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Agroecology for Food Security and Nutrition : Proceedings of the International Symposium on Agroecology in China

Steve Gliessman, Ruben Martinez, Si-Jun Zheng, Li Zeng, Xundong Li,
Zhixiang Guo, Kesuo Yin, Shengtao Xu, Tingting Bai, Yanxian Yang, et al.

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Food and Agriculture Organization
of the United Nations



AGROECOLOGY FOR FOOD SECURITY AND NUTRITION

PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM ON AGROECOLOGY IN CHINA

Kunming, Yunnan, China, 29-31 August 2016

BIODIVERSITY & ECOSYSTEM SERVICES IN AGRICULTURAL PRODUCTION SYSTEMS

AGROECOLOGY FOR FOOD SECURITY AND NUTRITION



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INTRODUCTION

In September 2014 the Food and Agriculture Organization of the United Nations (FAO) convened the International Symposium on Agroecology for Food Security and Nutrition. This was followed in 2015 by three regional meetings in Brazil, Senegal and Thailand. These meetings brought together stakeholders from academia, policy and civil society to facilitate better understanding of the role of agroecology in contributing to food security and nutrition. The meetings confirmed that the FAO's approach to agroecology should be based on regional and local realities as well as economic, social and environmental conditions. In order to continue to develop this regional approach a further symposium on agroecology the International Symposium on Agroecology for Sustainable Agriculture and Food Systems in China was organized by the Chinese Academy of Agricultural Sciences (CAAS), the FAO, and Yunnan Academy of Agricultural Sciences (YAAS), with the support of the Government of France¹.

China is a large agricultural country with a sizeable rural population. The country has rich agricultural resources and a long history of farming traditions; therefore agroecology is not a new concept in China. Traditionally, farms in China have developed ecologically-based farming systems, for instance intercropping and rotation, organic fertilization and integrated rice–fish farming. Land degradation, soil erosion, grassland degradation, deforestation, water shortages and significant deterioration of water quality standards are imposing severe threats to natural resources and biodiversity, for which technical capacities need to be further improved to address these changes.

Agroecology is seen as a key component of China's concept of 'ecological civilisation', a set of wide-ranging reforms, detailed in the 2015 plan, have been proposed to reconcile environmental sustainability with economic development. In May 2015, The State Council of China released the National Strategic Plan for Sustainable Agriculture Development (2015–2030). This was followed by the State Council's Guidelines for accelerating transformation of China's agriculture development mechanisms, which were issued in August 2015. These policies were developed to protect China's ecosystems and to promote ecological approaches to agriculture. Several key national projects have been initiated that use agroecological approaches, for example to protect grasslands, conserve soil and water and reforestation. In addition, effective science and technology models have been developed to conserve and control water consumption, reduce or even remove the use of synthetic fertilizers and pesticides and efficiently use animal waste.

¹ <http://www.fao.org/china/en/> 2 Report of the International Symposium on Agroecology in China Contents of the Symposium



The International Symposium on Agroecology for Sustainable Agriculture and Food Systems, held in Kunming (China) in August 2016, allowed for the presentation of multiple examples on how agroecological knowledge and science are applied in farming systems, with a special focus on Asia. The social change aspect of agroecology was strongly voiced by the organizations supporting and promoting the rights and needs of food insecure and malnourished communities.

The present Proceedings collect the lessons learned from the symposium, as well as the aforementioned knowledge, scientific research and case studies of agroecology in practice, both at the global level and those specifically focusing on China and Asian countries.



01

AGROECOLOGY: THE FOUNDATION FOR FOOD SYSTEM SUSTAINABILITY

Steve Gliessman, Carolina Starr and Rubén Martínez



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Abstract

Our current food systems have been successful in providing large quantities of food to global markets, but are causing significant negative effects on a number of fronts that have increasingly come under public attention. The food systems are responsible for several environmental impacts including greenhouse gas emissions, water and soil contamination. At the same time, the current food system is not helping overcome poverty. Agroecology puts in place a set of conditions and practices that allow diversified food systems to be self-sufficient, resilient, balanced, and multifunctional, such systems can endure over time reducing environmental impact while delivering many social results.

Agroecology in China has its origin in the late 1970s, stimulated by a combination of concern about serious environmental degradation and the introduction of ecosystem ecology theory into the country. The transition to agroecological food systems from those already existing is not a simple process. Five levels of transformation can be employed to better visualise the process. The first three levels occur at the farm level, while the fourth and fifth represent transformative actions that go beyond the borders of farms and include the entire food system. There is growing consensus that agriculture in China must transition towards sustainable practices that ensure food security and do not pose environmental risks.

INTRODUCTION

Our current food systems have been successful in providing large quantities of food to global markets, but are causing significant negative effects on a number of fronts that have increasingly come under public attention. Undernourishment affected 795 million people in the period 2014 to 2016, which means over 11 percent of the world's population went to sleep hungry (FAO, 2015). At the same time, obesity has more than doubled since 1980, over 600 million people were affected in 2014 (WHO, 2016) and about 1.3 billion tonnes of food is lost or wasted yearly (FAO, 2012a). Yields of maize, rice, wheat and soybean are no longer improving, but are stagnating or collapsing on 24 to 39 percent of growing areas (Ray *et al.*, 2012), while up to 75 percent of the genetic diversity of crops has already been lost (Thomas *et al.*, 2004) and up to 22 percent of the world's 8 300 animal breeds are at risk (FAO, 2012b).

Globally, food systems are responsible for 19 to 29 percent of all anthropogenic greenhouse gas emissions (Vermeulen *et al.*, 2012). Pesticide application and volatilisation of ammonia compromise air quality, while excessive phosphorous fertilization drives episodes of eutrophication and algal bloom (Gliessman, 2015a; Shiming, 2016). It is estimated that about 80 percent of the extremely poor, those living on less than USD 2.00 a day, were living in rural areas in 2010 (World Bank, 2015), a particularly stark situation for women, who comprise, on average, 43 percent of the agricultural labour force in developing countries (FAO, 2010).



When examined under a simplistic, cost-benefit analysis lens, diversified agroecological systems tend to be depicted as performing worse than the industrial. Increasing evidence suggests, however, that diversified systems can meet or even outperform the industrialised when additional aspects are taken into account. Diverse agro-ecosystems can deliver crucial benefits: ecological (carbon sequestration, biodiversity preservation, water quality regulation); social (preservation of local culture and traditions, nutritional well-being); and economic (poverty reduction, food price stability, generation of employment) (IPES-Food, 2016).

Agroecology puts in place a set of conditions and practices that allow diversified food systems to be self-sufficient, resilient, balanced, and multifunctional. Such systems can endure over time. They are, in other words, sustainable. Some of the features of agroecological systems that enable and define such sustainability are (Gliessman, 2015b):

- » having a minimal negative effect on the environment (soil, atmosphere, surface and groundwater) as a result of the use of eco-toxic substances;
- » reducing the release of greenhouse gases into the atmosphere while maintaining and enhancing the capacity for carbon sequestration of managed agricultural systems;
- » preventing soil degradation and erosion, as well as preserving and improving soil fertility;
- » using water in a way that prevents over-drafting of aquifers, allowing their replenishment and maintenance over time with both human and ecological needs being met.
- » replacing external inputs through recycling within agro-ecosystems and prevention of leakages and losses,
- » preserving and maintaining both wild and agronomic biodiversity;
- » granting equal access to agricultural practices, knowledge and techniques, as well as respecting the experience and practices of local and traditional agriculture, and indigenous knowledge systems;
- » eliminating hunger and ensuring a nutritious and culturally appropriate food provision on the basis of social and economic equal access.

These features are not unknown in China, where traditional agriculture is based on a solid relationship with nature that has evolved and adapted over the centuries. Rice-fish and rice-duck co-cultures, the use of green manure, intercropping of cereal and leguminous crops or pest control using natural enemies are a few ancient practices that embody several elements of the framework of modern agroecology (efficient nutrient cycling, maximising biodiversity or maintaining cultural identity) (Jiaen *et al.*, 2016; Xin 2016; Long *et al.*, 2016; Boqi and Yixiang, 2016).

Agroecology in China has its origin in the late 1970s, stimulated by a combination of concern about serious environmental degradation and the introduction of ecosystem ecology theory into the country. Agricultural production increased rapidly after the implementation of the “reform and opening up” policy in 1978 and the following years (Shiming, 2016). However, concerns about the detrimental environmental effects grew in parallel: overgrazing, overfishing, deforestation, heavy use of agrochemicals, soil degradation and erosion had become widespread problems. At the same time, during the late 1970s and 1980s, pioneers such as Professor Shen Hengli and Professor Xiong Yi began to recognise the application of ecosystem ecology principles to agriculture as a way to solve many of its problems (Shen, 1975; Zhuang, 1982). In 1981 and 1983, the Ministry



of Agriculture launched a training programme on agroecology for university teachers. Ecosystem theory and both national and international books on the subject were introduced in the programme. By the late 1980s, there were hundreds of publications on agroecology. Thousands were published each year after 2010. Ecology concepts and agroecology are currently well established and quite popular in China. Introductory courses are given in middle school while more detailed courses can be selected from university curricula (Shiming, 2016).

DEVELOPING AGROECOLOGY – RETHINKING THE ENTIRE FOOD SYSTEM

The transition to agroecological food systems from those already existing is not a simple process. Research has shown that it should be carried out in incremental steps towards the ultimate goal of globally transforming food systems. Five levels of transformation can be employed to better visualise the process (Gliessman, 2015b). The first three levels occur at the farm level, while the fourth and fifth represent transformative actions that go beyond the borders of farms and include the entire food system.

Level one

Improve the efficiency of conventional inputs and practices while reducing environmental impacts.

The first step towards sustainable agro-ecosystems is to reduce the use of non-renewable external or scarce inputs to minimise the associated environmental and economic costs. This has commonly been the target of conventional agricultural research and development. Precision farming, improved machinery, monitoring of pests to improve pesticide application and improvement of watering techniques are some examples of such practices. Although these measures reduce the use and environmental impact of external inputs, they do not break the need for external human inputs.

Level two

Substitute conventional external inputs for alternative practices.

This step aims to replace resource-intensive practices with alternative approaches. Organic farming and biological agriculture include many of these practices. Replacing nitrogen fertilizers can be accomplished by using nitrogen-fixing cover crops and rotations, biological pest management can replace pesticides and reduced tillage can prevent soil erosion and degradation. Although this step moves agro-ecosystems in the direction of sustainability, their fundamental structure is not altered, and many of the problems linked to industrial and conventional practices remain.

Level three

Redesign the agroecosystem so it functions under a new set of ecological processes.

Here, fundamental changes in the design of agro-ecosystems eliminate the basis for many of the problems that still occur at the previous two levels. The study of entire systems and their ecological potential and limitations allows for the use of system design measures to



prevent future problems. Implementing spatial and temporal diversity and crop rotation or the development of agroforestry are two examples of this step.

Level four

Re-establish a close connection between farmers and consumers.

Long lasting transitions occur within a certain social and economic context. Thus, this context must support the shift towards sustainable food systems. For local communities this translates into consumers valuing sustainable, locally grown food and, through their food purchasing decisions, supporting farmers who are willing to make the transition. The more communities that shift towards sustainable local food consumption, the closer the world will be to creating the new culture and economy of sustainability that is the basis of the last level.

Level five

Build a new global food system based on equity, participation and justice, that is not only sustainable, but helps restore and preserve the planet.

This level, unlike the rest, entails a fundamental change at the global scale that goes beyond farm, economy or social aspects, as it targets a profound change in our current understanding of human civilisation.

Depending on the starting point for the transition, each food system will begin at different levels, and can even integrate aspects of several levels simultaneously. For this reason, these levels must be adapted to each location, situation, and culture, depending on the current trajectory in which the food systems occur.

Courageous action on many fronts will be required by farmers, consumers, policy-makers, civil society and academia to bring about such a transition. One undeniable reality is the knowledge-intensive nature of and basis for this transition. In many parts of China, especially in the southern provinces, traditional farming systems have a long history of functioning at **Level three** thanks to practices such as integration of crops and livestock, crop rotations, maintenance of diversified systems and the use of local organic matter and other inputs. These systems can be strengthened by supporting local economies and a more direct relationship between farmers and consumers. Further integration and practicing agroecology and successfully convincing policy-makers about the necessity can move the transition towards **Level five**.

The term 'eco-agriculture', which in China refers broadly to sustainable agricultural practices, is very similar to what 'agroecology' represents outside China, and in China is often referred to as the practice of agroecology (Shiming, 2016). Eco-agriculture comprises two fundamental concepts that are interrelated: 'eco-agriculture technique' and 'eco-agriculture pattern'. 'Eco-agriculture technique', refers to a sound technical package used to develop and operate good and stable agroecosystem structures. Such agroecosystems are referred to as an 'eco-agriculture pattern' and can be further divided into three major areas according to the structure of agroecosystems: landscape planning, design of agroecosystem cycling and biodiversity arrangement.

Eco-agriculture techniques integrate different disciplines, combining traditional practices with modern knowledge to achieve fairer economic, socially appropriate and sound ecological results. These techniques mostly act within the boundaries of transitional **Levels one** and **two**. Resource replacement and saving practices such as biomass energy, use of green manure,



biological pest management or drip irrigation are examples of eco-agriculture techniques (Shiming, 2016). Eco-agriculture techniques are the stepping-stone for the development of sustainable agroecosystems beyond the farmgate and into transitional **Level three**, where the three areas of eco-agriculture patterns come into play.

Landscape planning provides a basic spatial framework for land use. This layout is based on measures such as balancing cultivated and preserved areas, allocating production of lumber, crops, livestock and fish to different altitudes, diversifying the spatial arrangement of different crops, including windbreak systems in flat areas or developing buffer zones along drainage systems, to name a few. The Yuanyang terraces system, in Yunnan Province, is an example of a landscape arrangement that dates back more than 1 300 years (Shiming, 2016). Agroecosystem cycling design covers five major cycles within a managed ecosystem: crop residues, animal waste, waste from factories, urban organic waste and carbon released into the atmosphere. A well-known example of an agroecosystem, based on recycling, is the fish-rice co-culture. Rice-fish systems (in fact, not only fish species are used, also in use are prawns, frogs, crabs, turtles) effectively reduce or eliminate the need for external chemical inputs, simultaneously provide carbohydrates and protein and reduce the risk of nutrient loss to the environment (Xin, 2016). A biodiversity arrangement refers to the preservation of both agricultural and wild biodiversity. The concept covers both genetic (such as intercropping of different rice varieties) and species diversity (such as intercropping of rice and legumes).

COCREATION OF KNOWLEDGE – THE WAY TOWARDS AN AGROECOLOGY TRANSITION

'Transdisciplinary' is a recently developed form of learning and problem-solving (Klein, 2001; Méndez *et al.* 2016). Different forms of already existing knowledge and experience are brought together and integrated in such a way that new knowledge is created. Transdisciplinary learning requires that different actors in society and science engage in a collaborative manner. Diverse approaches and visions are horizontally integrated in order to face complex problems and find positive and constructive solutions.

Local knowledge is a complex and dynamic body of know-how, practices and skills that have been developed and maintained by peoples and communities with shared histories (Beckford and Barker, 2007). It is knowledge that is constantly evolving, influenced by the environmental and socio-economic realities and continually being empirically tested. As mentioned before, agroecology is a knowledge-intensive discipline, based on its co-creation and dynamic preservation. Application of traditional and local knowledge is a necessary, but not sufficient, condition for the development of agroecology. Without the horizontal combination of traditional and scientific knowledge bodies, transdisciplinary activities cannot take place. Finding ways to horizontally integrate otherwise uncommunicative spheres of human experience remains a challenge, not only in agriculture but also in other sectors of society. Agroecology provides the framework for achieving such integration, necessary to build innovative solutions that can move our food systems towards sustainability.



Alternatives that respect, protect and promote traditional knowledge are a fundamental part of the change in the food system. One of the solutions adopted by many countries, including China, is the Globally Important Agricultural Heritage System (GIAHS) initiative. The concept of the GIAHS is distinct from, and more complex than, a conventional heritage site or protected area/landscape. A GIAHS is a living, evolving system of human communities in an intricate relationship with their territory, cultural or agricultural landscape or biophysical and wider social environment. Koohafkan and Altieri (2011) highlighted the importance of traditional agriculture systems, not just regarding food production, but also as a way to preserve the dynamic, ongoing traditional knowledge process.

There are 11 recognised GIAHS sites in China that cover almost 11 700 km² and include, among others, traditional rice-fish co-culture in Guizhou, mountain *Torreya* forest cultivation in Zhejiang, millenary dryland farming systems in Inner Mongolia or traditional Pu'er agrosystems in Yunnan, to mention a few (FAO, 2017). Furthermore, the Chinese Ministry of Agriculture initiated the identification and conservation of China Nationally Important Agricultural Heritage Systems (NIAHS) in 2012 and issued the Procedures on the Administration of Important Agricultural Heritage Systems¹ in 2015 (Min *et al.*, 2016). By the end of that year, 62 China-NIAHS had been recognised as “ingenious cultural production systems created from the long-term co-adaptation of a rural community with its environment and inherited to the present, which are rich in biological diversity, traditional knowledge and technologies, remarkable ecological and cultural landscape and are of important scientific and practical relevance to the inheritance, sustainability and multi-functionality of agriculture in China” (Min *et al.*, 2016).

All the aforementioned heritage systems cradle many traditional crop varieties, livestock breeds and ancient practices that, with the appropriate support, can be scaled up and out by other farmers for their dynamic preservation. Protecting and respecting traditional knowledge and linking it to the expanding body of agroecological science in China will set the foundations to reach **Level three** and go beyond to pursue the agroecological transition of food systems in China.

BUILDING A TRANSITION PROCESS – FROM THE FIELD TO THE POLICIES

There is growing consensus that agriculture in China must transition towards sustainable practices that ensure food security and do not pose environmental risks (Wenliang *et al.*, 2016). The potential of diversified agroecological systems to deliver better outcomes than industrialised agriculture has been increasingly documented over the past several years, particularly the capability of diversified systems to maintain stable outputs despite external shocks.

Several challenges lie ahead for the transition process in Chinese agriculture. The first development of agroecology in China took place in the 1980s and 1990s, when the most common

¹ The Procedures can be consulted here (in Chinese): http://www.moa.gov.cn/sjzz/zhengfasi/fagui/201509/t20150907_4818823.htm [accessed on 31 May, 2017]



type of agriculture was still small-scale, family farming. Currently, many young farmers have left the countryside and have moved to urban areas. In 2011, for the first time, more people lived in urban areas than in rural regions (Shiming, 2016). Smallholders are increasingly abandoning rural land while the scale of production grows and increasingly relies on the use of chemical fertilizers and other petrochemicals.

The transition process will require combined action from several fronts. Professor Shiming identifies three main actions for promoting agroecology in China: identify and build agroecosystems with ecologically sound structure and function; establish legislative and economic systems that support the development of agroecology and switch the dominant top-down approach to a combination of both top-down and bottom-up (Shiming, 2016). Extensive new research is needed to fully understand the ecological functions of agroecosystems. This research must bridge the traditional divisions in agronomic research and should adopt a more holistic approach. Local and traditional knowledge must be an integral part of this new research.

The second element is to establish legal and economic plans that support agroecology on both a short and long-term basis. The Chinese National Plan for Sustainable Development of Agriculture (2015-2030) was released in May 2015 and sets the framework for sustainable agriculture development in China (MOA, 2017). It divides the country into three main types of developing areas and establishes five key tasks. 'Optimised', 'moderate' and 'protected' development areas represent, respectively, areas of principal agricultural production that benefit from good conditions, areas of distinctive features of agricultural production but limited resources and environmental capacity and areas in strategic locations for addressing ecological protection. The five key tasks are the optimisation and enhancement of agricultural productivity, the protection of arable land and the promotion of sustainable use of farmland, to efficiently use water and to ensure the safety of agricultural water, to curb environmental pollution and improve the agricultural and rural environment and, finally, to restore the agricultural ecology, enhance ecological functions, protect grassland ecosystems, preserve biological diversity and restore the aquatic ecosystems.

The third element responds to a Chinese idiosyncrasy. The country's centralised planning approach means that government and scientists have to design, guide and manage the implementation of any agricultural development plan. The current situation has changed since that of several decades ago after following the implementation of the "reform and opening" policy. Although centralised planning continues to be the principal form of policy development and implementation, market oriented, civil society and non-governmental organizations (NGO) play an important role in shaping the outcome of governmental plans. Farmer's technical associations can be key actors in the transmission of traditional knowledge and in the co-creation and sharing of new insights. Agricultural cooperatives can ensure fair economic conditions for their members and consumers. NGOs and consumer associations can raise environmental awareness and support local food consumption initiatives. The transition of Chinese agriculture towards sustainable agroecological systems will surely benefit from a combination of bottom-up initiatives and top-down planning and guidance.



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02

AGROBIODIVERSITY AND AGROECOLOGICAL INTENSIFICATION IN YUNNAN

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Abstract

Yunnan is known not only for its abundance of ecological characteristics such as differences between day and night temperatures, extreme aridity and humidity, and the intensity of the light but also for its rich agrobiodiversity. Biological diversity includes the variety of geographical landscapes, climate, ecology and ethnic cultural diversity, which include 25 ethnic groups, of which 15 are exclusive to Yunnan province. Most areas in Yunnan are rich although ecological advantages are accompanied by poverty. It is foreseen that the development of the use of this biological diversity within ecological agriculture will reduce poverty and increase the livelihoods of local people.

The authors have presented several case studies from four counties in Yunnan province: Fumin, Yuangyang, Yuangjiang and Hekou as examples of

policy support for agrobiodiversity and ecological intensification to improve local livelihoods. The Yunnan Academy of Agricultural Sciences (YAAS) has taken on the responsibilities for the regional agricultural development objectives for the nation and, overall, the main strategic research tasks in the province.

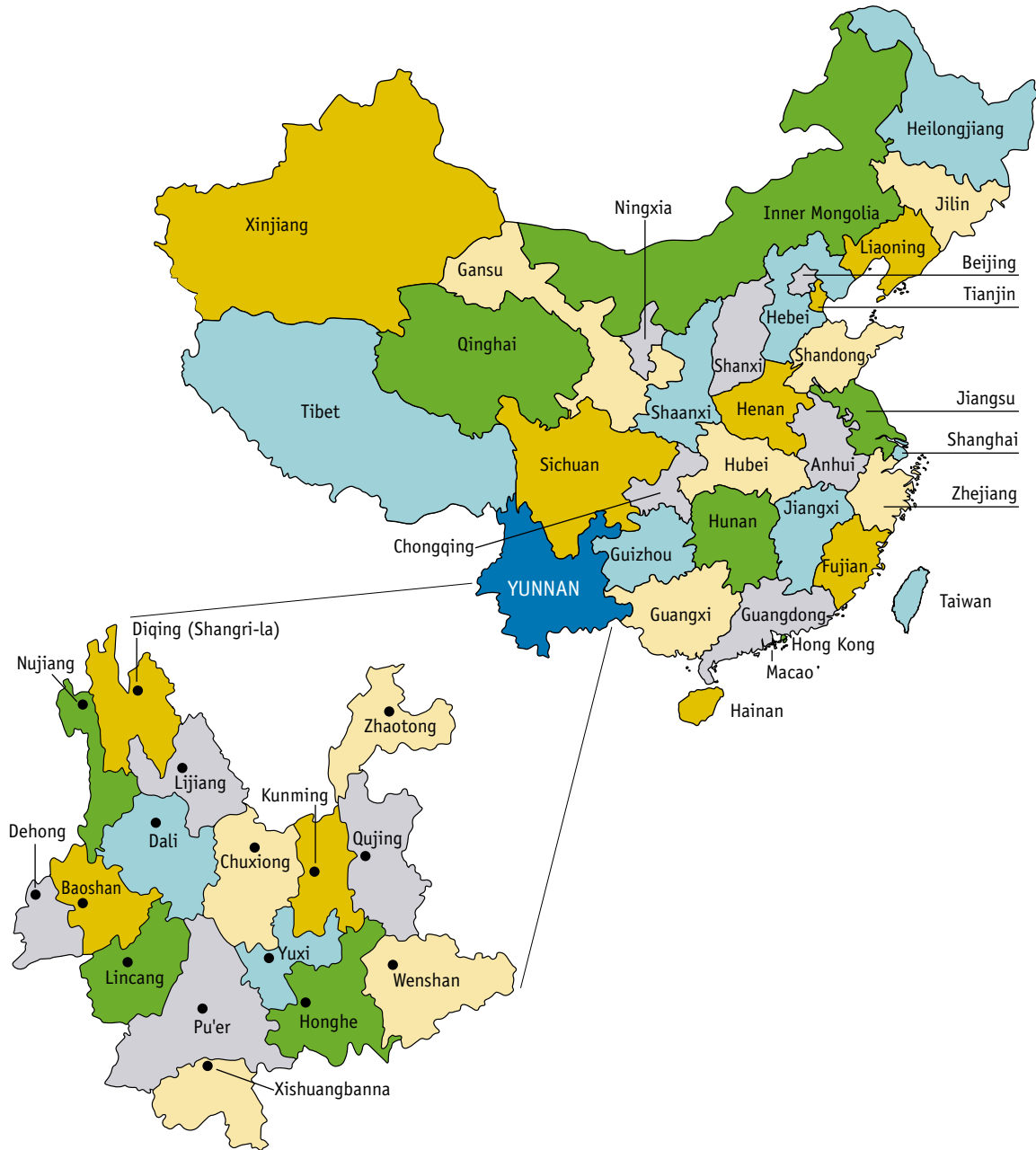
The studies include 'Livestock (pig)-Waste-Banana' ecological recycling production system and 'Banana-Cattle-Waste-Banana (or other crops)' ecological recycling production system are from ongoing research projects. YAAS has contributed significantly to the sustainable development of agriculture and the rural economy in Yunnan province. The 'One Belt and One Road' policy in China is turning Yunnan into a more important link to the Greater Mekong Subregion (GMS) and Southern Asia countries.

INTRODUCTION

Yunnan is a remote inland province in southwest China. Compared to the highly developed provinces in the coastal areas, the province is still relatively poorly developed economically because of its transportation infrastructure. Looking at the map, it can be seen that this province is just a small part of China (Figure 1). However, Yunnan province, which covers 32 931 km² has different temperature zones and many advantages are related to its resources and ecology. In the south of Yunnan province, Honghe prefecture shares an 848 km border with Viet Nam, while Xishuangbanna prefecture borders Myanmar and Laos. Yunnan covers 32 931 km² of land area the Red river runs through the southern Yunnan plateau monsoon low latitude region, and the Mekong river flows from Xishuangbanna to Myanmar, Laos, Thailand, Cambodia and Viet Nam. The province has a diverse ecology and climate, elevations vary from 76.4 m above sea level in the valley, to the highest mountain peak at 3 074.7 m above sea level. Yunnan province has a long tradition of crop production such as banana and rice cultivation.



Figure 1. Map of the People's Republic of China and map of Yunnan province.



Banana is a very important crop in Yunnan province; the province is ranked as producing the largest amount of bananas in China. In 2014, the 1.6 million mu (1 mu = 1/15 ha) cultivated area yielded 3 million tonnes. Honghe prefecture is currently one of the main banana producer's in the province. Yunnan is also one of the original centres for banana, such as *Musa yunnanensis* and its wild relatives. The province has maintained its original ecological environment, green, natural and pollution-free, suitable for the development of high-grade, top quality bananas. Yunnan banana-producing areas are located inland, far from possible damage by frost and typhoons.



These unique geographic conditions create large differences between day and night temperatures, resulting in the production of high quality 'plateau banana'. However, Yunnan, together with the national and global banana industry, is facing serious challenges. The banana industry is suffering from fungal diseases, especially banana Fusarium wilt disease Tropical Race 4 (TR4) is caused by *Fusarium oxysporum* f. sp. *ubense* (Foc), which directly threatens the income of local farmers and even the survival of the industry chain. Examples from Yuanyang and Honghe counties are given in Figure 2 and Table 1.

In 2013 the direct economic losses in China were an estimated USD 125 million because of banana Fusarium wilt disease, while direct economic losses in Yunnan were an estimated USD 41 million. However, it is difficult to estimate the amount of indirect losses resulting from this disease. Tropical Race 4 (TR4) was first discovered in 1996 in bananas produced in Brazil, and 'Guangdong No. 2' variety was found in Guangdong province, China. In 2001 the disease spread to Fujian province and it was then found in Hainan province in 2002. The disease spread to Guangxi province in 2006, and in 2009 TR4 was found for the first time in Mengla, Yunnan province. Today, this devastating disease can be found on banana plantations almost everywhere. TR4 causes serious problems; particularly for smallholder farmers with banana plantations on both sloping and flat lands.

Table 1. **Banana Fusarium wilt occurrence in Honghe county, Yunnan Prefecture in China**

No.	NAME OF COUNTY	OCCURRENCE AREA IN 2013 (MU)	OCCURRENCE AREA IN 2014 (MU)
1	Hekou	8 925	9 715
2	Jinping	5 170	6 170
3	Yuanyang	3 035	4 735
4	Gejiu	1 000	1 000
5	Pingbian	300	300
6	Honghe	200	200
7	Total	18 630	21 220

Figure 2. **Banana Fusarium wilt occurring in Yuanyang county, Yunnan province in China.**



All photos: © Si-Jun Zheng

A: Sloping banana plantation with serious TR4; B: Flat banana plantation also having serious TR4. Open field training course was organized for local banana farms on how to prevent TR4 from further spreading



Another serious problem is soil degradation, after the land has been used for a banana plantation and chemical fertilizers have been applied. Disease-suppressive soils, where organic fertilizer is applied, have been shown to be healthier and banana plants perform better against specific soil-borne pathogens such as TR4 (Yuan *et al.*, 2013). Another alternative method used as a biological control of TR4 is to manipulate the banana rhizosphere microbiome (Xue *et al.*, 2015). The management of banana disease is expected to be achieved by using agroecological approaches, such as rotation with other crops, intercropping and use of cover crops to improve soil health and to promote the increase of beneficial micro-organisms that are antagonistic to soil pathogens.

Rice is also a very important crop found in the origins of Chinese agriculture. Domestication of wild rice began more than 10 000 years ago and cultivated rice was an important starting point for early agriculture. The ancient agricultural of the mid and downstream areas of the Yangtze river, was characterised by rice and then spread to the huge area of Asia, which was an important ancient civilization. The simultaneous appearance of rice and millet culture in the Yellow river basin was the basis for the formation of the Chinese civilisation. Rice is also very important in Yunnan, where many wild rice species are found at the centre of the province's rich agrobiodiversity.

Furthermore, Hani Rice Terraces are an outstanding representative of Chinese rice terraces (Li *et al.*, 2016; Yang *et al.*, 2017). In order to contain costs, the Chinese people also invented Ratoon rice, which is a method of increasing food production in areas where the period of favourable temperature for rice production is too short for a double rice crop, and where labour scarcity constrains crop establishment (Dong *et al.*, 2017). Ratoon rice has been produced for more than 1 700 years, the method is easily adapted for climate change, has low input needs and can save on labour costs.

This section provides several typical examples, along with the case studies of agroecological practices related to food, fruit, flower and traditional Chinese medical crops in Yunnan province.

REVIEW OF THE EVIDENCE BASE

Agroecology in humid tropical systems is particularly important for the sustainable development of agriculture, especially for enabling smallholder farmers to achieve more sustainable management of the agricultural ecosystem, increase their incomes and achieve greater food security. One of the major challenges to a sustainable future for people and the planet is to ensure adequate and equitable distribution of food that is nutritious, affordable, safe, and accessible and of high quality for the world's growing population (Godfray *et al.*, 2000; Steffen *et al.*, 2015).

Globally, more than 2 billion people depend on smallholder farms for their livelihoods and food produced in different ecological regimes. The humid tropical ecological region in Asia includes the Great Mekong Subregion (GMS) of China (Yunnan province and Guangxi Zhuang Autonomous Region), Cambodia, Laos, Myanmar, Thailand and Vietnam, covering 300 million ha, with a population of about 326 million people, of which 63 percent depends directly on agriculture. Currently, 20 percent of the GMS population lives below the poverty line, and includes some of the world's poorest countries, such as Cambodia, Laos and Myanmar (Humidtropics Central



Mekong Action Area Report, 2013). Therefore, the application of agroecology is extremely important for the region's sustainable development. In Yunnan province, a total of 25 ethnic groups are distributed in different areas, 15 are exclusively located in Yunnan province itself (Wang *et al.*, 2014), and provide a good example of cultural biodiversity. The province is known for both primary ecological integrity and for its rich resources in agrobiodiversity and long history of applying agroecology.

EXAMPLES AND CASE STUDIES

Several examples of agroecology application and case studies are presented from the counties in Yunnan province: Fumin (located in Kunming, Figure 1B), Yuangjiang (located in Yuxi, Figure 1B), Yuangyang, and Hekou (located in Honghe, Figure 1B).

Fumin, under the jurisdiction of Kunming, Yunnan province is 23 km northwest of Kunming. The county covers 993 km² with a total population of 14.9 million (2012). Fumin has a rich production of rice, maize, wheat, tobacco, melons, wild rice, chestnuts, herbs, bayberry, grape, winter peach, cherry and grain. As Fumin has a good ecological environment, it was listed as the provincial hub for eggs and chestnuts, it is also the centre for high-quality rice production and the 'vegetable basket' project. Various altitudes are present in Fumin county, as most of the territory is mountainous with a few basins. The climate is typical low-latitude plateau subtropical monsoon, the annual average temperature is 15.8 °C, and the frost-free period lasts 245 days.

Fumin One

Chonglou (*Rhizomaparidis*) cultivation centre in Luomian town: unique traditional Chinese medicine

Rong Heng Agricultural Science and Technology Development Co., Ltd. is mainly involved in the production of Chinese medicine. The production areas display plateau characteristics where Chinese herbal medicines are cultivated such as Chong Lou (*Rhizoma Paridis*) with more than 1 000 mu of sloping land at an altitude of more than 2 020 m. Chong Lou is a very important Chinese medicine and has detoxification and analgesic effects. Three major traditional varieties are produced. The entire Chong Lou life cycle, from seed to product, is a long 10 years. The crop is produced using natural mountain spring water recycling irrigation system. Because the Chinese medicinal plant Chong Lou needs shade to grow, trees provide the unique environment to ensure better growth. Therefore, the system of production is agroforestry, where traditional Chinese medicine Chong Lou is intercropped with trees creating a 'Forest + Medicine' intercropping ecological system (Figure 3).



