Integrated system design: exploring scientific principles in traditional Chinese agricultural practises[1]

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Abstract: *Crop yields in ancient China led the world. Mixed farming and multiple enterprise activities (MFMEA) providing various products were a feature of traditional Chinese agriculture. With a trans-disciplinary analysis employing theories and principles of ecology and economics, the role of multi-enterprising in sustainable livelihood of farming households are analyzed in this paper. Concepts of eco-ecological unit and eco-ecological niche are explored. Traditional Chinese farming practices are explained using scientific principles with an expection of providing useful scientific principles for farming system design for small farming families, especially those in under developed countries.*

Keywords: *Biodiversity, small farmer, multi-enterprising, livelihood, eco economical niche, EEN, traditional Chinese agriculture*

Introduction

China is amongst the four widely recognized ancient civilizations. Its splendid ancient culture was underpinned with well-developed agricultural economics. Emergence of the two origin centers of farming in China, the North China dryland farming region and the rice farming region in the middle and lower reaches of the Yangtse River, was consistent with civilization development in the Yellow River and in the Yangtse River regions. At the time of 7000 BC -5000 BC, dry farming developed in North China.

Crop yields in ancient China led the world. According to the record in Walter of Henley's Husbandry, the harvest/sowing ratio of cereals in west Europe in the 13th century was 3, while that of China in the 6th century was 20-24 for millets and 20-44 for wheat, according to The Essential Skills of The Qi People, the most famous ancient Chinese book on farming. The reasons that China had such high land productivity in ancient time have been concluded as: aborative land husbandry with intensive labor input in the field to retain soil water for resisting drought, good balance between utilization and conservation of land to increase fertility, active fertilization and use of green manure, crop rotation, multiple cropping, use of selected and improved seeds, seed treatment, tactical supplementary irrigation with limited water, and well-designed suitable farm implements for various field operations. Mixed farming and multiple enterprise activities (MFMEA) providing various products was paid great attention in traditional Chinese agriculture. Traditional Chinese practises have been effective in recovering agricultural productivity to support population booms again and again after famines or wars. Scientific principles can be explored from those successful experiences for the development of sound approaches to design efficient and effective integrated farming systems for multipurpose small households on subsistence or semi-subsistence status, under risky environments and resource-poor conditions. This presentation discusses theoretical principles drawn from the experiences of China.

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Traditional experiences and practices in Chinese agriculture: cases and principles

More than 4600 years ago, the Yellow Emperor, also known as Huang-di, has taught his people to apply the strategy of sustainable resource use of sowing various crops and planting trees, domesticating different animals, utilizing all kinds of natural resources, utilizing intelligence and labour continuously by observation, and using water, fire and materials in a limited and economical way（Si Maqian, 91 BC.） 'He taught his people to harvest, collect, hunt in mountains, forests, plains and wetlands in proper time periods, and to use the resources in a limited and economical way for getting benefits from them.' In Chinese history, although there were no clear concepts on sustainable development and food security, with the perspective and philosophy of 'the state is based on the people, and food is the God to the people' in mind, wise rulers had to pay great attention on the resources and environments for production and living.

In studies on the many effective traditional practises in ensuring food security and livelihood, there have been many research and publications on crop rotation, intercropping, agroforestry, etc. This paper will discuss roles of those practises in system design rather than describing the details of the practise per se.

Characteristics of traditional Chinese agriculture in major cropping areas can be summarised as follows:

- Multiple enterprising, including mixed farming, intercropping and sequential cropping.
- Diversified farming systems and farm products.
- Various ways of appropriate Intensification.
- Various and multiple means of soil fertility and soil-water conservation practices.

