia*, among which *Paulownia tomentosa*, *P. elongata*, *P. catalpifolia* and *P. fortunei* are the most commonly used in this agro-forestry system. Under normal conditions, a ten-year-old *Paulownia* can reach 30-40 cm in diameter,10-12 m height with the timber volume of 0.2-0.5 m^3. However, in a good habitat, individual eleven year growth trees can demonstrate much better growth indicators (Table 5).

Table 5. Growth of trees of different species of *Paulownia*.

Species	Diameter (cm)		Height (m)		Timber volume (m^3)	
	Average	Annual increment	Average	Annual increment	Average	Increase (%) Index (*P. glabrata* = 100)
P. elongata	39.6	4.0	13.2	1.3	0.6232	306
P. catalpifolia	25.0	2.5	11.5	1.2	0.2996	140
P. tomentosa	28.1	2.8	10.2	1.0	0.2426	120
P. glabrata	27.3	2.7	9.9	1.0	0.2020	100

Paulownia is a deep rooted tree and can reach 0.8-1.5(2.0) m with limited a spread in the upper part and a large spread in the lower part.

Paulownia trees, especially *P. elongata*, are deep rooting. In sandy and other soils, an average of 76% of the absorbing root systems is a depth of 40-100 cm, and only 12% in the cultivated land at a depth of 0-40 cm (Table 6). In contrast, root systems of the main crop plants are distributed mainly near the surface layer. Nearly 80% of the roots of wheat, 95% of maize an 97% of millet are found within a soil depth of 40 cm. Therefore, competition for water

Table 6. Distribution of roots of *Paulownia* roots and crops.

Soil depth (cm)	*Paulownia* absorbing roots		Wheat		Millet		Maize	
	weight (g)	%	weight (g)	%	weight (g)	%	weight (g)	%
0-10	12.4	1.1	12.9	26.6	33.8	79.2	58.6	61.7
10-20			15.7	21.9	5.4	12.6	18.6	19.6
20-30	119.2	10.9	14.3	20.0	1.4	3.3	8.3	8.7
30-40			8.1	11.3	1.0	2.3	4.4	4.6
40-50	327.6	30.0	4.8	6.7	1.0	2.3	3.5	3.7
50-60			4.2	5.9	0.1	0.3	1.6	1.7
60-70	224.8	20.6	3.1	4.3				
70-80			1.0	1.4				
80-90	271.6	24.9	0.9	1.3				
90-100			0.2	0.3				
100-120	81.9	7.5						
120-140	38.2	3.5						
<140	16.4	1.5						

and fertilizer between the trees and food crops is almost negligible. On the contrary, the water in the deeper layer and the fertilizers leached into it may be absorbed by the roots of the *Paulownia* trees. In the dry season, *Paulownia* can absorb underground water from the deeper layers and humidify the air by transpiration, which is beneficial for the growth of food crops.

The crowns of *Paulownia*, especially of *P. elongata,* are thin and a large amount of light can pass through. The light penetration through the crown of 7-8-year-old trees at the beginning of summer (in June) is 40-50%, and remains stable around 20-40% in the middle and later periods of crown growth. Since the branching angle of *Paulownia* is large, the leaves are spread systematically and seldom overlap, so food crops may obtain much light at all times. The light penetration through *P. elongata* crowns is 20% higher than that of poplars (*Populus tomentosa*) and 38% higher than that of black locust (*Robinia pseudacacia*). The leaf renewal and leaf fall periods of *Paulownia* are later than most of the other tree species. Late leaf renewal favours the growth of summer crops and late leaf fall protects autumn crops from damage.

The spatial arrangement of the intercropping system depends on its objectives. Three kinds of intercropping are common:

a) Primary objectives is silviculture and intercropping is secondary: In this case the spacing should be 5x5-10 m, with 200-400 trees/ha. In the first three years after planting the trees, it is normally possible to obtain yields similar to those in the control plot. After four to six years, the yield of summer crops (wheat, rape seeds and vegetables) is still normal but the yield of autumn crops, except some shade-intolerant crops, is significantly reduced. After six to ten years, 80% of the normal yield of summer crops can still be obtained. Under usual conditions in the north central area, if the rotation is ten years, the total yield of crops can be about 37.5 tons and timber volume 80-140 m^3/ha during this rotation.

b) Intercropping and silviculture are equally important: In This case the spacing is usually 5x15-25 m, with 80-133/ha. In the first five years after intercropping, the yield of the agricultural crops is rather higher than in the control plot. In the next five years, the yield of summer crops usually increases but the yield of autumn crops decreases. Over ten years, the total yield of the agricultural crops is approximately the same as that in the control plot and the *Paulownia* timber volume reaches 36-53 m^3/ha.
c) Primary objective is intercropping, silviculture is secondary: The spacing should be 5x30-50 m, with 40-67 trees/ha. This method is most widely used at present and has been the main object of our research since 1976. In intercropped areas with 5-11-year-old trees, (diameter 16-34 cm, height 6-12 m, crown diameter 6.2-8.4 m, spacing 4-6 x 30-50 m), observations were made on the root distribution, the light penetration through the canopy and the variation in the output of different food crops. In addition, systematic observations were also made on different factors of the microclimate, such as radiation, temperature, moisture, wind speed, evaporation and moisture content of soil. The conclusions reached are as follows.

Comparisons made between an intercropped field and a control plot show that intercropping can reduce the wind speed by 21-52% on an average, and reduce the evaporation rate by 9.7% in the day time, 4.3% at night. The moisture content of the soil at 0-50 cm is 19.4% higher than that of the control land. Intercropping also favourably influences temperature. At the end of Autumn, in winter and in early spring when the trees are leafless, the wind speed is reduced by the wind resistance of the branches. As a result, the temperature is 0.2-1°C higher than the control land. In summer, in the intercropped land, the temperature is reduced by 0.2-1.2°C during day time. All this helps to protect against natural disasters such as drought, wind, sandstorm, dry and hot wind, and early and late frost.

Random samples were collected to compare the yields of intercropped and control land, basically under the same management conditions. On the incropped land, the yield of wheat increased by 6-23%, millet by 20%, maize by 7.5-17%. The yield of cotton and soya beans was basically the same as in regular fields but sometimes the yield increased or decreased depending on climatic conditions. Normally, it increased when it was dry but decreased when it was wet due to either rain or irrigation. The yield of sesame decreased by 5-10%, and sweet potato by 32-38%. These crops are not suitable for intercropping with *Paulownia*, especially with large trees more than 5-year-old.

During intercropping, the intensive management of the agricultural crops creates better growing conditions of *Paulownia* than in a pure *Paulownia* plantation.Under intercropped conditions, 10-year-old *Paulownia* trees reach a mean diameter of 35-40 cm, yielding a timber volume of 0.4-0.5 m^3/tree, and sometimes up to 1.5 m^3/tree. If 50 trees are planted per hectare, 20-25 m^3/tree of timber will be produced in ten years. This is of great significance for increasing the income and improving the living standard of the rural people.

The whole *Paulownia* tree is a valuable asset to the farmer. Besides the timber, the branches, leaves and flowers are used. One 10-year-old *Paulownia* tree can produce 350-400 kg of branches for fuel. The leaves and flowers are rich in nutrients and are suitable for feeding pigs, sheep and rabbits. The leaves are rich in nitrogen (3.09% dry weight). A single *Paulownia* tree, 8-10 years old, normally produces 100 kg of fresh leaves per year (equal to 28 kg of dry leaves). Therefore, intercropping is a natural source of nutrients.

In conclusion, intercropping over large areas in the plains promotes timber production. Thus, the vast area of farmland will be used for producing agricultural products, but also for producing timber and fire-wood. This constitutes a new type of shelter belt forest for farmland which creates a proper environment for growth of both food crops and *Paulownia* trees.

4.3.2. Poplar-crop intercropping system

Poplar, regarded as an agriculture crop by the local farmers, is widely cultivated in combination with wheat, cotton, vegetables etc. on the northern plain and in the northwestern region of China. Among these combinations poplar-wheat intercropping is the most widely used.

This intercropping system can make full use of agricultural resources for the production of both grain and timber, as well as sustaining the good quality of the environment.

Within the past 30 years, cultivated poplar clones have experienced several replacements. Every replacement has greatly raised the productivity of the poplar plantation. For example, in the Linfen Prefectures of the Shanxi Province, the major species used were *Populus simonii* and *P. canadensis* in the 1950s, *P. nigra* var. *thevestine* and *P. nigra* var. *thevestine* x *P. nigra* var. *italica*, in the 1960s and 1970s, and *P. euramericana* cl. 'Luisa Avanzo' were introduced in the 1980s.

There are two major forms of poplar-wheat intercropping. The first form is widely spaces rows (8-15 m) of closely planted trees (1-2 m). Clones with narrow crowns, such as *P. nigra* var. *thevestina* and *P. nigra* var. *thevestina* x *P. nigra* var. *italica* are particularly suited to this form. The trees are thinned in the fourth or fifth year. The plantation is not closed in the crowns. Apparently, wheat yield does not decrease in comparison with monocultures.

The second form is trees planted as far apart as the space between rows (5x5 or 6x6 m. Poplar clones with large crowns, e.g. *P. euramericana* 'Sacrau', *P. euramericana* 1-214, *P. euramericana* 1-72/58, *P. euramericana* Luisa Avanzo and *P. deltoides* 1-69/55 are suitable.Thinning is conducted in the eight to the tenth year.

The economic effect of the poplar-wheat plantation depends on environmental conditions, the pattern of the plantation, as well as management measures. In general, both pure wheat and pure poplar plantations yield less than an intercropped field with widely spaced rows of closely planted trees. A distance of 10-20 m between rows and 2-3 m between trees, and one thinning, or 1-1.5 m and two thinnings, and then a harvest in the eighth or tenth year have proven to be best pattern with mechanical ploughing. It ensures a steady wheat and timber yield and thus, a good income.

Winter wheat is sowed in October. It turns green in March of the next year, is in the milk and mature from May 15 to the middle of June. Poplar buds in mid March and all leaves are open by May. The fast growing stage of poplar begins in the middle of June when the wheat has already been harvested.

On the northern plain, the xerothermic wind and extremely hot weather, which usually occur in the milk period, generally reduce the wheat yield by 20-30%. However, in the intercropped field, relative humidity is increased by 10-20%, temperatures are reduced by 1-2°C, and wind speeds by 2-4 m/sec. Intercropping obviously improves the microclimate to favour high wheat yields.

By the fifth year, as the trees' crowns and root systems increase in size, competition with the wheat for water, nutrients and light has become quite sharp. In this case, the trees should be thinned in order to maintain the stability of the system, thereby increasing the income and ensuring that the farmer's requirements are met.

4.3.3. Date tree-crop intercropping system

Chinese date tree (*Zizyphus jujuba*)-crop interplanting is widely distributed in the northeast of the Shandong Province and in the eastern part of the Hebei Province where drought and flood often occur. About 50'000 hectares of this interplanted land are located in the area of the Cangzhou Prefecture in the Hebei Province (no estimations of any other areas are available).

In the Cangzhou Prefecture, Chinese date tree interplanting patterns vary in different places having three patterns of combination.