Figure 3. **Chonglou (Rhizomapharis) cultivation base in Luomian town: Unique traditional Chinese medicine.**



All photos: © Si-Jun Zheng

A: Seedling stage; B and C: Flower bud stage; D and E: Flowering stage; F: Mountain spring water irrigation system.

Fumin Two Baihuashan sweet apple production centre with plateau characteristics in Luomian town

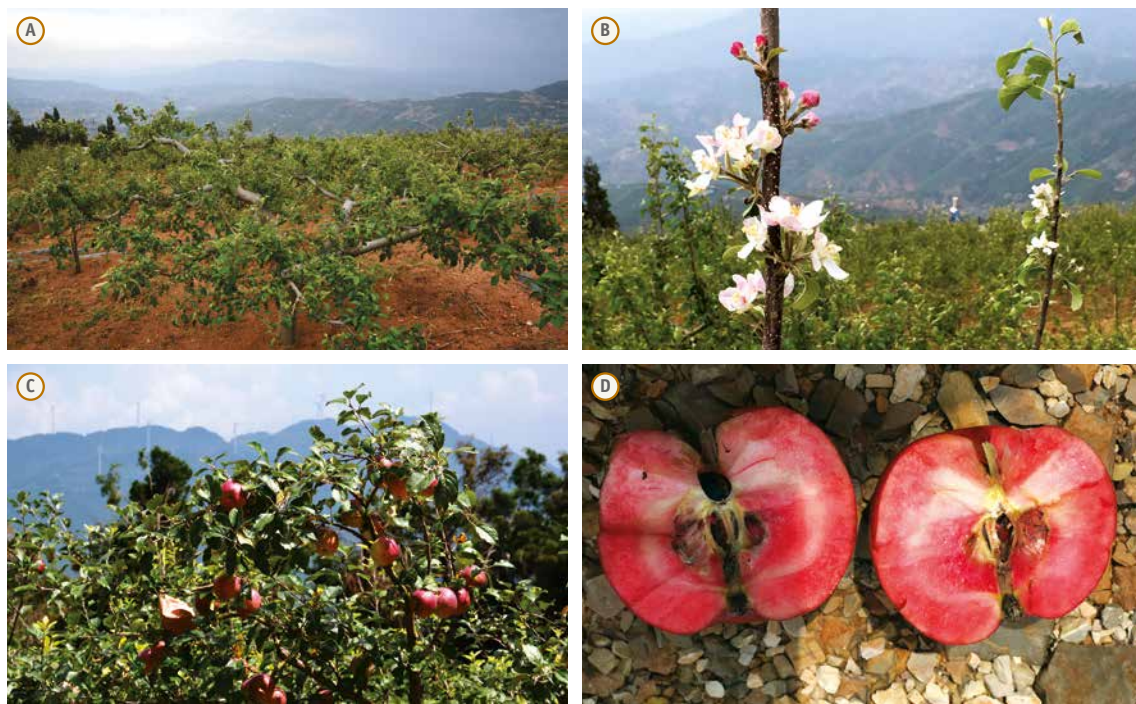
Baihuashan apple standardisation demonstration centre is in Luomian town at an elevation of 2 100 to 2 300 m. The company aims to develop a high quality brand of apple that is able to grow in a landscape having plateau ecological characteristics. The natural condition is suitable with moist air, temperature difference between day and night and strong sunlight. The company



produces excellent, quality apples in an agroecological environment, including sweet and sour, juicy Sauvignon, with bright colours, crispy flesh, fruit containing soluble solids along with many distinctive features such as the 'honey apple'. Currently, apple plantations cover 870 mu and are operated by 23 households run a 'company + centre + farmers cooperative' marketing model.

Forty-three varieties of germplasm are being conserved, which are being evaluated for their agronomic characteristics. Currently seven varieties are being produced commercially. There are early maturing variety cultivars (Gala, Sansa), mid-maturing varieties (Red General, 108) and late-maturing varieties (Fuji, etc.). In 2015 the yield was 900 tonnes, with an output value of RMB 12 million. This area has rich agrobiodiversity, and is a plateau, ecological agriculture system, combined with water and fertilizer integration (Figure 4). High quality, richly diverse green products are provided to markets.

Figure 4. **Baihuashan sweet apple production centre with plateau characteristics in Luomian town.**



A: Panorama of apple plantation; B: Flowering stage; C: Fruit setting; D: Specific germplasm with red colour of fruit.

Yuangjiang One

'Banana-Cattle-Waste-Banana (or other crops)' ecological recycling production system

Yuanjia Agricultural Development Co., Ltd has created a platform for innovation based on an integrated system of intensification: the 'Banana-Cattle-Waste-Banana (or other crops)' ecological recycling production system. After harvesting the bananas, a great amount of biomass



is usually left behind as waste in the plantations. On average, there are 29 kg of bananas per stalk and 6 tonnes of biomass waste in one mu of banana plantation. In Honghe county there are 1 million mu of banana plantations.

In Yuanjiang, Yunnan, there is a cattle farm that holds 1 162 cattle of which 836 are cows (Figure 5) where waste from the banana plantation is used as cattle feed. In this system, after the fruit is harvested, the leftover banana plants are combined with hay and sugarcane shoots and used as cattle fodder. On average, banana plants from one mu plantation can feed one cow. The manure from the cattle is applied to the banana plantations, or other crops, as organic fertilizer. This system has the advantage of combining the recycling of the huge amount of banana biomass waste with the integration of organic fertilizer, so as to conserve resources, promote animal husbandry enterprises, and protect the environment by employing soil and plant health-oriented management. This system is currently being scaled up in China.

Figure 5. **'Banana–Cattle–Waste–Banana (or other crops)' Ecological Recycling Production System was identified as an effective innovation system at Yuanjiang site, Yunnan.**



A: Banana pseudostem; B: Banana fruit column and leaves after harvesting; C: Chopping banana pseudostem into pieces; D: Cattle feed mainly derived from banana pseudostem, fruit column and leaves; E: Feeding cattle; F: Cattle waiting for feed.

All photos: © Si-Jun Zheng



Yuangyang One

Qinkou village using agrobiodiversity for disease and pest control in Hani Rice Terraces

The Hani Rice Terraces are an outstanding representative of Chinese rice terraces, and are also a phenomenon in the history of world agricultural civilizations. The special landform and climate contribute to this splendid, unique marvel – the Hani Rice Terraces. The forests, villages, terraced fields and the rivers of Yuangyang county, together form the original ecological system and the special terrace culture landscape, are without parallel in the world. The Hani people exercised great creativity by digging thousands of ditches on the mountains to help solve the main problem, the shortage of water.

The unique planting method has been employed for more than 1 000 years, which has effectively preserved the original genes of the hundreds of local landraces, including rice (Figure 6). Chinese ancients have left many cultural relics along the Honghe riverbanks, and the Hani Rice Terraces

Figure 6. **Qinkou village using agrobiodiversity for disease and pest control on Hani Rice Terraces.**



All photos: © Si-Jun Zheng

A, B and C: Terrace rice at the fallow stage; D: Terrace rice at the seedling stage; E and F: Terrace rice at the later maturity stage.



provide valuable information for those studying the history of the development of world farming and biological evolution. The Hani Rice Terraces include forests, villages, terraced fields and rivers that form the original ecological system and the unique terraced culture landscape.

Yuanyang Two 'Livestock (pig)-Waste-Banana' ecological recycling production system

Yuanjia Agricultural Development Co., Ltd have created an innovation based on a 'Livestock (pig)-Waste-Banana' ecological recycling production system in Yuanyang, Yunnan, (Figure 7). This farm combines pigs with banana production. The banana plantation covers 1 600 mu and most of the varieties are 'Brazilian', 'Guijiao No.6' and 'Hongyan No.1', which have been planted at altitudes from 360 to 1 000 m. The banana plantation employs 100 people and each person takes care of 2 500 to 3 000 banana plants.

Figure 7. 'Livestock – Waste – Banana' Ecological Recycling Production System was identified as an effective innovation system at Yuanyang site, Yunnan.



A: Pig farming nearby banana plantation at elevation 780 m above sea level; B: Pig production system; C: Pig manure into pool with effective micro-organisms (EM) for fermentation; D: Pig manure into banana drip irrigation system after filtering; E: The banana grower is also the owner of the pig farm, he is explaining the irrigation system and the advantage of combining pig farming and banana plantation; F: Banana plantation with pig manure as the organic fertilizer system.

All photos: © Si-Jun Zheng



The advantage of this system is that by combining crops and animal husbandry, and integrating water and fertilizer, resources are conserved and the environment is protected through the efficient use of pig manure (Bai *et al.*, 2016). In this case, more than 5 000 tonnes of liquid pig manure is produced and routinely used in the banana drip irrigation system. In 2013, a total of 7 050 tonnes of high quality bananas were produced at Yuanjia Agricultural Development Co., Ltd. Using pig manure in the irrigation system, solves the problem of the continuous and increasing demand for organic fertilizer for the banana plantation.

Banana Fusarium wilt TR4 was not found at this plantation because pig manure has an antagonistic effect upon TR4 pathogens as it contains potentially beneficial micro-organisms. In this way, after drip irrigation and soil improvement, soil fertility is increased, organic content improved along with the quality and yield of banana, while conventional fertilizer use has been reduced, soil-borne diseases such as TR4 are suppressed and environmental sustainability is maintained. After continuing to apply the organic fertilizers, beneficial micro-organisms, such as *Bacillus*, were found to be the most abundant bacterial group in the disease suppressing soils in the banana rhizosphere. The plant health status was correlated to the composition of the soil microbial community Xue *et al.*, 2015.

Hekou One Banana production system in sloping land

Yunshan Agricultural Science and Technology Co., Ltd has been innovative in preventing damage to bananas at harvest. The ecologically intensified banana production system is in Hekou, Yunnan (Figure 8). This banana plantation covers 1 500 mu and the main banana variety 'Guijiao No.6' is planted between 150 and 500 m. This company was the first to introduce the 'no damage banana harvesting system' to Yunnan province. The banana bunches are moved using a cable system instead of having bunches hand carried (See detail in the image C of Figure 8).

This system is extremely important in this province because most banana production is on sloping land, although there are also flat land banana production systems in other counties such as Xishuangbanna. This system can save labour costs and, most important, it improves banana quality as damage during harvest is reduced. Bananas play an extremely important role in boosting local incomes in Hekou county. Bananas are a favourite of local people and a cash crop that helps improve the quality of life tremendously. Therefore, even well-educated young women prefer to work at home as smallholders (Figure 8).

The associated biodiversity, however, may be threatened or may disappear if the sloping land continues to be planted with banana monocultures. The loss of genetic diversity and wild ecosystems is one of the major threats to the planet. Of course, another major threat is TR4, which requires careful management. An alternative production system could include cover crops such as the Chinese medicinal plant, Chong Lou, in an agroforestry system. As mentioned previously this option could be employed to limit the loss of agrobiodiversity and soil erosion on sloping land.



Figure 8. **Banana production system in Yunnan.**



All photos: © Si-Jun Zheng

A and B: Sloping banana plantation as overview; C: Banana harvest system; D: Ethnic Miao women enjoying working at home on their banana plantations; E: Local banana varieties; F: Ethnic Dai woman carrying her grandchild to sell local bananas.

DISCUSSION AND CONCLUSIONS

Further investigation is needed so as to understand the mechanisms and enhance productivity and the resilience of agricultural systems and rural landscapes. The innovative sustainable banana, pig and cattle integrated production systems, increases ecosystem services and the environmental sustainability of banana plantations.

Several examples are presented in this review that are related to livestock and plantations such as pig, cattle and banana. The eco-agriculture model, such as integrated systems employing 'pig-biogas-fruit-fish' has been reported in other provinces of China (Liu *et al.* 2010; Hu and Hu 2006; Xi *et al.*, 2014; Fang *et al.*, 2012).



Here specific attention is placed on banana as an entry point, because Yunnan is one of the largest producers in China and, historically, Yunnan is one of the centres of origin for banana (Liu *et al.*, 2007). Furthermore, banana as a cash crop has contributed greatly to the improvement of smallholder livelihoods.

It is known that banana and plantain (*Musa* spp.), which are among the oldest cultivated plants, are native to tropical South and Southeast Asia. With a production of over 100 billion bananas annually, they are the fourth most important food crop in the world (Manzo-Sánchez *et al.*, 2015). Nearly all commercially grown banana plants are clones, which means that globally banana cultivation is extremely prone to disease epidemics (D'Hont A, 2012). This became evident in the middle of the twentieth century when the banana Gros Michel was wiped out by Panama disease (Fusarium wilt). Eventually, Cavendish bananas replaced Gros Michel globally, because they are innately resistant to the Foc Race 1 strains that caused the iconic epidemic.

In the last decade of the twentieth century a new Foc genotype, known as Tropical Race 4 (TR4) was identified, which also affects Cavendish bananas. Recently, TR4 has been causing irreparable damage, especially in Asia where it has devastated entire plantations, including areas planted with Cavendish (Silva *et al.*, 2016). TR4 is extremely virulent on a wide variety of banana germplasm, including many local cultivars that are destined for regional markets, and so far neither fungicides, nor cultural or biological control measures have been identified that sufficiently warrant sustainable production of susceptible varieties in infested areas (Ploetz, 2015).

The loss of production in Indonesia, Taiwan and Malaysia is an estimated USD 400 million each year (Aquino *et al.*, 2013). Disease management is largely restricted to excluding the pathogen from non-infested areas. TR4 has now spread throughout Southeast Asia and has been detected recently in the Near East (García-Bastidas *et al.*, 2013), the Indian subcontinent (Ordonez *et al.*, 2015a) and Mozambique. Furthermore, TR4 has proven to be a single pathogen clone (Ordonez *et al.*, 2015b). This would be a disaster for the global industry as it could potentially disseminate to Latin America, where banana is grown as a large-scale monoculture for the export trade.

Fusarium wilt is a vascular wilt disease. The pathogen spores infect the roots of susceptible banana cultivars and the hyphae grow into the vascular system of the plant, which eventually (in)directly occlude the xylem vessels, causing wilting and finally plant collapse (Li *et al.*, 2011). Infectious resting chlamydospores survive for many decades in the soil. Polymerase chain reaction (PCR)-based diagnostic tools have been developed to specifically detect TR4 in various complex substrates (plants, soil and water) (Dita *et al.*, 2010; Lin *et al.*, 2012; Yang *et al.*, 2015). Evidently, these tools assist in the detection of Foc and the implementation of quarantine measures to prevent dissemination. It is anticipated, however, that this will not prevent the pathogen from spreading globally.

It has been suggested that beneficial micro-organisms can be employed to suppress Panama disease in banana plantations, since healthy plants are found in endemic areas, most likely because of disease suppressive soil. Xue *et al.* (2015) previously identified potential beneficial microorganisms such as *Bacillus amyloliquefaciens* from the banana rhizosphere microbiome as another alternative method for the biological control of TR4. It was found that pig manure



may have an antagonistic effect on TR4 infected banana plantations through the actions of potentially beneficial micro-organisms

An integrated approach, using organic manure or fertilizer, is a good choice for future control of TR4 (Zhou *et al.*, 2013; Li *et al.*, 2012; Membrive *et al.*, 2012; Phirke *et al.*, 2008; Saravanan *et al.*, 2003; Silverstone, 1997; Yuan *et al.*, 2013; Zhong *et al.*, 2015). On banana plantations, where there has been long-term use of pesticides, microbial activity in tropical volcanic soil is highly activated and easily adapts to organic inputs (Blume and Reichert, 2015).

Currently, Yunnan province employs a strategic plan to develop a modern 'manor economy', as an important method of development to promote development and changes in Yunnan agriculture with plateau characteristics. Yunnan planned the building of 100 provincial agricultural estates in 2017. The local policy is to develop agroecological systems having plateau characteristics and to explore a path of agricultural modernisation to take advantage of the unique characteristics found in Yunnan. These include the advantages related to the Yunnan geography, climate and species biodiversity.

The idea is to build on the competitive green brand of its agricultural products; enhance agricultural modernisation; promote the six specialised agricultural systems: 'Plateau granary, featured crops, mountain animal husbandry, freshwater fisheries, efficient forestry, open agriculture'. In developing the plateau characteristics of agriculture in Yunnan, efforts are concentrated on exploring the various forms of agriculture modernisation, so as to continuously open up capital and farmers to win-win cooperation as with the 'Yunnan map'.

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03

AGROECOLOGICAL FOOD SYSTEMS AS A WAY TO ENHANCE ECOSYSTEM SERVICES

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Abstract

The debate about how to continue feeding the world in the face of the rapid growth of the world population is ongoing. Agriculture depends on ecosystem services, so ensuring food security requires a transition to sustainable food systems that sustain ecosystems. Agroecology is an example of applying an ecosystem services approach to food

systems. The Food and Agriculture Organization of the United Nations (FAO) recently adopted a dynamic and innovative framework on agroecology composed of 10 elements that addresses current issues in food systems. This paper reviews how agroecology contributes to ecosystem services beyond producing food, based on the 10 elements. framework.

INTRODUCTION

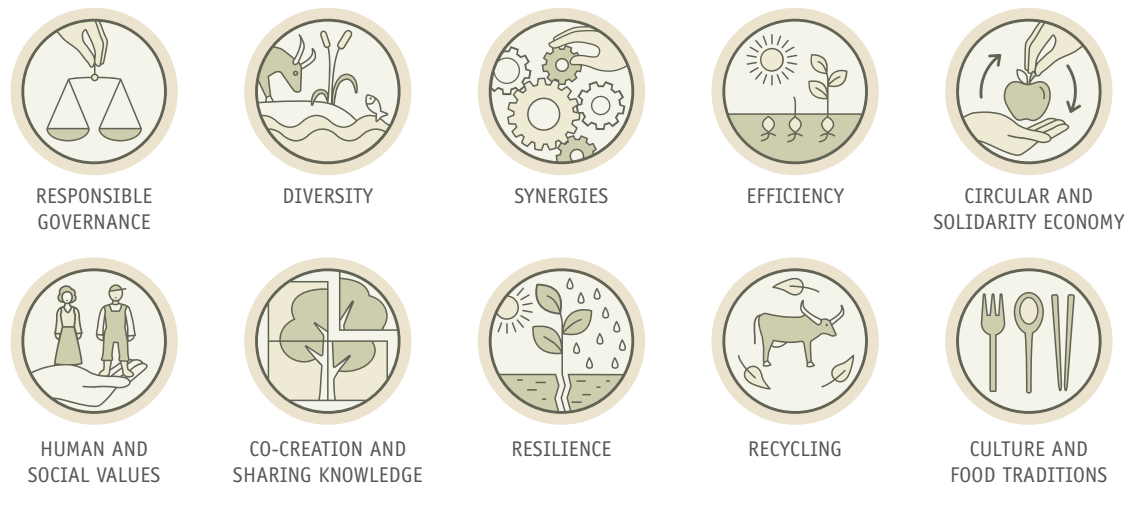
The debate about how to continue feeding the world in the face of the rapid growth of the world population is ongoing. The increase from 7.5 billion people today to the forecasted world population of 9.3 billion in 2050, combined with dietary changes, will require an increase in food production (Tittonell, 2014; Wezel *et al.*, 2014; FAO, 2014; UNFPA, N.D.). The growing demand for food has resulted in a decline in the provision of ecosystem services (Bommarco *et al.*, 2013). Current food systems face ecological, social and economic challenges such as hunger, poverty, inequalities, inadequate diets, soil degradation, water scarcity and pollution, loss of biodiversity and climate change (FAO, 2014).

Agriculture depends on ecosystem services; therefore ensuring food security requires a transition to sustainable food systems that sustain ecosystem services (FAO, 2014). There is the need to transition to food systems that meet future economic, environmental, climatic and social challenges, that sustainably increase production and minimise the impact on the environment (Tittonell *et al.*, 2016; FAO, 2017).

Agroecology is an example of applying an ecosystem services approach to food systems. Agroecology applies ecological concepts and principles to optimise interactions between plants, animals, humans and the environment, while taking into consideration the social aspects that need to be addressed for a sustainable and fair food system (Agroecology Knowledge Hub, 2016).

The FAO recently adopted a dynamic and innovative framework for Agroecology composed of 10 elements that address current issues in food systems (FAO, 2018). The 10 elements are derived from the general principles articulated for agroecology and composed of agronomic elements for the design and management of agroecological systems (derived from seminal work on agroecology, i.e. Altieri, Gliessman, Tittonell) and socio-economic elements that are important to consider and value in food systems (Figure 1).

This paper reviews how agroecology contributes to ecosystem services while producing food, on the basis of FAO's 10 elements. Shifting from simplicity to complexity, the food system can deliver more than just food and nutrition and can be transferred from being an environmental

Figure 1. **The 10 Elements of agroecology**

enemy to being a strong ally. Although the results section of this paper is structured by the elements, it is important to note that agroecological practices or systems are not based on only one sole element, but on a dynamic and integrated combination of agronomic and social and economic elements (as demonstrated in Boxes 1 to 10). As agroecology is an innovative approach that analyses the entire food system and its problems, socio-economic elements are key as they form the context in which the food system is embedded. The benefits agroecology confers to ecosystem services are the sum of the combination of these elements.

In this way, agroecology is able to support countries in achieving the Sustainable Development Goals (SDGs); most of which can be supported by using agroecology within food systems. Moreover, agroecology could potentially improve the achievements of the SDGs, whose realisation is threatened by ecosystem degradation. Agroecology, as a holistic approach, can contribute to several SDGs (SDG 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16 and 17).

The following key ecosystem services will be discussed in this paper: Food production; Genetic resources (diversity); Pollination; Biodiversity; Water regulation (quantity and quality); Soil health; Climate mitigation (including carbon sequestration); Resilience to climate disturbance; Biological control; Cultural services.

RESULTS AND DISCUSSION

Agroecological elements

Diversity

Diverse farming systems are those that have a variety of components within the food system at multiple levels (Agroecology Knowledge Hub, 2018). Various studies have shown that diverse farming systems suffer less crop damage caused by pests and diseases and extreme weather



events, maintain similar or increased yields, higher productivity and greater yield stability compared to monocultures (Frison *et al.*, 2011; Altieri *et al.*, 2015). Diverse cropping systems also lead to more diverse diets as farmers have access to a greater variety of food. Diverse cropping systems ensure greater availability of food within the year, which improves nutrition and hence health (Altieri, 1999; Frison *et al.*, 2011).

Diversified agricultural systems use the system's multiple genetic resources and benefit biodiversity (Brussaard *et al.*, 2010). Elements such as field margins, hedgerows or agroforestry systems, increase provisions to habitat as well as connectivity between different habitats, which enhances biodiversity (McNeely & Schroth, 2006; Wratten *et al.*, 2012; McNeely, 2006). Also, such elements provide cultural services through their aesthetical value (Gurr *et al.*, 2013; Wratten *et al.*, 2012). Moreover, increased habitat provisioning and habitat connectivity have a positive effect on pollinators (Potts *et al.*, 2010).

Diversified systems are highly beneficial to biological control. Studies of diversified farming systems (e.g. provisioning of habitats), have shown increased levels of natural enemies, reduced levels of herbivore presence, reduced rate of disease development and reduction in crop damage (Frison *et al.*, 2011; Kremen and Miles, 2012; Hacket and Lawrence, 2014; Altieri *et al.*, 2015). Increased biological control is also related to crop species and niche selections, such as the distance between susceptible host plants and competition between pathogens (Frison *et al.*, 2011). Intercropping and crop rotations, because of better soil cover, have the potential to suppress weeds (Mucheru-Muna *et al.*, 2010; Kremen and Miles, 2012). Furthermore, an increase in biological control has a positive effect on water quality as fewer pesticides are needed (Gaba *et al.*, 2015). Likewise, field margins protect the quality of (bordering) waterways (Wratten *et al.*, 2012).

Soil organic matter (SOM) contents have been shown to increase in more diverse farming systems compared to conventional systems (e.g. through green manure, cover crops, or compost) (Marriot and Wander, 2006; Kremen and Miles, 2012). SOM increases the water-holding capacity, decontamination of water and water infiltration, which results in higher water-holding capacity (Kremen and Milese, 2012; Altieri and Nicholls, 2017). SOM also increases the formation and stability of surface soil aggregates, preventing runoff of soil particles and erosion (Altieri *et al.*, 2015; Kremen and Milese, 2012).

Modern monocropping farming systems are highly vulnerable to the effects of a changing climate (Altieri *et al.*, 2015). In contrast, diverse farming systems have the potential of mitigating climate change and increasing resilience. In the case of climate change mitigation, for example, trees and shrubs in agroforestry systems have been demonstrated to sequester significant amounts of C in above- and below-ground biomass and in the soil (Jose and Bardhan, 2012; Chauhan, 2015). Diversified farming systems are better able to buffer the system from climate change and climatic variations and are more resilient (Altieri and Koohafkan, 2008; Lin, 2011). Research in the Republic of Nicaragua after hurricane Mitch (Holt-Giménez, 2002) and in the Republic of Cuba after hurricane Ike (Rosset *et al.*, 2011) has demonstrated that diverse farming systems suffered lower losses compared to conventional systems and recovered faster. For instance the research after hurricane Mitch has shown that agroecological farms had 40 percent more top soil, 63 percent less occurrence of gully erosion and 193 percent higher incomes compared to conventional farmers (Holt-Giménez, 2002). In



addition, Rosset *et al.* (2001) observed that the most agroecological farms following the hurricane had recovered 80 percent after 60 days and almost 100 percent after 120 days. In contrast, the least integrative farms only achieved 80 to 90 percent recovery 180 days after the extreme event.

Box 1.

AGROECOLOGICAL DIVERSIFIED SYSTEM

(elements: diversity, synergies, co-creation and sharing of knowledge, human and social values)

An example of an agroecological diversified farming system is described by Gandon (2016). The diverse farming system includes rice-fish-duck integrated farming, an agroforestry component, a livestock component and flower margins. The synergies between each of these components are maximised. Knowledge is co-created at the farm's learning centre, while human and social values are reinforced by the sharing of knowledge, strategies, seeds and tools among family farmers in the area.

Efficiency

The agroecology element 'efficiency' is an emergent property of agroecological systems that are carefully planned and diversity is managed to create synergies between different system components; it reduces external inputs and their negative impacts on ecosystems, while improving or maintaining food production. Biological processes are optimised (such as nutrient cycling) and the loss of resources from the system, such as nutrients, is limited (Agroecology Knowledge Hub, 2018).

Practices that increase resource use efficiency have been shown to have positive effects on nutrient management, while decreasing dependency on fertilizer inputs and decreasing pollution. Agroecological diverse farming systems have shown higher nutrient use efficiencies as there is better uptake of nutrients into crop biomass and soils (Kremen and Miles, 2012). This leads to a decreased reliance on fertilizer inputs and lower levels of nutrient losses to the air and to waterways. Losses of nutrients into the air (such as the greenhouse gas nitrous oxide) contribute to climate change and runoff or leaching of nutrients to waterways pollutes the water and can cause eutrophication (Tilman *et al.*, 2002; Kremen and Miles, 2012).

Intercropping, crop choice and crop rotations can increase the efficiency of resource use. The agroecological design of intercropping systems takes into account specific plant niches and plant interactions. For example, in a legume intercropping system, with a cereal crop such as maize, the legume crop fixes N from the air while the cereal crop uses soil N. The legume crop adds the fixed N into the soil, which is incorporated into the soil. A second example of agroecological design in intercropping involves crop varieties with different rooting depths or different sowing times. This avoids competition for nutrients and water, and plants are able to use a larger soil volume with nutrients and water (at different depths, including recovery of residual soil N) (Hauggaard-Nielsen and Jensen, 2005; Li *et al.*, 2007; Kremen and Miles, 2012; Gaba *et al.*, 2015).



Nitrogen inputs contribute to emissions of the greenhouse gas nitrous oxide (Tilman *et al.*, 2002). Therefore, in the context of climate change, an increase in nutrient use efficiency and reduced inputs of N fertilizer are crucial to potentially reducing Nitrous oxide emissions (Scialabba and Müller-Lindenlauf, 2010). In addition, increased water use efficiency will help adapt farming systems to (severe) drought and reduced rainfall (Power, 2010).

Box 2.

EFFICIENT AGROECOLOGICAL SYSTEM

(elements: efficiency, diversity, recycling, co-creation and sharing of knowledge, culture and food traditions)

An example of a diversified, efficient, agroecological farming system in the Republic of Malawi is described by Chikowo *et al.* (2016). Groundnut and pigeon pea are grown as intercrops and are part of Malawi's culinary tradition. Both crops have different growing cycles, minimising competition for resources, and both crops fix N that reduces fertilizer applications in the rotational maize crop. The doubled-up legume technology is based on traditional knowledge, and knowledge is co-created by farmers' action groups.

Recycling

The element recycling within agroecological approaches is about imitating natural ecosystems. Agroecological practices support biological processes that drive the recycling of nutrients, biomass and water within production systems (Agroecology Knowledge Hub, 2018). Recycling does not only provide nutrients, it also reduces chemical fertilizer inputs and can diminish the loss of nutrients from the farming system (Lal, 1995; Granstedt, 2000).

Recycling of crop residues (such as straw) and green manure, through incorporation or retaining them in the field after harvest, has been shown to have positive effects on soil quality such as increased N content, SOM and soil organic carbon contents, recycling of nutrients and soil moisture retention (Dolan *et al.*, 2006; Dahlin, 2011; Turmel *et al.*, 2015). According to Altieri *et al.* (2015) "soil organic matter (SOM) and its management are at the heart of creating healthy soils with an active biological activity and good physical and chemical characteristics". For instance, an increase in soil organic matter has a positive effect on arbuscular mycorrhizal (AM) fungi – beneficial soil micro-organisms that are essential for plant productivity and soil health (e.g. for nutrient transfer, AM fungi increases nutrient uptake) (Gianinazzi *et al.*, 2010; Altieri *et al.*, 2015).

Crop-livestock integrated farming systems also increase nutrient recycling and reduce the need for chemical inputs, which increases the sustainability of food systems and enhances their provision of ecosystem services (Ryschawy *et al.*, 2012; Bonaudo, 2014; Moraine *et al.*, 2014). Integrated crop-livestock farming systems depend less on external inputs (Bonaudo, 2014) by improving internal nutrient cycling and thereby reducing environmental impacts (de Vries *et al.*, 2015). According to Lemaire *et al.* (2014) "Integrated crop-livestock systems could provide opportunities to capture ecological interactions among different land use systems to facilitate



the efficiency of agricultural ecosystems for cycling nutrients, preserving natural resources and the environment, improving soil quality, and enhancing biodiversity”.

Box 3.

AGROECOLOGICAL SYSTEM BASED ON RECYCLING

(elements: recycling, diversity, responsible governance, culture and food traditions, co-creation and sharing of knowledge, circular and solidarity economy)

La Via Campesina Africa (2016) described the agroecology farming system of the Shashe community in the Republic of Zimbabwe, who employ practices that are based on diversity and recycling, such as the use of organic manure from cattle, mulching and intercropping. Land and natural resources governance are key elements in this case study. Culture and food traditions are being maintained by the use of traditional seeds and varieties. Farmer to farmer methods are used to learn and share new farming practices and there is an agroecology school, which is increasing the co-creation and sharing of agroecological knowledge. Local markets have been created for farmers to sell their products.

Synergies

Building synergies into food systems delivers multiple benefits. By optimising biological synergies, agroecological practices enhance ecological functions, leading to greater resource-use efficiency and resilience. Agroecology pays careful attention to the design of diversified systems that selectively combine annual and perennial crops, livestock and aquatic animals, trees, soils, water and other components on farms and in agricultural landscapes to enhance synergies in the context of an increasingly changing climate. (Agroecology Knowledge Hub, 2018).

Synergies in an intercropping system have the potential to increase biological control, such as in the push-pull system. The push-pull system combines different crops that attract or repel pests and their natural enemies using different chemical signals. This system was developed in the Republic of Kenya to reduce the impact of stem-borers on maize production. Intercropped *Desmodium* species repel stem-borers, while a border crop attracts and traps the stem-borers (e.g. Napier grass) (Pickett *et al.*, 2014).

Much research has been conducted to study the synergies within integrated rice systems with fish, ducks and/or azolla. Integrated rice systems maintain or increase productivity and rice yields and improve dietary diversity, as compared to rice monocropping systems (Cagauan *et al.*, 2000; Hossain *et al.*, 2005; Cheng *et al.*, 2015; Xie *et al.*, 2011). To achieve the same yields as rice monocultures, less chemical fertilizer N inputs are required (Cagauan *et al.*, 2000; Xie *et al.*, 2011; Hu *et al.*, 2016). This can be explained by the release of unconsumed N in fish feed in the system (Xie *et al.*, 2011). Furthermore, the movement of fish and ducks in the rice field enhances aeration of the water, which increases the availability of nutrients (Berg *et al.*, 2012), and aeration of the soil, which prevents the build-up of harmful gases in the rhizosphere (Hossain *et al.* 2005). In addition, duck faeces provide essential nutrients for the rice crop and their recycling increases soil health (Cagauan *et al.*, 2000; Fan, 2012). Fish feed on pests, such



as planthoppers (that fall into the water when the fish bumps the rice plants), flies and snails, weeds and algae (which could carry diseases) within the rice field, while ducks feed on weeds. This increases biological pest and weed control by fish and reduces pesticide requirements (Hossain *et al.*, 2005; Xie *et al.*, 2011; Berg *et al.*, 2012; Cheng *et al.*, 2015).

In relation to climate change mitigation and adaptation, rice provides shade to the fish and regulates the temperature of the water during hot seasons (Frei and Becker, 2005; Xie *et al.*, 2011), which could increase the resilience of the system. In addition, Tilman *et al.* (2002) stressed that rice paddy systems are one of the main agricultural contributors to greenhouse gas emissions as a result of the high levels of methane emissions. Rice-duck integrated agriculture has been shown to reduce both nitrous oxide as well as methane emissions from the paddy field (Huang *et al.*, 2005; Li *et al.*, 2009).