Land parenting (*Qin-Tian-Fa*):

The practise of *land parenting* was promoted by GENG Yinlou who was the then county head of Linzi in Shangdong province in the end of Ming dynasty. He wrote in his book entitled 'The Vital of The State and The Top Important to The People' that:

> "In the regions of Qing and Qi, there are vast areas of cultivated land and farmers are farming the lands in an extensive way. If they follow the traditional farming practice of laboring the lands with equal inputs, those households having inadequate labour would not be able to farm all their fields. So I propose the practice of land parenting, i.e. put all the inputs on a limited land area just like to keep a more intimate relation to one than to others. For a household having 100 mu of land, they can farm 80 mu in the traditional extensive way, but should increase every kind of input on the left 20 mu. Plowing, harrowing, dragging & impacting, sowing and fertilizing should be done several times more than on the 80 mu, and the surface soil should be harrowed to be as fine as flour so as to keep water in the soil. Irrigate the land when drought occurs, but soil water in the 20 mu should be better than the 80 mu even if there is no irrigation. In years with plenty rainfall, the production of the 20 mu could be several times higher than the 80 mu while in drought or logging years the harvest could still competitive with that from the 80 mu. When there would be a burst of pests, it would be much easier for the whole family to capture and kill the insects on a 20 mu to avoid loss. The parented land would be rotated on the 100 mu of land in five years, thus even if the land is poor, after five years of practicing land parenting it would become fertile. If one household has only 20 mu, they can parent 4 mu of the land. It would be much better than not practicing this method if the household adopt this practice according to their capacity, no matter how much the land would be parented. This method is very simple, very easy and very fine. There would be assured gain if one would adopt this practice. "

The principle embedded in this practice is that an appropriate intensity should be achieved for higher efficiency and sustainability. In the practice of land parenting, there exists a relation between intensity and efficiency of crop production, though the original promoter did not realize this. Economically, apart from a dramatic increase in land productivity and total production, productivity of labor, the most scarce resource assumed by GENG Yinlou the promoter of the practise, could be greatly improved as well because of the increase of productivity and total production—this would result in an increase of whole farm efficiency. Ecologically, intensive crop production practice is more sustainable than extensive methods. Although outside inputs are needed for intensive cropping, it has been argued that water and light efficiencies on cultivated land can be increased fivefold, and energy cost can be greatly reduced (Loomis, R.S. & Connor, D. J. 1996). This principle can be applied in solving food security problems in the global scale in a sustainable way as well as in designing effective systems for resource poor small households in Africa.

Delicate design of cropping systems—crop rotation and multiple cropping

Crop rotation, intercropping and sequential cropping are a major characteristic of traditional Chinese agriculture, and have contributed much in the history for feeding the huge population with the production from limited land area.

Rotation of legumes with other types of crop, especially cereals, has played an important role in maintaining soil fertility and providing diversified farm products. Jia Sixie, a great agriculturalist in the Late Wei Dynasty, wrote in his book ‘The Essential Skills of The Qi People’ that “Millet field should be rotated every year ”, “mung bean and haricot bean are the best previous crops for millet” and ”haricot bean is the best previous crop for melons”. He not only addressed the importance and proper sequence of crop rotation, but also proposed the concepts of previous and succeeding crops on which the later principle of *Chakou* was based.

There are many proverbs on crop rotation popular among farmers, such as “Changing crops is like to manure the field”, “Good crops can be expected with frequent crop change”. The stubble field that gives various impacts on the following crop has been named *Chakou*, a very Chinese term in agronomy by the farmers. In old times when agricultural chemicals had not been invented and irrigation were not popular, *Chakou* was paid great attention. This could be proved by a farmers’ proverb which says “You would not be able to harvest enough oat for raising one chicken if you grow it on the *Chakou* of millet (oat after millet)”. Without knowing the scientific mechanism of alleloparthy etc., Chinese farmers have farmed successfully for thousands of years with traditional knowledge and wisdom on crop rotation that came from long time experience of success and failure.

Multiple cropping, growing two or more crops on the same piece of land during a year, has played and is still playing an important role in providing the nation enough and diversified products on limited land area. In the eyes of system agronomists, multiple cropping is a way of intensifying crop production in spatial or/and temporal dimensions. Although intercropping, owing to rapid development of mechanization, is seldom being practiced in plain areas, it is still popular in remote and hilly areas. Sequential cropping is playing a more and more important role in increasing crop production on limited and declining arable land area. The current cropping index of China is approximately 170% and is expected to further increase.