1. Interplanting with stress on the production of Chinese date trees: In this interplanting pattern Chinese date trees are planted 3-5 m apart in rows separated by 6-9 m distance. There are more than 300 Chinese date trees per hectare combined with cereal crops, like wheat and millet, or legumes, peanuts and sweet potatoes etc.
2. Interplanting with equal stress on crops and date trees: This design has Chinese date trees arranged 3-5 m apart with 10-15 m between the rows. This allows for less than 300 date trees per hectare. The other crops are planted in varying distances to the trees, commonly the smaller crops growing closest to the trees and taller crops, such as corn etc. planted more distantly to the trees.
3. Interplanting with stress on cereal crops: Less than 150 trees per hectare can be counted when they are planted 3-5 m apart in rows and 16 to 50 m apart.

Different varieties of Chinese date trees will be found in the fields where the interplanting system is used. In the Cangzhou Prefecture most are golden-thread dates. During the full fruit period the date tree grows about 4.5 m high, having a crown diameter of about 4 m. Branches and leaves are sparse and scattered. The shady area is small.

Compared with mono-agricultural farming the positive economic effects of the Chinese date tree-crop interplanting system is obvious. Twenty hectares of interplanted fields were cultivated in Xucun, Cangxian County, and the Hebei Province. From 1975 to 1983 the average yield of crops reached 622 kg per hectare and year and the yield of dry dates was 5.438 kg per hectare and year. According to the current market, the price for dry dates is 1 RMB per kg. The cash income is much higher compared to cereal crops. In addition, the interplanting of date trees among field crops has a favourable effect on their growth and development. In the Cangzou Prefecture of the Hebei Province, golden thread date trees begin to bud during the first ten days of April, developing through May and into June. After June the trees grow more densely, throwing more shade.

In the above mentioned area, wheat regeneration occurs in early March. During the heading stage in mid May, wheat needs much energy. If the date trees are to have only minimum negative influence on the grain field, the wheat must have completed its heading stage before the date trees' new foliage is fully developed.

In late May and early June, the wheat is in the milk stage and is sensitive to strong light and xerothermic conditions. But by this time, the date trees are fully developed and their shade prevents the light from inhibiting the wheat's milk stage. The trees also break the wind, thereby preventing intensive evaporation of the wheat leaves. The reduced wind speed also allows higher air humidity which decreases the danger of xerothermic damage. The result is a high yield of plump-grained wheat. According to a survey of wheat-grains raised in the interplanted fields of the Wenmiao Commune in the Jiaohe County, 1'000 pieces of grains weighed 2-3 g more than wheat raised in a monoculture.

The interplanting of the Chinese date tree with grain crops raises grain's resistance to water-logging and frost injury. The Jianghuangzhuang Brigade of the Liahoe County experienced heavy rainfalls in July, August and September of 1970. They reverted mostly to single crop farming because of the high water table. However, in the interplanted fields the problem was solved, because the date trees evaporate large amounts of water.

Sometimes, unusually low temperatures in winter and spring will kill off wheat seedlings. In the village of Huangdipu in the Cangxian County, the death rate of wheat seedlings in a monoculture was estimated at 25% and in some more heavily damaged plots, at 52%. In comparison, wheat seedling loss in fields interplanted with Chinese date trees was only 12.5%, and loss in a hard hit plot was 30%. The monoculture wheat yield averaged 615 kg per hectare and year, whereas interplanted fields yielded almost double as much as 1.125 kg ha/year.

4.3.4. Slash pine-tea intercropping system

This combination is practiced in the subtropical region of China and was studied by the Agricultural college of Anhui Province. The experiments were established in 1970. Tea bushes were planted 0.33 m apart with 1.5 m between rows. Slash pine trees were spaced at 7.5x7.5 m between the tea bushes. The results show that light intensity in the interplanted field is 38.2-45.2% lower than in a monoculture. The temperature is 1-3°C lower during the day time and relatively higher during the night. The daily temperature fluctuation is smaller in the intercropped area, the relative humidity of the air is higher in summer, and there are fewer nutrients in the upper and more in lower soil layers. Physiological studies establish that the net photosynthesis of tea is 4% greater and evapotranspiration is 20.3-21.3% less than in a pure tea plantation. The anatomical structure of the tea leaves in intercropped areas is different than in monocultures. The upper epidermis, palisade tissues of the leaves are thinner and the yield is 6% higher in comparison to those of exposed tea bushes. There are more caffeine and amino acids and the ratio polyphenol to amino acids is lower in the leaves of the intercropped area.
All this indicates that the quality of the tea leaves in the intercropped areas is higher as compared to those of pure tea plantations. In addition, the interplanted slash pine can provide 49.5 m^3 of timber. Therefore, the comprehensive economic benefit of the intercropped tea plantation is 30% higher than that of a monoculture.

4.3.5. Rubber-tea intercropping system

This system is widely practiced in the tropical region of the Yunnan and Hainan Provinces. The Yunnan Institute of Ecology, Chinese Academy of Sciences (CAS), and the Hainan Reclamation Bureau have carried out in-depth studies on this system. In the 20 years it has been practiced and researched, the artificial rubber-tea community has become widely popularized and covers over 13'300 hectares in the Hainan, Yunnan, Guangdong and Guangxi Provinces. The studies have shown that the rubber-tea plantation can increase land use efficiency by 50% as compared with in monoculture rubber plantations; the pre-production period is shortened by 1-2 years, and the production period extended from 22 to 27 years.
In addition to the above mentioned economic advantages, the intercropping system can combine long term with medium term profits. Usually, rubber tap-

ping begins in the tree's eighth year, whereas the companion tea bush may begin to produce 4-5 years earlier, thereby reducing investment and speeding up capital turnover.

Due to the increase of litter, soil microorganisms and animals, and the decrease of soil soil and organic matter erosion, and loss of mineral nutrient contents, the overall soil fertility in rubber-tea plantations is increased. The multi-layer community protects the soil surface from direct impact of the weather, thereby reducing run-off and soil erosion. In addition, the soil moisture is retained, providing a sufficient water supply for the rubber-tea community in the dry season.

The Yunnan Plant Research Institute of the Chinese Academy of Sciences has conducted studies in cooperation with the Hainan Reclamation Bureau, on an artificial colony of rubber trees interplanted with tea bushes. After an experiment of lasting 20 years, the rubber-tea companionship has become widely popularized in these tropical areas. The rubber-tea companionship on Hainan Island covers 13'000 ha, with marked ecological, economic and other social effects.

Yet, overall, there are disadvantages to the development of rubber plantations in China; lack of heat, inadequate rainfall, and the alternation of dry and moist seasons. On Hainan and the Leizhou Peninsula, furthermore, strong winds and even typhoons cause serious damage to local rubber production.

The tea bush can be planted a year before or simultaneously with the rubber tree. The distance between rubber trees is 2 m in rows 12-15 m apart, and the optimal orientation of the row is east-west. Rubber trees can be planted in single rows or in bushes 5 m apart. Tea-bush rows should be placed 2 m from the rubber-tree alignments.

The primary productivity of a rubber-tea community depends on a tapping age of 1-2 years earlier than in monocultures. Dissection has shown that the number and diameter of latex ducts are larger than those of a pure rubber forest. From the second to sixth tapping years, the latex yield is 13% higher than that of a pure rubber community.

Most tea bushes in rubber-tea communities are of the broad-leaved varieties, ombrophyte species. Their highest yield occurs in an environment of 30-40% shade. With rubber trees planted in rows 15-16 m apart, the radiation needs for the growth of tea is met. With a properly conceived and managed rubber-tea plantation, yield and quality can be guaranteed.

The intercropping of rubber and tea can prevent the erosion of soil, improve its fertility, and the economic advantage is greater and more stable than that

of pure rubber plantations. Tapping of rubber usually begins in the tree's eight year, whereas the companion tea bush my begin to produce 4-5 years earlier, thereby reducing investment and speeding up capital turnover. The experiment at Nanhai Farm in Hainan shows that the gross capital investment is recovered in the eight year, thanks to the tea productivity.
Rubber and tea supplement one another in times of natural calamity (which can actually produce bumper harvests of both). The cold and continuous rain of spring 1980 delayed the tapping of rubber for more than a month, but because of abundant rain, tea leaves were picked a month ahead of time and yielded double the usual crop. In summer 1983, there was a serious drought in Hainan Island which greatly diminished the tea harvest. Rubber was not affected, however, and its harvest compensated to a certain extent the loss in tea.
Emposa flavescens, the lesser green-leaf hopper, is the main plant pest in Southern and Southwestern China. It can have a great effect on tea production. It has been found, however, that the hopper's main natural enemy reproduces faster in a rubber tree community than in the usual monoculture. The enemy, *Pronoides schemkel*, can eat 3.6 to 8 hoppers daily, a typical example of the biological control possible in combined rubber-tea plantations.
Red rust algae infection is a common disease in all of Hainan's tea plantations; it reduces the rate of productivity as well as the quality of the tea. In an intercropped community, this malady occurs much less frequently than in a pure tea culture.

4.4. Phyto-animal symbiosis system

Great attention has been recently paid to the development of a system combining crop cultivation with aquaculture development. A few successful examples are: raising fish in rice fields, symbiosis between lotus and aquaculture, rice-duck symbiosis, and forest-frog symbiosis.
Raising fish in paddies, an effective measure to increase rice yields and develop fishery. By 1984, more than 650'000 ha were devoted to this scheme in the Sichuan, Jiangxi, Jiangsu and Guangdong Provinces. Rice is the primary producer in the symbiosis, competing with weeds for nutrients, space and sunlight. Weeds can also be intermediate hosts for rice disease and pest, reducing the rice harvest by 10-30%.
Fish raised in paddies feed on weeds, phytoplankton, zooplankton and photobacteria. According to an estimate made by the Chinese Academy of Scienc-

es' Aquatic Biology Institute, the weed weight in fields of early rice without fish breeding is 13-15 times that with fish farming. Using a bait coefficient of 1:80, 75 kg of grass carp can be raised on 1 ha. Fish activity evens the distribution of soluble oxygen in the rice field's water and improves the soil's oxygen content. Experience has shown that if 6000 carp are raised on a single hectare, their dung will amount to 2640 kg after 110 days of growth. The abundant nitrogen and phosphorus nutrients in the dung obviously benefit the growth of rice.

In general terms, raising fish in paddies augments rice production by about 10% while, at the same time, providing between 210 and 870 kg/ha of fish.

Another alternative is the **lotus-fish symbiosis system** This system has been made its appearance in a low lying saline-alkaline area of Jiangsu Province The system consists of salt-resistant, shallow water lotus grown together with fish intended to improve the economic and ecological management of the saline-alkaline field. Under careful management 30 t of lotus roots and fish were harvested in 1 ha. The net income is twice as high as from a conventional rice field.

Rice-duck symbiosis has been used in China's southern provinces. A duck in paddies eats rice pests, stamps weeds, and loosens soil thus facilitating the human labour needed to loosen rice roots. Each fowl yields 2-2.5 kg of dung, increasing the rice field's available organic manure and accelerating the plant's growth. Duck production costs are diminished, since the raising of a single spring duck requires only 3-3.5 kg of grain: 60-70% of that required during growth in an enclosure. Autumn ducks required also 3.25 kg of grain, and the final weight of the average duck is 2.5 kg.