Crop-livestock integrated farming systems also benefit from synergies between components, including on-farm and area-wide integration. Crop-livestock systems differ widely in the different regions of the world (Entz *et al.*, 2005). According to Herrero *et al.* (2010), “mixed systems enable the farmer to integrate different enterprises on the farm; in such systems, livestock provide draft power to cultivate the land and manure to fertilize the soil, and crop residues feed livestock. Moreover, income from livestock may be able to buffer low crop yields in dry years.” Crop-livestock integrated systems increase productivity, nutrient use efficiency and recycling (Herrero *et al.*, 2010). Depending on the farming system, livestock can be managed on natural pastures or on cropland during fallow periods, returning the nutrients directly back to the soil (Entz *et al.*, 2005). On an area-wide scale, fodder for livestock can be exchanged for manure between specialised farms (Moraine *et al.*, 2014).

Integrated farming systems also provide cultural services. For example, in the People’s Republic of China, various rice-fish-duck farming systems are designated as Global Important Agricultural Heritage Systems (GIAHS) and researchers stress the potential for development of ecotourism in the rice fields. This will increase the income of local areas and will help conserve indigenous agriculture (Lu and Li, 2006; Sun *et al.* 2008).

Box 4.

AGROECOLOGICAL SYSTEM WITH SYNERGIES

(elements: synergies, efficiency, diversity, human and social value, circular and solidarity economy)

Small-scale farmers in the Mekong Delta in Viet Nam have been practising rice-duck farming since the mid-1990s, as described by Mayo (2016). The successful farming system is based on synergies, efficiency and diversity. Based on the traditional farm knowledge, a non-governmental organization (NGO) has introduced this system to other small-scale farmers in the region. Farmers can borrow ducks from the ‘duck bank’ and receive technical training as part of the scheme.



Resilience

Diversified agroecological systems are more resilient – they have a greater capacity to recover from disturbances including extreme weather events such as drought, floods or hurricanes, and to resist attacks by pests and diseases. (Agroecology Knowledge Hub, 2018). A resilient system and its components are described by Altieri and Nicholls (2013): “research shows that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils. Soils with high organic matter and active soil biology generally exhibit good soil fertility. Crops grown in such soils generally exhibit lower abundance of several insect herbivores, reductions that may be attributed to a lower nitrogen content in organically farmed crops. On the other hand, farming practices, such as excessive use of inorganic fertilizers, can cause nutrient imbalances and lower pest resistance”.

Thus, a resilient agricultural system enhances ecosystem services as it is based on fertile soil, biological control, enhanced food production and reduced use of external inputs. In previous sections there has been discussion of several examples of practices that increase soil fertility and biological control at farm and landscape level. Biological control reduces the need to apply pesticides, which have a negative impact on the soil biota that underpins various soil functions (Altieri, 1999).

An example of a resilient system is the system of rice intensification (SRI). SRI is a set of soil, plant, water and nutrient practices that aim to improve production, while reducing inputs of water, agrochemicals and competition between plants (Uphoff and Randriamiharisoa, 2002; Abraham *et al.*, 2014). Thus, the system improves the productivity of land, labour and water (Uphoff and Randriamiharisoa, 2002). This allows resource-poor farmers (even with infertile soils) to produce more compared to the conventional system (Stoop *et al.*, 2002). Because water use decreases under SRI, careful weed control is necessary (Satyanarayana *et al.*, 2007; Krupnik *et al.*, 2012). The combination of practices within SRI increases nutrient uptake by plants (Uphoff and Randriamiharisoa, 2002) and SRI has the potential to decrease methane emissions and the potential for global warming, although nitrous oxide emissions could increase (Uphoff and Randriamiharisoa, 2002; Jain *et al.*, 2014).

Box 5.

RESILIENT AGROECOLOGICAL SYSTEMS

(elements: resilience, efficiency, diversity, human and social value, co-creation and sharing of knowledge, circular and solidarity economy)

The agroecological Red H farm in California, the United States, prioritises balance in the farming system (Hachmeyer, 2016). Rather than relying on chemical inputs, the farm relies on agroecological practices that enhance soil health, as this ensures healthy and strong plants that can resist pests. The agroecology system integrates both traditional and modern diverse and efficient practices. There is substantial community support for the work and products are sold at a local farmers' market. A supporting community has been developed to exchange knowledge and support.



Socio-economic elements

Human and social values

Agroecology places a strong emphasis on human and social values, such as dignity, equity, inclusion and justice, which all contribute to the improved livelihoods dimension of the SDGs. It puts the aspirations and needs of those who produce, distribute and consume food at the heart of food systems. By building autonomy and adaptive capacities to manage their agro-ecosystems, agroecological approaches empower people and communities to overcome poverty, hunger and malnutrition, while promoting human rights, such as the right to food and stewardship of the environment so that future generations can also live in prosperity. (Agroecology Knowledge Hub, 2018).

Various examples of the importance of human and social values within food systems can be found in the literature. For example, Asrat (1996) reported on the ability of farmers from the Federal Democratic Republic of Ethiopia to manage soil and water and how these management practices are uniquely adapted to the different crops and patterns of labour demand and the physical conditions found in the agroecological/altitudinal zones of the highlands. By their ability to manage their soil and water sources farmers increase soil health and water regulation, which benefit food production. As stated by Lamarque *et al.* (2014) "In agro-ecosystems, flows of ecosystem services are directly affected by farmers' behaviours and land management decisions. Ecosystem Services stress the need to integrate ecological and social science to study coupled human and natural systems". Leclerc *et al.* (2013) described how indigenous people from Kenya are able to use their own knowledge to take decisions with regards to climate change and these decisions are used to develop their cropping calendar. This will increase their resilience to climate change and thereby food security in a changing climate.

These experiences show that farmers and local communities have an intrinsic value linked to nature and this knowledge is based on the co-evolution of the people with the environment that surrounds them (Marten, 2001). To promote human and social values within a food system it is necessary to understand that farmers play a critical role in determining our food system. In this way, farmers are brought to the centre of the decision-making process, which is essential for supporting the provision and maintenance of ecosystem services. Asrat (1996) calls attention to the fact that some top-down approaches are jeopardising fundamental (and fragile) natural resources.

Box 6.

AGROECOLOGICAL SYSTEM EMPHASISING HUMAN AND SOCIAL VALUE

(elements: diversification, co-creation and sharing of knowledge, resilience, human and social value)

An example of a farm system that recognises and promotes human and social values is described by ORRISSA (2016). Through practices based on traditional knowledge and community decisions, women were able to take over the ownership of their seeds and improve the diversity of their food system. The system became more diversified after the empowerment of women in the community and traditional crop management was rescued and re-incorporated into the system. This diversification improved the balance of the system.



Co-creation and sharing of knowledge

Agroecology is knowledge-intensive and depends on context-specific knowledge. It does not offer fixed prescriptions – rather, agroecological practices are tailored to fit the environmental, social, economic, cultural and political context. The co-creation and sharing of knowledge plays a central role in the process of developing and implementing agroecological innovations to address challenges across food systems including adaptation to climate change. (Agroecology Knowledge Hub, 2018).

The importance of co-creation of knowledge for enhancement of ecosystem services can be found in the literature. First of all, various researchers consider traditional knowledge of food systems to be a type of cultural ecosystem service (Tilliger *et al.*, 2015). Kosaka and Shirahada (2013) called attention to the need for innovative and integrated solutions for achieving sustainability across its different dimensions (social, economic and environmental). They argued that without a horizontal integration of different levels and sources of knowledge, the solutions will always be less innovative, as fewer aspects and backgrounds are taking into consideration.

More specifically, Lamarque *et al.* (2014) studied how farmers' knowledge of ecosystem services influence farming decisions. They argue that the diversity of stakeholders' knowledge contributes to the enhancement of different ecosystem services. Also, the literature shows that knowledge of ecosystem services is embedded in governance and policy-making (Posner *et al.*, 2016; Tilliger *et al.*, 2015; Tengo *et al.*, 2014) and complementarities across knowledge systems have, in many cases, enhanced ecosystem management (Posner *et al.*, 2016). According to Posner *et al.* (2016) "to enhance legitimacy, ES researchers must engage meaningfully with decision-makers and stakeholders in processes of knowledge coproduction that incorporate diverse perspectives transparently". Farmers, and other stakeholders, around the world are facing environmental challenges, such as the effects of climate change. In order to cope with and adapt to such changes, and enhance ecosystem services, a diversity of knowledge systems should be recognised (Posner *et al.*, 2016; Tengo *et al.*, 2014)).

As we can see, traditional and scientific knowledge are complementary and have different starting points for understanding and addressing problems. Agroecology, as a knowledge intensive approach, is embedded in the co-creation of knowledge, and is able to support and to be supported by ecosystem services. In this way, through the co-creation of knowledge, sustainable livelihoods can be supported as well.

Box 7.

CO-CREATION OF KNOWLEDGE – THE COMMON BASE FOR AGROECOLOGICAL SYSTEMS (elements: co-creation and sharing of knowledge, efficiency, diversification, recycling, responsible governance, culture and food traditions)

A successful case of co-creation of knowledge that is supporting ecosystem services is described by Gungaa (2016), on extensive rangeland pastoralism in the Gobi Desert of Mongolia. The importance is stressed of combining traditional knowledge of how to best manage the animals with modern practices for tree planting and vegetable growing. This has resulted in improved food production as well as improved soil regulation. The improvement of the system would not have been possible without an adequate land governance system being in place. Incomes of the pastoralists have increased, providing them a better livelihood.



Circular and solidarity economy

Agroecology seeks to reconnect producers and consumers through a circular and solidarity economy that prioritises local markets and supports local economic development by creating virtuous cycles. Agroecological approaches promote fair solutions based on local needs, resources and capacities, creating more equitable and sustainable markets. Strengthening short food circuits can increase the incomes of food producers while maintaining a fair price for consumers. These include new innovative markets, alongside more traditional territorial markets, where most smallholders market their products. (Agroecology Knowledge Hub, 2018).

A circular economy can be supported in different ways, such as community supported agriculture (CSA), which was developed in the 1980s and to date CSA has been used in many countries as a tool to support agroecology (Volz *et al.*, 2016). Another institutional innovation that can help promote agroecology is the participatory guarantee system (PGS), which is a local quality assurance system that certifies producers based on the active participation of stakeholders (rather than an external third party) (IFOAM, 2009). Other forms of circular economy also support the enhancement of ecosystem services. As an example from China, Liu and Coté (2017) suggested the following: “Circular Economy should be defined as prevention and control of pollution, full utilisation of resources and realisation of the harmony between human and nature during the overall material flow process including restoration and regeneration of ecosystem services, which aims to achieve an ecologically and economically sustainable development”. An example could be recycling/re-using of resources, such as nutrients, within or among farms, and thereby enhancing ecosystem services such as increasing soil health and decreasing water pollution (Source: EIP-Agri, 2015).

Box 8.

CONNECTING FARMERS AND CONSUMERS

(Circular economy, diversity, balance, efficiency, humans and social value, culture and food tradition)

In the Republic of Ecuador thousands of families have joined a campaign that promotes fresh, agroecological food produced by family farmers. Most of this food comes from native crops and is sold directly to consumers at outdoor markets and food fairs. These rural and urban families strengthen local cultures and economies as well as social organization. Based on their daily need to eat, they generate new value for food, for example by working with chefs who promote new flavours and plates linked to Andean cuisine. The public creates support for agroecology as it organizes around the advantages of “eating well”, i.e. utilising food as a means for health, sustainability and social equity. The campaign’s motto is: We are 250 000 families who eat healthy, delicious food from our land (Cano and Sherwood, 2017).

Culture and food traditions

Agriculture and food are core components of human heritage. Hence, culture and food traditions play a central role in society and in shaping human behaviour. In many instances, however, our current food systems have created a disconnection between food habits and culture. This



disconnection has contributed to a situation where hunger and obesity exist side by side, in a world that produces enough food to feed its entire population. Agroecology plays an important role in re-balancing tradition and modern food habits, bringing them together in a harmonious way that promotes healthy food production and consumption, supporting the right to adequate food. In this way, agroecology seeks to cultivate a healthy relationship between people and food (Agroecology Knowledge Hub, 2018).

Ecosystem services can benefit from culture and food traditions as the latter promotes biodiversity, food production and different cultural services (Daniel *et al.*, 2013). As omnivores, diversity is part of the mind-set of the human being, as the human brain favours diversity while eating (Pollan, 2006). Pollan (2006) explored the need for diversity in our food as well as the consequences in a modern society where traditional food cultures play a diminished role. Today, we are facing problems such as overweight and obesity, considered to be an epidemic by the World Health Organization (WHO, N.D.), which can be linked to the absence of strong culture and food traditions (Roux, 2007). By promoting short value chains, agroecology (re)strengthens the link between farmers and consumers. Furthermore, a consumer who knows the origin of the product is a citizen with a better level of awareness of the social and ecological impacts of the food (Tallontire, *et al.*, 2001).

In addition, culture and food traditions are at the source of cultural ecosystem services. An example can be found at the Ifugao Province rice terraces in the Republic of the Philippines, which are a major tourist attraction. These traditional rice systems also provide other ecosystem services such as they increase biodiversity, flood mitigation, heat mitigation and erosion control (Castonguay *et al.*, 2016). The terraces were constructed in the sixteenth century and the rice planting is based on ancient traditions, rituals and symbols to enhance the ecological balance within the agricultural system (e.g. throughout the various stages such as seeding, plant protection and harvest). Today, many of the terraces are being abandoned, which is strongly related to young people not working in rice fields anymore, and is also associated with the decline of heritage values and cultural identity (Tilliger *et al.*, 2015). As cultural services, such as traditional knowledge and traditions, are increasingly being lost, this may also affect the rituals of agricultural practices, which in their turn may have a negative impact on ecosystem services such as pest control and genetic diversity (e.g. related to synchronisation of planting and a decreasing demand for heirloom varieties) (Castonguay *et al.*, 2016).

Box 9.

PRESERVING CULTURE AND FOOD TRADITIONS

(elements: diversity, co-creation and sharing of knowledge, human and social values and culture and food traditions)

In the Occupied Palestinian Territory, farmers are promoting local seed banks to protect, store and reproduce their seeds and to be able to keep their food traditions alive while living in a food insecure environment. This case, described by Al-Jibeihi (2017), has a strong social connection and social values are respected and preserved. The seed banks do not only support food security in the communities, but they are also used as a way to preserve the diversity of the species that are traditionally used by the communities.



Responsible Governance

Agroecology calls for responsible and effective governance to support the transition to sustainable food and agricultural systems. Transparent, accountable and inclusive governance mechanisms are necessary for creating an enabling environment that supports producers in the transformation of their systems following agroecological concepts and practices. Successful examples include school feeding and public procurement programmes, market regulations allowing for branding of differentiated agroecological produce, and subsidies and incentives for ecosystem services. (Agroecology Knowledge Hub, 2018).

Pretty (2003) affirmed that traditional communities have shown their capacity through the years to sustainably manage their natural resources. Yet, Young (1998) stressed that the lack of governance and tenure of natural resources tend to increase the pressure on traditional communities. In addition, Hayes and Persha (2010) stress the importance of giving communities the autonomy to take decisions on their own and to respect traditions and local culture. Agroecology, by promoting governance and autonomy of communities and people, can ensure better use of natural resources and reduce the pressure on biodiversity, which also has the potential of enhancing ecosystem services. This argument is affirmed by the research of Hausner *et al.* (2015), who examined the distribution of ecosystem services by land tenure compared to protected areas. As indicators of ecosystem services, they studied spatial distribution of participatory mapped ecosystem values. Their results state: “We found land tenure to be a significantly stronger predictor of the distribution of ecosystem values and land use preferences than protected area status”. Also other studies confirm this. For instance, Swallow *et al.* (2002) state that insecurity over land is one of the reasons for soil degradation in Africa (negative impact on ecosystem service ‘soil health’), as lack of secure tenure could lead to overuse of resources and lack of investment (e.g. investment in soil conservation enhances water regulation). Also, Swallow *et al.* (2005) state that land tenure is conditional for the provision of Ecosystem Services such as biodiversity and carbon sequestration. They mention the following

Box 10.

RESPONSIBLE GOVERNANCE AS A WAY TO DELIVER SUSTAINABILITY

(elements: resilience, efficiency, circular and solidarity economy, responsible governance)

At a practical level, an example of the important role that agroecology can play in stimulating ecosystem services by land and natural resources governance can be found in Roop (2017). This practice demonstrates that, by using agroecological approaches, land could be reconverted from a completely degraded area into a highly productive one. The farmer stated that a precondition for being able to use agroecological practices to increase soil fertility is the formal tenure of the land and compliance with the regulatory requirements on preservation of the environment. Hence, with legal security, the farmer was able to invest, protect and recover the land, soil and other natural resources.



example from Tomich *et al.* (2001) “Farmers operating on plots without secure tenure tend to practice extractive short-duration agriculture, while farmers operating on plots with secure private title tend to practice complex multi-strata agroforestry systems. In those areas, the agroforestry systems are associated with higher levels of profit, greater carbon stocks, and higher levels of biological diversity than short-duration agriculture”.

CONCLUSION

By prioritising efforts to foster local food production and smallholder operations, agroecology contributes to the success of family farming, herding, and aquaculture, helping the areas and people in greatest need. Agroecological systems optimise the use of local, natural and renewable resources, reducing reliance on external inputs and thereby enhancing inherent ecosystem services such as food production, pest control, pollination, soil health, water quality, climate change resilience and more. Agroecology promotes the integration of biodiversity in farming systems and landscapes. This has the added benefits of diversifying risk and varying diet. As a result, farmers reduce production costs, leading to greater economic stability and resilience. Since agroecology also encourages the sale of products locally, food security for rural communities and their countries is increased by reducing dependence upon economically volatile foreign markets.



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04

AGROECOLOGICAL PRACTICES FOR THE MANAGEMENT OF DRINKING-WATER CATCHMENTS IN AGRICULTURAL LANDSCAPES

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Abstract

With the intensification of agriculture over the past decades, yields have significantly increased, but at the cost of increasing and ongoing contamination of drinking-water resources. Over the past two decades different initiatives, action programmes, and policies in many countries throughout the world have been implemented to improve water quality in drinking-water catchments. But a real improvement in drinking-water catchments in agricultural landscapes can only be achieved if a landscape approach is implemented. This means that in order to establish a combination of different farming practices in large parts of the catchment, restoration or conservation of different seminatural landscape elements, and in very crucial areas strong extensification or even, if necessary, abandonment of agriculture.

Among the most promising farming practices are different agroecological practices, as many showed reduced leaching or transfer of nutrients to groundwater or surface waters and decreased pesticide use. Examples are diversified crop rotations, intercropping, cover crops, cultivar mixtures, no or reduced tillage, direct seeding, split fertilization, agroforestry, biological pest control and integration of seminatural landscape elements around fields and at the farm and landscape scale. An example is provided in how to evaluate at landscape scale the needed establishment of seminatural landscape elements with the goal to improve conservation biological control in drinking-water catchments. Finally, some examples of water protection programmes are given which are based on paying farmers for certain measures or practices.

ONGOING CONTAMINATION OF DRINKING-WATER RESOURCES

Over the past four decades, with the intensification of agriculture, yields have significantly increased. Meanwhile, significant environmental problems have also emerged, such as the loss of biodiversity, pesticide contamination of soils and food and eutrophication of water bodies. Since the 1970s, one major issue has been the increasing degradation of water quality in drinking-water catchments as a result of increasing nitrate and pesticide concentrations (for example in Europe: European Commission, 2002; European Environment Agency, 2003). In particular, in different regions of the world, high nitrate contamination of groundwater resources has been ascertained (Li *et al.*, 2007; Lerner and Harris 2009; Alcott *et al.*, 2013; Gu *et al.*, 2013). In many regions in Europe, the nitrate concentrations are still very high in surface and underground water, despite the various European directives and programmes to address these issues (European Commission, 2011).



PROPOSED SOLUTIONS

In general, over the past two decades different initiatives, action programmes, and policies by either national, regional, or local authorities in many countries throughout the world have been implemented to improve water quality in drinking-water catchments (Bluemling and Horskoetter, 2007; Heinz, 2008; Grolleau and McCann, 2012; Alcott *et al.*, 2013, Grolleau, 2013; Nitsch and Osterburg, 2013; Barataud *et al.*, 2014). The proposed solutions applied to catchments, where agricultural land use dominates, are limitation of the use of agricultural pesticide and nutrient inputs by implementing adapted or new practices, including conversion of cropland to grassland; improvement of manure management and stocking facilities; purchase of agricultural land by the institution managing the catchment and, in certain cases, lending the land to farmers with fixed rules for agricultural practices; reforestation; exclusion of agriculture; or partially or completely converting to organic agriculture.

LANDSCAPE MANAGEMENT AND AGROECOLOGICAL PRACTICES

A real improvement in drinking-water catchments in agricultural landscapes can only be achieved if a landscape approach is implemented. This means the establishment of a combination of different farming practices in large parts of the catchment, restoration or conservation of different semi-natural landscape elements and, in crucial areas, strong extensification or even, if necessary, abandonment of agriculture. Among the most promising farming practices are different agroecological practices that have showed great potential for reducing leaching or transfer of nutrients to groundwater or surface waters and reduced use of pesticides (Figure 1).

Figure 1. **Different categories of agroecological cropping practices and their scales of application.**

SCALE OF APPLICATION OF AGROECOLOGICAL PRACTICE	↑	LANDSCAPE SCALE		
	MANAGEMENT OF LANDSCAPE ELEMENTS			
	<ul style="list-style-type: none"> › Integration of semi-natural landscape elements at field, farm, and landscape scales 			
CROPPING SYSTEM SCALE		CROP CHOICE, SPATIAL DISTRIBUTION, AND TEMPORAL SUCCESSION		WEED, PEST, AND DISEASE MANAGEMENT
		<ul style="list-style-type: none"> › Agroforestry › Cover crops › Intercropping and relay intercropping 	<ul style="list-style-type: none"> › Crop choice › Diversified crop rotations › Cultivar choice and mixture 	<ul style="list-style-type: none"> › Biological pest control - Natural pesticides - Allelopathic plants
FIELD SCALE		TILLAGE MANAGEMENT	CROP FERTILIZATION	CROP IRRIGATION
		<ul style="list-style-type: none"> › Direct seeding into living cover crops or mulch › Reduced tillage 	<ul style="list-style-type: none"> › Split fertilization - Organic fertilization - Biofertilizer 	<ul style="list-style-type: none"> - Drip irrigation

The practices contributing to reduce nitrate, phosphate, pesticides or herbicides concentrations in surface or groundwater in drinking-water catchments are indicated in bold and in blue

Source: Adapted from Wezel *et al.*, 2014



For example, at the field scale, these practices include no or reduced tillage, direct seeding, and split fertilization. At the scale of cropping systems these may include diversified crop rotations, intercropping (Figure 2), cover crops, cultivar mixtures, agroforestry and biological pest control. The integration of semi-natural landscape elements such as hedges, grass strips, shrubbery (Figure 2) around fields and at the farm and landscape scale allows not only for a contribution to reduced nutrient leaching or the transfer to surface waters, but also the enhancement of so-called conservation biological control. Through the maintenance or creation of habitats and over-wintering sites for various natural enemies, pesticide application can be reduced or stopped as these natural enemies can penetrate the fields and predate or parasitise the pests.

The way to implement these different practices needs to be adjusted in relation to local, regional, and national regulations and policy-framework conditions. Also local pedo-climatic and cultural situations in the catchment, farmers' constraints and possibilities for adapting or redesigning their systems also have to be taken into account. Thus, no universal solutions can be proposed. Farmers' voluntary adoption of practices should be encouraged, but experiences indicate that a combination of voluntary adoption, incentives and regulations may be more feasible.

The implementation of agroecological practices using a landscape approach is important, given the management of seminatural landscape elements in agricultural landscapes. The establishment of these elements is of great importance for improving conservation biological control in drinking-water catchments. Therefore, risk zones for groundwater contamination and for certain productions can be identified. For example, the risk zones in Figure 3 are characterised by shallow soils and short distance to groundwater, or dominance of high input, intensive maize or rapeseed production.

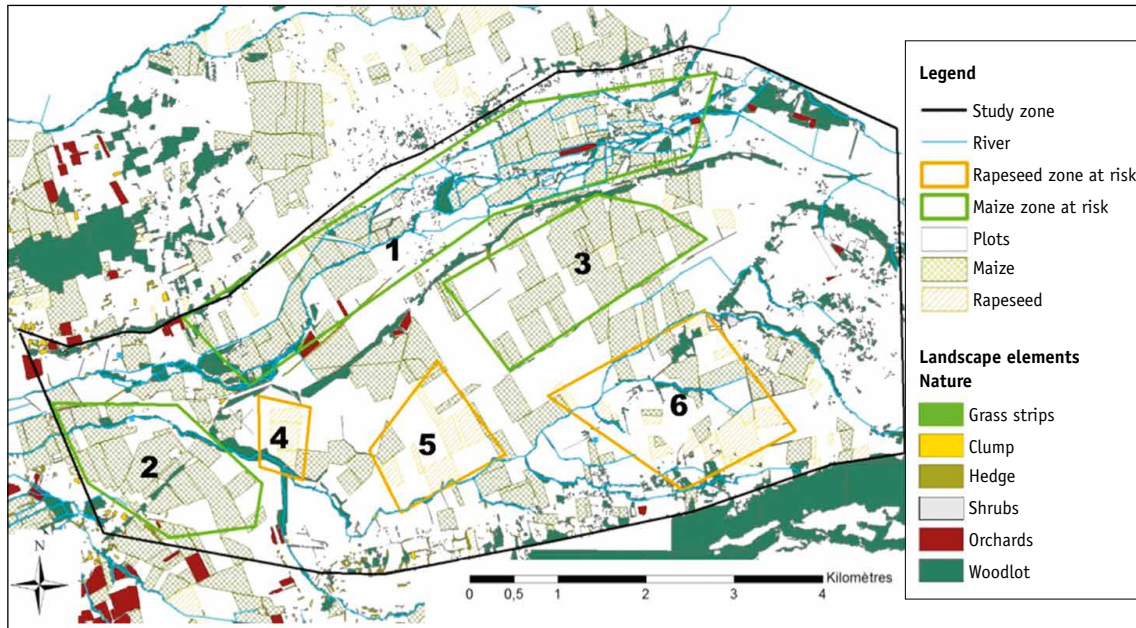
In respect to conservation biological control, if we now apply a buffer zone of, for example, 100 m around the existing seminatural landscape elements (Figure 4), areas can be delimited where management would be most beneficial, e.g. in zones 3 and 5, which have a low number and cover of seminatural landscape elements (Figure 3). In the present example 100 m was taken, representing a distance over which more mobile natural enemies would be able to move. In contrast, less mobile natural enemies would normally not be able to move beyond a distance of 50 m or less.

Figure 2. **Maize-clover intercropping (left) and semi-natural landscape elements in an agricultural landscape (right).**



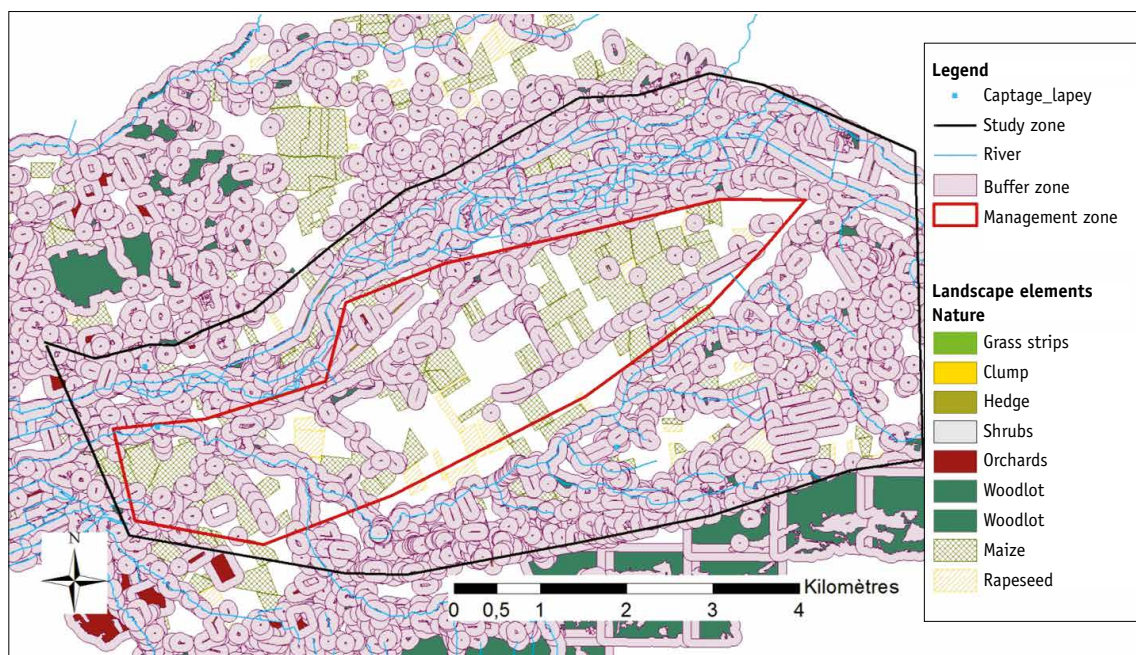


Figure 3. **Delimitation of risk zones for groundwater contamination in a drinking-water catchment.**



Zones 1 to 6 are risk zones with shallow soils and short distance to groundwater, and/or dominance of high input intensive maize or rapeseed production.

Figure 4. **Application of a 100 m buffer zone around seminatural landscape elements to identify the management zone for the establishment of new landscape elements for improved conservation biological control.**





With the establishment of hedges, grass strips, or beetle banks in well-selected locations, this 'gap zone' can be reduced enormously and thus conservation biological control potentially improved. The selection of the different landscape elements to be implemented, and their associated plant species (e.g. different woody species in hedges), should be based on the evaluation of the principle pest in the target crops in the drinking-water catchment. Depending on the main pests, landscape elements and plant species should be selected that have greater potential for harbouring these pests' natural enemies.

WATER PROTECTION PROGRAMMES AND PAYING FOR IMPROVEMENTS IN WATER QUALITY

Most water protection programmes for drinking-water catchments in Europe are based on paying farmers for certain measures or practices (Bluemling and Horskoetter, 2007; Heinz, 2008; Grolleau and McCann, 2012; Grolleau, 2013; Nitsch and Osterburg, 2013; Barataud *et al.*, 2014). For example, to reduce nitrate pollution of surface and groundwater, agri-environmental measures have been frequently proposed over the past decade throughout Europe. An example of an agri-environmental measure that has been recently developed for cereal-dominated systems in France also includes different elements concerning reduced fertilization and crop protection inputs, crop diversification, and maintenance of woody infrastructure (Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, 2015). These and other measures or programmes that have been applied outside Europe (e.g. for the United States see Alcott *et al.*, 2013, Wezel and Francis, 2017) are almost exclusively based on paying for only the specific measure or action, without controlling its direct outcome. However, action-oriented schemes such as agri-environmental measures may not be efficient in changing farmers' practices and may fail to significantly restrict drinking-water pollution (Howarth, 2011).

A results-oriented payment approach is, so far, less developed for the conservation of water quality, in contrast to the management of biodiversity. With a result-oriented approach farmers are only remunerated if they achieve a certain result. So far, there is a relative rare example in Germany where a water protection programme has been successfully implemented, and a significant reduction in nitrate concentration has been achieved. Within a voluntary contract framework, which was developed together with the water supplier and farmers, farmers had the freedom to choose the best practice for managing their farmland in most areas of the drinking-water catchment (Wezel *et al.*, 2016). Upon successful achievement of a specific result, in this case a certain nitrate concentration in soils in autumn, farmers were provided with different payment levels depending on the nitrate concentration levels, to compensate for yield reductions. Using this approach, a very good drinking-water quality has been reached for many years, and this without any water treatment. The successful implementation was achieved in relation to the following factors: investment of significant amounts of money for high compensation and remuneration payments; different contract options; farmers' participation in the negotiation process for result-oriented payment contracts; involvement of 'outside' people and institutions in the negotiation processes; anticipation of starting a programme when nitrate levels were still far below legislated thresholds; and a political and legislative framework allowing decisions to be made directly by a water supplier.



CONCLUSIONS

With the intensification of agriculture over the past decades, yields have significantly increased, but at the cost of increasing and ongoing contamination of drinking-water resources. Over the past two decades different initiatives, action programmes, and policies in many countries throughout the world have been implemented to improve water quality in drinking-water catchments. But it became obvious that a real improvement in drinking-water catchments in agricultural landscapes can only be achieved if a landscape approach is implemented. This means that in order to establish a combination of different farming practices in large parts of the catchment, restoration or conservation of different semi-natural landscape elements, and in very crucial areas strong extensification or even, if necessary, abandonment of agriculture.

Among the most promising farming practices are different agroecological practices, as many showed reduced leaching or transfer of nutrients to groundwater or surface waters and decreased pesticide use. Examples are diversified crop rotations, intercropping, cover crops, cultivar mixtures, no or reduced tillage, direct seeding, split fertilization, agroforestry, biological pest control and integration of semi-natural landscape elements around fields and at the farm and landscape scale.

Besides the local pedo-climatic and cultural situations in the catchment, farmers' constraints and possibilities for adapting or redesigning their systems should be taken into account. Thus no universal solutions can be proposed. A voluntary adoption of practices by farmers should be favoured, but experiences indicate that a combination of voluntary adoption, incentives, and regulations could be feasible. Favourable policy framework conditions should be created to facilitate adaptation and adoption of farming practices.



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05

EXPLORING INNOVATIVE WAYS FOR MODERN AGRICULTURE TO ACHIEVE RURAL URBAN COORDINATED DEVELOPMENT. A PARTICIPATORY STUDY OF TWO CHINESE FARMS: SHARED HARVEST COMMUNITY SUPPORTED AGRICULTURE (CSA) AND LITTLE DONKEY FARM

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Abstract

Food safety issues in the People's Republic of China are frequent. One of the most notable events took place in 2008 – the powdered milk melamine-poisoning incident. Other major issues have included the use of recycled sewer oil for cooking, as well as Mengniu Milk Corporation's overuse of antibiotics and the remaining traces of the additive in consumer goods. Agriculture is also the largest contributor of non-point pollution in China. These issues are driving the social movement for food safety.