The practise of sequential cropping on the North China Plain began in Han dynasty (206 BC-220 AD), but it’s significant contribution to the increase of cropping index was started in early nineteen sixties (end of Ming dynasty and beginning of Qing dynasty). According to the book A Collection of Beauties (flowering ornamental plants) written by Wang Xiangjin, the major limiting factors of adopting sequential cropping were soil fertility and land-labour ratio, while factors promoting the popularization of sequential cropping in the area include the wide cultivation of winter wheat, replacement of green manure with composted manure, and rapid increase of population.

Principles can be concluded from the tradition of rotation and sequential cropping that crop production should be organized on the basis of a good balance of use and conservation of resources. To increase intensity by sequential cropping is the way of making full use of the available resources and adoption of crop rotation and green manure in mono cropping systems is a way of maintaining soil productivity.

Life-saving irrigation

In transplanting crops, it's common that farmers water the seedlings with very limited amount of water to ensure the revitalizing and establishment of the seedlings. In areas where there are irrigation facilities but not adequate water resource to irrigate all the crops, farmers irrigate their crops with limited amount of water before or after sowing to ensure emergence and establishment and at critical stages of crops to avoid big yield loss or even complete failure. This practise has been named 'life-saving watering' by the farmers and has become an important option of strategic irrigation. The mechanism underlined in this practise has been concluded as a stimulating effect (Liang Weili, 2000) , i.e. a small amount of water simulates/ triggers the crops to use much greater amount of water and nutrients stored in the soil and received during growing season.

Mixed farming and multi-enterprise activities in major cropping areas

Unlike big farmers in the US, Australia and Canada, Chinese farmers usually grow several crops as well as raising animals at their homestead. This semi-subsistence type of agriculture system is the character of farming systems in many under developed countries.

Animal husbandry and crop farming have been combined since the origin of agriculture. Use of animal manure has been one of the most important means of maintaining soil fertility in major cropping areas in China. Until the late 1970s, before the communes were disbanded in the mainland, making compost with animal manure and crop residues was one of the most important tasks for most rural 'brigades'. And, before the 1980s, livestock have long been used as major draft power in the field and for transportation. Even during the time of the Great Cultural Revolution when household-raised animals were considered 'capitalist tails' thus were forbidden, collective animal raising were encouraged with the main purpose of providing manure for crops and draft power. Even at present, farmers in remote and mountainous areas are still using animals as the major draft power in the field and for transportation.

Ecologically, the combination of animals and crops makes a circle and collects more nutrients from outside hence improves nutrient and energy efficiencies within agricultural systems. Chinese farmers have developed many patterns of animal-crop integration, such as the mulberry or rice or sugar cane -fish - swine system in Guangdong province, rice-duck-fish systems in Jiangsu province and crop-draft animals and swine or sheep or goat in northern China. This combination also increases the stability of the relevant farming systems as well as providing higher and more reliable income to the farmers.

Lessons learned from traditional Chinese farming practises–designing optimum diversity and intensity in both temporal and spatial dimensions

Multiple enterprise activities (MFMEA), including mixed farming, had played an important role in the history in China, but it would only be possible to be useful in other places of the world if the embedded principles would be summarized.

MFMEA, biodiversity and farming livelihood

Farming households decide their livelihood strategies according to the features of their resources and social economical environments. Chinese traditional faming systems are characterized as small farm size, poorly equipped, under-developed marketing system, semi-subsistent, etc. Thus, to improve the effective utilization and efficiency of natural resources with reasonable labour input has been the basic livelihood strategy of Chinese farmers for thousands of years. Adoption of MFMEA is a tradition in Chinese agriculture and has played an important role in maintaining livelihoods of the farming families and rural economy of the country in the history. The sustainability of traditional livelihood systems supported by MFMEA has been proved by the rapid recovery of farm production after frequent wars in the history and by the fact that a huge population has been fed with the production from limited arable land area.

MFMEA, working on agricultural species and their by-products, is the process of employing biodiversity from the point of view of ecology. Biodiversity is important in maintaining stability of ecosystems (Lowrance et al, 1984). Outputs and efficiencies of an agricultural system rely on ecological processes of the system. Biodiversity results in economical diversity. In other words, economical diversity in agricultural systems is achieved through biodiversity. Therefore, biodiversity decreases economical risk and increases stability, which is very important for livelihood of small farm households that are weak in bearing risks. Biodiversity also extends the food chain in an agro-ecological system, i.e. industrial chain in economy, add value and meet diversified needs of the family members for living and production purposes.