4.5. Terrestrial-aquatic interrelated system

This is a set of integrated farming systems and is widely practiced in tropical and subtropical China in wetland habitats.

According to the composition and structure of the system it can be subdivided into aqua-pastoral, agro-aquacultural, agro-aqua-pastoral, silvo-aquatical and agro-silvo-aqua-pastoral systems.

In wetlands, wet soil is a major obstacle in land use. Chines scientists and farmers have developed dike pond systems based on traditional practices and have achieved great success. This scheme was developed in the tropical and subtropical region of China and recently introduced to the Northern Plain.

According to the fluctuation of the water table and the method of land reclamation engineering, this system can be further divided into dike-ditch and dike-pond system. On the terraced lands agronomy, forestry animal husbandry are practice, while the ponds and channels are good for fishery and aquatic crops. This is the most complicated integrated system with great varieties.

The integration of aquaculture and agricultural systems is an ancient, widespread and enduring practice in South and Southeast China. According to literature research, aquaculture and agricultural systems have existed in China since the Tang Dynasty (17th century A.D.). They did not flourish until the 14th century of the Yuan Dynasty. In the Zhujiang Delta ponds were dug to drain marshes and natural ponds in order to create arable land, and the excavated soil was used to construct dikes. The first commercial crops grown on the dikes were fruits, particularly Litchi and Longan, while the early artificial ponds were utilized for breeding and rearing fish on a commercial bases. However, there was apparently little or no conscious organization of an integrated fruit dike-fishpond system in terms of linked input and output of material and energy, although both activities might have been undertaken on the same farm unit.

By the 1620s, however, mulberry was being widely cultivated on the dikes between the fishponds, experience having shown that the economic returns from integrated mulberry dike-fishpond systems were greater than those obtained from cultivating fruit trees on the dikes. Moreover, pond mud enriched with silkworm excrement and other wastes that had been first used to fertilize the pond and feed the fish was found to be a superior fertilizer for mulberry bushes than was the raw silkworm excrement applied hitherto, which when applied to an excess damaged the mulberry leaves. With this discovery an integrated dike-pond system was found to be beneficial to both mulberry and fish, and for better than growing rice.

By the end of the Qing Dynasty (1911) the Zhujiang Delta had some 66'700 ha developed in this kind of agro-ecosystem, and by 1925, the peak of Guangdong silk production, 93'000 ha of dikes were planted in mulberry. But a massive decline was soon to set in with the worldwide 'Great Depression'.

A great number of varieties of aquaculture and agriculture interactive systems has bee development in China. Sugar cane has been cultivated on the dikes since the beginning of this Century. Despite the widespread adoption of sugar cane cultivation, many former mulberry dikes were converted to vegetable production or paddy rice.

Although historically seen, excavation of fishponds and dike construction is considered to be the best way of transforming nature to make an area formerly economically marginal and subject to a range of natural disasters more productive in economic terms, until 1949 cropping patterns on the dikes were dictated by market prices rather than by ecological considerations.

In recent years these systems have been studied more deeply by the Guanzhou Institute of Geography and the Nanjing Institute of Geography under cooperation of a number of international organizations and have made some encouraging progress.

There are three kinds of dikes: flat topped, tile shaped, and tortoise-shell shaped. The surface of the flat topped dike is fairly flat, which favours the retention of water and assures convenient management. Dike width can vary from 5-10 m, its ideal height is 0.5-1 m above the water surface.

The fish pond is usually rectangular, with a length-breath ratio of 3:2, and its ideal area is 0.3-0.4 ha, with a maximum size of 0.7 ha. If the pond is too small, it receives more shade from the nearby crop and insufficient wind to transfer oxygen to the water. If too large, feeding and harvesting the fish will be inconvenient, and the strong'wind could break down the bank of the pond.

Some general information about the dike-pond system is introduced below by using the Zhujiang Delta in the Guangdong Province as an example.

The dike-pond system of the Zhujiang Delta contains at first sight an extremely complex range of matter and energy linkages among pond, dike, and the general environment. In reality, however, the components of the system are amenable to relatively easy integration.

At the heart of the system is the pond. To produce or maintain a fish pond, soil is excavated and used to build or repair the dikes that delimit it. Prior to being filled with water, the pond is prepared for fish cultivation by clearing, sanitizing and fertilization. The required inputs are quicklime and tea-seed cake, which derive from the general environment, and organic manure, which is produced from the animal husbandry sub-system on the dike.

Under natural conditions, soil and organic materials gradually refill the pond through the process of dike erosion. But this is interrupted two to three times a year when organically enriched mud is dug from the pond bottom and used to fertilize and build-up the upper surface of the dike. Pond mud is also used to make mud-beds for mushroom cultivation on the floor of the silkworm shed in winter, when silkworms cannot be raised.

The pond is then filled with river water, which bears nutrients, pollutants, fauna, flora and disease organisms. Water also enters directly as rain, as well as through run-off from the dike. Water, enriched with additional nutrients and bearing pollutants, fauna, flora and disease organisms, leaves the pond in controlled discharges via the pond drainage outlet. Water is also lost through evaporation and transpiration, and via seepage into the dike, as well as being removed at regular intervals for the irrigation of crop planted on the dike.

Fish are then stocked in the pond. Under the system of polyculture practised in the Zhujiang Delta these are, principally, the Crass carp (*Ctenopharygodon idellus*), Silver carp (*Hypopthalmicthys molitrix*), Bighead carp (*Aristichthys nobilis*), Black or Snail carp (*Mylopharyngodon piceus*), Mud carp (*Cirrhus moitorella*) and Common carp (*Cyprinus carpio*).

Some fish of marketable size are consumed locally but most enter the market; 70% of the fish produced in Shunde County, for example, are sold live, mostly to Guangzhou, Hongkong and Macao. Fish sales contribute the largest source of income in the agricultural sector of the region, the Zhujiang Delta yielding 90'000 t/year of fish (1979), or 50% of the total production of the Guangdong Province, and 80% of the live fish exports of the nation.

A range of linked sub-systems functions on the dike. Mulberry and sugar cane are the main cropping sub-systems. Mulberry is planted on the dikes and is fertilized with pond mud and irrigated by hand with nutrient-rich pond water. The principal objective of mulberry cultivation is to produce leaves used as forage by silkworms. Mulberry bark is also harvested for making paper, and after pruning, the branches are used as sticks to support climbing vegetables, or as firewood.

Inextricable bound-up with the mulberry sub-system is silkworm-rearing. Silkworms are reared in special sheds in the settlement and sent to the filature in the nearby urban centre for the production of yarn, much of which enters international commerce. Waste water, together with cocoon waste and dead larvae, is returned from the filature and use to enrich the pond and feed the fish. Silkworm excrement, admixed with the remains of mulberry leaves (*cansha*), is removed from the rearing sheds and used in the pond as fish feed.

During the off-season for silkworm production mushrooms are cultivated on mud-beds, prepared from pond mud, on the floor of the silkworm rearing shed, using spores obtained from the general environment. Some mushroom 'buttons' are consumed locally but most are marketed fresh, bottled or canned. After the final crop of mushrooms has been harvested the nutrient-rich mud-bed on which the mushrooms are raised is used to fertilize those sections of the dike on which vegetables, fruit trees, and grasses are cultivated.

Vegetables and grass production is a fundamental component of the dike-pond system, providing both essential food for fish and vegetables for home consumption and marketing. These crops are also fertilized with pond mud and used mushroom mud-beds, and irrigated manually with pond water. Gourds and melons, trained on trellises over the pond, provide shade, and when necessary the vegetable gardens themselves are shaded using old sugar cane leaves. Small groves of bamboo are also a fundamental part of the system and provide poles for construction and materials used to fabricate baskets, traps, screens, trellises and frames which are the basic tools in other sub-systems. Bamboo waste is also used as fuel.

Sugar cane, some of which is either annually or biennially with mulberry, is also an essential sub-system in the dike-pond complex. The principal product is refined sugar, but ancillary products are young leaves fed to the fish and to pigs, old leaves used to shade crops, for roofing thatch, and for fuel, and roots used as fuel. Refinery wastes are returned to the dike-pond in the form of fish and animal feed.

Pigs, raised mainly to provide manure but also for meat and ancillary products are kept in sites constructed on the dike. Young stocks are either obtained from the external environment or bred locally. External inputs to the sub-system consist principally of feedstuffs from the sugar refinery as well as occasional medicines and similar requirements. The concentrated feed requirements of pigs are met by feeding weaned piglets a diet of greens, particularly aquatic macrophytes such as water hyacinth, sugar cane tops, and other vegetable waste. Pigs are regarded as 'walking fertilizer factories' and their faeces and urine is the essential fertilizer of the fish pond. Water buffalo dung, mixed with coal dust and dried, is also used as fuel.

Apart from rice the basic food and shelter needs of the human settlements in the dike-pond district are met from the system itself. Local food sufficiency assures a balanced diet. Fuel needs are largely met from waste products, and bamboo, and dike mud, used to manufacture unglazed tiles and bricks, provide the principal materials for housing and furnishings. Other basic social and physical needs are satisfied within the commune. In addition to providing fundamental inputs into the dike-pond system in the form of capital, management skills, labour and technology - in conjunction with the higher order organized social units - human settlements provide excrement, urine, and other household wastes that form the principal organic inputs into the fish pond.

Integrated systems of agriculture and aquaculture are not well known scientifically. In particular, little is known of the techniques and technologies used, and data on levels of productivity and farm economy are seriously deficient.

Since 1980 many in-depth studies on the structure and functions of this system, including nutrients and energy flow, and the operation and economic aspects of the system on the household level have been carried out. A book entitled 'Integrated agriculture-aquaculture in South China', was published in 1988 which systematically summarized the results of the research on this system (GONGFU ZHONG and RUDDLE 1988).

Also the dike-pond system is a clearly sophisticated and highly productive system, it is by no means perfect in its operation. The major weaknesses can be listed as follows:

1. The mulberry bushes are completely stripped of all leaves seven to eight times a year to feed silkworms. The mulberry canopy is usually too sparse to make full use of solar energy for photosynthesis It is better to leave some leaves on the bushes at each harvest.
2. Comparative studies should be carried out between different compositions of plants on the dike.
3. Owing to high BOD loading, early morning DO levels often fall below 5 ng/litre, making the fish lethargic. Stocking rates cannot be increased and under such anaerobic conditions, the pond mud produces methane, nitrogen sulphide, hydrogen sulphide, and other gases, which in turn leads to a further deterioration in water quality.
4. A large amount of biological detritus is deposited at the bottom of the pond, where it decomposes under anaerobic conditions and produces gases which eventually dissipate into the atmosphere.
5. Mechanical aerators and mechanical mud sprayers should be introduced to increase labour efficiency.

Another variety of terrestrial aquatic integrated system is the dike-ditch system, which is successfully practiced in the Lishiahe area of the Jiangsu Province. The Lishiahe Plain is located in the central part of the Jiangsu Province with a total land area of 15'149 km^2.