Beginning in 2008, the social movement for food safety has been practiced on community-supported agriculture (CSA) farms in Beijing, Jiangsu

and Fujian. For the development of a safe-food market, China will need more civil-society driven organizations brought together by strong supervision, coordination, and promotion, in addition to strong agriculture techniques, institutional design and innovation. Little Donkey Farm and Shared Harvest Farm have participated in this work from the beginning, observing how the CSA movement has changed farmers' and consumers' behaviour and Chinese public policy.

Keywords: Food Safety, Social Movements, Shared Harvest Farm, Community Supported Agriculture, Rural Reconstruction.

BACKGROUND: CSA AND THE CHINA RURAL RECONSTRUCTION MOVEMENT

Since the advent of the social and economic 'opening' under Deng Xiaoping, the fate of Chinese rural society has been a matter of continued debate (Day, 2013; Douwe van der Ploeg and Ye, 2016). Starting in the 1960s the collective system in the countryside was dismantled (Wen, 2001). Formerly collectivised land was portioned out to individual households for individual management (Wen, 2001).¹ As younger and more able rural labour migrated to larger towns and cities in search of better paying jobs, and with the increasing availability of labour saving synthetic inputs, farming shifted from subsistence to market-oriented cash cropping (Lora-Wainwright, 2009; Ebenstein *et al.*, 2011). Since reform, and Chen (2015) estimate that around 269 million people have migrated from China's villages to its cities in the decades despite 'hukou'² restrictions.

¹ The village collective retained land ownership; but use rights were distributed to individual families.

² Under the *hukou* system, each individual is assigned an official location of residence either, 'rural' or 'urban'. A person's ability to access health, education and other services are only fully available in their



Scholars often describe China's contemporary farmers as weak and atomised, small households facing the big market (Day, 2013b). Under successive administrations, the government has encouraged 'agricultural modernisation' programmes to transform small-scale peasant agriculture into something more 'industrial,' 'professional,' and amenable to global markets (Schneider, 2015). More recently, the government has placed emphasis on policies promoting 'ecological' farming methods; however, these methods are defined to coincide with ideas of modern, industrial agriculture (In other words: *not* traditional small-scale peasant agriculture). Practically, this has resulted in complex arrangements of land rights, labour, private agribusiness and public investment; in some cases, small farmers have been turned into wage labourers on their own family land³. At the same time, many villages have become socially 'hollowed out' – only the old and the very young remain (Yan and Chen, 2013). The 'missing' people have not left permanently – they return from temporary jobs; they come to help with the big harvest; they come back on school breaks, and for major holidays, but day-to-day village life is impoverished.

Since the early 2000s, a network of rural organizing initiatives, known as the New Rural Reconstruction Movement, has sought to offer practical solutions to challenges in the countryside⁴. New Rural Reconstruction takes its name and inspiration from an earlier generation of rural organization efforts in the 1920s and 1930s; as with these earlier efforts, contemporary rural reconstruction projects emphasise economic cooperation among farming households. Many New Rural Reconstruction initiatives have close ties with Renmin University in Beijing, and to Renmin Professor Wen Tiejun, a public intellectual and a prominent critic of the state's brand of capitalist 'developmentalism' (Wen, 2007).

The Chinese community-supported agriculture (CSA) movement has taken shape within the larger context of rural reconstruction and rural organization. Indeed, many of the organizations fostering CSA projects in China have been closely affiliated with New Rural Reconstruction. For instance, the Hong Kong-based non-governmental organization (NGO) Partnerships for Community Development (PCD) began advocating for CSA farming models in Mainland China in 2003. Later, training of sustainable farming was supported at the earliest official New Rural Reconstruction project, the James Yen Rural Reconstruction Institute in Hebei Province.

One of these projects, Little Donkey Farm, has become, perhaps, the most prominent CSA farm in China. Shi Yan created the farm in 2008 when she was a PhD student at Renmin University. Shi Yan's vision and research were at the heart of the project, but the farm ultimately came into being through a layered series of institutional agreements. Little Donkey was founded as a joint 'research base' for the university and local (city district) government, to be 'operated'

place of registration. Migration away from your registration area is, therefore, a difficult choice. For more information on the '*hukou*' system see Chan (2009). The household registration system has been undergoing reform in recent years, under the Xi Jinping administration. In future, more 'rural' residents will be eligible to obtain 'urban' registration. However, 'rural' residency status means entitlement to a share of collective village property, including village land. Giving up 'rural' residency means the possibility of a stable life in the city; but it also means giving up guaranteed access to a vital asset.

³ See, e.g. Ho (2005) and Ye (2015).

⁴ For a concise history, see Ou (2014) and Day (2013).



by an arm of the university-affiliated rural organizing network with official non-profit status⁵. Gaining access to land, especially for novel or innovative projects, can be a difficult endeavour in China. The accumulated experience of the New Rural Reconstruction network helped make Little Donkey a success – both a model and an incubator for other sustainable farming projects around the country.

Since 2009, Little Donkey's first year of full operation, Renmin University has been involved in hosting a yearly national CSA conference. While the conference started out small, with only a handful of participants, the event now draws participants from hundreds of different projects related to food and farming. Conference participation indexes the growth of a robust movement around 'good food' in the country. In China, the vocabulary of CSA serves as inclusive shorthand for a wide array of practices⁶. Along with more conventional CSA farm models, participants in the CSA community also run small-scale non-subscription organic farms, craft food businesses, consumer cooperatives, farmers' markets and so on.

The aggregate story of CSA in China is partly about a diverse group of determined people learning from each other to create new forms of rural-urban cooperation. It is also a story about a network of institutions that make these innovative projects workable. In China's current political climate, 'social organizing' of any kind can seem suspect at best, and dangerously disruptive at worst. New Rural Reconstruction organizations and NGOs, such as PCD, fund and support new ventures in the wide world of 'CSA' in China; but they also do the significant work of giving these ventures the political alibi of affiliation with formal structures – be they universities, research institutes, or simply officially-registered organizations. This network of institutions further supports the available formal training opportunities for prospective 'new farmers'⁷ and other young people who hope to establish livelihoods in the countryside.

Interns from Little Donkey farm have gone on to start their own successful CSA projects around the country. Shi Yan's more recent project, Shared Harvest Farm, was founded in 2012 with support from Tsinghua University. Like Little Donkey, it serves as a training ground for aspiring new farmers. Little Donkey and Shared Harvest differ primarily in their configurations of land and labour. The use-rights for Little Donkey's land – a roughly 40-acre plot in Beijing's suburban Haidian district – are leased from the local village. 'New farmers' supply some of the farm labour and all of the customer-facing and managerial labour. These "new farmers" include

⁵ The Ground Green Eco-Tech Centre (Beijing).

⁶ CSA was initially translated literally into Chinese; in recent years, movement participants have favoured a more capacious translation of "social sustainable agriculture."

⁷ 'New farmers' is a term translated directly from the Chinese; it is generally used to designate young people who are interested in building dignified careers in farming. 'New farmers' are implicitly defined in contrast to 'peasants'. The former choose farming, among an array of options, because of their personal values and ideals. By contrast, 'peasant' is a political class designation, not a chosen profession. 'New farmers' may be urbanites with no prior experience of farming. They may also come from rural backgrounds: their parents and grandparents might be 'peasants' who farm the land in their home villages. 'New farmers' from rural backgrounds may even embrace farming against their family's wishes. (Zou, 2014; Xinhua, 2016).



a permanent staff of younger people and a rotating group of interns. At the same time, the farm hires local village residents, lifelong 'peasant' farmers, to contribute much-needed skilled farm labour.

Shared Harvest places a relatively greater emphasis on collaboration with lifelong farmers. The first Shared Harvest location, in Beijing's Tongzhou district, centres on an arrangement between the Shared Harvest organization and an experienced local farmer. The Shared Harvest team, comprised of 'new farmers', manages share-member services, outreach, consumer education, and production planning. A local farmer oversees vegetable production on his own family land, and makes all day-to-day decisions about cultivation. At the second Shared Harvest location, in Shunyi district, the local village government invested in greenhouse infrastructure that it hoped to rent out to agribusiness. When the village had a hard time finding tenants, it welcomed Shared Harvest to take over a section of the greenhouses. Village government reaps the political benefits of supporting a 'green' agricultural production base with ties to Tsinghua University, while Shared Harvest enjoys favourable terms for using local land and infrastructure. For the Shunyi location, Shared Harvest recruited a farmer from Shandong Province, with decades of experience growing produce in greenhouses. This farmer now oversees cultivation, directing a team composed of 'new farmers' – employees, interns and volunteers – and farmers hired from the local village.

Interns usually work for a full season, and receive a small stipend in addition to room and board. While some prospective farm interns find placements by contacting CSA farms directly, the broader institutional network of Rural Reconstruction organizations and allied NGOs helps to fund and support training opportunities across the wider food movement. For example, the Social Agriculture Youth Entrepreneurship Training Programme, which had its first class of fellows in 2016, is a joint project of the Rural Reconstruction Centres at Renmin University, Southwest University, Fuzhou Agriculture and Forestry University and the Beijing-based Liang Shuming Rural Reconstruction Centre.

The programme accepts between 30 and 40 fellows each year, matching them with food-and-farming projects seeking additional personnel. In 2016, these projects included Little Donkey; a sustainable peach orchard and farmer cooperative in suburban Beijing; a local government-sponsored rural development organization with a focus on water stewardship in Jiangsu Province; two sustainable farming initiatives near Chongqing and another near Fuzhou, Fujian; and a well-established farmer-run cooperative in Anhui Province. Similarly, PCD regularly supports training and educational opportunities for young people in its network. In 2015-2016, for example, it funded a staff member from Tusheng Liangpin, a farmer cooperative-affiliated restaurant chain in Guangxi Province, to spend a season learning from staff at the Beijing Farmers' Market.

Access to land and urban markets are major considerations when interns 'graduate' and venture out to start their own projects. Although some 'new farmers' may prefer to start CSA farms in their home villages, they may not be able to arrange access to sufficient land, or to land that is relatively protected from chemical inputs on neighbouring fields. Furthermore, their home villages may not be close enough to major urban centres to make regular produce delivery feasible. One former Little Donkey intern, Liu Jihu, has created a thriving direct-sales pig farm in his wife's home province of Fujian, where he initially gained access to land through



negotiations with a property development company. Another Little Donkey intern, Tang Liang, worked at Shared Harvest before returning to his home village, near Chengdu, Sichuan, to start a diversified small farm on family land. As these examples suggest, each 'new farmer's' story is different: they may draw on their own family's resources, or work with local governments; they may find opportunities through universities, NGOs, or large companies. China's system of state land ownership, and the current climate of political ambivalence around rural organization efforts, turn starting a CSA farm into a sometimes-tricky matter; successful 'new farmers' have to be persistent, hardworking, and politically shrewd.

The proper role of 'new farmers' in a country with a huge population of 'peasant farmers' is a subject of keen debate within the growing food movement in the past ten years. In some cases, 'new farmers' have been able to help lifelong 'peasant' farmers to find new livelihood opportunities and new markets (Zuo, 2014). The work of maintaining a website and a responsive social media presence is beyond many older farmers. Younger 'new farmers' – 'digital natives' – do this kind of work with ease. Some food movement participants feel that it is inefficient, or backward, for young, highly educated people to run their own farms, when farm work requires years of experience to do well; precisely the kind of experience that older 'peasant' farmers have. Additionally, some CSA farms have faced challenges when different groups of farm workers have invested in the farm in very different ways. For example, local 'peasants', who are hired by a farm may see themselves simply as wage labourers, while ideologically-invested 'new farmers' may have a totally different relationship to farm management, compensation, working conditions, and so on.



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LITTLE DONKEY FARM, WHERE THE CSA MOVEMENT STARTED

Background

The rising middle and high-income groups in cities have become the new driver of food culture (Cheng and Shi, 2014). Beijing, as an economically developed city with a large number of middle and high-income earners, is well equipped for the development of citizens' agriculture.

As a producing, teaching and research base, Little Donkey Farm sees itself as a response to the official national development strategy. Beginning in 2003, under the Hu Jintao – Wen Jiabao administration, the central government put forward a series of policy goals related to environment and agriculture (Wang *et al.*, 2014). Against this background, Little Donkey Farm aims to promote mutual aid between the urban and the rural through sustainable agriculture, and has embarked on a road that explores the national strategies in practice.

Innovation

Innovation of Little Donkey Farm includes the following aspects:

Innovative project operation

A production model featuring sustainable agriculture and integrating crop and animal agriculture is combined with the operating and management model characteristic of community-supported agriculture (CSA). This model lets the market play a role in generating social and environmental benefits.

Agricultural services

In addition to production, Little Donkey Farm also provides multiple agriculture-centered services including education, entertainment, sightseeing, and experiential learning opportunities. It is an attempt to make peri-urban agriculture a tertiary industry. Besides fresh food, it also yields social benefits and provides ecotourism. Little Donkey Farm, therefore, offers a model for balanced development in economic, social and environmental spheres.

Innovation in management model

As more members engage in services on the farm and as societal attention continues to grow, Little Donkey Farm needs to prioritise the discussion on ways to improve its service with limited hands and funds. With the 400 subscribing members, the 'Subscribers' Community' was established in 2012 to coordinate and facilitate communication between farm managers and the members, as well as to try self-management. The community aims to become the ambassador for promoting sustainable agriculture and the CSA model beyond the farm.



Innovative organization

Little Donkey Farm promotes intermediary between consumer cooperatives and agricultural production cooperatives, which is a 'win-win' for both the small household farmers and the middle-income consumers.

Good practices

Establishing a direct supply chain between communities, households and the production base

By subscribing to Little Donkey Farm, the CSA members and the farm cooperate and share risks throughout the production and establish such relationship into a direct supply chain between the two parties. This method not only promotes the development of the community, but also strengthens trust between consumers and producers.

The Little Donkey CSA programme was officially launched in 2009, but only 37 households joined the produce subscription programme that year. In 2010, the number grew to 280 households. To meet members' year-round demand for vegetables, a special delivery service was developed of the stored vegetables for winter. In 2011, the members reached 460. These numbers have been maintained.

Developing an urban base for agricultural leisure

The CSA farms as a form of peri-urban agriculture, is important in offering a platform for farming, leisure and entertainment. The labour-sharing subscription⁸ was the first business model of Little Donkey Farm and also embodies the multiple functions of agriculture, serving as a typical example of agriculture going into the tertiary industry. At the same time, such innovation changed the way citizens relax, with a shift from traditional sightseeing outside of the city to work-based, agriculture-related activities. Members establish unique relationships with each other and with farm staff through communication and mutual help, forming an urban farming community that prospers through vegetable planting, leisure for seniors, education for children and holiday entertainment.

The number of subscribers to Little Donkey Farm's work-share programme has been growing over the last few years, from a mere 17 households in 2009, to 107 in 2010 and 263 in 2011, to almost 400 in 2015.

Establishing an eco-agriculture technology research and promotion platform

The design of Little Donkey Farm reflects the concept and thinking of sustainable agriculture and country life. Various elements are integrated for enhanced benefits, forming a positive ecological cycle within the farm itself.

⁸ Little Donkey has offered 'working shares' since its first year of operation. In this arrangement, the share member pays for farmland and supplies, while working to grow their own food under the guidance of farm staff members.



In terms of production, Little Donkey Farm makes full use of the local natural resources of light, heat, water and soil that replaces capital with labour to improve the quality of the soil. The farm has also adopted technology from the Republic of Korea to make use of local micro-organisms to break down animal waste so as to reduce pollution, save water, and enhance the health of pigs and other animals. Little Donkey Farm has established partnerships with eco-agriculture practicing groups from more than ten countries including the United States, the Republics of India, Peru and South Korea, the Kingdom of Thailand and Japan. It serves as a pilot workshop, which has developed a set of applicable technologies and standards that are effective, low-cost and suitable for China's national conditions. Little Donkey Farm also helps different kinds of farms, rural cooperatives (rural communities) and small households with their shift toward more sustainable production.

In 2011, Little Donkey Farm organized a two-session training that saw nearly 100 participants coming from Malaysia, the Republic of Singapore and across the nation. The training received guidance from the Beijing Agriculture Technology Promotion Centre, Haidian Agriculture Science Institute and generated positive results.

Training eco-agriculture professionals

The rise of ecological farming in China is epitomized by the growing interest of young people in agriculture. Every year, Little Donkey Farm launches internship programs to recruit passionate young people interested in sustainable agriculture and CSA operations from universities, NGOs and other social sectors. In this way, farms can become an intermediary for youth to get closer to rural areas and learn more about agriculture. At the same time, Little Donkey trains talented people that can help develop the farm itself, promote pilot sustainable agriculture programs, and contribute to the common development of both rural and urban areas.

Since the launching of Little Donkey's internship programme in 2008, altogether eight groups of young people, about 100 in total, have taken part. Interns receive nine months training, during which time they can experience the whole production cycle and participate in all aspects of the farm's operation and management. The concept of combining learning with work, practice with theory is promoted. In addition to interns, large numbers of volunteers are also welcomed.

Over the last few years, Little Donkey Farm has accumulated rich experience in running the intern training system. It has helped college graduates find jobs and has trained a large number of people interested in agriculture, farmers and rural areas. This system also creates a favourable environment that respects and highlights agriculture development and advocates the philosophy of returning to the countryside.

Promoting a sustainable way of life

As China has modernised, urbanised and industrialised, there have been many positive benefits but also costs such as environmental pollution and food safety issues (Holdaway and Husain, 2014). Therefore, helping farmers change their farming methods, to supporting healthy agriculture and opting for healthy consumption are all important efforts the entire society needs for sustainable development.



Availing itself of the network of members and the communication platform of the farm, Little Donkey Farm has held more than 400 events and activities and hosted about 30 000 visitors since opening to the public in 2009. The farm has also cooperated with different institutions in carrying out promotion activities in various communities. In 2011, a school was built in the fields to offer children, as well as adults, targeting agriculture education and providing opportunities to experience farm life. One year later, the farming education activity began to allow households to engage in various activities that include experiencing agriculture, environment protection activities and handicrafts.

Promoting the rise of new farmers' markets nationwide

One direct form of community-supported agriculture is to build trust between producers and consumers through face-to-face communication.

In September 2009, Little Donkey Farm hosted the first small-scale national farmers' market. More than ten institutions came from across the country to gather together and introduce consumers to their healthy products. Since then, such farmers' fairs have attracted tens of thousands of citizens, providing trustworthy products with convenient delivery, facilitating communication between consumers and producers, as well as playing a pivotal role in the establishment of Beijing Farmers' Market in 2001.

In October 2011, as Little Donkey Farm celebrated its harvest season, more than 60 institutions related to healthy agriculture came to the event from across the country and made it a farmers' fair that boasted a large number of participating agencies and activities.

As farmers' markets became popular in Beijing, farmers and consumers in many other cities followed in organizing local fairs. Guangzhou, Shanghai, Chengdu, Nanjing, Wuhan are all such examples. Farmers' markets serve as a channel for transmission of knowledge and communication. Not only do these markets draw producers closer to citizens with enhanced mutual trust and transparency of production, they also allow consumers to play a supervising role in agricultural production as they come to know more about the producers and the entire production process.

Promoting the establishment of a nationwide Eco-agriculture network

In order to promote innovative agriculture projects across the nation, Little Donkey Farm has hosted six CSA experience-sharing meetings in Beijing, Shanghai and Fuzhou. More than 2 000 practitioners and researchers around the country have attended and contributed to the discussions.

To further boost the development of CSA, Little Donkey Farm has started a 'National CSA and Family Farm Training Class' twice a year starting in 2013. So far, five training sessions have been completed with more than 200 trained members.



SHARED HARVEST FARM: A CSA STARTED WITH CORE VALUES

Background

Shared Harvest is a Chinese social enterprise managed by a group of young people in Mufang Village in Eastern Beijing since May 2012. This initiative began on a 5 ha farm with the idea of solving the social needs of urban people for safer food and to reconstruct rural China through reconnecting young people with sustainable agriculture. The farm had adopted the community-supported agriculture model to cooperate with local farmers in Beijing for the local, seasonal and organic production of fruits, veggies and other food products.

The CSA model at Shared Harvest invites Beijing customers to pay subscriptions in advance to shield the farmers from instability, and the risks associated with agricultural production, and encourages the growth of a new generation of farmers, especially young people, to choose to stay on their land rather than migrating to cities, so as to meet political, socio-economic and environmental challenges. Shared Harvest believes that inviting citizens who are concerned about food production and consumption to be part of the initiative as members, allows both the connection with farmers who grow the food and with nature.

Through the major principle of 'Real Food, Real Farmers, Real Community', the model places importance on food as the bridge for people to reconnect with the soil, with healthy bodies and to form close and harmonious relationships between people and nature. As a result, a community builds around food production and the consumption process and a strong connection develops between urban dwellers and farmers.

At the beginning, Shared Harvest operated and cooperated with local farmers on a farm in Tongzhou district and, in 2013, in order to meet growing market needs, the initiative was scaled up in the operation of a second farm located in Shunyi district. In 2016 another plot of land in the same town in Shunyi district, was acquired. Meanwhile, the farms have expanded their products into other market channels: from exclusively serving CSA members they now sell to farmer's market, local restaurants, schools and other organizations interested in purchasing directly.

Agroecological practices

Following the agroecological principles of safe and healthy food, Shared Harvest Farm has a key principle: 'No pesticides, No fertilizers and No GMOs'. Briefly, agroecological food is defined as food grown under natural conditions. Producers and consumers mainly define this type of agriculture as: local agriculture practiced and grown by local farmers who take an active role in the production process. The core principles are being free from chemical inputs in a production system where environmental factors such as the quality of water and soil are considered critical to growing food and to achieving healthy and sustainable agrofood systems.



Shared Harvest Farm is active as a promoter of the sustainable agricultural movement at the national and international levels, a role that has been important in the extension of their agroecological principles and practices. Shared Harvest Farm:

- » shares information through the CSA members with other people and communities;
- » serves as a field testing station for food safety studies carried out by Universities;
- » participates in seminars and conferences funded by local government;
- » is part of the international community through the CSA Network URGENCI;
- » exchanges information and ideas with visitors from the international community during paid visits.
- » promotes CSA membership individually and through mainstream and social media.

Market Innovation

Shared Harvest Farm is a social enterprise that is coordinated by a group of young people dedicated to production, processing, trade and the provision of other agricultural services to the community of Eastern Beijing. Since 2012, this initiative promotes the CSA model through which, based on trust and familiarity between farms and their customers, connections are facilitated among producers, consumers and traders. Shared Harvest has 1 000 CSA members and 50 employees (producers, food service and traders).

The business model has the following characteristics:

- » **Community integration:** the CSA model encourages conviviality, solidarity, trust, respect and familiarity with the communities involved. These social relations and values integrate the communities and encourage them to participate as decision-makers in the initiative. Before beginning, the Shared Harvest Farm initiative learned about the local context and took into account the unbalanced distribution of rural and urban demographics, which has been characterised by a lack of young people participating in agricultural production. This context has led to the design of an agroecological food system that responds to the specific needs of young people and the community. Furthermore, Shared Harvest Farm invites residents of Beijing, who are concerned about sustainable food production and consumption, to take part in the initiative as members and, in this way, connects consumers and the entire community to farmers who are growing the food and helps create a community around food production and consumption processes. The initiative is integrated into other economic approaches that encourage a network of community cooperation and promotes connections with other community initiatives.
- » **Participatory decision-making:** Spaces created by the initiative allow various actors (producers, processors, intermediaries and consumers) to participate in the decision-making process. However, members do not participate in much governance decision-making because of reasons related to time constraints, their trust in the initiative to govern and because products are their main concern. This initiative attempts to create quality links within the member network and sometimes between people outside the usual social network.
- » **Financially autonomous:** This initiative is financially autonomous and managed with collective capital resulting from the funding of its CSA members. Other institutions, however,



participate in the division of revenues acquired by the initiative. For example the Department of Sociology at Tsinghua University donates a small amount of funding as the Farm serves as a station for food safety studies, international visitors frequently visit to exchange information and ideas and, in cooperation with the Shunyi district Government, the Farm is funded for research visits and conferences.

- » **Written agreements:** Shared Harvest Farm bases its business philosophy on the CSA model where the principles of trust and familiarity between farmers and their customers are present. These principles allow for the use of engagements with producers and processors. The agreements principally contain the prepaid amount of vegetables (or product) per month that the producers need to provide, terms of quality and the price per kilogram of vegetable.
- » **Informal quality management system:** The quality standard depends on the people. Each day, the employees of Shared Harvest package the products for the following day and make a visual and manual selection of products.
- » **Informal agroecological verification system:** The verification system ensures that the agroecological practices are an informal social control without a label. Trust and reputation are the main values involved in ensuring agroecological quality. Sometimes, the initiative sends staff to work with producers on the farms, which is a way to monitor the ecological quality of products.
- » **Facilitating entrepreneurship:** The Farm also functions as a project incubator for new generations of farmer entrepreneurs. Young entrepreneurs can find support in the creation of new businesses with the facilities, tools and assistance provided by the farm.
- » **Reputation and trust:** A good reputation has been gained through the constant efforts made to engage public media and the international network. This initiative has spread its reputation in both the public domain and the agrofood sector making it much easier to seek collaborators to achieve its geographical expansion. Trust has been essential in choosing the market channels to allocate products and services.
- » **Inclusivity:** The CSA approach employed by Shared Harvest Farm promotes community activity planning with the objective of involving the community and people in their agroecological activities and vision. The initiative includes a wide-range of young people who are passionate about sustainable agriculture and work hard to generate local employment opportunities, small and local farmers as business partners, families, and disadvantaged groups such as ethnic groups and women with young babies. Shared Harvest seeks collaboration with other networks and social groups at the national and international level.
- » **Overall efficiency:** The initiative has achieved stable market channels and a sufficient and constant cash flow. The number of members has increased from zero to 500 in three years.

As part of its goal of reviving rural communities, Shared Harvest aims to educate urban residents about healthy eating and sustainable food systems. The Farm's consumer base comprises over 800 members. In addition, there is a growing number of 'group buyers' (300 at the time of the research) who collectively order goods for weekly pickup at five locations throughout Beijing. While these buyers are not members and do not invest in farm production, the amount they consume makes up an increasingly significant portion of Shared Harvest's sales. The CSA



has achieved rapid growth without the use of conventional advertising. Rather, marketing has been exclusively through new media channels such as WeChat (an influential Chinese social media platform), Weibo and blogs. The Farm currently conducts most of its outreach, sales and arrangement of deliveries through WeChat. In the summer of 2015 a software application was launched called *Real Farm* to promote sales of sustainably grown foods from CSAs throughout China. CSA farmers can use this application also to manage their memberships.

In 2016 Shared Harvest farm had an estimated total income of CNY 8 million (USD 1.2million) and a net profit of 10 percent, without direct subsidies or government policy support. Staff members are paid regular salaries based on profits, while farmers' earnings as labourers at the Shared Harvest Farm are based on their production. In Tongzhou, farmers work their own land and are paid for the goods they provide; annual profits from sales made by the village collective are distributed among the farmers.

CSA MOVEMENT IN CHINA

The CSA movement in China aims to bring more young people back to farming livelihoods. Most of the staff at Little Donkey and Shared Harvest are young and college-educated. Some of the staff are from rural areas, and aspire to starting CSAs in their own hometowns. These staff have 'accumulated a rich store of technical knowledge' about applying aspects of sustainable agriculture such as biopesticides and organic soil treatment. In addition, staff members gain experience in marketing approaches and the functions of a CSA, such as ensuring that each week's harvest can meet the needs of customers, and ensuring that customers receive the freshest possible vegetables.

It has been estimated that there are about 1 000 CSA farms in China, with an estimate total of 500 000 to 1 000 000 members.

However, 95 percent of CSA farms in China are not certified as organic; although they are producing using organic techniques. Instead, they prefer to rely on close oversight of farming practices, supported by active communication with their consumers to ensure the marketability of their goods. In this context, 'organic' food is not the end goal, but rather a means to an end in promoting a sustainable food system. The consumer's trust is more important than certification.

Organic products can sell at three to eight times the market price of conventionally produced food, and consumers are understandably reluctant to pay this premium when they cannot trust the authenticity of the products in a poorly regulated organic market. Instead, consumers want to be personally involved in the production process, to visit the farm and see how the food is produced – or at least hear about how it is produced from friends who have visited. From the farmer's perspective, this direct link to the consumer through the CSA model is a form of income guarantee. They receive the investment up front, and do not have to worry about producing goods that may be difficult to market later in the season. Urban consumers are willing to pay a premium for high-quality food from a trusted source.

The main challenge facing farmers practicing sustainable methods is marketing, not production. China's farmers and cooperatives have no real problem with sustainable agricultural



production using both traditional and modern technologies. The main problem is the market, and the difficulty of communicating the ecological value of sustainable food products. The CSA model promises an innovative solution to achieving ecological, economic and social sustainability for food production in China.

Economic, societal and environmental impacts

Generally speaking, CSAs have created tremendous economic, environmental and social benefits. The organic way of cultivating land has significantly improved the soil's physical and chemical nature and restored the balance of farmland ecological systems. It has helped with ecological restoration at low cost. Over the last 10 years, many CSAs have received government officials from different places and visitors from home and abroad who engage in field investigations and learning.

In 2015, Shared Harvest and Little Donkey Farm co-hosted the Sixth International CSA Conference in Beijing. Before the conference, vice premier Wang Yang listened to Shi Yan's report about the CSA movement. In early 2017 the CSA network was formally registered as a CSA alliance in Beijing.

Major factors for success

- » Geographical advantage: Little Donkey Farm enjoys around 37 acres of land in the sixth ring of Beijing city, the foot of the picturesque Fenghuang Valley. It boasts superb water and land resources with beautiful scenery and convenient transportation.
- » Strong team of professionals: Little Donkey Farm is guided by Tiejun Wen, who is an expert in issues related to agriculture, farmers and rural areas. Jia'en Pan, Xiaohui Yan, Zhiyou Huang, Qinghua Yuan, Guoliang Huang are all members of the Rural Reconstruction team that has dedicated itself to promoting eco-agriculture for the past ten years. Also, thanks to scholars such as Yan Shi and Fang Zhong, and the CSA internship system, the farms have been constantly attracting new lifeblood and benefiting from their innovation and participation.
- » Perfect timing: Back in 2008, Haidian district government embraced the idea of developing urban agriculture. In that year, the melamine incident triggered grave concern about food safety issues. Also, the rise of the middle-income class in the urban area gave people the financial ability to offer increased protection to family health.

Challenges

Prominent gap

There is still a prominent gap between the real needs of consumers to solve their food safety issues and the concept of CSA that advocates shared risks among agrifood producers and consumers. This poses grave challenges to the capability of CSA producers' production and service. There are two ways of resolving the issue. First, improving the production capability as well as service philosophy and quality, thus becoming closer to citizens through improved



efficiency of management; second, continuing with citizen education so that consumers come to know more about agriculture production, the environment and patterns, and establish effective communication channels and trust between consumers and producers. The concept of 'mutual help between the urban and the rural with healthy consumption' needs to take root in people's minds.

Despite their strong and growing consumer base, Shared Harvest's message of supporting local-food production still only reaches a small niche group. Wealthy consumers still prefer foreign goods (He, Zou and Jin, 2010) and food safety issues have led to increased consumption of foreign brands (Jacob, 2013). There is still much work to be done throughout the country to gain consumers trust in the domestic market, so they believe that good-quality food can be produced in China, and so they understand the importance of buying locally.

By buying local, organic food, consumers can create the reality of more local, organic food, along with vibrant rural communities (Tsui *et al.* 2017). The importance of dedicated staff, coupled with new social media tools, is a lesson that can be learned from the success of Shared Harvest. To succeed with this type of project, full use needs to be made of the new media tools such as WeChat, as well as ensuring there are continual activities and meetings to reach out to consumers.

Education and outreach are an essential part of developing acceptance for organic CSAs in China. Consumers with disposable income in both developed and developing countries have a tremendous range of choices. Thanks to international trade in food products, they are able to enjoy fresh produce out of season, and have been conditioned by supermarkets to expect it to be cosmetically perfect. From personal experience, a tremendous amount of perfectly good food that does not meet these standards is wasted.

On the other hand, CSA consumers receive a regular supply of fresh produce, but can only select the types of foods they want to receive, not the individual specimens. Thus they may have to accept oddly shaped, or otherwise imperfect produce that they may have rejected at the supermarket. Accepting the value of irregular-looking and seasonal-only produce will take education and a shift in consumer views.

Educating consumers is a key aspect of CSAs, although not necessarily the main objective.

By giving members a chance to visit the farms and participate in activities, CSAs connect members directly with the agricultural production process, and give them a new appreciation of what it means to grow, market and distribute food in a healthy manner. This is an aspect that is all too often lost in our modern food system.

Challenges with communication

CSA represents a model based on a high level of trust between producers and consumers and poses great challenges to each other's communication pattern and information management capability. When both the delivery share and the labour share multiply, effective communication and interaction among all members holds the key to trust. Solutions under discussion fall into two aspects: first, establishment of the information management platform, which promotes improved management efficiency with state-of-the-art information technologies. Second, introduction of the world-class philosophy of 'service design', which strengthens communication



and interaction by improving the service pattern and increasing innovation to engage more citizens and establish an open, harmonious society that advocates mutual help.

Securing uniqueness

As a large amount of capital flows into the agriculture sector, the most daunting task is to stand on firm ground and secure the uniqueness of the CSA concept. Many CSA farms adhere to the principle of maintaining a clear understanding and judgment of the situation, refusing to permit a herd mentality and making up for lack of capital with continued innovation. This remains the basic principle that will act as a guide into the future. At the same time, positive capital is open-mindedly explored that is not in the form of 'hot money' for potential cooperation.