Summarizing eco-economical rationales from MFMEA

The concept of eco-economical (ecological-economical) niche was proposed (Liang and Wu, 2002) to understand the features of farming activities from economical and ecological perspectives. The rationale could be borrowed to explain the historical success of MFMEA and to guide sustainable livelihood development of small poor farming households in developing countries.

Understanding ecological niche and ecological adaptability of agricultural species

In a natural ecological perspective, the process of agricultural development is to obtain biological products in a more efficient way by managing agricultural species and resources. In this process, adaptability to the environment and extent of resource utilization of species decide technical and economic efficiencies of an agricultural system. Thus, analysis and designing of a farming system often begins with analysing adaptability of its biological species. The ecological niche of a species is the position it fills in the environment comprising the conditions under which it is found, the resources it utilizes and the time it exists. Similarly, a functioning unit that is conducting ecological processes, such as nutrient cycling and energy transfer in an ecosystem, is defined as an eco-unit. According to the above definition, niche is the part that could be occupied or utilized by an eco-unit in the sequence of environmental factors. Thus, depending on an eco-unit's demands to environmental conditions and the sufficiency of environmental factors to the eco-unit, a niche may be divided into a fundamental niche and realized niche, as well as existing niche and potential niche (Liu and Ma, 1990). The fundamental niche is the part of environmental factors that could be actually or potentially occupied by an eco-unit, which is in fact the requirement of the eco-unit to the environment. The niche which is in exist in the realistic space is existing niche, while the niche which is not currently in existence in the realistic space is no-existing niche, and the niche which is not occupied by an eco-unit but is in existence is the potential niche of the eco-unit.

The superposing extent of the fundamental niche and existing niche indicates the adaptability of an eco-unit in a specific ecosystem. The more the fundamental niche superposes the existing niche, the better is the adaptability of the eco-unit in the system, and visa versa. Ecological adaptability of an eco-unit is directly related to its productivity.

Explaining farming activities with theory of eco-economic niche

Agricultural production integrates ecological and social economic processes, in which all of the components have both ecological and social economic features and function in both aspects and based on ecological processes. Although the concepts of ecological niche and adaptability are important to understand the role of a species in ecology, economy, production and livelihood, it is impossible to have a trans-disciplinary analysis to MFMEA only with the concepts of eco-unit, niche and adaptability. To solve this problem, we define the basic ecologically and economically functioning components of an agricultural system as eco-economic unit (EEU) (Liang and Wu, 2002).

Obviously, in farming livelihood systems an enterprise or production activity, such as chicken raising or cotton growing, is an EEU.

In order to explore the productivity potential of agricultural species, people always try to make them best adapted by superposing their fundamental niches with existing niches. Irrigation, fertilization, growing tropical vegetables in green houses in cold areas during winter, etc. are practises for this purpose. Obviously, ecological adaptability of an agricultural species can be changed by management practises, i.e., potential niche can become realistic niche (Liu and Ma, 1990) with human interference. However, since an agricultural species has both ecological and economic attributes, whether its adaptability would be artificially changed or not and to what extent it would be changed depend on both its natural attribute (ecological adaptability) and economic attribute (economic value of its product). The better the ecological adaptability or the lower the economic value of a species, the less interference would be needed; the worse the ecological adaptability or the higher the economic value of a species, the stronger human interference would be required.

The adaptability of an EEU in an agriculture system, availability of resources in the system that can be used by the EEU and social requirements of the product of the EEU together decide the economic standing of the EEU (its price, potential profit and importance in people's daily life and productive activities) in the system. In a farming system, the regime of resources occupation by an EEU and its economic standing that is decided by its ecological adaptability and social requirement for its product of the EEU is define as eco-economic niche (EEN) (Liang and Wu, 2002). EEN indicates the position and function of an EEU in an agriculture system. For example, various animals differ in biological features, need different feeds and management, meet different social demands and thus have different EEN. Similar to ecological niche, we can divide EEN into fundamental eco-economic niche and realized eco-economic niche; or potential eco-economic niche, existing eco-economic niche, and non-existing eco-economic niche.