This is a low flat plain with high groundwater tables. The soil of this area is humus swamp soil. In recent years, farmers have cooperated with technicians in constructing a model of dike-ditch network, which has produced some very good results.

There are three different types:

1. 2-5 m wide ditches with 10-40 m wide dikes
2. 5-10 m wide ditches with 15-20 m wide dikes
3. 15-20 m wide ditches with 20-40 m wide dikes

The height of the dike is commonly between 50-80 cm.

Differently structured combinations have been implemented in this terrestrial aquatic systems:

1. Agro-silvicultural system
2. Agro-aqua-silvicultural system
3. Silvo-aquacultural systems
4. Silvo-mushroom integrated system
5. Silvo-aqua-pastoral system

The following species are commonly used in these systems: water willow (*Salix babylonica*), long peuncled alder (*Alnus trebeculata*), paulownia (*Paulownia tomentosa*), mulberry tree (*Morus alba*), Water fir (*Metasequoia glyptostroboides*), swamp cypress (*Taxodium distichum*), and pond cypress (*Taxodium scandens*) etc.

It has been observed that this system not only improves the local environment but also significantly increases the farmers' income up to 5-10 times as much as the monoculture of cereal crops.

An experimental dike, 8, 12, 16 and 20 metres wide and a ditch 3, 6 and 15 metres wide were built in 1978 in the marsh land of the Gaoyou County, Jiangsu Province. The main tree species here is *Taxodium ascendens* which is planted at varying distances (2x2 m, 3x2 m, and 4xl.5 m).

In general, *Taxodium ascendens* grows very well on the dike. An 8-year-old *Taxodium ascendens* can yield 14.15 cm DBH at an average height of 9.97 m and a growing stock of 16.49 m^3/ha. The growth of the swamp cypress varies with different crop combinations.

The Tables 7, 8, 9 and 10 show the growth and income of intercropping *Taxodium ascendens* with different crops.

It has been demonstrated that the microclimate is changed in the intercropped systems. The general trend is that temperatures under the forest canopy are lower during the day and higher at night than above canopy. Humidity is increased and with increasing canopy growth light intensity diminishes. In a 4-year-old forest the illumination at 10 o'clock is as much as 26% less than in open areas, while under the canopy of 10-year-old swamp cypress trees the illumination can be reduced up to 63%. So normally, after four years, only shade-tolerant species can be cultivated or animal husbandry developed under the forest canopy (Table 11).

Table 7. Growth of *Taxodium ascendens*.
DBH - diameter at breast height

Age	Area (ha)	Total stock (m^3)	Average DBH (cm)	Average height (m)	Average stock (m^3/ha)	Annual average growth increment			Tree biomass (t/ha/year)
						DBH (cm)	height of tree (m)	stock (m^3/ha)	
5	6.2	315	8.79	5.47	50.8	1.76	1.09	10.16	7.25
6	6.2	506	10.40	6.41	81.6	1.73	1.07	13.60	9.50
7	6.2	673	11.79	7.22	108.5	1.68	1.03	15.50	11.18
8	6.2	818	14.15	9.97	131.9	1.77	1.25	16.49	12.13

Table 8. Income of intercropping *Taxodium ascendens* with crops.

Items	Inter-cropping species	Year of planting	Year of inter-cropping	Area (ha)	Total yield (t)	Total income (Yuan)	Per unit area yield (t/ha)	Income/ ha (Yuan)
cereal crops	oil seed	1982	1985	0.57	0.87	799.08	1.53	1'401.90
	barley	1982	1985	1.20	3.28	1'568.16	2.73	1'306.80
	wheat	1982	1986	73.33	335.85	167'749.71	4.58	2'287.60
	green cowpea	1978	1984	0.52	0.90	448.50	1.73	862.5
cash crops	soybean	1982	1985	65.33	95.38	95'551.66	1.46	1'462.60
	water melon	1982	1984	0.53	7.00	2'098.99	13.21	3'962.26
	peanut	1982	1985	0.23	0.46	456.76	2.00	1'985.90
	radish	1983	1985	0.53	7.50	2'481.59	14.15	4'682.26
	cotton	1982	1985	1.15	0.75	2'880.98	0.65	2'505.20
tree seeding	swamp cypress	1982	1985	0.80	7.00	9'100.00	8.75	1'137.50

Table 9. Relationships between intercropping and growth of *Taxodium ascendens*.
DBH - Diameter at breast height

Intercropping species	Year of planting	Area (ha)	Tree growth increment DBH (cm)	Height of tree (m)	stock (m^3/ha)
cypress + oil seed + soybean	1979	0.57	1.04	1.19	17.25
cypress + wheat + soybean	1982	73.33	0.97	1.10	13.20
cypress + barley + water melon	1982	1.20	0.82	0.81	10.20
cypress + vegetable	1982	0.53	0.95	0.84	10.65
cypress + green cowpea + cotton	1983	1.15	0.79	0.78	8.25

Table 10. Incomes of combinations of forestry with poultry, fishery and animal husbandry.

Items		Area (ha)	Time	Form of input	Yield (t)	Income (x 10^4 Yuan)	Output value (Yuan/ha)
forestry + aquatic	major fish	36.9	1984	650'000 young fish	45.85	6.28	1'702
		36.9	1985	1'300000 young fish	93.50	18.70	5'068
		4.4	1985	spawn	11.00	5.72	13'000
forestry + poultry	duck	8.93	1985	11'200 duck	2.25	3.49	3'908
	goose	6.2	1986	200 goose	0.45	0.103	166
forestry + husbandry	sheep	3.2	1986	102 sheep	2.02	0.66	2'063

Table 11. Soil temperature.

Time of investigation / Depth	*Taxodium ascendens* of a 6-year-old plantation			Open area		
	0.5 cm	2.5 cm	5.0 cm	0.5 cm	2.5 cm	5.0 cm
6 a.m.	17.5	19.0	17.2	18.4	20.1	19.4
10 a.m.	25.6	18.8	16.4	27.1	19.8	18.9
2 p.m.	33.3	19.4	17.7	36.0	19.3	19.1
6 p.m.	22.8	18.9	18.4	24.1	20.1	17.3

4.6. Multi-step and diversified rural development system

This system has developed very fast, along with the diversification of the rural economy. A model exists for the cultivation of edible fungi and the breeding of earthworms using crop stalks, in multiple steps. For generations these stalks were used without further treatment as fuel or mulch, but in recent years, saccharification (the conversion of starch to sugar) has made them preferred by livestock. The latter's excretions combined with the decaying debris of stalks can be used to cultivate fungi. After the harvest, mushroom beds can

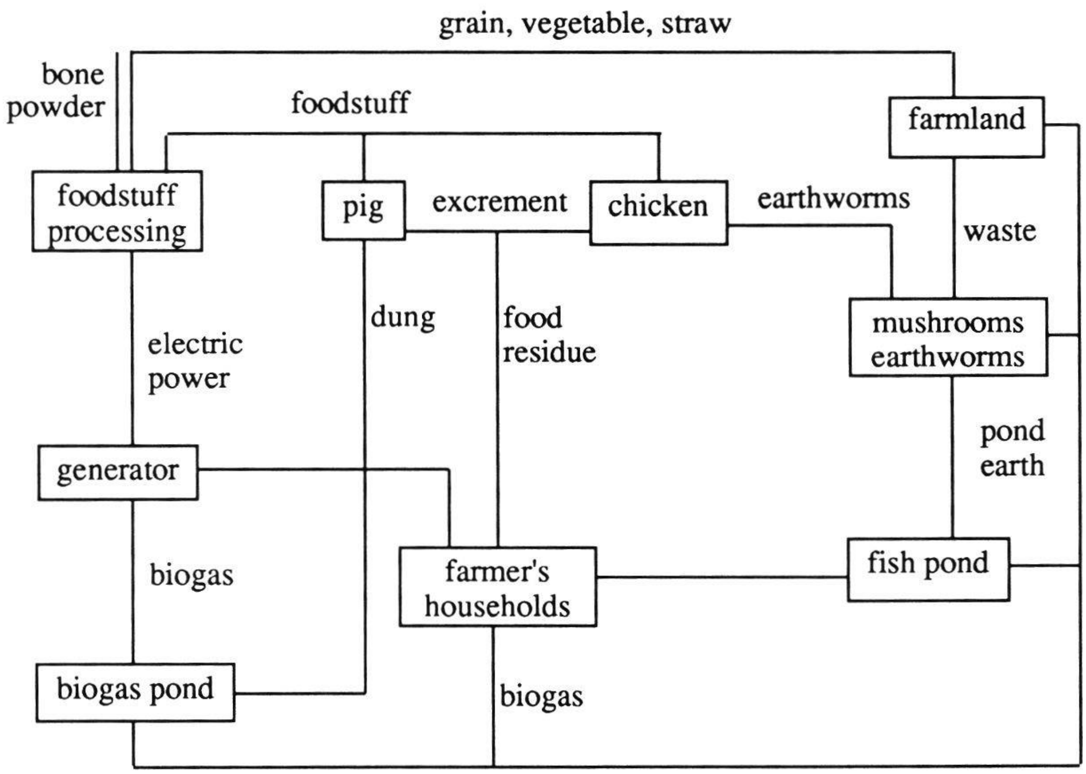

Fig. 5. Cyclic structure of food/feed production.

be used by earthworms or other organisms to produce methane. This maintains the manuring efficiency of stalks and directly raises the economic benefits of fungi-earthworms production.

Another successful example of applying ecological principles to the rural economy is a system developed in the villages of Dong Xu (Yan Cheng County, Jiangxi Province). This community has raised its production of grain, vegetables and mushrooms, and developed its animal, poultry and fish farming by means of the multiple use of biomass (Fig. 5). Result: a steady rise in village's income.

The integrated rural development model (IRD) is even more holistic in scope than what we have discussed so far. IRD focuses on projects going beyond agricultural improvement to encompass fish, forest and field production, side employment, and the provision of health, educational and other communal services.