Policy barriers to organic production

Even if Shared Harvest did decide to pursue organic certification, new requirements would make it cost-prohibitive. In 2013, the government issued new standards for organic certification that require each crop to be certified separately. The cost of certifying Shared Harvest's products would therefore be over CNY150 000 per year. Furthermore, explains Shi Yan, current standards and subsidies are geared towards industrial production⁹. And there are currently no government-sponsored programmes that support Chinese farmers in learning best practices for organic farming, or how to purchase or implement new sustainable technologies.

The result is that few small-scale farmers are able to engage in sustainable agriculture livelihoods. Instead, larger companies that are operating larger-scale farms tend to dominate organic production (Cadilhon, 2009). Despite this challenging policy environment, Chinese agriculture is likely to remain dominated by small and medium-sized farms of 3 to 4 ha.

Shared Harvest's success is related to the dedication of very committed people. We would like to see policies in place that support small-scale farmers in more tangible ways. We also suggest that agricultural policies need to shift from a myopic focus on food production to a more holistic focus on food systems. Ultimately, overcoming these barriers is about changing mind-sets and social norms.

Logistics and transportation

Other challenges in accessing market channels are logistics and transportation. The farms are at some distance from the consumers, product prices are high and consumers argue that there is a lack of full family support for their purchasing decisions.

⁹ See also; Schneider (2015)



CONCLUSIONS

This study has attempted to understand CSA in terms of its ecological, social and economic sustainability. Despite the inherent and considerable challenges of achieving organic food production in China, CSA seems to be succeeding, largely because of its holistic vision of sustainability as a socio-economic and ecological system.

As a staff member wrote on the Shared Harvest blog, “An old Chinese proverb says that the common people value food as they value heaven – above all else. However, this value has seriously diminished. ‘So-called modern cultivation – which is industrialised and chemical-dependent – is gradually replacing China’s centuries-old agrarian culture.’ The writer continues, ‘More and more, we do not recognise the importance of the Earth’s life-sustaining resources: clean air, water, and soil... During this modernisation process, the farmers who provide our food do not make enough money to maintain a dignified livelihood.’ For these reasons, concludes the writer, ‘we cannot use a purely economic lens to evaluate our agricultural system; its significance vastly exceeds its strictly ‘economic’ attributes, as it provides the very basis of healthy human existence.’

We also note the increasing food-safety issues that inevitably arise from the lengthening of market chains for food commodities. We believe that there should be planning around what we eat, not just for the goods in the field, but for the entire system that produces and delivers our foods.’ Such planning would encompass the ecological health of farming practices, the economic profitability of food production and the social viability of farming as a livelihood.

In the meantime, initiatives that are similar to Shared Harvest will continue to expand, spurred by passionate individuals and the increasing hunger of urban consumers for healthier, trustworthy food options. ‘In the face of food safety problems, environmental pollution, and the decline of village life,’ writes the Shared Harvest blogger, ‘we cannot help but feel alarmed. However, we believe that through collective action and the sharing of knowledge we can change the present and work towards a better future.’



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06

ENHANCING ECOSYSTEM SERVICES THROUGH AN AGROECOLOGY APPROACH

SESSION BEYOND PRODUCTIVITY: MULTIPLE CRITERIA FOR ASSESSING PERFORMANCE OF AGRICULTURE SYSTEMS

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Abstract

It is now widely recognised that agriculture is multifunctional; beyond useful food and non-food products, it provides a wide-range of other key services from environmental health and protection, livelihoods and economic opportunities, to social stability, maintenance of culture, tradition and identity. The debate about measuring the performance of agriculture production is increasingly gaining momentum, and cannot be reduced to labour or productivity of the land. Ecosystem services and amenities, as well as negative externalities, should be included in this performance estimate. Furthermore, they must be computed over time so the long-term impact on ecosystem potentialities and sustainability can be evaluated. This multi-criteria performance is being debated and there are no tools to build consensus.

Agroecology pathways represent a true rupture with the way agriculture has been understood by mainstream science for over a century; these pathways are essentially based on the use of biodiversity and ecosystem services (ES) in agricultural production. Therefore, these pathways act in complementary ways: first by enhancing the services provided by living organisms and by taking the optimal advantage of natural resources – especially those that are abundant

and free, and second, by reducing the negative externalities that generally arise from conventional intensification caused by pollution, conformity and the erosion of biodiversity at different scales, energy balance, etc. Because the horizon for sustainability is over the long-term, these interactions, which are cumulative over time, feed the long-term vision of improving the local natural capital that is specific to family agriculture.

Ecosystem services are many and very diverse. Some are easy to document and measure, but others are not, sometimes because the process behind their production is not well known, sometimes because their nature is highly qualitative and subjective. Researchers and policy-makers have explored several hundred indicators but, as yet, no consensus has emerged concerning a consolidated list of well-documented services, with attached measurable indicators. Furthermore, because trade-offs are mostly implied between different ecosystem services, a common metrics is required to construct a comprehensive measure of the performance; inevitably this common metrics is an economic value that is not always compatible with the very nature of some services. Examples from different regions of the world will illustrate these questions.



INTRODUCTION: A RADICALLY NEW WAY OF LOOKING AT AGRICULTURAL PERFORMANCE

In the 1990s, several important actors who were engaged in international discussions banned the use of the concept of agriculture multi-functionality because of the suspicion it would hide non-tariff protectionist agendas. After several worldwide surveys and prospective works, such as the Millenium Ecosystem Assessment (MEA), the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), there is now common ground on which to recognise that agriculture plays several roles beyond production and hence is, by its very essence, multi-functional. Beyond useful food and non-food products, agriculture provides a wide-range of other important services ranging from environmental health and protection, livelihoods resources through to social stability, maintenance of culture, recreation, tradition and identity.

The MEA, in its global surveys of planet ecosystems, attempted to define and characterise the services they provide and their links to human well-being (MEA, 2005). This worldwide survey produced a basic definition of ecosystem services that can be defined as *“the benefits people obtain from ecosystems”* and helped to indicate the great connectivity, and therefore relationship, between the different ecosystems, including those that are cultivated. These ‘agro-ecosystems’ were either cropped, planted as forests or grazed, and represent nearly 40 percent of the Earth’s land; it is essential that they provide ecosystem services along with their classical produce. To do so, agriculture should place special attention on biodiversity, because the functional diversity of the living organisms is its primary engine.

More recently, with the Paris Agreement on Climate Change, the role of agriculture in mitigating climate change has been recognised and, although it does not appear directly in the target definition, most countries are using their agriculture as a lever to mitigate greenhouse gas emissions (gaz à effet de serre – GES). Through increasing organic soil carbon for example (4/°°°), different cropping systems perform in various ways to mitigate greenhouse gas emissions, and this service, which is provided by specific techniques, could be revealed as being extremely important for humanity in the near future.

At the same time, there is a crucial need to intensify productivity of agroecosystems in many regions around the world, where yields are still extremely low. Facing multiple and urgent challenges in southern countries including food and nutrition security, the green economy, poverty reduction, rural development, jobs and income in rural areas, agriculture must increase its output because it is one of the main primary activities able to catalyse and feed development. But in doing so, ecosystem services should also be enhanced, as they are crucial for population livelihoods. Therefore performance should encompass both production and ecoservices services – and the trade-off between these and production expectations – and a long-term framework in which to assess sustainability.

The question of measuring the performance of agriculture production is gaining momentum and cannot be reduced to labour or land productivity. Ecosystem services and amenities, as well as negative externalities, should be included in the estimation of the evaluation of performance.



Furthermore, they must be computed over time so that the long-term impact on ecosystem potentialities and sustainability can be evaluated. They should be considered as reinforcing the ecosystemic capital, i.e. the potential capacity of the ecosystem to deliver a wide-range of services, including production over the long term. Even if this multi-criteria performance is well recognised, the debate continues and there are no consensual and ready-to-use tools and metrics.

AGROECOLOGY ENHANCES SPECIFIC ECOSYSTEM SERVICES FOR PRODUCTION AND IS EXPECTED TO LOWER NEGATIVE EXTERNALITIES

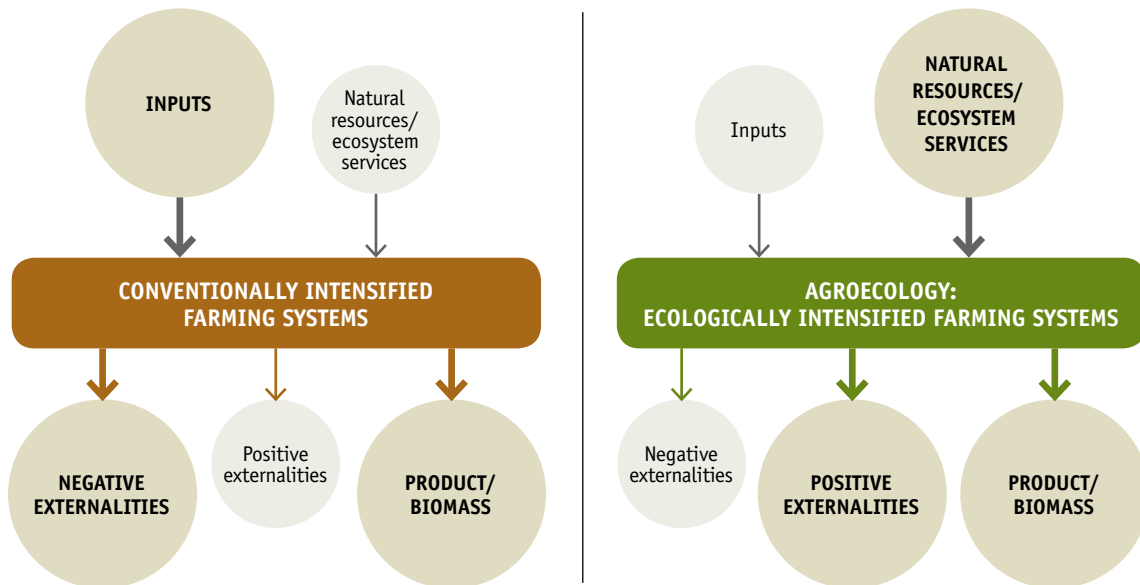
Agroecology represents a real rupture with the way agriculture has been understood for over a century by mainstream science taking a reductionist viewpoint. According to this conventional perspective, agriculture should follow a pathway for intensification through the use of high-yielding varieties and an increasing use of external inputs such as fertilizers, pesticides and irrigation. This model of intensification, that creates a great number of dependencies, has fed both 'industrialised', and been transformed by the agricultural 'green revolution': a strong crop specialisation was promoted that was often reduced to a uniform and synchronous canopy, ultimately consisting of a single genotype of a few major species, with the rest of the living organisms being systematically eliminated as 'limiting factors'. Despite an incredible increase in productivity, industrialisation has caused extreme impoverishment in biotic interactions, even at the landscape level. It has been forgotten how much biodiversity is the driving force behind production and is the regulating process in ecosystems. Today, this model of sustainability is being profoundly challenged.

Agroecology, on the other hand, is based mainly on stronger provision and mobilisation of natural resources, biodiversity and the relevant ecosystem services that sustain agricultural production such as natural pest control, maintenance of soil fertility, water dynamics, pollination, etc. In this way, the intensification of ecosystem services is driven by the amplification of ecological processes produced by biodiversity. In principle, because agroecology is essentially based on the use of biodiversity and ecosystem services in agricultural production, the performance of agroecology must take these ecosystem services into account (Figure 1).

This does not mean that agroecology is a panacea, always able to increase productivity and, at the same time, able to restore depleted ecosystem services; it means that, being built upon the mobilisation of these services for production, the attention given them is greater than with the conventional approach. It also means that agroecology systems are far more context dependent, since ecosystem services are linked to available biodiversity that may be locally available. The innumerable incarnations of basic agroecology principles in cropping systems indicate the diversity of innovations that have been specifically designed regarding natural resources and the constraints of the local ecosystems. Incidentally, it is implied that agroecology systems cannot be prescriptive recipes, created by research and 'passed' to farmers, as a one-size-fits-all, and will require much stronger participation of farmers in the innovation process and hybridisation of scientific and local knowledge.



Figure 1. Comparison of intensification of cropping systems



Source: adapted from Griffon, 2013

Even though the primary objective of agriculture remains production and the growing constraints that are linked to the availability of land and natural resources requiring intensification of most agriculture in the world, agroecological pathways of intensification – or ‘ecological intensification’ – will have to take into account an integrated measure of performance and sustainability. The agroecological intensification pathways interact with ecosystem services in complementary ways by first enhancing the services provided by living organisms and by taking the optimal advantage of natural resources, especially those that are abundant and free, and second, by reducing the negative externalities that generally come with conventional intensification such as pollution, conformity and erosion of biodiversity at different scales and energy balance (Figure 1). Again, because the horizon of sustainability is far into the future, these interactions, being cumulative over time, feed the long-term vision of improving the local natural capital that is very specific to family agriculture.

THE CHALLENGE OF MEASURING ECOSYSTEM SERVICES

Ecosystem services in nature are many and very diverse, but mostly, they are only partially known and understood. Several global experts have been led to list and describe ecosystem services. The first large-scale study, the Millennium Ecosystem Assessment (MEA, 2005) provides a framework that organizes 23 of these systems into four functional groups providing services: provisioning; regulating; cultural and supporting. These four groups have been further refined by the Economics of Ecosystems and Biodiversity (TEEB, 2008), which proposes a typology of



22 ecosystem services that have been divided into four main service categories: provisioning; regulating; habitat, cultural and amenity, in consideration of the MEA, the supporting services are thought of more as a subset of ecological process, and 'habitat services' as being directly linked to the protection of biodiversity gene pools.

Finally, the Common International Classification of Ecosystem Services (CICES), to be used for accounting natural capital and fluxes, offers a structure for linking to the framework of the United Nations System of Environmental-Economic Accounts (SEEA, 2003). CICES builds on the existing classifications that focus on the ecosystem service dimension but introduces the new idea of system services that are either provided by living organisms or by a combination of living organisms and abiotic processes.

Abiotic outputs and services, for example provision of minerals from mining or the capture of wind energy, can affect ecosystem services, but do not rely on organisms for delivery. These ecosystem services are therefore considered as part of the overall natural capital, which comprises subsoil assets, abiotic flows and ecosystem capital and services. This CICES classification allows a national accounting tool for natural capital and fluxes, integrated in space and comparable over time. This allows for the accountability of natural capital in systems of economic-environment accounting. Table 1 lists the ecosystem services that have been classified based on these three sources.

The 'Mapping and Assessment of Ecosystems and their Services' initiative is an illustrative example of an attempt to quantify ecosystem services over large areas (Maes, 2013). Maes led a detailed inventory and mapping of the services of different ecosystems as one of the actions taken by the European Union to slow the erosion of biodiversity on the continent by Horizon 2020. Multistakeholder discussions validated a general conceptual framework, linking ecosystem services and components of human well-being, recognising the influence in both directions (Figure 2) and a set of 30 quantitative indicators allowing an evaluation of their economic values and a precise monitoring of the land use including agriculture, protected zone, forest and urban. This method first allows for the characterisation of the ES produced by each type of ecosystem and second provides a spatial integration of the quantification of these services based on their mapping. Analysis of the trends of change spatial extent and hence the supply and use of ES at the European scale has been completed for 2000 and 2010. This integration of a large space and time scale is helpful for feeding the information to society and for public policies. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) continues to work on these questions along the same line and is refining the tools for assessing and quantifying ES at the global level.

Measurements of ES, and identification of indicators, raise some key questions:

- » Some ES are easy to document and measure, but others are not, sometimes because the process behind their production is not well known, for example the services involving underground biodiversity, sometimes because their nature is very qualitative and subjective such as 'cultural services', which are extremely dependent on the local context. Researchers and policy-makers have explored several hundreds of indicators but no consensus is likely to emerge on a consolidated list of well-documented services, with attached measurable indicators that are adapted to a range of ecosystems.


 Table 1. **As used in Millennium Ecosystem Assessment (MA), The Economics of Ecosystems and Biodiversity (TEEB) and Common International Classification of Ecosystem Services (CICES)**

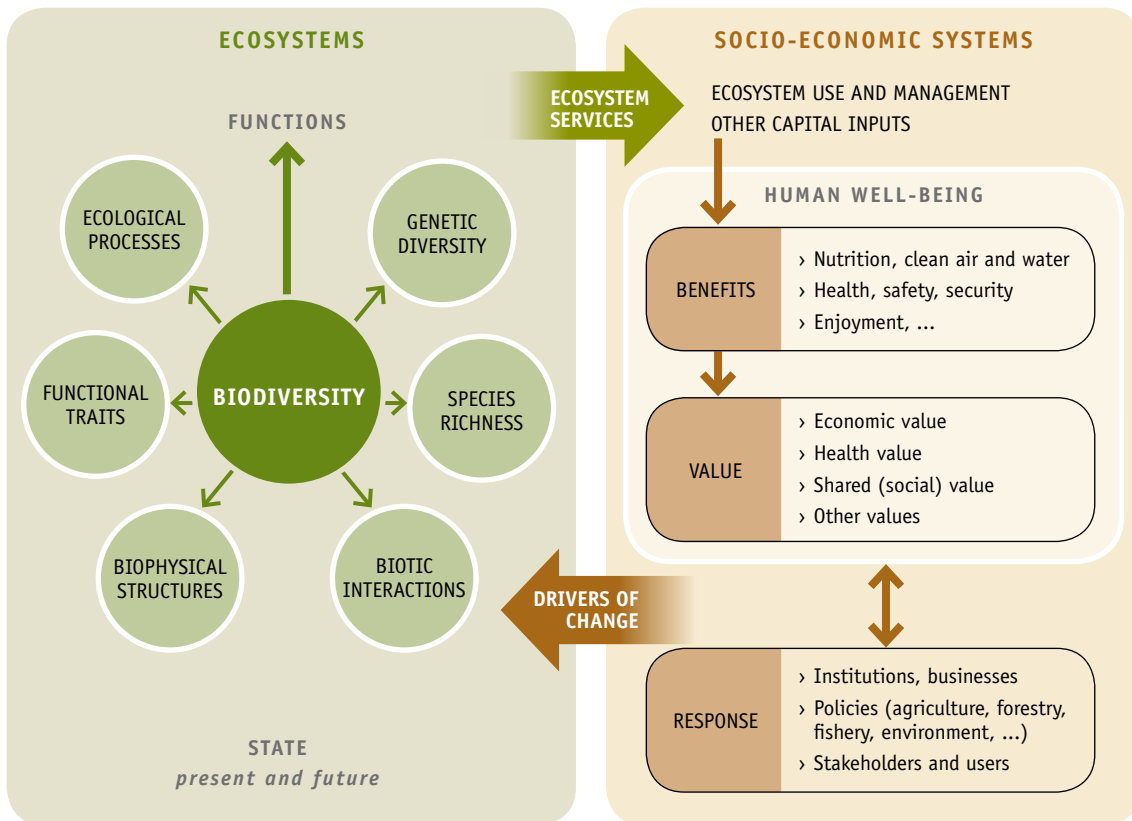
MA CATEGORIES	TEEB CATEGORIES		CICES V4.3 GROUP*
Food (fodder)	Food	Provisioning services	Biomass [Nutrition]
			Biomass (Materials from plants, algae and animals for agricultural use)
Fresh water	Water		Water (for drinking purposes) [Nutrition]
			Water (for non-drinking purposes) [Materials]
Fibre, timber	Raw Materials		Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Genetic resources	Genetic resources		Biomass (genetic materials from all biota)
Biochemicals	Medicinal resources		Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Ornamental resources	Ornamental resources		Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
			Biomass based energy sources
			Mechanical energy (animal based)
Air quality regulation	Air quality regulation	Regulating services (TEEB)	[Mediation of] gaseous/air flows
Water purification and water treatment	Waste treatment (water purification)		Mediation [of waste, toxics and other nuisances] by biota
			Mediation [of waste, toxics and other nuisances] by ecosystems
Water regulation	Regulation of water flows		[Mediation of] liquid flows
	Moderation of extreme events		
Erosion regulation	Erosion prevention	Regulating services (TEEB)	[Mediation of] mass flows
Climate regulation	Climate regulation		Atmospheric composition and climate regulation
Soil formation (supporting service)	Maintenance of soil fertility	Regulating and supporting services (MA)	Soil formation and composition
Pollination	Pollination	Regulating and maintenance services (CICES)	Lifecycle maintenance, habitat and gene pool protection
Pest regulation	Biological control		Pest and disease control
Disease regulation			Lifecycle maintenance, habitat and gene pool protection
Primary production	Maintenance of life cycles of migratory species (incl. nursery service)		Soil formation and composition
Nutrient cycling (supporting services)	Maintenance of genetic diversity (especially in gene pool protection)		[Maintenance of] water conditions
			Lifecycle maintenance, habitat and gene pool protection
Spiritual and religious values	Spiritual experience	Cultural services	Spiritual and/or emblematic
Aesthetic values	Aesthetic information		Intellectual and representational interactions
Cultural diversity	Inspiration for culture, art and design		Intellectual and representational interactions
Recreation and ecotourism	Recreation and ecotourism		Spiritual and/or emblematic
			Physical and experiential interactions
Knowledge systems and educational values	Information for cognitive development		Intellectual and representational interactions
		Other cultural outputs (existence, bequest)	
<i>MA provides a classification that is globally recognised and used in sub global assessments.</i>	<i>TEEB provides an updated classification, based on the MA, which is used in on-going national TEEB studies across Europe.</i>		<i>CICES provides a hierarchical system, building on the MA and TEEB classifications but tailored to accounting.</i>

* Explanatory information from CICES division level [between squared brackets] and from CICES class level (between parentheses)

(Maes, 2013)



Figure 2. **Conceptual framework of Maes**



Source: Adapted from the Maes, 2013

- » The assessment of the multiple ES for human well-being implies the analysis of synergies and trade-offs that are present between these services most of the time. Because of this, a common metrics is required to build a comprehensive measure of the performance; inevitably this common metrics has an economic value that is not always compatible with the very nature of some services. First, economic value is essentially based on the well-being of humans living today and does not take into account future generations or even ecosystem needs; some of these ecosystem needs may not be clearly perceived today, but could be of vital importance for the viability of the planet system. Second, in theory, the economic value is based on the utility and rarity of a specific good but both utility and rarity are subjective: utility depends on appreciation, and rarity depends on the expression of a demand whereas many services are not marketed. The notion of total economic value has emerged to integrate the different sources of value: use, potential use or non-use, present and future, market linked and non-market linked to represent the best proxy for the social value.
- » It is difficult to construct indicators that capture the importance of the time factor. Many ES evolve over long periods of time, with threshold mechanisms and irreversibility. Their measure should enable us to think about recapitalisation of ecosystems over the long term.



- » Although today we do not have comprehensive metrics tools that allow for the integration of the values of the different ES at different scales, much research is based on quantification of specific services, but without an integrated framework, an *ad hoc* combination of indicators are used to explore the question of trade-offs. This will be illustrated by a few examples, among many, from different regions of the world.

SOME ILLUSTRATIVE EXAMPLES

Conservation agriculture, 'zaï' traditional system, agroforestry can be considered as some of the numerous incarnations of an agroecology approach. These systems are employed in all climate environment and agrarian systems by all kinds of farmers, from large mechanised with equipment and capital to small, family farms with no such assets. One of the trickiest questions about the performance of these systems is to be able to make wise choice about trade-offs or conflicts between the farming system and the ecosystem services.

Conservation agriculture applied to large mechanised farms

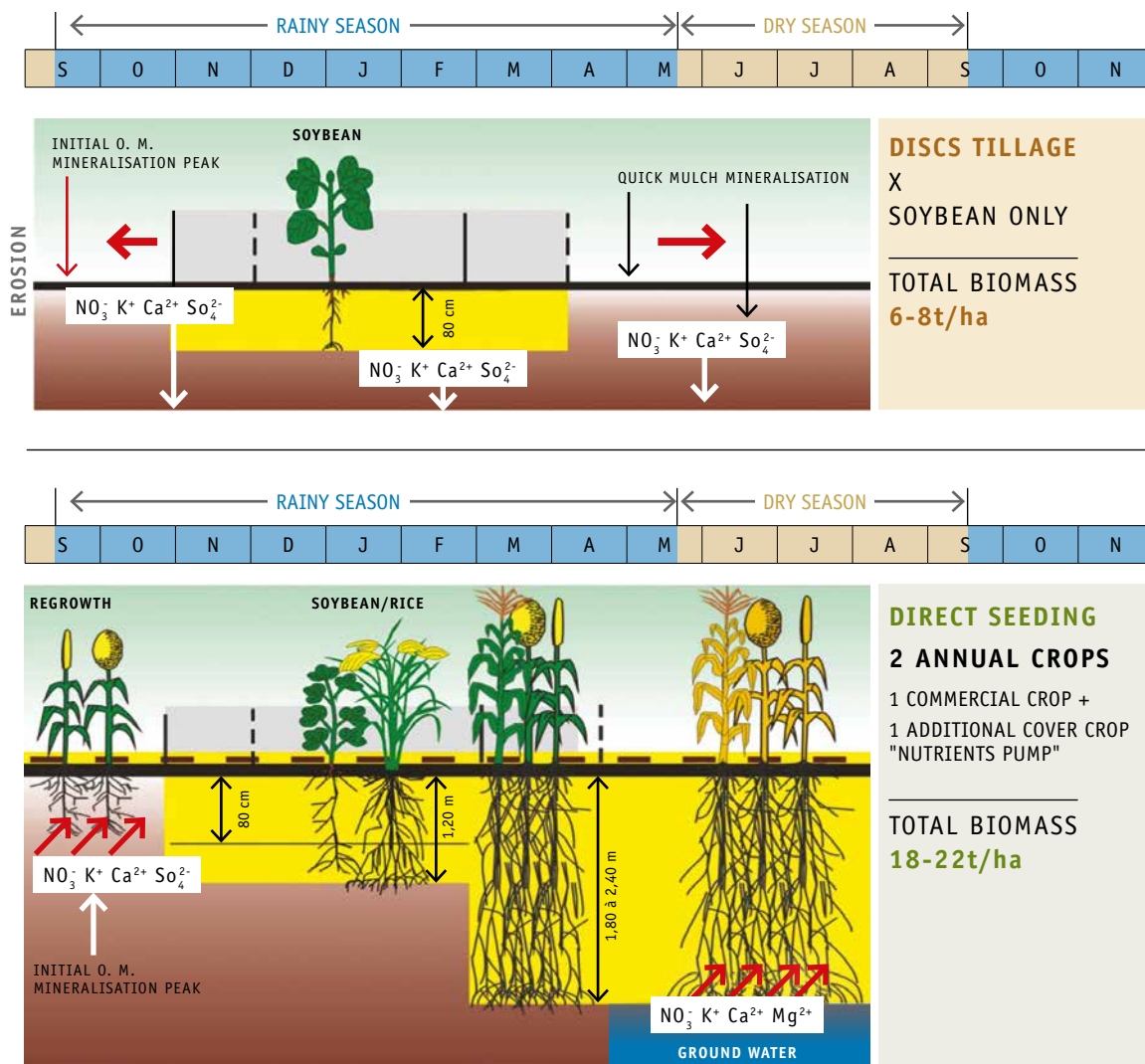
Conservation agriculture is based on three basic principles: no-tillage, mulch and crop diversification. Its first interest is related to its potential for conserving soil and water and for enhancing soil fertility by reducing soil erosion, decline of soil organic matter, and the breakdown of soil structure. Its second interest is to use crop diversification to increase biological diversity and their interactions to increase production and limit aggressors.

Conservation agriculture techniques have been applied in very humid regions of southern Mato Grosso in Brazil on several millions of hectares on large mechanised farms; it replaced the original unsustainable monocropping system, which was employed after forests were cleared. The project is replacing these unsustainable systems with a range of species associations and successions. (Figure 3). This has allowed the cropping season to be taken advantage of fully, increasing the total biomass output, from 6 to 8 tonnes/ha up to 22 tonnes/ha, at the same time reducing soil erosion, nutrient lixiviation and losses, nutrient cycles in very deep soil horizons (Seguy *et al.*, 2009).

In these conditions, the soil is protected with abundant mulching associated with no tillage and the crops' rooting systems and canopies are managed in a complementary way throughout the season, allowing for the enhancement of the ES, helping both production year-round and the quality of the environment. In these conditions, amplification of ES linked to carbon (Corbeels *et al.*, 2006); nitrogen (Maltas, 2009), water (Scopel, 2004) and aggressors (Ratnadass *et al.*, 2010) have been documented and measured. In this case, conservation agriculture also reduced fossil fuels and generated the diversification of production, for example with forage production for cattle during the dry season, and there was no real trade-off between ES and production and the farmers possessed sufficient equipment and capitalisation to make informed choices.



Figure 3. Conservation agriculture in Mato Grosso



Source: Seguy *et al.*

Conservation agriculture applied to smallholders in Africa

The same principles, applied to small family farms in Africa, led to different outcomes because of contextual limitations and farmers' constraints and interest. In a meta-analysis based on 41 research papers on conservation agriculture in Sub-Saharan Africa in various climates and conditions, Corbeels *et al.* showed that, as long as the three principles are correctly applied (no tillage, mulching and crop diversification), conservation agriculture generated amplified ES (nutrient and water cycles, limitation of erosion) and higher biomass output (Corbeels *et al.*, 2014); its relatively low rate of adoption (only one million ha after twenty years of promotion) is the result of the intense competition between the use of crop residues, either as mulch or as



forage for animals that is generally present on these farms. The profitability of the forage choice is generally better for small farmers (Rusinamhodzia L. *et al.*, 2015) and, without the mulch; the positive effect of conservation agriculture on yield is off set. In this case, the trade-off between ES improving soil and environment status and biomass production was too great to be managed by small farmers, who did not have the chance to choose a long-term strategy to improve the ecosystemic capital.

Traditional zaï technique applied to Sahelian degraded land

The 'zaï', is a traditional technique employed in the Sahel regions in Africa to reclaim degraded, 'crusted land' or zipellés. It consists of modelling the land, before the rainy season, into small impluvium holes, with locally applied organic matter or manure to give biological cycles more chance to start and thrive. The aim is to locally improve soil water infiltration and retention, concentrating the rainwater into this depressed space to improve the organic status of these cultivated holes in a virtuous cycle (Roose *et al.*, 1995). One of the main elements of this technique is the installation of fungus grower termites' in the holes to create galleries that in turn improve the soil structure and organic status (Kaisera, 2017; Jouquet, 2011).

This technique is adapted to regions having an annual rainfall between 400 and 800 mm and requires hard manual work during the first year of installation, although mechanisation is possible. The farmers employing this technique are actually using biodiversity to start and amplify the ES and, if well managed over several years, reinstall ligneous plants that are able to provide new ES including nitrogen fixation, deep rooting improving soil structure, shade, pollination, auxiliaries. A few studies have evaluated the carbon fixation using the zaï technique at around 10 tonnes/ha/year with *Acacia albida*, which also provides nitrogen fixation. The particularity of this agroecology technique is to reconstruct, using very simple means, an improved ecosystem capital, which eventually ends with a real and stable Sahelian agroforestry system.

Agroforestry in large cropping systems in temperate areas

Agroforestry is based on intensive land-use management combining trees and/or shrubs with crops and/or livestock. In many tropical regions agroforestry is a traditional farming system, as it once was in temperate regions until the twentieth century. The association between annual and perennial species can be very complex and may result in different benefits including better exploitation of resources, diversity of products, complementarity over space and time, improved capacity to buffer shocks. Researchers have shown great interest in re-introducing tree species into large areas of intensified and mechanised crops.

The results from the large European project 'SAFE' in seven countries in association with cereal crops and different tree species, (walnut, cherry, poplar, oak) have been quite positive in terms of global yield (up to 30 percent more than separate plots), with additional ES benefits for carbon sequestration (Cardinael, 2017), water dynamics, profitability, adaptive capacity, auxiliaries habitats, cultural services and landscape beauty, etc. The re-introduction of trees into large mechanised monocrop farms in Europe would require a real mental revolution, since it is a kind of step backwards, compared to conventional intensification, but because of its



performance both in productivity and ES production, it could impact tens of millions of hectares in Europe (Dupraz, 2005). Using the same rationale, agroforestry systems in the tropics, which are, in their diversity, widely spread, present a huge number of possible combinations of species and therefore a very promising pathway to increasing ES production as well as productivity. Among many studies in the tropics, cocoa (Vaast, 2014) and coffee agroforestry systems (Allinne *et al.*, 2016) have been thoroughly studied for their potential for increasing ecosystem services.

CONCLUSIONS

The agroecology approach offers a wide-range of transformative pathways for agriculture, well adapted to the urgent necessity of thoroughly renewing the notion of performance, while taking into account both production of goods and ecosystem services. The balance between the different functions of agriculture that mostly results from managing trade-offs, should be analysed at different scales, and cannot be the sole responsibility of the farmers; since ES are provided at the landscape scale and benefit many people who are distant from agriculture, therefore public policies should be created to motivate and remunerate the production of ES. Policy-makers require evidence on which to base, develop and monitor new policies and programmes that lead to the creation of indicators and metrics.

There is an urgent need for common metrics for ES; these metrics should allow: 1) application to both agro-ecosystems and natural ecosystems since they are connected in many ways, especially for ES production; and 2) integration of the time factor, including the long timeframe which is important for some degradation or aggradation.



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07

FUXIAN LAKE PRESERVATION AND ECO-AGRICULTURE: POLICIES AND PRACTICES IN CHENGJIANG COUNTY

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Abstract

In recent years, many lakes are increasingly being threatened by industrialisation, urban expansion and intensive agriculture, especially by eutrophication. Lake pollution continues to pose a significant risk to regional ecosystems, public health and sustainable socio-economic development. At the regional level, a substantial body of research has been carried out on control of non-point source (NPS) water pollution in China. Few studies, however, have been carried out at the level of the administrative division. This study begins to address this research gap by discussing how to control the pollution of the lake at the scale of the Chengjiang County administrative division. This paper introduces the background information on Fuxian Lake, and analyses the factors affecting lake pollution. It also makes an assessment of how to introduce government, national and local policies, practices, mechanisms and projects that would provide the right incentives

to support lake preservation and eco-agriculture. On the basis of the principle of giving priority to prevention and protection, the local government should take steps to improve the management of the technical and governance aspects, including in the areas of self-restraint in headwaters; improving the process of governance; end purification; conservation of the waterbody; optimising the industrial structure; restoring the eco-environment around the lake; controlling pollution in villages; improving the water quality of the river; and establishing a mechanism for clean water. This article discusses the following experiences: combining science and policies; non-point source (NPS) control by promoting positive cycles between agriculture and water; establishing systems of cooperation between the government and farmers.