Compared to an ecological niche in natural systems, EEN has the following features:

(1) Eco-ecological efficiency of EEN is decided by the eco-economic adaptability of the EEU to both local economic and ecological environment, i.e., the superposing of fundamental EEN with existing EEN. Quality and quantity of resource supply and its distribution along spatial and temporal profiles have a great influence on the economic and ecological performance of an EEU.

(2) Within a farming system, EENs of several EEUs might overlap partially, but their realised EENs would be separated by human management to avoid competition.

(3) Change of economic standing of an EEU would result in a change of its EEN, and visa versa. However, EEN of an EEU is stable over a relatively long period although some variation occurs in a short period. This is because ecological adaptability of the species would not change much in a short period of time and the structure of people consumption that is decided by tradition and costume of consumption would not change fast, hence the economic importance of the produce of the EEU would be relatively stable.

(4) The adaptability of an agricultural species is different to that in a natural system. 'Adaptability' in a farming system does not refer to growth and development in order to survive and reproduce, but good for the 'economic traits'. Sometimes these two adaptabilities are consistent but sometimes not. So, EEN does not simply equate to ecological niche plus 'economic niche'.

Applying EEN theory in MFMEA

In order to achieve the objectives of sustainable farming systems design, the theory of EEN could be employed. Principles in applying EEN theory in farming system design include

(1) Making full use of existing EEN and develop potential EEN to get integrative and efficient use of resources in both temporal and spatial dimensions as well as in quantity and quality aspects in a system. Methods for this purpose include introducing new EEU into the system, keeping an optimum intensity of production and increasing the grade of the industrial chain (i.e., length of

food chain), etc. The more completely the existing EEN is occupied, the higher the sufficiency to the society it indicates and the higher the efficiency of the entire system. Practises under this principle include row and relay intercropping, mixed farming, pursuing reasonable intensity of production, processing of farm products, etc. 'Courtyard economy' in rural areas is one of the successful examples.

(2) Exploring non-existing EEN. When an EEU does not adapt to a place where the requirement for its product is great, it usually has a high economic value and a great profit would be expected from improving its adaptability. For example, in the winter season of north China, farmers make great profit from growing warm season vegetables in greenhouses. In this case, the potential EEN of vegetables becomes existing EEN in greenhouses. There are tremendous numbers of successful cases of this, and the great success of this practise in Shouguang county of Shandong province could be a good example (Wang, et al 2005 and Han, et al, 2005).

(3) Improving the traits useful to human being, in quality or/and quantity, of an EEU by changing the environmental condition. For example, when a vegetable crop is grown for stem and/or leaf use, tenderness of its product could be improved by shading. Another example is that if a fibre crop is grown under a condition that is beneficial to fibre growth but unfavorable to seed development, the quality and yield of the fibre would be improved.

(4) Keeping an optimal number of EEU in a system. According to the principle of cybernetics (Jin and Hua, 1983), it is essential to enlarge possibility space as much as possible in order to achieve the desired result. Therefore, it is necessary to utilize the existing EEN as completely as possible by means of keeping an optimal number of EEU in a system in order to increase efficiency of the entire system. Too few EEUs would result in low stability and inadequate use of resources. On the other hand, too many EEUs would result in too much competition and increase internal consumption hence cause efficiency decrease in the entire system. So, multi-enterprise does not mean as many as possible. There should be a balance between benefits in short term and in long run, as well as between commercialization/industrialization and diversity.

Summary

Optimum intensification, delicate cropping system design, strategic/optimal resource allocation, together with MFMEA have played important roles in the history without the scientific rationale known by the practitioners and may play more important roles in the future being supported with scientific principles.

According to the theory of EEN, diversification of enterprises and appropriate number of niches being occupied integrated with optimal level of intensity, as well as improving adaptability of farming activities to local bio-physical and social-economical environments result in higher stability and efficiencies of agricultural systems, which are often crucial for small farming households to sustain their livelihoods, especially for securing their food supply. Multidisciplinary principles and transdisciplinary approaches may be needed, and the relationship between researchers and farmers in the design and development of MFMEA could be topics worth of further study.

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