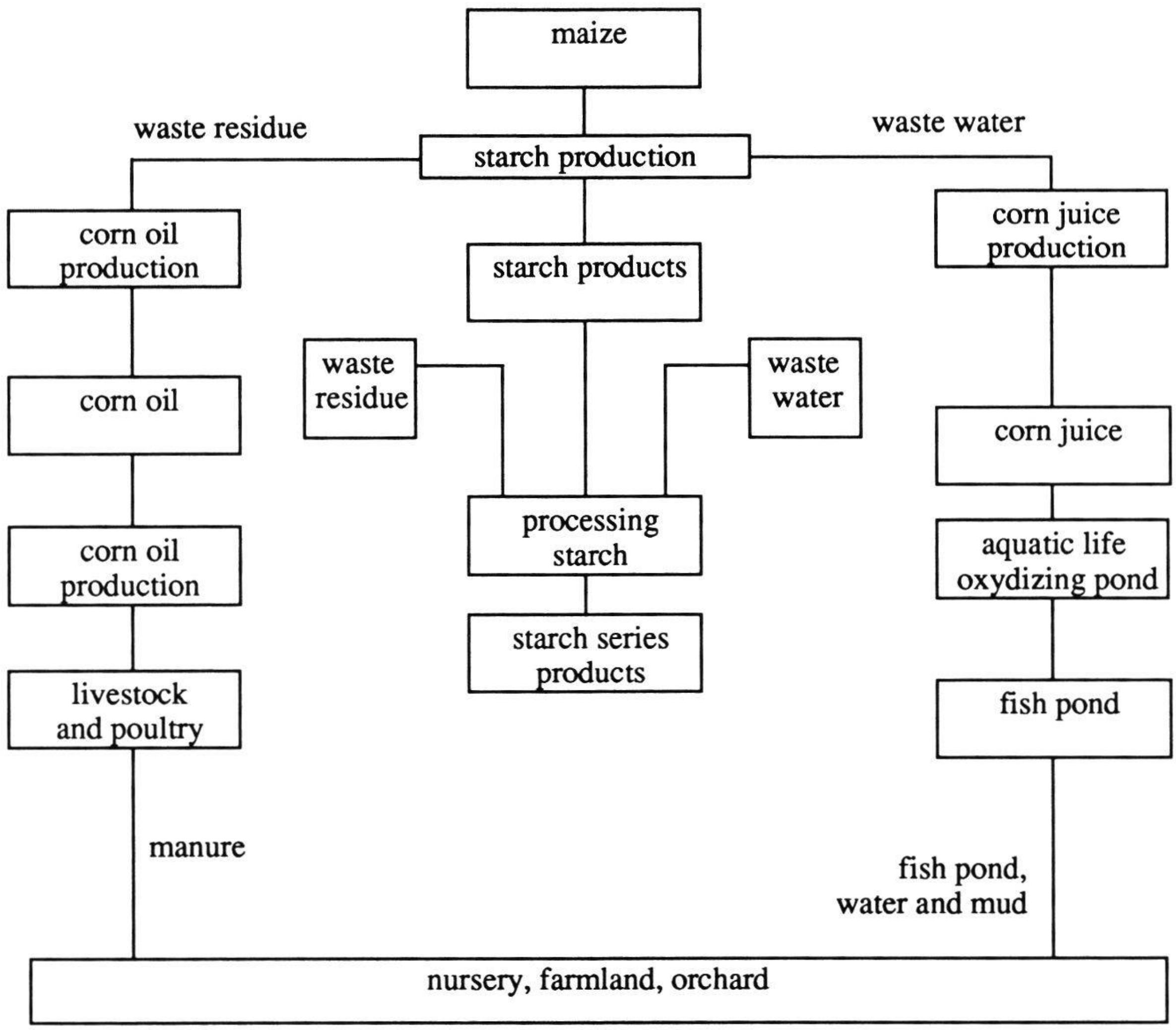

Fig. 6. Multistep use of maize in the southern suburbs of the city of Kaifeng, Henan Province.

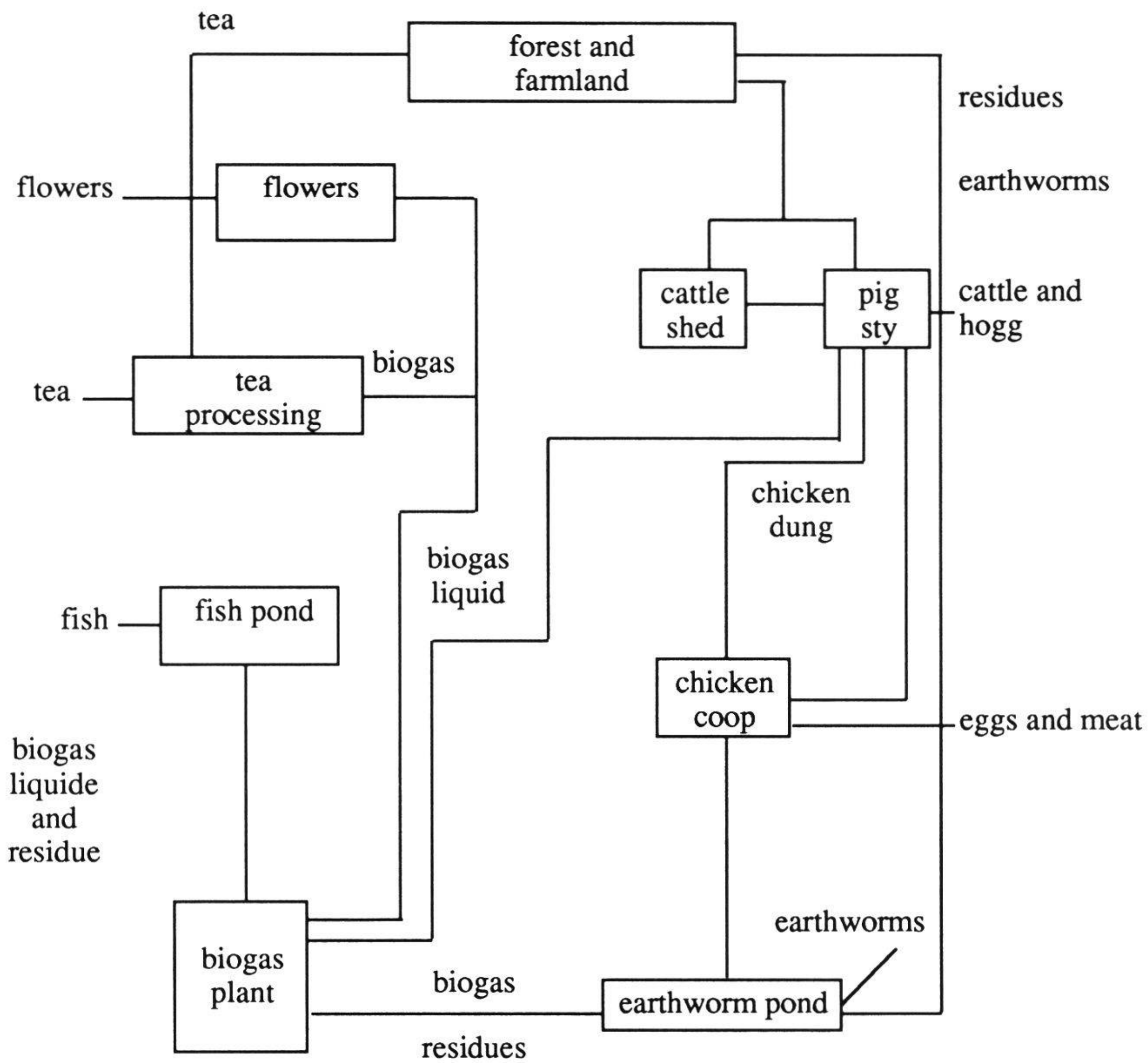

Fig. 7. Production cycle in the Bao Feng forest farm.

Furthermore, the development of ecological farming utilizes agricultural products as raw materials for the processing industries. Figures 6 and 7 idealize the general structure of an agro-industry system combined with aquaculture and subsidiary production. Integrated rural development, particularly the agricultural processing industry, should keep pace with the population and the community's plan for development.

4.7. Integrated farming system in watershed management Integrated farming system on a macro-scale

(Introduction of the Qian Yan Zhou Project)

As we have mentioned before, the integrated farming system can be implemented at different hierarchical levels. It can be implemented not only at the agricultural ecosystem level but also can be practiced on the landscape, watershed and even at the regional level if a region, within the boundaries, is considered an integrated management unit.

A watershed is a topographically delineated area that is drained by a stream system. Although a watershed is a physical unit, it can provide a useful framework for the implementation of a sustainable development concept into practice. Political boundaries were the logical ones to use within development efforts. However, natural forces neither recognize nor respect political boundaries. This is because many natural processes, such as water-flow, erosion, fish migration, and pollution, are taking place and these are effected by watersheds. Similarly, any development activities including hydropower, irrigation, transportation and production systems in turn influence watersheds.

Watershed management, in its wide sense, implies the process of formulating and carrying out a course of action involving manipulation of natural, agricultural and human resources on a watershed to achieve sustainable development objectives. Watershed management emphasizes that economic growth, poverty alleviation and environmental protection can be made to complement each other, or at least a workable integration of economic, social and environmental concerns can be developed if the appropriate approach and integrating mechanisms are used. (BROOKS et al. 1991).

More than half of the world population lives in Asia almost one quarter of which are concentrated in the mountain areas. Rural poverty, combined with the alarming population growth rate of recent years have driven people to take a short sighted approach when exploiting natural resources. Among other natural resource degradation problems, deforestation is one of the most serious. People inhabiting upland watersheds find themselves in a dilemma. They need a minimum of land to produce food and harvest firewood to exist. Shifting cultivation, conversion of marginal forest land to agricultural use, overharvesting firewood and timber, uncontrolled lopping for fodder, overgrazing improper collection, transportation and use of water, forest fire and construction of roads on marginal land, etc. has caused significant degradation of forest resources. This in turn leads to a long list of hazards and disasters, including soil erosion, desertification, sedimentation load, loss of cropland, pollution, ecosystem degradation and destruction, and extinction of species and varieties. Increasingly, large areas in the lowlands are flooded each year, causing loss of crops, property and lives. Environmental degradation is particularly serious in highly populated tropical and subtropical, fragile mountains and hilly regions, where high intensity, long rainfall duration, extreme variations in land formations within short distances, steep stream gradients, earth quakes, mass movements, landslides and other natural hazards are common.

Within the last few years many efforts have been made to improve this situation. A very effective approach is to designate the watershed as a basic unit for management. Integrated farming concepts and practices are very useful tools for reaching the goal of sustainable development in this aspect. There are many successful examples in China as well as in other developing countries. Here the Qian Yan Zhou project serves as an example.

The Qian Yan Zhou project is a study and development project aimed at creating a model for the sustainable development of agriculture and economy in the degraded, subtropical, red soil hills of China. The case study is being carried out at the Qian Yan Zhou experimental station (Taihe County, Jiangxi Province) and jointly supported by the Chinese Academy of Sciences and the local Government.

The subtropical region of South China occupies an area of some 990'000 km^2 with 451.8 million inhabitants. In this region approximately 466 million ha are mountains and hills with only 10% of the total land presently being cultivated. The natural vegetation here consists of broad-leaved, evergreen, subtropical forests. Following the devastation of the vegetation cover in ancient times, severe soil erosion, distinction of species and general deterioration of the environment have been the results. The mountains and hills of the region are bare or covered by sparse secondary forests consisting in *Pinus massoniana*, oil tea bushes and graminal grassland.

The Jiangxi Province has become one of the poorest provinces in China as a result of excessive emphasis on cereal crop cultivation in the limited basin area, failure to utilize the vast hilly areas which constitute more than 80% of the region, lacking soil protection measures, and last but not least, the local people's struggle to meet their needs for fuel and timber.