Keywords: Fuxian Lake, pollution, preservation, policy, practice, agriculture

INTRODUCTION

Non-point Source Pollution

In Yale University's 2016 Environmental Performance Index, China is one of the worst performers (ranked 109 out of 180 countries) with respect to its performance on changes in water quantity as a result of consumption, including industrial, agricultural and household uses (Yale, 2016). In recent years, many lakes are increasingly threatened by industrialisation, urban expansion and intensive agriculture, especially by eutrophication (Ongley, 2004). Lake pollution continues to pose a significant risk to regional ecosystems, public health and sustainable socio-economic



development. Studies have shown that the quality of lake water is mainly affected by factors such as geographical location, vegetation, land use and pollution from atmospheric sediments (Mosello *et al.*, 2002; Sheng *et al.*, 2002; hang *et al.*, 2007; Yang and He, 2012).

In China, Zhang (2004) argues that farmland, livestock and domestic sewage from rural areas is the main reason for the nitrogen and phosphorus eutrophication of waterbodies in heavily polluted watersheds, with a contribution rate that is much higher than the point source pollution of urban sewage and industrial activities. Chemical fertilizers are typically over-used by up to 50 percent more than is necessary for the requirements of intensive vegetable production (Norse, 2005). Soil nutrients such as nitrogen and phosphorus cause pollution of surface water and groundwater through surface runoff or leaching, and are the main pollutants in eutrophication of reservoirs and lakes (Trenkel, 1997; Huang *et al.*, 2010; Smith and Siciliano, 2015).

Pollution control at the scale of the administrative division

The understanding of the relationship between the quality of the lake water and land use on different spatial scales, such as entire catchment, riparian zones, and proximity of the monitoring site, is critical to the rational planning of riparian land use in watershed drainage areas, strategies for the effective protection of watersheds and management practices to reduce NPS pollutants (Carey *et al.*, 2011; Pratt and Chang, 2012). Based on such an understanding, a significant body of research has focused on the regional control of NPS water pollution in China (Yang *et al.*, 2006; Kong *et al.*, 2012). Most studies, however, are at the watershed scale, or for specific types of pollution, which have no significant meaning for the making of macro policies. Furthermore, pollution control at the watershed scale often causes various governments to attempt to avoid their responsibilities, resulting in delays in the timing of and reduced effectiveness of pollution control.

Researchers and the Government in China have usually ignored pollution control, and few studies have been carried out at the scale of the administrative division (Duan, 2010). Pollution control at the scale of the administrative division (city, county) could maintain the integrity of the county or city boundaries, so as to facilitate the application and promotion of the research results under the existing environmental management regime. In order to achieve pollution control at the administrative level, many international governments and organizations, including the United States, use environmental payment for eco-system services (PES) and subsidies by way of central government grants and taxes (Paschyn, 2014). Many domestic researchers have introduced the idea of industrial structural adjustment into urban environmental district planning (Liu, 2001; Zhao and Liu, 1999).

The objective

The characteristics of NPS pollution, including wide-area distribution, dispersion and randomness, make it difficult to implement targeted pollution control measures. Consequently, it has become urgent to solve the problem of improving the effectiveness of pollution control. Both policy and good practices are needed to provide support for pollution control in drainage basins.



This study introduces the challenges and discusses how to control lake pollution at the scale of the administrative division in Chengjiang County. This paper first describes the background information on Fuxian Lake, and analyses the factors affecting lake pollution. It then assesses how to introduce government policies (including at the national and local scale) and practices (including mechanisms and projects) that would provide the right incentives to support lake preservation and eco-agriculture.

Study area

Fuxian Lake (24°21'28"–24°38'00"N, 102°49'12"–102°57'26"E) is in the middle of Yunnan Province. It is the second deepest lake in China, as well the largest storage capacity lake in Yunnan Province (Wang, 1998), and has the best water quality as it is a nutrient-poor lake (Jin, 1990). The lake stretches out through Chengjiang, Jiangchuan and Huaning Counties in Yunnan Province, spanning an area of 212 km², with an average depth of 89.6 m, a maximum depth of 155 m, and a water storage capacity of 206.2 billion m³. These reserves represent 9.16 percent of all freshwater lakes and 91.4 percent of Class I lake water in China (Ai *et al.*, 2010). The management of Fuxian Lake poses implications for the quality of downstream water affecting six provinces in China and northern Vietnam.

Table 1. Water system and morphological characteristics of Fuxian Lake

PRIMARY INFLOWS	PRIMARY OUTFLOWS	MAX. LENGTH	MAX. WIDTH	SURFACE AREA	AVERAGE DEPTH	MAX. DEPTH	SURFACE ELEVATION	WATER VOLUME	INFLOW RUNOFF	OUTFLOW RUNOFF
Liangwang river, Dongda river, Jianshan river	Haikou river	31.5 km	11.5 km	212 km ²	89.6 m	155 m	1 721 m	206.20×10 ⁶ m ³	160×10 ⁶ m ³	90×10 ⁶ m ³

(Wu *et al.*, 2002)

This tectonic lake is known to have unique fauna and 14 endemic species have been described. In total, there are 25 native fish species in the lake, including 12 endemic species (Sket, 2000; Cui and Wang, 2005). Fuxian Lake is in the subtropical evergreen broad-leaved forest zone, where there is an annual average temperature of 15.6 °C, and annual rainfall of 800 to 1 100 mm. It is a semi-enclosed inter-mountain basin freshwater lake, mainly fed by precipitation and the surrounding mountain streams. Based on the shape of the lake, the kT value is 15.4, so the disturbance of the lake is very weak, and the water temperature is obviously stratified (Chinese Academy of Sciences, 1990). The Luozang Mountain stretches from north to south in Chengjiang County. The mountain area accounts for 73.4 percent of the total basin area, the water area accounts for 18.6 percent, and the dam area 8 percent. Chengjiang County is dominated by red soil, accounting for 68.1 percent of the land area, with purple soil making up 13.5 percent.

The Fuxian Lake basin area is 674.7 km², with a population of 180 000 people in 2016 (Chengjiang County Statics Office, 2017). In the primary protected area, there is a total population of 28 000 people, 746 ha of farmland and a village land area of 160 ha.



Factors affecting pollution

Previous studies have shown that chemical oxygen demand (COD), total nitrogen (TN) and chlorophyll A (Chl.a) in Fuxian Lake water have deteriorated from 1980 to 2011 (Gao *et al.*, 2013), and phytoplankton growth has increased 10.5 times from 1980 to 2003 (Li *et al.*, 2003).

Natural factors

Fuxian Lake is a fault lake that developed in rocky canyons, and as a result, more than 90 percent of the lakeshore is composed of rock, while coastal shoals are poorly distributed. There are no favourable conditions for growth of large aquatic plants and benthic animals, resulting in a single ecosystem structure, mainly composed of plankton and small fish and shrimp that feed on the plankton. The situation for many of these organisms is precarious because they have been negatively impacted by habitat degradation and water pollution. Beyond this, the lake's relative isolation makes it vulnerable to pollution (Qin *et al.*, 2007; Cui *et al.*, 2008). Therefore, large depositions of nitrogen and phosphorus, caused by surface runoff or leaching, threaten to cause algal blooms.

Fuxian Lake is similar to a deep bucket that needs a long period of 167 years to refresh the waterbody (Wang, 1998). Once the water is polluted, this is irreversible within the span of a human lifetime. Therefore, it is very important that Fuxian Lake is protected from contamination.

Anthropogenic factors

The northern plain, with a larger land area, is the economic centre of Chengjiang, while the southern plain is largely an agricultural area. On the northern plain, domestic sewage, farmland drainage, yellow phosphorus slag from the Chengjiang phosphate factory and floods during the rainy season are either directly or indirectly discharged into the lake (Zhang *et al.*, 2004; Feng *et al.*, 2008). Compared to the eastern shore, the western has a relatively flat terrain; runoff is primarily from the farmland and dryland areas on the western shore, and from the mountains and forests on the eastern shore (Wu *et al.*, 2002; Zeng and Wu, 2007; Dai *et al.*, 2017).

Important anthropogenic factors affecting lake pollution include:

- » **Residents** – Every year, residents around Fuxian Lake area produce 54.32 million tonnes of sewage, 5 658 tonnes of domestic waste, 4 795 tonnes of chemical oxygen demand, 34.96 tonnes of total nitrogen and 53.35 tonnes of total phosphorus. If not properly managed, this threatens the environmental safety of Fuxian Lake. A study by Gao (2013) shows that the number of people in the basin is the main factor driving the change in the quality of the lake water, thus mitigation of population pressure in the basin is highly important in solving the water quality problem.
- » **Livestock** – About 80 percent of the pollution load in Fuxian Lake is contributed by livestock production and farmland NPS pollution. According to the government report (Chengjiang Government, 2017), there are 7 747 households, of which 127 are massive livestock breeders, with 702 000 head of livestock within the runoff area (from the area where breeding is forbidden to an elevation of 1 900 m). Within the Fuxian Lake Primary Protected Area



(including waters and lakeshore¹), there are 1 388 households, of which 45 are massive livestock breeders, with 66 800 head of livestock.

- » **Fertilizer dependent agriculture** – The evidence from numerous studies has shown that one of the direct sources of pollution of the water system is leakage of nitrogen and phosphorus (Kong *et al.*, 2012; Paschyn, 2014; Dai *et al.*, 2017). This is mainly related to the fact that small-scale farmers typically over use chemical fertilizers, by up to 50 percent more than the required needs (Norse, 2005), which according to the report by the Ministry of Environmental Protection (PRC, MEP, 2010) agricultural runoff was stated as being the main cause of pollution. It still remains difficult, however, to explain why farmers overuse these fertilizers in China by giving a single reason. Fertilizer overuse is not only for socio-economic reasons but policy reasons also account for the behaviour of small-scale farmers.
- » **Out-dated agricultural water management practices** – Problems include poor water infrastructure in the irrigation district, unclear agricultural water rights, minimal guarantees and inefficient water use. First, the major water conservancy project has not been repaired for many years, and field-engineering facilities have not been completed in the irrigation area. Field irrigation, drainage and flood discharge occupy the same channel. Second, agricultural water rights are unclear and the cost is unreasonable. Total quantity control and the quota management of agricultural water consumption have not been implemented. From 2000, the price of agricultural water has been RMB 0.06/m³ and RMB 360/ha per year– far less than the cost of water supply. This makes it difficult to maintain the operation and maintenance of water conservancy projects. Third, irrigation methods are too extensive to effectively use water, and the effective coefficient for irrigative water use is only 0.49 percent.

Policy factors

Governmental policies usually provide direction to the development of local agricultural through government planning, based on the geographical location, natural conditions, and social and economic development, especially from the Chinese Government. Therefore, the preservation of the lake and agricultural environmental protection are greatly dependent on the guidance of government policy.

The current agricultural policies and environmental protection laws of China have failed to internalise the externalities brought about by farmers' production activities. On the contrary, some policies encourage farmers to make production decisions from the perspective of short-term benefits and to engage in production activities in environmentally unfriendly ways. For instance, price subsidies for fertilizers and pesticides provide negative incentives to farmers to reduce the use of fertilizers and pesticides; they help farmers acquire short-term high yields but neglect the sustainable use of land resources.

The lack of specific quantitative penalty regulations or instruments of encouragement means the current system of local policy and institutions are unable to achieve the successful implementation of relevant policies, although a few environmental protection laws and agricultural policies have been generated.

¹ Waters refers to the area below the maximum storage level and lakeshore refers to the area where the maximum storage level extends outward by 110 m along the surface of the ground.



Policy decision-making is a complicated process, as the process of policy implementation involves balancing the costs and benefits of different partners. For example, the issue that must be taken into consideration by government is how to compensate farmers during the process of returning farmland to forest.

Policies

Based on the principle of giving priority to prevention and protection, preservation of the Fuxian Lake waterbody has been controlled from source to estuary, including self-restraint at the headwaters, process governance, end purification and waterbody conservation. Specifically, the main policies regarding the preservation of Fuxian Lake and eco-agriculture are as follows: Optimising the industrial structure, repairing the eco-environment around the lake, controlling pollution from villages and improving the water quality of the river, establishing a clear water mechanism and carrying out '15530 projects' (maintain water quality at Class 1, implement 30 projects in 5 categories over 5 years).

Agricultural structure adjustment

National policies

In order to generate sustainable growth and higher quality, the Central Government has established the "supply-side structural reform" policy for one year, which aims to cut low-end supply while increasing high-end supply as well as public products and services. The policies concerning agriculture focus on the following:

- » **Structural adjustment of animal husbandry:** large-scale, standardisation and strengthening of ecological aspects.
- » **Transform management methods for agriculture:** develop various forms of appropriate scale operations; transform the productive mode of agriculture: conserve water, fertilizers and pesticides.
- » **Protect agricultural resources and the ecological environment:** control the amount of water used, reduce the use of chemical fertilizers and pesticides, prevent livestock pollution, recycle plastic film and control pollution from burning straw.

Local policies

Local policies should be made within the framework of national policies, combined with the local conditions of agriculture. The objective of local policies leads to the development of ecological agriculture, improves the efficiency of agricultural production, increases the added-value of agriculture and reduces agricultural NPS.

- » **Develop agriculture for plateau characteristics** – including blueberry, lotus, walnut and plants for the landscape industry. The government has recognised that decreasing NPS should be accomplished by decreasing the planting of crops having a high-fertilizer demand such as vegetables, while increasing the planting crops with low fertilizer requirements such as lotus.



- » **Support rural land transfer** – Small-scale farmers have usually caused excessive fertilization; to some extent this risk can be reduced through the promotion of land circulation and large-scale planting.
- » **Change traditional agriculture production methods and promote ecological agriculture techniques** – Scientific and efficient planting methods can effectively reduce the unnecessary use of chemical fertilizer inputs and circular agriculture can increase the efficiency of nutrition.
- » **Improve the organization of agricultural production and establish agricultural product brands** – This is mainly to improve the degree of agricultural organization, thereby promoting the use of brands to increase farmers' incomes by employing more effective sales methods and creating better products.
- » **Encourage the construction of livestock pollution control facilities** – promote the development of 'Planting and Cultivating Farms', strengthen environmental supervision and strictly implement pollution reduction.

Agricultural water management

National policies

According to Central Document No.1, released by the Central Government in 2017, agricultural water should be given priority for conservation by construction of an efficient irrigation project, promotion of systematic governance and strengthening of the corporation between the government and the market.

Local policies

The local government policies for agricultural water can be summarised as '1234 Policies', which means one objective, dual tactics, tripartite interests and four principles. Specifically, highly efficient water-conservation is the one objective that should be achieved; the focus should be on the two aspects of the government and the market; the three participating parties should be the government, businesses and farmers; and finally, the principles that should be followed include: first-mechanism and post-project; innovative mechanisms; well-managed operations with overall planning; and full coordination with all-parties participating in the entire-process.

Based on the above-mentioned policies, the mechanisms of agricultural water management were established, which are allocation of a mechanism for agricultural water rights; designation of a price for water used in agriculture and an incentive mechanism; engineering construction and a mechanism for operations management by the leading government, with social participation and mass investment, having the distinction of property rights; a monitoring and evaluation mechanism and a contract management mechanism. The mechanism to allocate water rights allows the government to control, allocate and plan water consumption as a whole, which is expected to decrease the amount of agricultural water used. Moreover, the designation of a price for water and an incentive mechanism, along with monitoring, evaluation and contract management will ensure farmers use water more efficiently, accurately and legally.



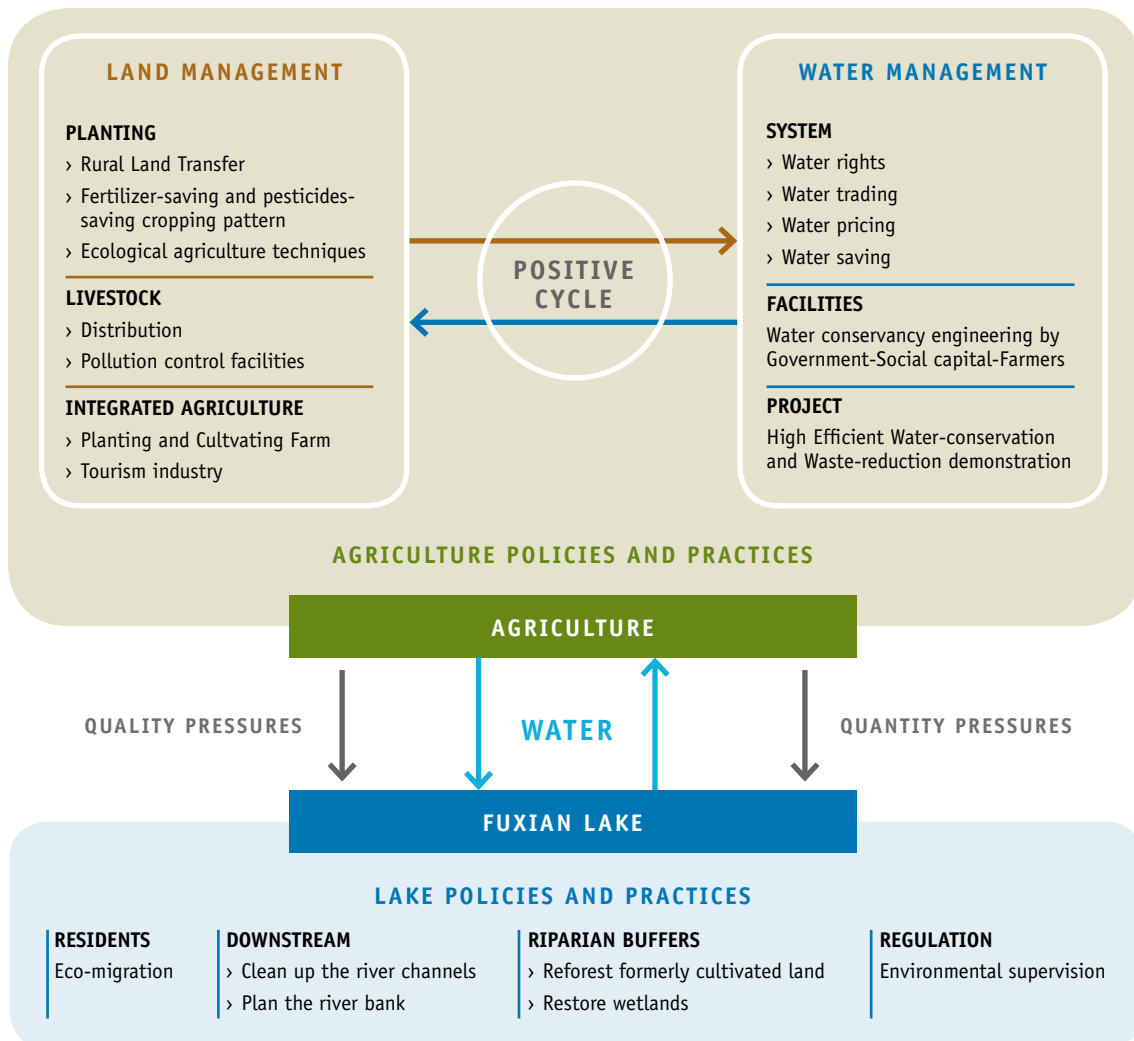
- » **Launching projects** – To establish a micro-irrigation area on 167 ha, including water source projects, engineering for photovoltaic pumping of water, engineering for the transmission of water, farmland works, drainage engineering, computing facilities, automatic control system and monitoring facilities.

Ecological rehabilitation of the lake basin

National policies

The Central Government encourages the local government to protect the lake in the following ways: building capacity for the conservation of lake water, promoting soil and water conservation and returning farmland to forest; protecting and restoring the environment in the lake buffer

Figure 1. **Fuxian Lake systems**





zone by cleaning the shoreline, applying phytoremediation technology to be implemented from fish to lake; protecting biodiversity by establishing an Aquatic Nature Reserve. The first policy aims to reduce nutrient loss from farmland, thus protecting the waterbody of the lake at the source. The second and final policy has been designed to increase the capacity of the lake for self-purification and to protect it from the pollution from the upper reaches.

Local policies

The policies of the Chengjiang Government covering the preservation of Fuxian Lake originated with the Central Government, as mentioned above, were refined to form five policies, based on local conditions.

- » **Agricultural NPS pollution prevention and control project** – It is widely known that agricultural NPS pollution is the main cause of lake pollution. Controlling NPS pollution has become fundamental to solving pollution of the lake; this project allows a manager to control the pollution at the source.
- » **River regulation and eco-restoration project** – Nutrients from farmland usually enter the river with rainwater, and then flow into the lake by way of the river. Consequently, river regulation and eco-restoration need to be established to intercept and absorb pollutants.
- » **Lake watershed ecological rehabilitation project** – The lake watershed usually contains large amounts of pollutants, considering that it is the place where rivers converge, in addition, it is the last barrier protecting the lake from pollution. Therefore, ecological rehabilitation of the lake watershed is vital to the entire process of protection.
- » **Sewage interception and treatment project** – Sewage from factories is the second major source of pollution, interception and treatment of sewage is an effective way of reducing pollution.
- » **Organization of a system of supervision** – was established to prevent pollutants from entering the rivers especially point-source pollutants that include sewage and domestic waste.

PRACTICES

Agricultural structural adjustment programme

Measures

The agricultural structural adjustment programme, proposed by the local government, mainly focuses on reducing the use of fertilizers and pesticides, popularising scientific technology, developing eco-agriculture and changing the form of farmers' organizations, with the aim of improving the efficiency of production and reducing the risk to the ecological environment.

- » **Development of cropping patterns for reduced use of fertilizers and pesticides** – such as blueberry, lotus, and landscape plants on the north shore of Fuxian Lake, and growing walnuts on sloping fields between 1 800 to 2 200 m, replacing traditional greenhouse vegetable cultivation. For some time vegetables have been one of the main crops in Chengjiang County, especially in the areas around Fuxian Lake, because they are considerably profitable. However,



the high fertilizer requirement of 4.83 tonne/ha and high pesticide demand of 120 kg/ha has increased the risk of eutrophication of the ecological environment. For this reason, the government has attempted to change the agricultural structure by replacing crops with a high fertilizer demand with crops requiring less fertilizer.

- » **Popularising soil testing and formulated fertilization, biocontrol technology and farm film recovery technology** – Local farmers have not yet fully accepted soil testing and formulated fertilization, considering the small area of their farmland and lack of economic means, this concern is expected to be eliminated by implementation of a land transfer policy. Technologies for biocontrol and recovery of farm film aim to reduce farmland pollution especially in the soil.
- » **Developing leisure agriculture** – Leisure agriculture is a new kind of industry that combines agriculture with tourism. The local government encourages the local agricultural enterprise to build lotus gardens along the river that contains a large volume of pollutants. This will not only bring benefits from tourism but also intercept pollutants in the river.
- » **Supporting the leading enterprises and specialised cooperative society** – Most agricultural in this area is still involved in retail operations, so farmers find it difficult or uneconomic to use agricultural technologies such as formulated fertilization and biocontrol technology unless they are in a farming group. Leading businesses and specialised cooperatives are, therefore, the effective organizations for agricultural production.

Impacts

The government report showed that remarkable results have been achieved after implementation of the above-mentioned practices.

First, according to the data, a large area of cropping land that was formerly used for vegetables or rice has been planted with a low-fertilizer use crop. About 364 ha of blueberry, 203 ha of lotus, and 7 500 ha of walnut and 666 ha of landscape plants have been planted.

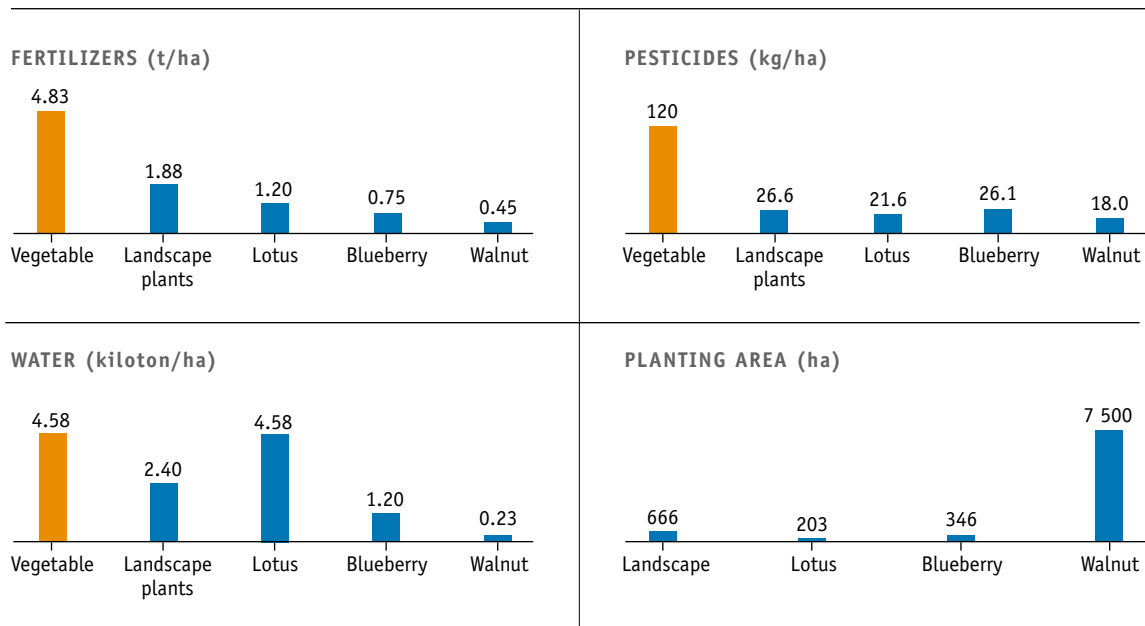
Second, agricultural technology has been expanded to the local farmland. The accumulation of the promotion area has been completed using soil testing with a formulated fertilization area of 33 700 ha, biocontrol technology on 8 400 ha, and nitrogen and phosphorus reduction on 1 200 ha. The amount of fertilizer, pesticides and irrigation has been reduced by 41 700 tonnes, 816 tonnes and 42 million m³, respectively, each year.

Third, five farmhouses have been built for agritourism including Jihua Lotus Ecological Farm and Gaoxi Blueberry Ecological Farm. These farmhouses attract large numbers of tourists from neighbouring regions especially during festivals and holidays. In addition, 'Chengjiang lotus root starch' and 'Chengjiang lotus' have been certified under national agroproduct geographical indications.

Finally, the policy regarding organization has given impetus to the development of local enterprises and cooperatives. According to the author's statistics, 15 leading enterprises and 105 specialised cooperative societies have been set up, the production capacity of the former is 360 000 tonnes and the area covered by large-scale agricultural production farmland was 5.3 ha in 2016.



Figure 2. Fertilizer, pesticide and water use plus planting area of the main five crops in 2015



Livestock relocation project

Measures

To counteract the environmental impacts of livestock in the runoff area around Fuxian Lake, the local government has sought to exercise greater control over the location of livestock, farming technology.

- » **Optimising livestock industrial distribution** – Farms have been encouraged to move out of the runoff area and any construction of new farms has been banned. The government planned four large-scale breeding parks that can accommodate more than 350 000 livestock outside the runoff area, and encouraged the existing farmers to move out. Moreover, the government provided a subsidy of RMB 30 000; RMB 60 000 and RMB 100 000 for breeding farmers who relocated outside the runoff area, to cover new construction, reconstruction or expansion, at the scale of 10 to 50, 50 to 100 and more than 100 head of livestock, respectively.
- » **Farmers were encouraged to build a biological fermentation bed outside the runoff area using subsidies** – A subsidy of RMB 200/m³ was awarded to farmers who built farms with biological fermentation beds, and RMB 20 000 was awarded to farmers who built sewage pools costing more than RMB 100 000 and measuring no less than 50 m³.
- » **Planting and cultivating farm project** – To promote the development of ecocycle system models such as the 'livestock-biogas-grain/vegetable/fruit' model. In cooperation with local farmers the government has set up several demonstration farms.
- » **Strengthening awareness-raising using brochures, radio, television and other media** – As a tool to promote policy, the media has become the most effective way of informing farmers about the project.



Impacts

In recent years, significant advances have been made in protecting water from livestock pollution, notably and as a result, nutrients from farms have been drastically reduced.

Along with these measures, 99 000 animals have been moved out of the runoff areas along with 177 scattered livestock raising-households and 36 scale livestock raising-households. As a result, pollution from livestock has been reduced by 446.2 tonnes of COD, 67.05 tonnes of total nitrogen and 12.88 tonnes of total phosphorus. Moreover, the government has promoted the use of a biological fermentation bed with an area of 4 800 m² and a biogas digester of 900 m³. Two planting and cultivating farms have been built and another seven are under construction.

Agricultural highly efficient water-conservation and site-reduction project

Measures

This plan aims to help farmers meet their requirements for water-conservation, and is based on the use of drip irrigation and a water-saving management system; the participation of the local government and farmers has been sought.

- » **Highly efficient water-conservation and site-reduction demonstration project in Gaoxi community** – The project is located 7.2 km north of Fuxian Lake, with a total investment of RMB 9.95 million from the government and businesses (each own about 50 percent) and covers 167 ha of cultivated land. The project includes a water source project, photovoltaic pumping irrigation project, drip irrigation and automatic control system.
- » **Water-saving management system** – Clearly defines water rights; establishes the incentive and restraint mechanisms for agricultural water; promotes water-saving technologies; improves on the water contract management mechanism.
- » **Agriculture water rights allocation mechanism** – Total water consumption is divided from the top down, and total water demand is calculated from the bottom up, then, the quota of irrigation water is provided based on the combination of the two. Based on the allocation of the initial water property, net water consumption is 4 050 m³/ha, and the total amount of irrigation water is 10 million m³.
- » **Agriculture water price formation and incentive mechanism** – First, the cost of water is calculated based on use; second, the different output value of the crops and different costs of businesses and farmers are considered as a whole; finally, the water price is determined after subtraction at RMB 0.4/m³ for small farmers and RMB 1.3/m³ for large farmers. A control to measure water use has been set up, using a prepaid fee and rated water consumption; water prices are scaled to stimulate the trading of rights.
- » **Engineering construction and operation management mechanism** – Peasant farmers are organized into agricultural water cooperatives, and social capital is encouraged to participate in the construction and operation of a water conservancy project. The government entrusts the irrigation and drainage companies with the design, construction and management of partial field engineering. The government encourages large-scale farmers to construct, manage and operate field engineering projects on their own and to purchase specialised services.



- » **Monitoring and evaluation mechanism** – to create a monitoring programme and install monitoring facilities. Twenty-eight observation-points and monitoring-points for emission reduction are set out in the runoff area, and are implemented in accordance with the items and frequency of monitoring. There is expanded technology of integral control of water and fertilizer use, farmers are assisted to establish soil moisture monitoring and to use irrigations systems that integrate the application of water and fertilizers.
- » **Contract management mechanism** – Water conservation contracts are signed with agricultural water cooperatives and large-scale farmers, management of the mechanism is transformed into contract management with a prepaid fee, rated water consumption and scaled water price. On the basis of the contract, long-term operational mechanisms have been established for highly-efficient water saving. The responsibilities and obligations of water cooperatives, large farmers and small-scale farmers are clearly defined in the contract. With the government leading, social capital has been introduced and farmers have been encouraged to construct water-saving facilities, which now form the new pattern of ‘government-social capital-farmers’ for engineering to strengthen water conservancy.

Impacts

Economic, social and ecological benefits have been obtained through increased incomes for family farmers from RMB 4 500 to 8 000 each year; profits of RMB 11.88 million have been created for Wanjiahuan Company from 118 ha of farmland; the conservation water rate is 54.1 percent, total nitrogen and total phosphorus drained into the lake has been reduced by 72.5 and 78.3 percent, respectively.



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Wetlands ecosystem construction project

Measures

Migration is the first thing that must be taken into consideration when it comes to the construction of a wetlands ecosystem. This is mainly because large numbers of residents have settled in this area over many years.

- » **Eco-migration project** – Villages, the Central Government owned enterprise and Provincial State owned enterprise were moved out of the first-grade protection zones of Fuxian Lake, along with 28 000 ecological migrants. The returned land is used for ecological rehabilitation and landscape regeneration.
- » **The wetlands ecosystem construction project** – This involved reforestation of formerly cultivated land, covering from fish to lake, planting riverbanks, cleaning up the river channels and restoring the wetlands.

Impacts

The total planning area for the project is 866 ha; the first stage covering 42 ha has been built, including Dahekou Wetland Park and Mafangcun Wetland Park. The amount of sewage, total nitrogen and total phosphorus drained into the lake has been reduced by 28 000 tonnes, 6.4 tonnes and 2.6 tonnes each year, respectively. It is expected that, after completion of the project, there will be a reduction of 228 000 tonnes of sewage, 66.4 tonnes of total nitrogen and 13.6 tonnes of total phosphorus,.

Tourism industry

The tourism industry, as a representative of a modern service industry has developed rapidly, and the proportion of the tertiary industry has increased by more than 45 percent, the tourism industry accounts for more than 50 percent of the third industry in the Fuxian Lake watershed.

Green Tourism products and the processing of green agricultural products has begun to take shape, and there has been comprehensive promotion of ecological agricultural modernisation, standardisation and landscape, ensuring that benefits from the Fuxian Lake ecosystem will be harvested.



CONCLUSIONS

Experiences of policies and practices concerning lake water and eco-agriculture management

The implementation of lake-preservation and eco-agriculture should not be seen as a one-sided project, instead, it should be treated as having issues in common that involve both agricultural and water, science and policies, government and farmers. First, control of the pollution of the lake water should be achieved by promoting a positive cycle between agriculture and water. The second experience, based on other samples, illustrates that significant advances in pollution control cannot be achieved by employing policies that are not based on scientific guidance, this can be improved by integrating and expanding current scientific research and the capacity for data collection. Furthermore, a system of cooperation between the government and farmers should be established. Here it is important to understand farmers' choices and incentives, and that implementation measures are developed when adopting policies that take farmers' choices into consideration. Finally, there is a need to increase the capacity of stakeholders (farmers, industry and community groups) to allow them to participate in the design and delivery of policy responses concerning the integrated management of land and water (Barraqué, 2003).