The Qian Yan Zhou experimental station was established in the Jian County, Jiangxi province, with the purpose of creating an integrated development model to the needs of this area. Although the station consists of only 3000 mu of land, the characteristic features of the station are considered to be represen-

Table 12. Income structure of Qian Yan Zhou (1983-1989) in Yuan.
*total income, ** net income

	1983		1984		1985		1986		1987		1988		1989	
	T-I*	N-I**	T-I	N-I	T-I	N-I	T-I	N-I	T-I	N-I	T-I	N-I	T-I	N-I
Plantation														
- farming land	5040	4447	5915	5205	7667	5158	11819	8816	16000	11800	28000	19600	6000	3000
- garden plot	1780	1661	5367	4850	17867	15399	17437	14955	14310	12210	18200	10400	19000	11000
- young plant nursery	-	-	9552	7145	12751	5719	3075	572	3500	2830	3000	-	6000	2900
Total	6820	6108	20834	17200	38285	26303	32331	24343	33810	26840	49200	30000	31000	16900
Orchards (oranges)	-	-	-	-	-	-	10090	4836	40500	32500	84000	57000	300000	250000
Animal husbandry														
- domestic animals	2160	974	4722	2201	7514	2972	22666	11837	74490	3900	199000	71800	90000	6000
- poultry	1542	1054	2491	1800	5858	2810	8131	3774	8100	5860	13000	7200	3000	1100
Total	3702	2028	7213	4001	13372	5782	30797	15611	82590	44860	212000	7900	93000	71000
Fishery	880	505	5049	2244	6820	5395	8603	7284	8800	7300	9000	7200	10000	6000
Sideline occupation	7372	7372	5205	5205	10803	10803	16594	16594	15000	15000	15800	15800	2000	2000
Processing industry	-	-	-	-	-	-	-	-	-	-	35000	18000	20000	8000
Total	18774	16013	38301	28650	69280	48283	98415	68668	180700	126500	405000	207000	456000	290100

tative of the area: limited forest coverage, excessive precipitation in the monsoon season but a water shortage during the dry season, monocultivation in the limited basin but vast hilly and mountainous areas unutilized, transportation difficulties and an undeveloped economy etc. (Table 12).

Based on an integrated survey, a general design was made with consideration of the following principles:

1. Transformation from the monoculture system to the integrated multi-sectorial agriculture system;
2. Transformation from limited cultivation in the flat valleys, only 15% of the land, to overall land resource utilization of hilly areas by means of the proper arrangement of agriculture, horticulture, forestry, aquaculture and animal husbandry, emphasizing the interrelationship between components and supplement in time and space.
3. Development of small village industry and the provision of biogas energy supply;
4. Establishment of a contract, responsibility system with small incentives to start with;
5. Combined development with scientific research, training, demonstration and diffusion;
6. Establishment of management mechanisms with participation of farmers, decision makers, scientists and technicians.

Since the Qian Yan Zhou project was implemented, preliminary experiences in sustainable development have been gained in successful management of the area.

Before the project was launched, the Qian Yan Zhou was an impoverished and backward area with little forest, little water resources, and no electricity and no auto-transportation. Vast areas of land were out of cultivation and only some scattered farming activities were practised. At that time, there were only seven farm households living in this area, with 31 persons, of which 11 were labourers. Crop yields were very low, with an average of only 855 kg/ha. The annual agricultural output value was just 1'600 US$ and the annual net income, only 32.30 US$ per capita. On the other side, the average land area available for farming was 6.3 ha per capita, of which only 0.68 ha per person was cultivated. Therefore, not only the arable land available to each individual was large, but there also existed a rich potential for agricultural development. This, in a sense, indicated a positive future for expanding production, for providing a basis of sustained agricultural growth and for improving living conditions of the local people in this poor area.

After nearly six years of experimental work, the results are quite satisfactory, from both the ecological and economical viewpoints. Viewed from economic aspects:

1) The pattern of land use has changed from a single type of production into a diversified farming system. By the end of 1989, the land utilization rate

had gone up from 10.9% to the present about 86.3%. An area covering 1'810 mu was planted in trees, of which about 800 mu is now covered with 2 m high seedlings. The orchard area covers another 410 mu, 120 mu of which began to bear fruit in 1987. The land used for farming was reduced from 314.8 mu to 226.6 mu, but the multiple crop index rose from 124% to 190%. Grain output increased from 114.5 kg/mu to 258 kg/mu, with a growth rate of 124%. The water area was expanded from 62.8 mu to 145 mu and, in the same period, a fodder processing factory was built to boom agricultural and aquacultural industry. By the end of 1987, the number of pigs had jumped from eleven to 400 head, cattle increased from 8 to 64 head. The annual increase of livestock through breeding rose from 150 to 1'674, and fish yield from 150 kg to 3'585 kg.

2) The agriculture production structure must be suited to the characteristics of local resources such as land and climate conditions, in order to maximize resource utilization. In 1983, the plantation income (mainly from grain) dominated a large portion of the total income (81.8% of the total net income). To increase productivity, a readjustment of the production structure was started in 1983. The ratio of total incomes from plantation, horticulture, animal husbandry and sideline occupation has greatly changed during the period between 1983 and 1989 (Table 12). Apart from grain production, fruit, seedlings, oil crops, vegetables and melons are increasing. Orchards are not only planted in oranges, but also in other fruits, like tangerine, pear, peach, chestnut, etc. Forest land includes timber forest, fuel wood, trees for landscape beauty, production forests and trees for water conservation. Various species of trees have been planted: *Paulownia fortunei, Metasequoia glyptostroboides, Trachycarpus fortunei, Camellia cleifera, Pinus massoniana,* bamboo, *Melia azedarach, Camptotheca acuminata, Liquidambar formosana, Taxodium ascendens, Albizia jutibrissin*, and *Quercus fabri*. Different experiments are arranged throughout the site; in the example of animal husbandry, the plot is divided into several areas for different purposes, such as grazing, herd rotation, natural grazing, etc. Compared with the land use in 1982, the land has been obviously developed from monocultural use to integrated use and from single grain production to an overall development of grain, forestry, fruit, livestock and fishery (see Table 13).

3) According to the 1987 statistics, the number of farm households in Qian Zhou increased from seven to 50 with a total 206 people, of which are 101 labourer. The total annual output value reached 100'755 yuan, 30 times as

Table 13. Changes of land use in Qian Yan Zhou (1983-1989)*.

* the total land area was 3'062.5 mu during the period from 1983 to 1988. In 1989 the land use was expanded to 3'490 mu for afforestation.

	Cultivated land					
Year	Farmland	Forest	Orchard (oranges)	Forage (grasses)	Aquaculture (fishery)	Total
1982	314.8	13.2	-	2.1	2.0	332.1
%	10.3	0.4	-	0.1	0.1	10.9
1983	13.0	310.0	13.2	37.8	70.0	344.0
1984	250.0	524.8	168.2	160.0	64.7	1167.7
1985	226.6	1323.8	335.0	140.0	66.7	2092.1
1986	1492.2	385.0	140.0	66.7	2310.5	82.4
1987	226.6	1690.0	410.0	106.0	90.0	2522.6
1988	226.6	2810.0	410.0	106.0	90.0	2642.6
%	7.4	59.1	13.4	3.5	2.9	86.3
1989	226.6	2547.6	500.0	126.0	90.0	3490.0

		Non-farmland		
Year	Roads and buildings	Non-aquaculture water surface	Wasteland	Total
1982	41.6	60.7	2628.1	2730.4
%	1.4	2.0	85.7	80.1
1983	61.0	107.0	2500.0	2668.5
1984	70.0	80.0	1744.5	1894.8
1985	77.0	64.3	829.1	970.4
1986	82.4	67.3	602.3	752.0
1987	90.0	55.0	394.9	539.9
1988	90.0	55.0	274.9	419.9
%	2.9	1.8	9.0	13.7
1989	100.0	55.0	217.3	272.3

Table 14. Population and net income per capita (1982-1989).

Year	Total population	Contract households	Labourers	Net income per capitat (yuan)
1982	31	7	11	120.0
1983	68	14	37	235.5
1984	94	29	54	304.8
1985	149	33	64	324.0
1986	156	40	82	440.2
1987	206	50	99	614.1
1988	252	50	101	821.4
1989	269	56	120	1078.4

much as before the project began, and the annual net income per capita rose to 614.2 yuan, 4.1 times that of the pre-development period. During the period 1988 to 1989, economic returns increased sharply. The total agricultural output value reached 456'00 yuan, of which net income was 290'100 yuan. By the end of 1989, the total number of contract farm households increased to 56, with a population of 269 people, among them 120 labourer. Net income per capita in this year increased to 1'078 yuan (Table 14).

Not only positive economic effects have been achieved in Qian Yan Zhou, the quality of its ecological environment has also greatly improved. Although Qian Yan Zhou is characterized by a subtropical climate, the whole area, prior to the project, had become almost barren with wide spread wasteland and soil erosion. This condition was due, except for a few sparsely wooded areas and a few *Pinus massoniana* trees around the villages, to the disappearance of the virgin forest. Now, after the project has advanced, Qian Yan Zhou has a completely new look. Forest coverage has been restored, from less than 1% to 63.3%. According to recent investigations, forest plantation covers 2'547.6 mu (*Cunninghamia lanceolata* 186.2 mu; mixed coniferous and broad-leaved forest, 648.4 mu; bamboo, 40 mu; oil-tea tree, 53.7 mu; *Pinus elliottii,* 1054.3 mu; *Pinus massoniana,* 470 mu; bamboo, 95 mu). The average quantity of soil erosion and surface run-off has been reduced from 0.486 t/ha and 260.343 t/ha to 0.13 t/ha and 167.523 t/ha. Soil erosion and water loss are now fundamentally under control.

Thank to the proper measures and methods of reclamation adopted in the project, the decline of the ecosystem in this area had been markedly restrained in a quite short period of time, and the biological production was quickly regained and had rapidly increased. Since 1983, the growth of forest in plots has gone up to 3.8-4.8 t/ha, compared to 2.5-3.0 t/ha before. Another example demonstrating this change is the artificial forest planted in 1984, which now has a growth rate of 3.0-3.8 t/ha instead of 2.2-2.8 t/ha before. At the same time, some shade tolerant plants are growing in these vegetation groups, which indicates that an ecological balance in this area has been restored.

4.8. Integrated farming system in the regional level
(Introduction of the three north forest protection systems)

Development of a shelterbelt system on the regional level is a good example for implementation of the integrated farming concept in macro-scale.

The shelterbelt system in the North of China covers 3'890'000 km^2 which amounts to 40.5% of the total land area of China, including its 1'280'000 km^2 of deserts. Scarce in vegetation, the area plagued with grave problems of water run-off and soil erosion. As a result of this and frequent occurrences of natural calamities, particularly strong winds and insufficient rainfall (less than 400 mm/year), the productivity of agriculture, forestry and animal husbandry remains very low. In order to eliminate the ecological imbalance in the area and to improve economic conditions as well as the quality of people's lives, the Chinese government started a project of gigantic proportions, known as the 'Green Great Wall'. The essential objective of the program is to create a shelterbelt system through planting trees, shrubs and grasses. The entire program is to be executed in three phases. Scheduled for the period from 1978 to 1985, the first phase would establish plantations over 5'930'000 ha. By the end of 1984, 92% of the task had been accomplished. In the second phase, scheduled for the five years between 1986 and 1990, 6'510'000 ha should be planted to trees. The third phase for the decade from 1991 to 2000 is expected to cover 10'660'000 ha. On completion of the three phases of the program, the forest cover should be brought up to 10.6% from 4% in 1978. Farmland and pastures will be put under the protection of the shelterbelts, water run-off and soil erosion in the Loess Plateau will be brought under control, and the problem of firewood shortage will be basically solved. All this will lead to a great improvement in the economy and the standard of living of the local people.
In the light of the particular situation of the area, the development of the shelterbelt system requires an orientation to ecologically balanced agriculture. This means rationalizing farming, forestry and animal husbandry to proportions which complement one another from a macroscopic as well as a microscopic point of view. The development of such an ecological environment can be accomplished by means of protection for the existing forests, large-scaled afforestation, closing mountains to public access to enable forest regeneration, and the cultivation of protective grasslands. All this is expected to lead to the creation of a green shelterbelt system. The program's objectives are planned to be achieved by means of the following measures:

1) Establishment of high forests and shrubs, as well as grasslands;
2) Building large-scale shelterbelts, small patches of woodlands and forest networks;
3) Creation of a forest system consisting mainly of shelterbelts, but also of firewood, economic plantations and commercial timber;
4) Development of new plantations and grasslands, closing mountains and deserts to enable natural regeneration, and placing existing forests under protection.

Table 15. Main species used for reafforestation in the Deng Kou Experimental Bureau.

Scientific name	Common names	Uses and features
TREES		
Leguminosae		
Caragana arborescens (Lam.)	Pea tree	Indigenous
Elaeagnaceae		
Elaeagnus angustifolia (L.)	Russian olive or narrow-leaved marsh willow	Indigenous
Pinaceae		
Pinus sylvestris (L.) var. *mongolica* (Litv.)	Mongolian Scots pine	Indigenous
Pinus tabulaeformis (Carr.)	Table pine, Chinese pine, Flat topped pine	Indigenous to more southern areas of China
Salicaceae		
Populus bolleana (Lauche)	Xinjiang poplar	Used widely in S. America for shelterbelts and in hybridization. Indigenous
Populus euphratica (Oliver) (syn. *Populus diversifolia*)	Diverse-leaved poplar	Tolerant of heat and salinity. Indigenous with a large natural range.
Populus nigra (L.) var. *thevestina* (Dode)	Greyish bark poplar	Fairly drought tolerant. Indigenous
Populus simonii (Carr.)	Weeping poplar	Largely ornamental but widely planted in early shelterbelts in China. Indigenous
Salix matsudana (Koidz) var. *pendula* (Schneid.)	Pendulous willow	Produces fodder for livestock. Indigenous
Salix matsudana (Koidz) cv. *"Tortuosa"* (Vilmorin)	Contorted willow	Ornamental. Indigenous
Salix mongolica (Suizev)	Mongolian willow	Indigenous
Tamaricaceae		
Tamarix chinensis (Lour.)	Branchy tamarix	Deciduous. Indigenous
Ulmaceae		
Ulmus pumila (L.)	Siberian elm	Indigenous
Sapindaceae		
Xanthoceras sorbifolia	Yellow-horn tree	Deciduous. Edible nuts and high-grade oil for cooking and machinery use. Indigenous
SHRUBS and SUB-SHRUBS		
Leguminosae		
Ammopiptanthus mongolicus (S.H. Cheng)	Mongolian ammopiptanthus	Indigenous
Amorpha fruticosa (L.)	Shrubby false indigo	Deciduous. S.E. United States

Table 15 (continued)

Scientific name	Common names	Uses and features
Astragalus adsurgens (Pall.)	Milk-vetch	Perennial, deep rooted, prostrate shrub, found on dry stony or gravel slopes and bogs. Indigenous.
Caragana korshinskii (Kom.)	Korshink pea shrub	Indigenous
Caragana microphylla (Lam.)	Little-leaved pea shrub	Indigenous
Halimodendron halodendron (Voss.)	Saltbush	Very salt tolerant. Indigenous
Hedysarum mongolicum (Turcz.)	Mongolian sweetvetch	Suitable for aerial seeding. Indigenous.
Hedysarum scoparium (Fisch et May)	Slenderbranch sweetvetch	Suitable for aerial seeding. Produces fodder for livestock. Indigenous.
Lespedeza bicolor (Turcz.)	Shrub lespedeza, Bush clover	Deciduous. Indigenous.
Compositae		
Artemisia ordosica (Krasch.)	Ordos wormwood	Suitable for aerial seeding. Indigenous
Artemisia sphaerocephala (Krasch)	Roundhead wormwood	Drought tolerant. Suitable for aerial seeding. Indigenous
Polygonaceae		
Atraphaxis bracteata	Saltbush	Very drought tolerant. Deciduous. Indigenous to nearby parts of Mongolia.
Caligonum mongolicum (Turcz.)	Mongolian broom	Very drought tolerant. Indigenous
Chenopodiaceae		
Haloxylon ammodendron (C.A. May)	Saxoul	Xerophytic pioneer shrub. Uses include fuel, fodder timber for building and roots for nedicine.
Elaeagnaceae		
Hippophaë rhamnoides (L.)	Buckhorn	Deciduous. Indigenous
Zygophyllaceae		
Nitraria tangutorum (Bobrov.)	Edible-fruited nitraria	Indigenous
Zygophyllum xanthoxylon (Maxim.)	Common beancaper	Edible buds. Indigenous
Tamaricaceae		
Reaumuria soongarica (Maxim.)	Songory reaumuria Songory tamarix	Indigenous

The program is being carried out in accordance with existing management plans for specific mountain ranges and valleys, concentrating efforts in small areas.

As in most of the Three North area, the shortage of water so seriously hinders tree survival and growth, that the key to successful afforestation lies in meeting the desperate need for water. During the implementation of the program, efforts are made centring around fighting droughts, conserving water and preserving soil moisture. Technical designs are drawn up in light of local conditions, e.g. planting the species best suited to the site, enabling integration of the trees, shrubs and grasses. Due attention is given to avoid monocultures, which is likely to invite plant diseases and insect pests. On the Loess Plateau, where soil erosion is extreme preference is given to drought-resistant shrubs, conifers and broad-leaved trees such as little-leaf pea-shrub (*Caragana microphylla*), common seabuckhorn (*Hippophaë rhamnoides*), wild peach (*Persica davidiana*), oriental arbor-vitae (*Biota orientalis*), Chinese pine (*Pinus tabulaeformis*), black locust (*Robinia pseudo-acacia*), etc. In sandy, wind-blown areas, in addition to use of drought-tolerant species, emphasis is put on shrub species most resistant to scouring sand, like sacsaoul (*Holoxylon ammodendron*), *Hedysarum scoparium, Hedysarum mongolicum* and *Calligonum mongolicum*, etc. In places with relatively favourable water conditions, quick-growing species of high quality are planted, i.e. Scotch pine, poplar and narrow-leaved oleander (*Elaeagnus angustifolia*). In planting and maintenance, stress on technical measures for fighting drought runs through the whole process, from site preparation before the rainy season, water conservation and soil moisture preservation to careful planting with strong seedlings and intensive management (Table 15).

Establishment of shrub plantation is possible everywhere in the area, but is particularly suitable for arid and semi-arid regions. The success rate of shrubs is often twice or three times that of arbor trees. Increase of forest cover through closing the mountains will lead to great development of the entire region because it is labour-saving and less costly and good results can be obtained in a short term. With adequate rainfall (no less than 200 mm/year) and some scattered trees, as well as careful management, it takes no more than three to five years before pleasing views begin to emerge. Aerial seeding is carried out in some areas with sparse population. Positive experiences of successful aerial seeding of shrub species have been gained in some places where annual precipitation is limited to 200 mm.

The funds required for execution of the program are raised from whatever sources possible. Private contribution in form of investment or workdays on individual or group basis are encouraged. Investment from collectives is taken from the gross revenue of various sectors of agriculture. The government also allocated funds, totalling 267'000'000 yuan RMB for the past seven years. Another 9000 million yuan RMB have been raised from other sources through either state or local channels.

The funds from the state and collectives go mainly to planting and nursery activities. There are special plans to govern the use of the state funds which are put into key projects. Preference is given to those who have the best chance for success, and contracts are signed and payments by instalments requested. From time to time, assessment takes place when rewards and punishment are duly meted out. This approach functions well, guaranteeing proper use of funds and resources.

5. STRATEGY FOR THE IMPLEMENTATION OF INTEGRATED FARMING SYSTEMS

There is no universal answer to these problems. Each should be carefully examined in the context of the given conditions and existing environment.

A strategy for the implementation of integrated farming can generally be divided into the following steps: 1) preparatory work, 2) site selection, 3) diagnostic, 4) design, 5) experiment, 6) development and .0, 7) evaluation an redesign.

Preparatory work includes national reconnaissance, collection of data, and preliminary diagnostic survey of the existing land use system.

A quick reconnaissance type of survey, assisted by aerial photographs is often used to design an ecological farming system on the macro-scale. At the local or watershed level, further survey or investigations are needed to obtain basic information for formulating an action plan on the meso-scale. Valuable existing data, maps and reports should not be overlooked in order to save time, money or efforts. There is a general tendency in survey and planning to collect more data than necessary in one area and insufficient information in another. Therefore, before data collection, preparatory work should determine what is really needed, how it can be collected and where to get it.

Data required for ecological design varies for different management objectives, but can generally be categorized as follows:

1) Physiographical data including location, elevation, soils, geology, land forms, slopes, drainage patterns, etc.
2) Land use and cover types including forest, grass range land, cultivated lands, orchards, wildlife reservations, recreation areas, water areas, eroded areas, land capabilities, etc.
3) Climate and hydrology including precipitation, wind, evaporation, temperature, stream-flow, sediment, etc.
4) Socio-economic data including demography, land tenure, farming systems, education infrastructures, human resources, farm enterprises, rural employment, production, income, marketing, transportation, credits, labour, etc.
5) Institutional and cultural data including policy and administration, legislation, extension services, farmer's organizations, community and private groups, traditions, religions, cultural practices, acceptance to innovations, group actions, etc.
6) traditional knowledge and existing models of integrated farming, their potential and limits are particularly important for the diagnostic and design of an ecological farming system.
7) Management oriented data including, environment impacts, land management, techniques, treatment needs, infrastructure requirements, research and training needs, unit cost, sectorial cost, cash flows, work schedule, financial arrangements, expected benefits and results, etc.

To the above surveys and analyses, multi-disciplinary teams of professionals and technicians are often needed.
The general techniques employed for such field-oriented surveys include simple statistics and sampling, interpretation of aerial photographs, mapping and design of questionnaires, most of which can be taught and learned by sub-professionals or technical assistants.
In some experimental stations, computers can be employed for storing most of the basic data for future use. For instance, periodic surveys on land use, farm incomes, and erosion/sediment data will provide clear pictures of changes. The effect of watershed management work over time can thus be evaluated.
The diagnostics and design of an ecological farming system should be developed and applied at different scales. There are at least three levels in the hierarchy of land use systems, namely,

- micro: the household management unit (e.g. the family farm, farmyard animals, or other elementary land management units)
- meso: local community or ecosystem (e.g. a neighbourhood, village or small watershed)
- macro: region, country, ecozone.