Next steps

There are a number of tools for controlling lake water pollution using policies. These include direct regulation (such as censoring certain practices), economic incentives (such as taxes, subsidies, allowances), and promotional activities (such as educational campaigns, training workshops, and pamphlets) (Paschyn, 2014). Water users should pay the full cost of the water services, including the environmental cost, (Boer *et al.*, 2013) and the government should create the conditions for implementing tradable pollution permits (Huang *et al.*, 2013). In regards to land management, agricultural taxation and fees should be applied to special products that overuse agricultural chemicals, including fertilizers and pesticides, and 'Green Box' subsidies should be paid for products where lower yields have been caused by reducing the use of agricultural fertilizer and pesticides. Moreover, nutrient trading can be employed as a means of providing incentives to reduce nutrient pollution, and as a way of achieving the flexibility of land use in the face of regulatory restrictions (Singletary 2013).

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08

TEEB AGRIFOOD VALUATION FRAMEWORK AND TRUE COST ACCOUNTING IN AGRICULTURE

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Abstract

Agriculture worldwide is at a crossroads and is under immense pressure to increase productivity and minimise impacts on the environment and human health. Currently, global agriculture is focused only on production, whereas ensuring food and nutritional security requires addressing the distribution and consumption side of the agrifood complex. Global agriculture and food systems need to modify the approach and bring about the desired change using new ways of integrating nature's values into the social and economic system in the context of agriculture and food systems. Here a new approach is required for adoption of the lens concerning the 'eco-agri-food' systems complex, the value of nature's contribution to agriculture and the securing of food and ecological security for all by 2030. This study builds on the United Nations initiative – the Economics of Ecosystems and Biodiversity (TEEB), which has been instrumental in internalising the

ecological and economic aspects of the loss of biodiversity and ecosystem degradation resulting from human activities since 2010. Recent efforts of the TEEB project are focused on agriculture and food systems, and aim to highlight the importance of all externalities of agriculture production, distribution and consumption through the ongoing TEEBAgriFood study. This study explains the TEEBAgriFood framework and provides the results of four case studies on four different types of farming systems based in the United States, which were assessed using the TEEBAgriFood approach to reveal the true cost of eight commodities: corn, soybean, milk, beef, pork, poultry, eggs and rice. The combined environmental and social benefits are proportionately higher on diversified farms followed by dairy, rice and corn/soybean farms. Diversified farms also generate elevated social benefits as compared to the other four farming systems.

INTRODUCTION

Global agriculture is at a crossroads as it aims to increase the productivity of food for a growing population and it intends to minimise the impact on the environment. However, it is designed as an inputs and outputs oriented system that aims to maximise returns on investment (Schutter, 2010; Wratten *et al.*, 2013). Nature's contribution, however, is not recognised or the social aspects of farming and the impacts on public and environmental health are unaccounted for (Pretty *et al.*, 2000). Nature's contribution includes material and non-material benefits that are provided by nature to support people's livelihoods and also provide recreational benefits. These include the provision of food from agriculture, the role of pollinators, carbon sequestration in soil, nutrient cycling and aesthetics. Thus, current agriculture is increasing financial capital at



the expense of both social and natural capital (Sandhu *et al.*, 2015, 2016). There is the need, therefore, to modify current agriculture by understanding the social and environmental costs and benefits so that the desired outcomes can be delivered to society.

One way to examine agriculture is by developing a holistic system that can help identify and capture all positive and negative impacts associated with current practices. Such a system can then be used to establish the links between production, processing, distribution and consumption of food, as advocated by the Economics of Ecosystems and Biodiversity for Agriculture and Food (TEEBAgriFood; UNEP, 2015) project hosted by the United Nations Environment Programme (UNEP).

TEEBAgriFood advocates using an ‘eco-agri-food’ lens to examine and include all externalities in agriculture production systems. The aim is to reflect the economic value of a range of inputs from nature, including nutrient cycling, pollination, freshwater flow and biological pest control, which are known as ecosystem services (Daily, 1997; Costanza *et al.*, 1997). Despite their immense value, these clear benefits are not typically accounted for in market transactions and are viewed as ‘invisible’ in economic terms.

The economic invisibility of these ecosystem services often leads to their degradation, and have serious human and environmental costs. Unfortunately, there are very few incentives for farmers to maintain these ecosystem services that are vital to farm productivity. Instead, farmers tend to be rewarded on the basis of agricultural intensification and expansion of agricultural land, both of which favour short-term gains. Maintaining healthy ecosystems and enhancing ecosystem services on-farm, storing carbon, crop residue management, enhancing biological control and other ecosystem services do not tend to generate direct income for farmers. Recognising these ecosystem services, demonstrating their economic value at farm and industry level is the core value proposed by the TEEBAgriFood project.

Drawing from the TEEBAgriFood project, which has developed a framework for examining agricultural systems using an ‘eco-agri-food’ lens, the current study elaborates the valuation framework of the TEEBAgriFood study and provides four case studies of different types of farming systems based in the United States by applying true cost accounting to monetise all positive and negative externalities.

TEEB AGRIFOOD VALUATION FRAMEWORK

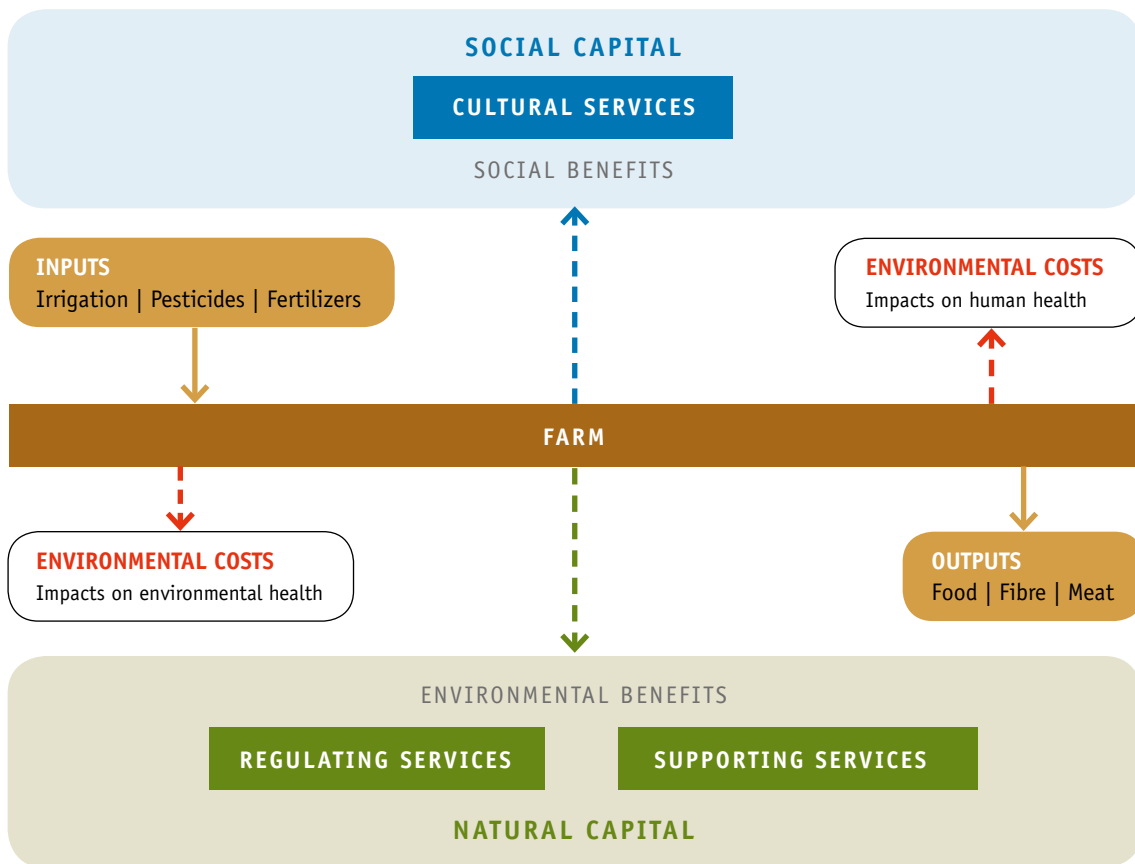
The TEEBAgriFood valuation framework aims to identify and value:

- » natural capital (well-functioning biodiversity and ecosystems);
- » human capital (skills and knowledge); and
- » social capital (societal interactions, relationships, formal and informal institutions)

The conceptual framework developed in this study to assess externalities is rooted in the economic and ecological theory of ecosystem services (Figure 1; Sandhu, 2016). Ecosystem services are typically classified into four categories – provisioning, regulating, supporting and cultural services (MEA, 2005; Wratten *et al.*, 2013; Sandhu *et al.*, 2008; 2010). Drawing from the



Figure 1. Conceptual framework used to assess externalities at the farm level.



Arrows indicate the flow of inputs and outputs from the farm. Broken arrows indicate those 'invisible' benefits and costs that are not accounted for in current agriculture.

Source: Adapted from Sandhu, 2016

description of these ecosystem services associated with agriculture, the framework used in this study has been modified to include social, economic and natural capital.

Natural capital is defined as the natural resources that are harvested from nature (Costanza *et al.*, 1997), which include provisioning, regulating and supporting ecosystem services. Provisioning services are production benefits or outputs, for example production of milk, grains and meat. Regulating and supporting services are grouped into environmental benefits, whereas cultural services provide social benefits and form social and human capital. Similarly, ecosystem disservices (impacts) are grouped under the category of environmental and social impacts and they result in an environmental cost.

Although ecosystem services are critical to the productivity and health of agricultural production systems, they are often invisible in the economic choices we make (UNEP, 2015). Market prices paid for farm produce cover the cost of inputs such as seeds, fertilizers, and pesticides, but not the value of positive externalities such as bees pollinating crops, or micro-



organisms cycling nutrients in the soil, the lack of which can cause crops to fail. Likewise, agricultural producers are typically neither fined for causing negative externalities, such as pesticide runoff or soil erosion, nor rewarded for positive ones, such as ensuring groundwater recharge through farm vegetation or preserving scenic rural landscapes. These invisible costs and benefits are lacking as key inputs in the economic system in which farmers and policy-makers operate, creating a skewed and incomplete picture. This lack also leads to a missed opportunity to incentivise environmentally friendly agricultural systems. The framework developed in this study recognises and captures the economic value of these invisible benefits and costs.

True Cost Accounting

Based on the three capitals described above (natural, social and human) this study focuses on monetising externalities that are divided into four categories – production benefits and their market value, environmental benefits (natural capital positive externalities), social benefits (social and human capital positive externalities) and environmental costs (natural capital negative externalities). Four farms were selected to carry out the assessment – a conventional corn and soybean farm, an organic dairy farm cluster (comprising of four individual dairy farms), a diversified livestock farm (Polyface Farm) and organic rice farms (Sandhu, 2016).

Farm input and output data is used to estimate the value of production benefits, environmental benefits, social benefits and environmental costs for each farm type (Equation 1).

$$TC = (P_v + E_b + S_b) - E_c \quad \text{Equation 1}$$

TC = True cost USD per acre

P_v = Production value USD per acre

E_b = Environmental benefits USD per acre

S_b = Social benefits USD per acre

E_c = Environmental cost USD per acre

Production value

Each farm produces a particular commodity that is recorded in the farm data for the production year 2015 (quantity and value, USD per acre). Its market value at farmgate, which is the price that the farmer gets at the farmgate, is obtained from the farm records in United States dollars (USD) in 2015.

$$P_q = \sum(P_{q1} + P_{q2} \dots P_{qn}) \quad \text{Equation 2}$$

$$P_v = \sum(P_{v1} + P_{v2} \dots P_{vn}) \quad \text{Equation 3}$$



Environmental benefits

These include ecological processes that are generated by the agriculture production system. In this study, the following benefits were assessed and valued. These were identified based on the review of relevant literature on the provision of ecosystem services in agriculture (Costanza *et al.*, 2014; MEA, 2005; Sandhu *et al.*, 2015).

$$E_b = \sum(E_{b1} + E_{b2} + \dots + E_{bn}) \quad \text{Equation 4}$$

Water regulation: Crop and livestock consumes water in the form of evapotranspiration by the crops and pastures (Ghaley *et al.*, 2015) (Equation 2).

$$\text{Deep drainage (water stored in soil profile)} = \\ \text{Total Water input (rainfall and irrigation)} - (\text{Water use by crops and pastures} + \text{Runoff})$$

Water recharged into the soil profile is estimated using the above equation and valued based on the market price of irrigated water at each site (USD 0.006 per gallon).

Carbon sequestration by soil and vegetation: Both above and belowground vegetation captures carbon in the field. This is estimated from the amount of soil carbon sequestered annually under different crops and pastures (Sandhu *et al.*, 2008) and the value obtained from the carbon price in the market (USD 15 per tonne; World Bank Group; ECOFYS, 2016). The price of carbon varies between USD 1 to 150 per tonne. Here the price of carbon trading in the United States has been used at the time the study was conducted.

- » **Nitrogen fixation** – varies under different cropping systems, and is estimated by the amount of nitrogen fixed, and is valued at the market price of nitrogen (USD 0.30 per kg; Sandhu *et al.*, 2008).
- » **Nutrient cycling** – varies under different management practices. Its value is obtained from the amount of nutrients made available after the breakdown of organic matter and is valued at the price of nutrients on the market (nitrogen, USD 0.30 per kg; phosphorus USD 0.16 per kg; potassium USD 0.24 per kg).
- » **Soil erosion control** – Permanent pastures prevent soil erosion (as compared to uncovered soil), which is compared to crop cover. The soil replacement cost is estimated from the market price of topsoil (USD 50.3 per acre; Sandhu *et al.*, 2008).
- » **Biological control of pests and diseases** – Different management practices use natural pest control of pests and disease and thus avoid the cost of pesticides. The biological control of animal disease (USD 14.37 per acre) is attributed to those systems that enhance biological control by using the avoided cost valuation method (De Groot *et al.*, 2002; Sandhu *et al.*, 2008).



Environmental costs

This includes the damage to human health and the environment. Various practices are used in pastures and cropping systems that are detrimental to the environment. The following categories are assessed and valued for each of the four farm types.

$$E_c = \sum(E_{c1} + E_{c2} + \dots + E_{cn})$$

Equation 5

- » **Greenhouse gas emissions** – Various inputs such as agrochemicals, tillage practices, use of animal feed, fossil fuel for transportation, enteric fermentation in animals, etc. generate a large amount of greenhouse gases. These are assessed as carbon dioxide equivalents for each farm. There is a social cost of carbon that takes into account the economic damage associated with a small increase in carbon dioxide emissions (USD 42.3 per tonne; EPA, 2015). This cost is used to estimate the environmental costs associated with each farm.
- » The external costs of pesticides and fertilizer used for agriculture in the United States are used to estimate the various impacts on human health and the environment (Tegtmeier and Duffy, 2004). This estimate is based on the annual cost in each category at the national level. There is an annual external cost of fertilizer use (USD 0.41 per kg) and pesticides use at USD 46.03 per kg of active ingredient used. This is applied to the corn/soybean farm, which applies pesticides. These costs are then calculated for each category as a cost per acre and considered for each of the four case study sites depending upon crops or livestock operations. These include the following categories.
- » **Damage to water resources** – includes facility infrastructure needs for nitrate and pesticide treatment (Tegtmeier and Duffy, 2004).
- » **Damage to soil resources** – includes soil sediments accumulated in water ways and the cost to the water industry, cost of replacing the lost capacity of reservoirs, water conveyance cost, flood damage, damage to recreational activities, cost to navigation as a result of shipping damage, dredging, in stream impacts to commercial fisheries, and off stream impacts such as industrial users and steam power plants (Tegtmeier and Duffy, 2004).
- » **Damage to air resources** – includes the cost of greenhouse gas emissions from cropland and livestock (Tegtmeier and Duffy, 2004).
- » **Damage to ecosystems and biodiversity** – includes honeybee and pollination losses, loss of beneficial predators after the application of pesticides, fish kills resulting from pesticides, bird kills linked to pesticides and pesticides poisoning (Tegtmeier and Duffy, 2004).
- » **Damage to human health** – includes pathogens and pesticides that cause human health issues (Tegtmeier and Duffy, 2004).

In addition, to the above-mentioned categories the annual budget of the agency responsible for managing the above is also included in the calculation of the external costs of agriculture in the United States for crops and livestock. These are the United States Environmental Protection Agency (USEPA) budget for non-point source programme, the USEPA budget for reduced public and ecosystem risks, the United States Department of Agriculture (USDA)



budgets for: natural resources, farm advisory; food safety; plant safety; microbiological data, the pesticides data programme and the Environmental Protection safe food programme (Tegtmeier and Duffy, 2004).

Social benefits

Social benefits are the contribution to society and each of the four farm types were assessed and the benefits are estimated in the categories below.

$S_b = \sum (S_{b1} + E_{b2} \dots E_{bn})$	Equation 6
---------------------------------------------	------------

- » **Farm employment** – is considered to be a social benefit of the production system. Data from the farm survey was used to calculate the annual employment generation per acre. This is considered to be a social benefit as the income from the farm is ploughed back into the local community to buy food and other amenities, farm workers’ children go to local schools; families support churches and contribute to the local economy.
- » **Recreation** – Many farms provide opportunities for ecotourism and recreation by offering farm tours and hence provide recreational benefits to the wider community. Data from farm visits and the amount charged is used to estimate the recreational benefits. Travel cost methods and other direct valuation was used to estimate the value of recreational benefits (De Groot *et al.*, 2002).
- » **Education** – Knowledge generated on-farm can be disseminated to the wider community through books, presentations at conferences, etc. Data were collected on such activities at the individual farm and were valued on a per acre basis. Direct valuation was used to estimate the value of knowledge generated from estimates of book sales (Sandhu *et al.*, 2008).

The above information was then used to calculate the environmental and social benefits and the environmental cost per unit of commodity (‘i’) using the below equations 7, 8 and 9, respectively.

$E_{b/unit_i} = E_{b1} \text{ per acre} / P_{qi} \text{ per acre}$	Equation 7
$S_{b/unit_i} = S_{b1} \text{ per acre} / P_{qi} \text{ per acre}$	Equation 8
$E_{c/unit_i} = E_{c1} \text{ per acre} / P_{qi} \text{ per acre}$	Equation 9
<p>where,</p>	
$E_{b/unit_i} = \text{Environmental benefit of commodity 'i'}$	
$S_{b/unit_i} = \text{Social benefits of commodity 'i'}$	
$E_{c/unit_i} = \text{Environmental cost of commodity 'i'}$	



TRUE COST ACCOUNTING CASE STUDIES FOR UNITED STATES FARMS

Maize and Soybean Farm

A family-owned maize and soybean farm, located in Blue Earth Township, Faribault County, Minnesota, comprises 795 acres of land with a cropping area of 766 acres and 29 acres of building sites. This farm produces maize and soybean in rotation using conventional farming practices with strip tillage.

Benefits and costs associated with this production system were estimated using the methods of true cost accounting described above and are summarised in Table 1. The farm produces maize at the rate of 221 bushels/acre per year, which is valued at USD 4 per bushel. Whereas the soybean yield is 69 bushels per acre valued at USD 10 per bushel. The total production value of corn was USD 884 and soybean USD 690 per acre per year.

Table 1. **Benefit and costs associated with different farms**

(USD/ACRE/YEAR)	CORN	SOYBEAN	MILK	DIVERSIFIED FARM	RICE
Production value	884	690	8 178	2 015	1 632
Environmental benefits	89	89	193	172	61
Social benefits	134	134	494	650	368
Environmental cost	219	219	599	153	22
Net (USD/acre/year)	888	694	8 266	2 684	2 039

The environmental benefits per acre were found to be USD 89 per year. Maize and soybean crops use 2 500 and 3 738 gallons of water for consumptive use. Out of the total rainfall at the site (31.11 inches annually), the groundwater recharge was an estimated 5 600 and 4 362 gallons for maize and soybean respectively. By using the market price for tap water at USD 0.006 per gallon, water regulation benefits were estimated as USD 33 and USD 26 per acre for maize and soybean, respectively. There is an area of 29 acres under trees that captures carbon at the rate of 1.22 tonnes per acre annually. At the market price of carbon (used in the study) of USD 15 per tonne, the annual carbon sequestration is valued at USD 18 per acre. Soybean fixes nitrogen through biological nitrogen fixation process. This is estimated to be 40 kg N per acre per year and is valued at the current price of nitrogen (USD 0.30 per kg N). Thus, the value of nitrogen fixation is estimated as USD 12 per acre. This farm employs two permanent and two part-time staff. Based on the annual wages, it is estimated that the farm generates employment benefits worth USD 134 per acre per year. The environmental costs on the farm involve greenhouse gas emissions from the use of seed (USD 1.1 per acre), strip tillage (USD 2.6 per acre), fertilizers (USD 30.3 per acre), pesticides (USD 78.23 per acre), external costs associated with damage to human and environmental health (USD 101 per acre), transportation fuel (USD 4.1 per acre) and electricity (USD 1.4 per acre) used to dry



corn. A summary of these values are provided in Table 1. The true cost of maize and soybean was calculated for each bushel of maize and soybean from the above data (using equations 7 and 9) and is provided in Table 2.

Table 2. **Summary of true cost of different commodities**

	CORN	SOYBEAN	MILK	BEEF	PORK	POULTRY	EGGS	RICE
	(USD/ bushel)	(USD/ bushel)	(USD/ gallon)	(USD/ pound)	(USD/ pound)	(USD/ pound)	(USD/ dozens)	(USD/ pound)
Production value	4	10	3.44	1.6	3.67	3.5	3.75	0.25
Environmental benefits	0.4	1.29	0.08	0.7	0.71	1.91	3.4	0.01
Social benefits	0.6	1.9	0.2	2.67	2.7	7.2	13	0.06
Environmental cost	-1	-3.17	-0.25	-0.63	-0.63	-1.7	-3.06	-0.003
Net cost	4	10.02	3.47	4.34	6.45	10.91	17.09	0.31

Dairy Farms

A cluster of four dairy farms were selected for the analysis of the true cost of milk. These four farms produce certified organic milk and supply to the Straus Family Creamery based in Petaluma. Dairy farms are spread across Marin and Sonoma County, California.

Milk production varies according to the size of herd (220 to 800) on each farm (area ranging from 180 acres to 2 500 acres) from 808 to 5 416 gallons per acre per year (with a mean of 2 377 gallons). The mean farmgate price of four farms is USD 0.40 per lb or USD 3.44 per gallon of milk. An average production benefit was yielded amounting to USD 8 178 per acre per year. The environmental benefits include carbon sequestration by soil and vegetation (pastures and biodiversity plantings), nutrient cycling as a result of the addition of manure and methane use in electricity generation.

On average, pasture management provides carbon sequestration at the rate of 0.5 tonnes per acre annually (USD 15 per tonne of carbon). Forest or planted trees and shrubs on farms sequester carbon 1.22 tonnes annually. Liquid manure addition ranges from 1 662 to 7 368 gallons per acre per year and adds a large amount of nutrients to the pastures. These nutrients are valued at USD 57 to 262 per acre (mean value of USD 138 per acre).

One of the farms has also installed a methane digester that generates electricity and also avoids greenhouse gas emissions associated with electricity from the grid. The methane digester provides benefits worth USD 156.43 per acre per year. These combined environmental benefits range from USD 65 to 270 per acre on the four farms (with a mean of USD 193). These farms employ 3 to 16 staff. Some farms also attract visitors from schools and environmental organizations. This recreational benefit ranges from USD 0.72 to 2.20 per acre. Some farms also generate knowledge and help in dissemination via conferences and workshops. This benefit results in a social benefit of USD 2.2 per acre. Based on the annual wages, it is estimated that the farm generates employment benefits worth USD 170 to 760 per acre per year (with a mean of 490). The combined mean for social benefits on the four farms is USD 494 per acre.



The environmental costs on this farm involves greenhouse gas emissions associated with milk production (USD 107 to 715 per acre), animal feed (USD 2 to 760), manure (USD 11 to 47), external costs associated with damage to human and environmental health (USD 13.29 per acre), fuel and electricity (USD 7 to 31 per acre). A summary of these values are provided in Table 1. The true cost of milk is calculated for each gallon of milk from the above data (using equations 7 and 9) and is provided in Table 2.

Diversified Farm

Polyface farm is in Shenandoah Valley, Virginia and is a unique pasture-based diversified farm that produces beef, pork, rabbit, poultry meat and eggs along with other products such as turkey, broilers, eggs maple syrup, honey and timber. As the name indicates this farm produces multiple products.

The combined value of these products is estimated based on the farm data and is valued at USD 2015 per acre per year. This farm generated combined environmental benefits, which are valued at USD 172 per acre per year. Diversified operations at this farm use 3.5 million gallons of water for consumptive use. Out of the total rainfall at the site (31 inches annually), groundwater recharge is an estimated 1 826 per acre per year. By using the market price for tap water at USD 0.006 per gallon, water regulation benefits are estimated as USD 10.95. There are 500 acres under forest that captures carbon at the rate of 2 tonnes per acre annually. At the market price of carbon (used in the study) of USD 15 per tonne, the annual carbon sequestration is valued at USD 30 per acre. Whereas soil under pasture also sequesters carbon at the rate of 4 tonnes per acre and is valued at USD 60 per acre per year. Legumes in the pasture fix nitrogen through biological nitrogen fixation process.

This is an estimated 22.7 kg N per acre per year and is valued at the current price of nitrogen (USD 0.30 per kg N). Thus, the value of nitrogen fixation is estimated as USD 6.81 per acre. Continuous vegetation cover also offers soil erosion prevention valued at USD 50.3 per acre annually. Since animal diseases are managed naturally, the value of biological control of diseases is an estimated USD 14.37 per acre. This farm employs 25 permanent and part-time staff. On the basis of the annual wages, it is estimated that the farm generates employment benefits worth USD 285 per acre per year. Apart from this, the annual recreational benefits produced on the farm are USD 80 per acre, and the value of knowledge generated comes to USD 285 per acre. The total value of social benefits is USD 650 per acre. The environmental costs on this farm involves greenhouse gas emission from livestock (USD 112 per acre), animal feed (USD 16 per acre), the external costs associated with damage to human and environmental health (USD 13.29 per acre), transportation fuel (USD 4.2 per acre) and electricity (USD 7.6 per acre) used to process and store meat products. A summary of these values are provided in Table 1. The true cost of various products was calculated for each pound of beef, pork, poultry meat and eggs from the above data and is provided in Table 2.



Organic Rice Farm

A cluster of two rice farms was selected for the analysis of the true cost of rice. These two farms produce certified organic rice for the Lundberg Family Farms based in Richvale, California.

Rice production is valued at USD 1 632 per acre per year (6 400 pounds/acre) with a price of USD 0.25 per pound. Total environmental benefits were found to be USD 61 per acre per year. These include carbon sequestration in soil as a result of the incorporation of rice straw and nutrient cycling from added chicken manure. Annually, rice straw adds about 1.7 tonnes of carbon (USD 15 per tonne of carbon). The addition of 3.5 tonnes per acre of chicken manure adds a large amount of nutrients worth USD 19 per year. Rice crops use 1.1 million gallons of water for consumptive use. Out of the total rainfall at the site, groundwater recharge is an estimated 2 101 gallons per acre per year. By using the market price for tap water at USD 0.006 per gallon, water regulation benefits are an estimated USD 12.60. Beans fix nitrogen through biological nitrogen fixation process. This is estimated to be 40 kg N per acre per year and is valued at the current price of nitrogen (USD 0.30 per kg N). Thus the value of nitrogen fixation is estimated as USD 12 per acre.

These two farms employ an average of 18 staff members and provide a benefit of USD 368 per acre. A few recreational and information tours are conducted on the farm that attract visitors from schools and environmental organizations. However, this information is not monetised because of the lack of any monetary data.

The environmental costs on these farms involve greenhouse gas emissions associated with rice production – diesel use (USD 8.5 per acre), electricity (USD 9.22 per acre) and tillage (USD 4.30 per acre). These combined environmental costs are USD 22 per acre. A summary of these values are provided in Table 1. The true cost of rice is calculated for each pound of rice from the above data and is provided in Table 2.



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CONCLUSIONS

These four case studies revealed the true cost of eight commodities that are associated with four different types of farming systems. The combined environmental and social benefits are proportionately higher on diversified farms followed by dairy, rice and the corn/soybean farm. Diversified farms also generate very high social benefits as compared to the other four farming systems. The associated environmental benefits, social benefits and environmental costs are specific to the type of farming operation and should not be generalised from these four case studies. The results can be used to develop sustainable farming practices and policies and to raise awareness among consumers as to the benefits and costs of various types of food and production systems.

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09

POLLINATION: A KEY AGROECOLOGICAL FUNCTION, AND AREAS OF CONCERN FOR ASIA

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Abstract

Pollination as a factor in food production and security has been little understood and appreciated in the past, in part because it has been provided by nature at no explicit cost to human communities. As farm fields have become larger, and the use of agricultural chemicals that impact beneficial insects such as pollinators along with plant pests has increased, pollination services are showing declining trends. The domesticated honeybee, *Apis mellifera* (and its several Asian relatives) have been used to provide managed pollination systems, but for many crops, honeybees are either not effective or are suboptimal pollinators. Thus, the process of

securing effective pollinators to 'service' large agricultural fields is proving difficult to engineer, and there is a renewed interest in helping nature provide pollination services. With more than fifteen years of attention being applied to pollination services at the global level, through the Food and Agriculture Organization of the United Nation's (FAO) coordination of the International Pollinators Initiative, we are well-placed to provide an evidence-based assessment of the importance of pollinators as an essential component of agricultural biodiversity, meriting focused conservation and management. Areas of particular interest and concern for Asia are highlighted.

INTRODUCTION

More than fifteen years ago, in 2000, the global community registered its concern about multiple reports of declining pollinators. Through the Convention on Biological Diversity, the International Initiative for the Conservation and Sustainable Use of Pollinators (also known as the International Pollinators Initiative – IPI) was created, adopting a plan of action two years later with four structural elements (assessment, adaptive management, capacity-building and mainstreaming) to address the threats of pollinator loss. The recently created Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) took up pollination as the focus for its first global assessment, completed in 2016. The assessment highlights the importance of pollination for global livelihoods and ecological resilience.

Over this last decade and half, a parallel process has been underway with respect to the perceived crises in global food systems. While recognising the centrality of agriculture to human well-being and sustainable development, essentially every statement about the future of agriculture over at least the last decade acknowledges that a transformation is needed in the way food is produced and how it impacts the environment, even if and while production is increased to meet food security needs (Foley *et al.*, 2011; Godfray *et al.*, 2010; IAASTD, 2009;



Royal Society London, 2009). Concerns about the sustainability of agriculture and the growing ecological footprint of conventional farming systems have grown exponentially over this period. To many, particularly those in the nature conservation and biodiversity realm, agriculture looms as the major global driver of biodiversity loss and greenhouse gas emissions (CBD, 2014; IPCC, 2017). As noted in the recent Global Biodiversity Outlook 4 (CBD, 2014) agriculture is thought to be the driver for around 70 percent of the projected loss of terrestrial biodiversity. As agricultural production is led by consumer demand, the overall global food system is under increased scrutiny.

To what extent do these two compelling global concerns share common ground? We argue here that the agendas and solutions, for both the pollination crisis and the concern about the sustainability of global agricultural, have important overlaps and synergies and can be most effective when building on each other. We will consider here the nature of the problem, the evidence base documenting current trends in both pollination services and agricultural production, and then review current thinking on measures to conserve and manage pollinators in the context of sustainable production. We highlight areas of particular concern or specificity in the Asian region.

POLLINATION: CONTRIBUTION AND CRISIS

Biodiversity and pollination

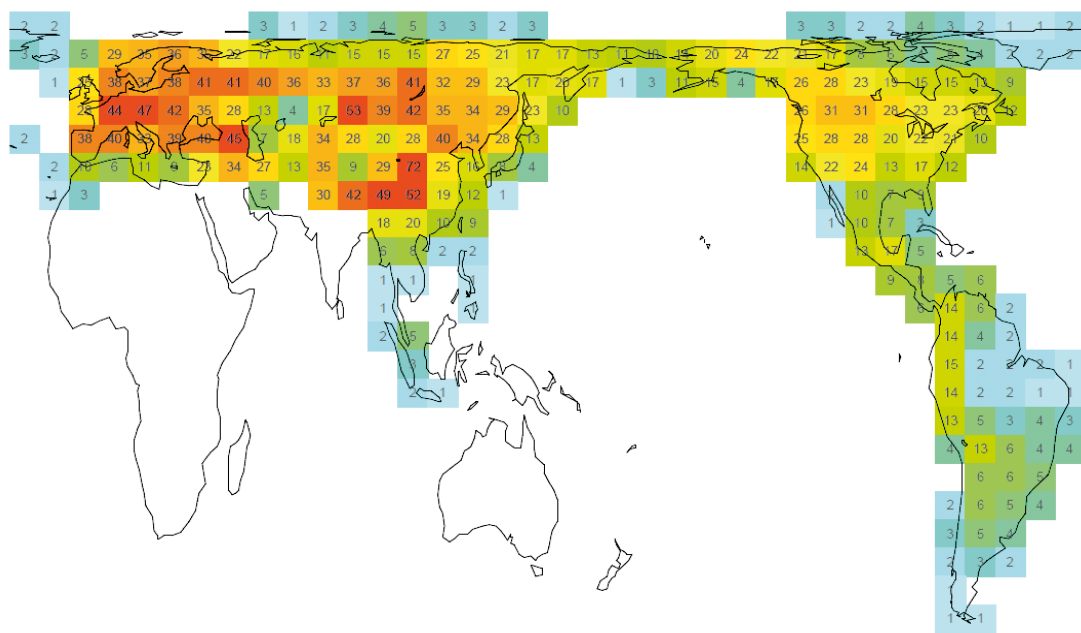
With well over 300 000 flowering plant species dependent on pollination by animals (Ollerton *et al.*, 2011), pollination is critical to the overall maintenance of biodiversity in many senses. Animal pollinators allow many kinds of flowering plants to coexist in an ecosystem, rather than limiting them to the dense, lower-diversity stands of wind-pollinated plants that dominated before flowering plants evolved. Pollination services thus shape plant communities and determine fruit and seed availability, providing tremendously important food and habitat resources for other animals.