Another important factor is the definition and selection of the local land use system. In selecting or developing locations or research sites, the following should be taken into consideration: severity of problems, regional representativeness, priority by land use systems, priority by region, potential and limits of ecological farming as well as the acceptance of the people, etc.

In the diagnostic stage we shall look at how well the system works, its limits, problem generating syndromes and leverage points?

1) Physiographical problems (e.g., steep slopes, heavy rains, excessive run-off, problem soils, etc.)
2) Resources use problems (e.g., shifting cultivation, forest destruction, fire, overgrazing, uncontrolled mining, poor road construction, etc.)
3) End problems (e.g., erosion, sedimentation, flood, water pollution, water shortage, etc.)
4) Socio-economic and other problems (e.g., illiteracy, low acceptance or innovation, labour shortage, land tenure, poor infrastructure, etc.)

Detailed surveys or investigations should be centred on the major land use problems identified during preparatory missions or preliminary investigations.

Based on the results of the diagnosis of the land use system, a design for land use should be made in accordance with the objectives, guidelines, hypotheses, available resources and people's acceptance, etc. The following points should be considered in the design:

1) Characteristic features of the prototypes.
2) The best overall development strategy for the system.
3) Problems and potential to be addressed by the design.
4) Functions should be performed separately or in combination.
5) Locations within the landscape where these functions should be performed.
6) Species components or component combinations best suited for the desired functions.
7) Number of each required to achieve the objectives of the design.
8) Precise arrangement of the plant and animal components envisaged (simultaneously in space and/or sequentially in time).
9) Management steps necessary to achieve the performance objectives.

The contents of the design may vary, but some general principles are suggested.

1) As concise as possible. The design is prepared mainly for practical use and not purely for academic study. An abstract or summary (including recommendations) should be put at the beginning of the report, leaving technical details, methodology, drawings and maps at the end or attached as appendices.
2) As practical as possible. Land use problems should be analysed; objectives, goals, and work progress be clearly set; responsibilities of each agency or sector should be well defined; budgetary sources should be identified; expected results, benefits and financial viabilities estimated; and strategies described. The report should present alternatives and be flexible for necessary adjustment.
3) As illustrative as possible. Charts, simple diagrams and photos should be included. 'A picture is worth a thousand words'.

Before implementing the design on a big scale it is necessary to carry out on-station and on-farm research trials and to study the feedback from these trials.

The suitability of the design should be assessed, the economic, ecological and social effects should be evaluated. The successful on-station and on farm experiments shall become demonstration models.

Development and diffusion of the integrated farming system into meso- and macro-scales. For the implementation of the concept of integrated farming in an area larger than the farm scale units, following an initial phase at householder level diagnosis and design, a full scale landscape planning exercise was conducted. An overall ecological farming plan for integrated development within the watershed was developed along with a detailed design for the rehabilitation and productive use of degraded lands between farms and other interstitial areas. It is necessary to examine differences between land use systems in different landscape zones within an area, to determine whether opportunities exist for complementary production.

For the successful implementation of the integrated farming system concept on a macro-scale level, it is necessary that the having representatives of all levels participate. If there are many organization involved, one agency should be designated to initiate the work. The primary responsibility of this agency should be managing the system or it should have an invested interest in products of the area.

A management committee should be organized involving representatives of essential agencies and local communities, with the organizer as the convener. The committee thereafter monitors the design, survey, analysis and final reporting. If required, the committee will be involved in implementation and evaluation. At the end of the planning, the agencies should agree to an overall plan consisting of work schedules, staff needs, and budget. Sometimes a liaison office is needed in the field to represent the management committee.

This kind of jointly coordinated planning and decentralized implementation proves effective in many countries. The work is done more effectively and fruitfully than piecemeal or independent approaches.

6. TRENDS AND RESEARCH NEEDS FOR THE DEVELOPMENT OF INTEGRATED FARMING SYSTEMS IN CHINA

Because integrated farming systems have demonstrated great advantages, i.e. full use of natural resources, intensifying nutrient cycling, rising the efficiency of industrial input, producing higher and more diversified products to meet the ever increasing needs of the people, providing a higher income for farmers and more opportunities for employment of surplus rural labour, as well as preserving environmental quality, it has developed very fast in different regions of China. However, integrated farming is by no means perfected. There are certain constrains which restrict its speedy development. These include:

1. Integrated farming is a more complex system and less understood than monocultures. Any experimental designs involve complex relationships between components. It is a difficult task to development models in selected experimental stations where appropriate land, funds, and specialists are available;
2. Because of the lack of well organized extension services in the village, many successful models are usually practiced in limited areas;
3. The uncertain market prices and the shortage of processing and semi-processing facilities may cause serious problems. Farmers sometimes experience heavy losses;
4. Pest, disease and pollution problems have not yet been solved in integrated farming systems;
5. The policy and infrastructure for the implementation of integrated farming systems have not been sufficiently developed.

For further improvement and development of the existing farming systems in China, scientists suggest the following points which, to some extent, already reflect the general trend of development of integrated farming systems in China.

1) Refinement of the concepts and principles of ecological farming systems; integrated farming is not a simple combination of some new conventional agriculture technologies with traditional experiences, but is rather a feat engineering, based on ecologico-economical principles, integrating many components in space and time. The holistic concept, systematical approach, the rule of energy and matter flux throughout the food chain of an ecosystem, the principle of ecological niches, the diversity and stability of

the ecosystem, the environmental consequences and economic effects etc. should be particularly considered.

2) The performance of an integrated survey and comprehensive appraisal of different ecological farming patterns as the basis for a scientific classification system, the creation of optimized designs and the identification of suitable conditions for implementation. Based on the integrated survey, the geographical information system should be established.
3) The performance of in-depth studies on the structure and function of different types of ecological farming systems. Although some excellent work has been done on some specific types of integrated farming systems, most of the information obtained so far is experiential and based on traditional practices. The moderation of traditional knowledge and quantitation of integrated agricultural practices has always been a difficult task because of their inherent complexity. However, efforts have been made to conduct comprehensive studies using the quantitative approach and modelling methods. These pioneers have the honour of taking the lead in formulating a hypothesis, the evaluation of which, though, will have to wait for the allocation of adequate experimental resources. Long-term ecological research (LTER) on carefully selected sites could play a very important role.
4) The refinement of methods for assessing the integrated economical-ecological and social effects of the different types of ecological farming systems. Dynamic system analysis will be a useful tool in this respect.
5) The improvement of the technological systems used in ecological farming. These include the optimum combination of components in time and space, selection and genetic improvement of species of trees, shrubs, cereal crops, fodder species and domestic animals; through breeding, genetic engineering, tissue culture, and grafting. The improved quality of species should include characteristics such as high productivity, broader adaptation, greater stress tolerance, multiple uses and others. The method of cultivation is also the topic of study.
6) The determination of appropriate infrastructure and organization form to enable implementation of the ecological systems. Rural reforms should always take the requirement of integrated farming into consideration. Some special enterprises aimed at the development of agroforestry and ecological farming systems have been established jointly by academic and development organizations.
7) A major limit on the implementation of integrated farming system is a lack of trained personnel. Training is required at four levels: decision maker,

professional, technical and user level.

- At the decision maker level there is a need to rise the awareness of the integrated farming system in achieving the goal for sustainable development and make the appropriate policies for its successful implementation.
- At the professional level there is a need both for specialists who are able to make detailed studies, surveys, and designs for specific practices, and for generalists with a broad grasp of the theory and practices and with understanding of the various disciplines involved in agroforestry.
- At the technical level there is need for a combination of institutional training and in-service training. In-service training enables the technicians to rapidly acquire essential practical knowledge and technology used in agroforestry.
- At the user level, adequate support for farmers, pastoralists, fishermen, loggers, plantation operators and other land and water users is necessary if they are to implement the techniques of multi-sectorial production. To be successful, extension services must take great pains to explain the need, purpose and expected results of any measures they recommended. Demonstration will be most important for convincing the community at large of the value of such measures.

8) International cooperation, starting from exchange of information and personnel to jointly sponsored workshops and training courses research and development projects have been increasingly supported. Many countries and international organizations such as FAO, UNDP, UNEP, UNESCO, UNU, IUFRO and ICRAF, etc. have expressed their great interest in supporting and collaborating in this field.

SUMMARY

The traditional integrated farming systems in China have developed over thousands of years and have been applied on the widest geographic and economic scale. Recently, this system has developed very fast and has aroused considerable interest among scientists both in China and abroad.

This report is intended to give a brief review about the history and the experience gained from implementing the integrated approach in agriculture in China.

This report is divided into three parts. The first part includes chapters 1 to 3 which present a general review of the challenge and opportunities in the development of agriculture and the definition and the characteristic features of integrated farming systems in China. The second part, chapter 4, describes successful examples of integrated farming. The report does not include detailed descriptions of all the existing integrated farming systems in China, but rather concentrates on a few typical examples of systems. Finally, part three, including chapters 5 and 6, discusses the strategies and the perspectives of the development of integrated farming systems in China.

The book presents the diversity and complexity of integrated farming systems. The descriptions and their analysis show their merits and potentials on the one hand, and the obvious gaps in our understanding of these systems on the other.

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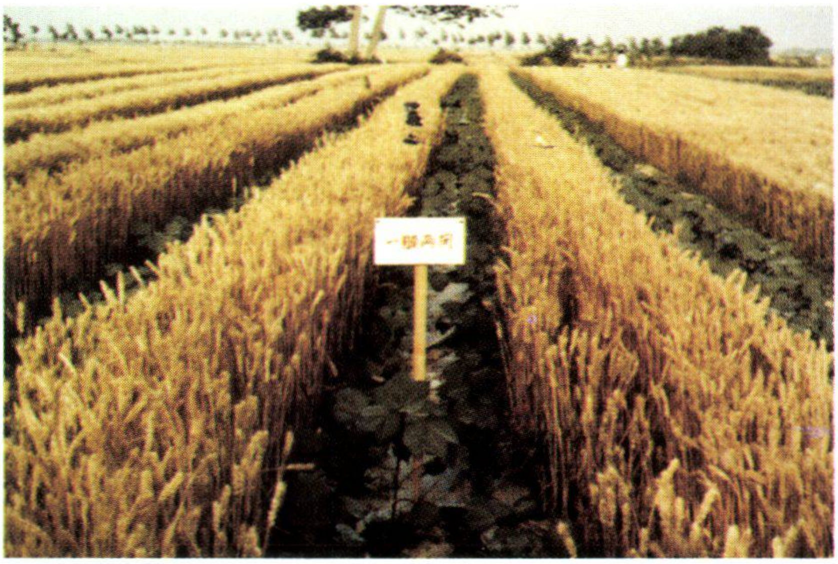
ILLUSTRATIONS TO DIFFERENT FARMING SYSTEMS



1. Cotton + wheat inter cropping system

2. *Paulownia* cereal crops intercropping

3. Swamp cypress + crop + fishery system

4. *Sapium* + tea system

5. Poultry + aquaculture system

6. *Eucalyptus* + tea system

7. Rubber + pepper system

8. Rubber + tea system

9. Integrated agriculture-aquaculture system