The diversity of pollinators and pollination systems is striking. Most of the estimated 25 000 species of bees (Hymenoptera: Apidae) are effective pollinators, and together with moths, flies, wasps, beetles and butterflies, make up the majority of pollinating species. Vertebrate pollinators include bats, non-flying mammals (several species of monkey, rodents, lemur, tree squirrels, olingo and kinkajou) and birds (hummingbirds, sunbirds, honeycreepers and some parrot species). Current understanding of the pollination process shows that, while interesting specialised relationships exist between plants and their pollinators, healthy pollination services are best ensured by an abundance and diversity of pollinators. While bees comprise over 50 percent of all pollinators, increasingly attention is being paid to other taxa of importance, such as flies (Radar *et al.*, 2015)

Asia is an important centre of diversity for a number of key pollinator groups. For example, regions of China are considered to be the centre of diversity for bumblebees, as indicated in the equal-area grid map of bumblebees produced by the Natural History Museum (Figure 1).



Figure 1. Equal-area map of the diversity of bumble bees (*Bombus* spp.) at the subgenera level.



Source: from Williams, 1998

Economic values and societal demands for pollination

In agro-ecosystems, pollinators are essential for orchard, horticultural and forage production, as well as the production of seed for many root and fibre crops. About two-thirds of the crop plants that feed the world rely on pollination by insects or other animals to produce healthy fruits and seeds. Of the slightly more than 100 crop species that provide 90 percent of national per capita food supplies for 146 countries, 71 species are bee-pollinated, and several others are pollinated by thrips, wasps, flies, beetles, moths and other insects (Klein *et al.*, 2007). The benefits of pollination for human nutrition include not just abundance of fruits, nuts and seeds, but also their variety and quality; the contribution of animal-pollinated foodstuffs to human nutritional diversity, vitamin sufficiency and food quality is substantial (Eilers *et al.*, 2011). On the continents of Latin America, Africa and Asia, an average of 40 percent of the land area under crops is planted with crops having some dependence on animal pollinators (as calculated from the FAO statistical database, FAOSTAT, using the degree of crop dependence on pollinators from Klein *et al.*, 2007).

Globally the total economic contribution of animal pollination services to the global economy has been estimated at € 153 billion – about ten years ago, representing 9.5 percent of the value of the world agricultural production used for human food in 2005. Those crops that depend on pollination services are high-value, averaging values of € 761 per tonne, against € 151 a tonne for those crops that do not depend on animal pollination (Gallai *et al.*, 2009). Table 1 shows that the leading pollinator dependent crops are vegetables and fruits that represent about € 50 billion each, followed by edible oil crops, stimulants (coffee, cocoa, etc.), nuts and spices. These figures do not include the contribution of pollinators to crop seed production, which can



contribute substantially to seed yields, nor to pasture and forage crops. Nor do these figures include the value of pollinators in maintaining the structure and functioning of wild ecosystems; as yet these are all uncalculated.

Table 1. **Economic impacts of insect pollination of the world agricultural production used directly for human food and listed by the main categories ranked by their rate of vulnerability to pollinator loss.**

CROP CATEGORY	AVERAGE VALUE OF A PRODUCTION UNIT	TOTAL PRODUCTION ECONOMIC VALUE (EV)	INSECT POLLINATION ECONOMIC VALUE (IPEV)	RATIO OF VULNERABILITY (IPEV/EV)
	€ per metric tonne	10 ⁹ €	10 ⁹ €	%
Stimulant crops	1 225	19	7.0	39.0
Nuts	1 269	13	4.2	31.0
Fruits	452	219	50.6	23.1
Edible oil crops	385	240	39.0	16.3
Vegetables	468	418	50.9	12.2
Pulses	515	24	1.0	4.3
Spices	1003	7	0.2	2.7
Cereals	139	312	0.0	0.0
Sugar crops	177	268	0.0	0.0
Roots and tubers	137	98	0.0	0.0
All categories pooled		1618	152.9	9.5

Source: Gallai *et al.*, 2009

More recent global assessments have shown trends of increasing values for the contribution of pollination, from 1993 to 2009 (Lautenbach *et al.*, 2012). A few countries dominate these increasing trends, with China showing the largest increase in the value of pollination to agricultural output, with India, the United States, Brazil, Japan and Turkey also showing large increases (Lautenbach *et al.*, 2012).

Accompanying the trends in the increasing economic values of pollination are trends showing striking increases in the demand for pollination services. Analysis of FAOSTAT production data in the studies referenced below has shown that:

- » Since 1961, crop yield (tonne/ha) has increased consistently at an average annual growth rate of 1.5 percent. Temporal trends were similar between pollinator-dependent and non-dependent crops in both the developed and developing world. Over this same time, agriculture has become more pollinator dependent because of a disproportionate increase in the area cultivated with pollinator-dependent crops (Aizen *et al.*, 2009).
- » The global population of managed honeybee hives has increased by 45 percent during the last half century. But with the much more rapid (>300 %) increase in the fraction of agriculture that depends on animal pollination during the last half century (Figure 1), the global capacity to provide sufficient pollination services may be stressed, and the increased demand is more pronounced in the developing world than in the developed (Aizen and Harder, 2009).



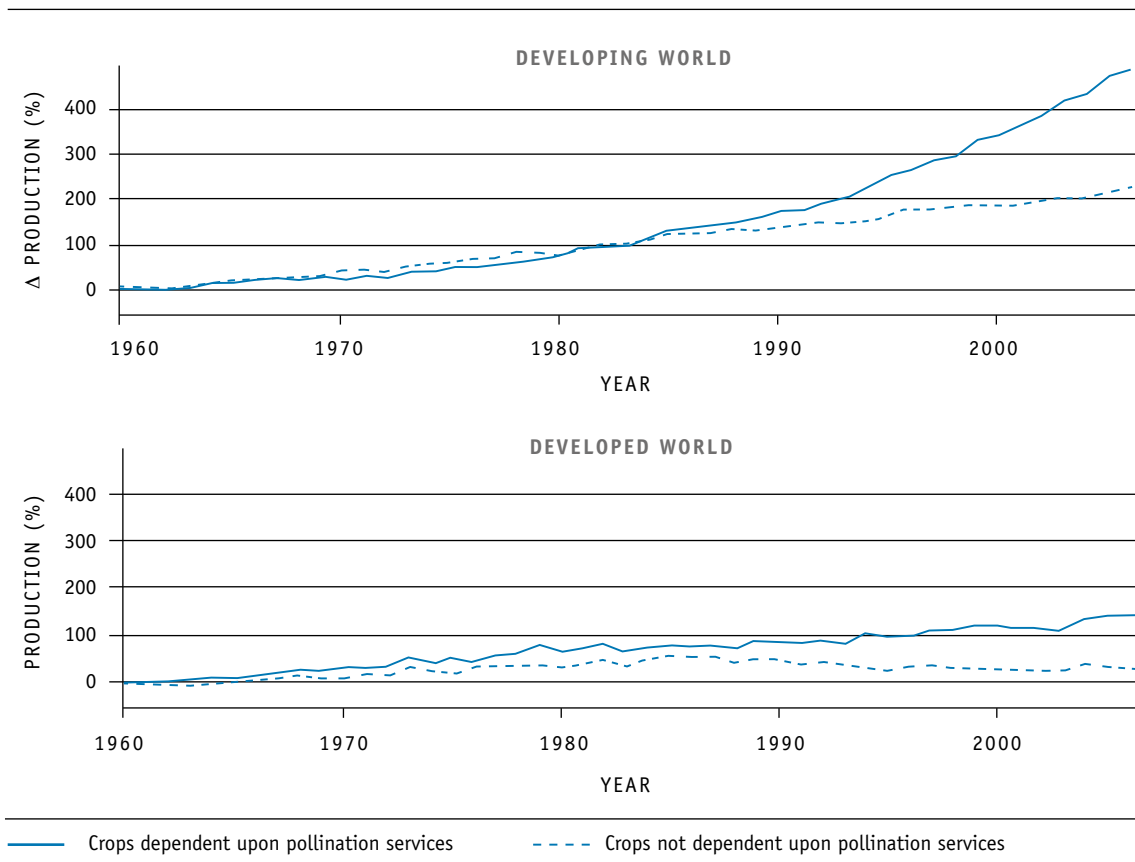
- » For those crops for which animal pollination is essential (i.e. 95 % average yield reduction without pollinators) there was higher growth in yield and lower expansion in area than for crops with less dependence, probably reflecting the effects of explicit pollination management, such as renting hives or hand pollination (Garibaldi *et al.*, 2009).

Pollinator declines

At the same time as the role of pollinators is gaining increasing attention, mounting evidence points to a serious decline in populations of wild pollinators. Globally, changes in the distribution of most pollinator taxa and pollination failures remain poorly described. To address such gaps, a special issue of the journal *Apidologie* produced in 2009 asked some of the world's leading experts to bring together current knowledge on the status of bees and their conservation, and factors determining bee abundance and biodiversity (Byrne and Fitzpatrick, 2009). Among the observations presented in this review were:

- » The critical importance of the nine indigenous species of honey bee native to East Asia, which are extremely valuable because they are key pollinators of many crop species, and provide

Figure 2. **Temporal trends in total crop production from 1961 to 2006.**



Source: from Aizen *et al.*, 2008



significant income to some of the world's poorest people. The most significant threats to local honeybee populations are deforestation and excessive hunting pressure (Oldroyd and Nanork, 2009).

- » The introduced honeybee (*Apis mellifera*) has had strongly deleterious impacts on indigenous honeybees (the cliff bees and Asian hive bees) in the Hindu-Kush Himalaya region (ICIMOD, personal comment).
- » In the Neotropics, where there is highly rich bee fauna, deforestation, agriculture intensification and introduction/spread of exotic competing bee species are considered to be the main threats to most indigenous species (Freitas *et al.*, 2009).
- » In Australia, the main threats to the native bee fauna include removal of nesting and foraging opportunities as a result of land clearing and agriculture, the spread of exotic plant species and the consequences of climate change (Batley and Hogendoorn, 2009).
- » In Africa, the bee fauna still includes a very large number of species that have not been described, making it difficult to determine their status (Eardley *et al.*, 2009).

To date, however, the strongest documented evidence of pollinator decline comes only from Europe and North America, and is focused on the precipitous decline of bumblebees. Sixteen of Europe's 68 bumblebee species are at risk of extinction, according to a recent report from the Red List of the International Union for Conservation of Nature (IUCN, 2014; Nieto, 2014). The report noted, "Of the five most important insect pollinators of European crops, three are bumblebee species. The populations of almost half of these European bumblebee species are falling and just 13 percent are increasing".

The assessment, the first by the Red List to look at bumblebees, identified the main threats as climate change, which is altering their habitat, and changes in use of agricultural land that is causing their natural environment to disappear. Equally, in North America, the results of a three-year interdisciplinary study of changing distribution, population genetic structure, and levels of pathogen infection in bumblebee populations across the United States compared current and historical distribution of eight species. It was shown that the relative abundance of four species have declined by up to 96 percent and that their surveyed geographic ranges have contracted by 23 to 87 percent, some within the last 20 years (Cameron *et al.*, 2011). It was also shown that declining populations have significantly higher infection levels of the microsporidian pathogen *Nosema bombi* and lower genetic diversity compared with co-occurring populations of the stable (non-declining) species. Higher pathogen prevalence and reduced genetic diversity could thus be considered realistic predictors of these alarming patterns of decline in North America, while the exact causes and effect of infections and declining genetic diversity remain uncertain.

Honeybee declines, particularly over the winter period in the United States remain a critical concern, and merit a more in-depth treatment than is possible here. As the primary domesticated pollinator, however, concern about domesticated bee colony disorders have contributed to an increasing focus on the role of wild pollinators for crop pollination, as discussed below.

Given the significant concern about the global decline in wild and managed pollinators, it is remarkable that no global programme exists that is focused on detecting these declines. The need for such a programme, or common approach that could be widely replicated across the globe, is urgent. At the time of the seminal Millennium Ecosystem Assessment, ten years ago,



pollination was the only ecosystem service where it was noted that its trend (declining) had only low to medium certainty (MEA, 2005). As yet, it is still not possible to report on global trends with a documentable level of certainty. Work has been underway, under the auspices of the Global Pollination Project coordinated in seven countries by the FAO, to develop an effective and efficient approach to monitoring pollinator population trends. A standard protocol was designed, capable of detecting at least a 10 percent decline in total abundance and species richness of bees over a five-year period (LeBuhn *et al.*, 2013). In initial applications of the protocol, it has been shown to adequately deal with the high levels of variability in mobile pollinator populations, and baseline data has now been established in a number of highly diverse, developing countries. This preliminary work established the groundwork for identifying local, regional and global trends in bee species richness and total abundance and in particular for detecting large-scale crashes in pollinator communities.

Pollination (as provided by biodiversity) as an agronomic input

Pollination as a factor in food production and security is little understood and appreciated, in part because it has been provided by nature at no explicit cost to human communities. It has only been over the last few decades, as farm fields have become larger, and the use of agricultural chemicals that impact beneficial insects such as pollinators along with plant pests has increased, that it has been widely recognised that pollination is a key agricultural input, as important if not more than conventional inputs of fertilizers, irrigation and pest control products, as can be seen in its potential for closing yield gaps (Garibaldi *et al.*, 2016). In the process of this assessment, the role of biodiversity and wild pollinators has come to the forefront.



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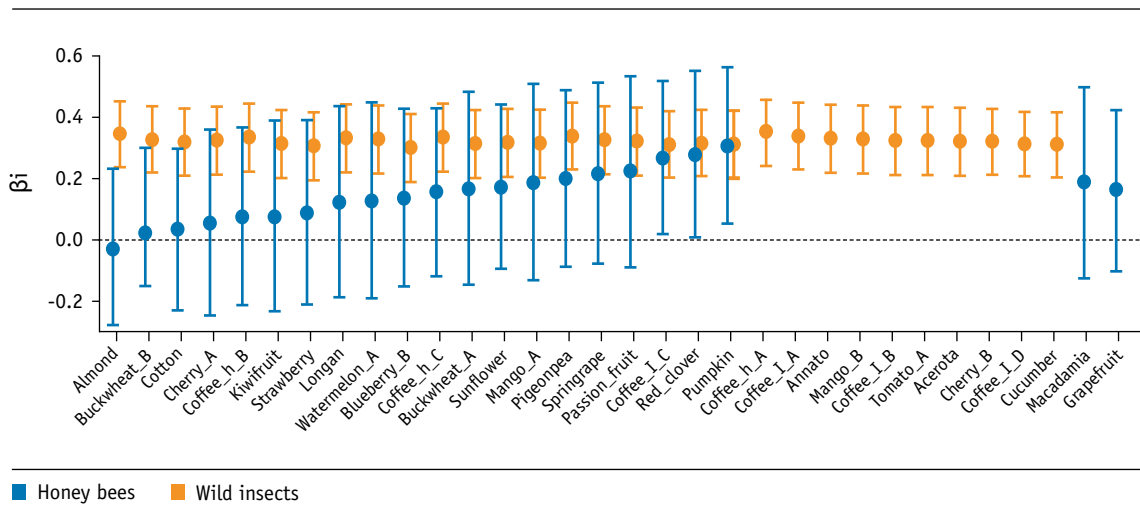
In a wide-ranging meta-analysis published recently, the pollination of more than 40 crops in 600 fields across every populated continent was studied based on a contribution from 46 scientists (Garibaldi *et al.*, 2013). It was found that wild pollinators were twice as effective as honeybees in producing seeds and fruit on crops including oilseed rape, coffee, onions, almonds, tomatoes and strawberries. Furthermore, bringing in managed honeybee hives did not replace wild pollination when that was lost, but only supplemented the pollination that took place (Figure 3).

The review indicates the substantial contribution of wild insects and suggests that honeybees cannot replace the wild insects that are lost as their habitat is destroyed. Authors of the study advise that relying on honeybees alone is a “highly risky strategy” because disease can sweep through a single species, as has been seen with the varroa mite, and a single species cannot adapt to environmental changes nearly as well as a group of wild pollinators. Wild pollinators perform better than honeybees because they deploy a wider range of pollinating techniques, such as ‘buzz’ pollination. They also visit more plants, meaning more effective cross-pollination than honeybees, which tend to carry pollen from one flower to another on the same plant.

In a new meta-analysis (Garibaldi *et al.*, 2016), for the first time the role of pollinators, including their diversity and abundance, in contributing to crop yields – not pollination alone – has been documented. Produced again under the auspices of the Global Pollination Project coordinated by the FAO, a common protocol was applied to detect and assess levels of pollination deficit in 344 fields in 33 pollinator-dependent cropping systems on small- and large-holdings in Africa, Asia and Latin America.

The findings are highly significant for a greater appreciation of agricultural biodiversity: for holdings that are smaller than two hectares, yield gaps could be closed by a median value of 24 percent, through improved pollination management resulting in higher flower-visitor density. For larger holdings, such an increase in yields could only occur if the pollinator community visiting the crop flowers was highly diverse. Thus, the inherent propensity for small, diverse

Figure 3. **Depicting pollination by wild insects and honeybees**



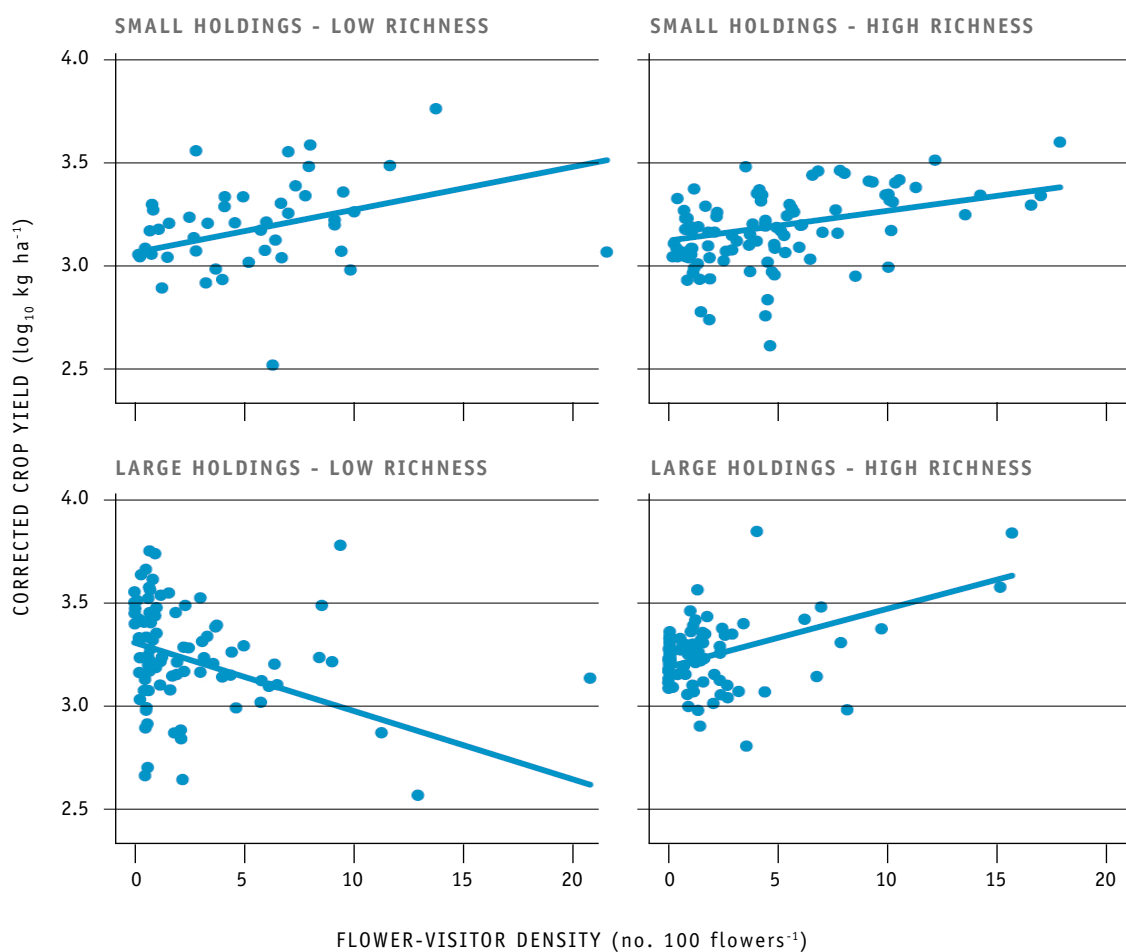
Source: from Garibaldi *et al.*, 2013, reproduced with permission



farming systems to host beneficial agricultural biodiversity that directly contributes to human livelihood is established, and also for the fact that biodiversity can compensate for the negative effects of field size, under larger holdings (Figure 4).

For many farmers, the stability of production is as important if not more than yield. It is well known what can increase crop yields – in the form of inputs – and yield tends to increase

Figure 4. **Worldwide, the benefits of flower-visitor density to crop yield are greater for smaller than larger holdings, and when flower-visitor richness is higher. Moreover, high richness can compensate this negative influence of field size.**



Each point is a field within a crop system; lines are the fixed-effect predictions from the best hierarchical model without covariables. Small (<2 ha) versus large holdings, and low (<3 species) versus high richness, are categories for graphical purposes only, while the model considers field size and species richness as quantitative variables. By using the same protocol, we could express density as number of visitors to 100 crop flowers, avoiding standardisations to integrate results from different crop systems. Because yield (kg ha^{-1}) is harvested in different magnitudes for different crop species (e.g. coffee versus tomatoes), we present the crop yield after subtracting the random intercept for each crop system.

Source: Garibaldi *et al.*, 2016, reproduced with permission.



asymptotically with such inputs, up to a certain point (Garibaldi *et al.*, 2011). When yield growth declines, this can often prompt the conversion of more land to cultivation. However, as it is increasingly being understood, crop yields and their stability also depend upon the ecosystem services provided by agricultural biodiversity, such as pollination and natural pest control. In the paper by Garibaldi *et al.*, 2011, a graphical model of yield-resource relations, as applied to animal pollination, predicts that incomplete and variable pollen delivery (through a loss of ecosystem services) reduces yield mean and increases the stability variability of crops with a dependence on pollinators; the model's predictions were validated with crop production data collected by the FAO over the 1961–2008 period. Specifically, crops with greater pollinator dependence had lower mean and stability in relative yield and yield growth, despite the global yield increases for most crops. Lower yield growth was compensated by increased land cultivation to enhance production of pollinator-dependent crops (Garibaldi *et al.*, 2011). These results reveal that pollination deficits, if not managed with specific measures to maintain pollination services, hinder yield growth of pollinator-dependent crops and decrease the temporal stability of global agricultural production, while promoting compensatory land conversion to agriculture.

Pollinator abundance and diversity may have greater impact as well on the yields and stability of forage crops. In Sweden excellent data with a long-term time element was gathered on the relative abundance of bumblebee species in red clover fields during three periods (1940s, 1960s and the present), and on clover seed yields since 1921. Drastic decreases were found in bumblebee community evenness, with potential consequences for the level and stability of red clover seed yield. The relative abundance of two short-tongued bumblebees increased from 40 percent in the 1940s to entirely dominate present communities with 89 percent. Average seed yield has declined in recent years and the variation in yield has doubled, suggesting that the current dependence on a few species for pollination has been especially detrimental to the stability of seed yield (Bommarco *et al.*, 2011).

Pollination provides other, more subtle contributions to agricultural production. It has long been known that pollination contributes to fruit and seed quality, resulting in better-shaped and larger kiwis and apples, for example. In a blind tasting experiment in Australia, bee-pollinated tomatoes were significantly preferred over human, hand-pollinated ones, as there was greater depth of flavour (Hogendoorn *et al.*, 2010). A recent study of exclusion experiments in Germany with strawberries showed bee pollination improved fruit quality, quantity and market value compared with wind and self-pollination. Bee-pollinated fruits were heavier, had fewer malformations and reached higher commercial grades. They had increased redness, reduced sugar and were firmer, thus improving the commercially important shelf-life. Longer shelf-life reduced fruit loss by at least 11 percent (Klatt *et al.*, 2014).

In the almond production region of California, a lack of bees and other wild insects to pollinate almonds can reduce harvest yields more drastically than a lack of fertilizer or a failure to provide the crops with sufficient water (Klein *et al.*, 2014). On the other hand, when almonds are adequately pollinated, the trees bear more fruit and their nutrient content changes, with increases in Vitamin E (Brittain *et al.*, 2014).

In the absence of pollinators, farmers may need to turn to hand-pollination, with its subsequent greater costs and complications. China in particular has had experience with this (Box 1).



Box 1.

HUMAN 'BEES' POLLINATE PEARS IN CHINA



China faces the task of continuing to support high agricultural productivity while both the agricultural land base is declining, and rural incomes are not keeping pace with incomes from other sectors. Cultivation of various fruit trees is considered one of the most important options for income-generation, on limited cultivated land. Pears are one of the important temperate fruit crops and their cultivation has been promoted, especially in mountainous and hilly areas of China. Most pear varieties are self-incompatible and cross-pollination by different varieties is required. Remarkably, most of the

pear trees are pollinated by hand. Extensive hand pollination began in the mid-1980s when large-scale pear cultivation started. An epidemic of pear lice some years ago led to the adoption of the intensive use of insecticides, and since then there has been a dearth of wild and domesticated bees. Growers estimate that without hand pollination, yields would fall by 90 to 95 percent.

The problems of low fruit set became more prominent when cultivation intensified, and attempts to introduce other varieties for cross-pollination were not very successful, in part because the other varieties flowered at times that were different than the main pear crop. Through hand pollination, farmers have learned the intricacies of how to prepare pollen for pollination and how and when to pollinate pears. The fact that humans are the main pollinators of pears in this area of China has given rise to a number of other dynamics. Some families have planted polliniser trees (that is, other varieties capable of cross-pollinating the flowers on the main pear variety) in home gardens, where the flowers cannot be stolen, and are selling the pollen. In some instances, pollen has even been exported to Japan. Having people replace insect pollinators is leading to new insights in just how demanding it is to employ human labour for an ecosystem service. In the case of pears in China, farmers now know that when it is sunny, clear and hot, most flowers bloom within one to three days, and pollination must be completed within that time; yet every flower must be 'visited' by a human pollinator twice. Usually a person can pollinate 30 to 40 trees a day. When it is sunny and the temperature is high, and flowers bloom for short periods, labour must be hired to help pollinate flowers. When it is very hot and pear flowers must be pollinated within a very short period, labour costs may double. Thus, weather determines the total labour inputs. Labourers are usually hired from areas where there is experience in hand pollination; untrained labourers are hired rarely and women are preferred for this work. Each tree is pollinated 2 to 5 times, and farmers recognise that this actually leads to over pollination, such that they must then spend considerable time thinning out young fruit, but this is preferred over risking insufficient fruit set. Understandably, growers in this area have strongly expressed their requirements for alternatives that can replace or reduce dependence on hand pollination.

Source: from Ya et al. (2004)



GLOBAL FOOD SYSTEMS: CRISIS AND CONTRIBUTION OF ECOSYSTEM SERVICES

As suggested by the evidence presented above, agricultural production systems suffer when insufficient attention is paid to the role of ecosystem services such as pollination. The implication of this lack of recognition of ecosystem services extends far beyond pollination declines, however. If a system is defined as, “an organization forming a network especially for distributing something or serving a common purpose¹”, the current global food system cannot be said to be functioning effectively.

Currently the world produces more than enough calories per day (2 700 kcal per person per day, above the required levels of 1 800 to 2 100 kcal per person per day). Yet nonetheless around 795 million people were estimated to be chronically undernourished in 2012–2014, and food production levels in many regions of high food insecurity remain at the same level as they were in the 1960s (FAO, 2014). At the same time, global levels of obesity have more than doubled since 1980; in 2014, more than 1.9 billion adults, 18 years and older, were overweight. Of these over 600 million were obese². Beyond counting calories, it is increasingly recognised that a food system must nourish, and not simply supply minimum levels of energy. Yet also over recent decades, a few major energy-dense cereals (maize, wheat and rice) and major oil crops such as soybeans have grown to dominate global diets. Food supplies worldwide have become more homogeneous and composed of processed food products, to the detriment of local, often better adapted and more nutritious food crops such as other cereals, root crops and diverse beans (Khoury *et al.*, 2014). This is a trend that is impacting health in rapidly developing countries more quickly than projected (Kearny, 2010).

On an environmental level alone, there is cause for considerable alarm at the level of impacts agricultural systems are imposing on the global environment. According to the FAO, the amount of soil lost worldwide is 75 billion tonnes; it is estimated that soil is being lost at between 10 and 40 times the natural rate of replenishment at an estimated cost of up to USD 500 billion per year (Pimental, 2006).

The current percentage of the Earth’s freshwater resources that are diverted to serve the agriculture sector is estimated at around 70 percent. More than half of the largest underground aquifers around the world are being used at rates that exceed sustainable replacement (Richey *et al.*, 2015). One of the most wasteful trade-offs of high-input agriculture is the fate of agricultural chemicals in waterways. The application of agricultural chemicals to annual row crops is extremely ‘leaky’; it is estimated that less than 15 percent of phosphorous applied to crops, and 40 percent of the nitrogen is actually absorbed by the plants; the rest remains either in soils or in waterways each year, contributing to the over 400 oceanic dead zones (Zeilinski, 2014). The solution to this problem has remained elusive; even after 40 years of efforts by federal, state, and local government in the United States nationwide progress on

¹ Merriam-Webster Dictionary

² <http://www.who.int/mediacentre/factsheets/fs311/en/>



controlling nutrient water pollution has not yet been achieved. Concentrations of nitrogen (N) and phosphorus (P) in streams and groundwater are 2 to 10 times higher than recommended to protect aquatic life (Dubrovsky *et al.*, 2010).

Yet an investigation of the multiple problems of intensive high production agriculture also opens the door to understanding the role of biodiversity and ecosystem services in preventing such pollution, and the importance of “learning from nature”. For example, the elevated nutrient levels, as described above, are attributed to the historic land use change in the central United States from deep rooted, drought resistant prairies to row crop production of maize and soy. The required annual tillage and planting, the wide row crops, the amount and type of fertilizer inputs required for the conventional production of maize, for example, means that much of the soil in maize fields has limited cover for over half of the year, and is then highly susceptible to water runoff, carrying off around 60 percent of the nitrogen applied (Porter *et al.*, 2015).

Solutions lie in the arena of developing agricultural production systems that mimic the ability of natural systems to maintain soil cover and sequester nutrients within the system. Indeed, studies are showing that the strategic re-integration of perennial grasses into this landscape in only 10 percent of row crop fields within a maize stand can reduce nitrogen in runoff water by 84 percent and phosphorus by 89 percent (Zhou, 2014).

The opposite side of challenges facing current agricultural systems is that in many parts of the developing world, conventional high-input agriculture has not – and has little chance of – taking hold. In such regions, resource-poor farmers contend with issues of marginal high-risk environments, and experience poor yields just where food security is most vulnerable. The agricultural research establishment has only recently begun to focus increasingly on such sites, and to recognise that highly site-specific resource management systems are needed to sustain productivity under these conditions (Altieri, 2002).

Yet the approaches that address both the heavy negative externalities of conventional production systems and the challenges of resource-poor farmers, have a central common thread: they recognise that agriculture and food systems are biological and social systems. They can be designed to build upon and harness the forces of biodiversity and ecosystem services such that the processes that underpin agricultural production – soil fertility, natural pest control, pollination, water retention – are optimised and encouraged. Farming systems can be regenerative, building on and adding to natural capital, rather than being increasingly dependent upon external inputs that the system cannot absorb and, more often than not, end up as negative externalities. For example, farming practices that maintain complex food webs may have tremendous benefits for natural pest control, for pollination services, and for wild biodiversity on farms. Farming has traditionally never been a solitary operation, being carried out over millennia by communities of people. An ecosystem perspective recognises that the regenerative aspects of agriculture occur on the level of the entire farming system, at the watershed, and or landscape or community level, with traditional knowledge, experience of farmers and empowerment of communities at its base. As such it contributes also to building and strengthening the social capital underlying agriculture. Thus it is critical in any formulation of the “true costs of agriculture” to recognise that well-formulated farming systems are capable of generating many positive externalities that are essential to human welfare, while minimising the negative.



Measures for conservation and management of pollination for agriculture

What does this have specifically to do with the importance of pollinators in agricultural biodiversity? With now more than fifteen years of attention being applied to pollination services at the global level, in good part through the combined efforts of the International Pollinators Initiative, there is now strong evidence of the importance of pollinators as an essential component of agricultural biodiversity, as they contribute in multiple ways to crop production. It is timely and appropriate that, on the basis of the evidence provided, pollinators and pollination merit explicit conservation and management. Yet, it is extremely unlikely that pollinators will be effectively conserved and protected by the farming community in isolation from harnessing the benefits of the whole suite of ecosystem services sustaining agriculture. It is in the totality of systems of agriculture that respect nature and promote the delivery of ecosystem services that measures to conserve pollinators will most effectively be employed.

In the context of the International Pollinator Initiative as coordinated by the FAO, an inventory of site-specific measures to conserve and enhance pollination services for agriculture is being compiled. A few of such measures are described below.

Soil management for ground-nesting bees

The majority of the important crop pollinating bee species nest in the ground. Managing for ground-nesting bees is, therefore, a critical component of sustainable crop pollination. Management methods that induce bees to nest in soil have been extensively worked out for only a few bee species. For this reason, the most important recommendation for management is to protect existing nesting sites. Other measures include minimising frequent, deep tilling, and avoiding flooding and other disturbances where nests may occur (Ullmann *et al.* in Azzu and Gemmill-Herren, in press).

Promoting on-farm diversity: wildflower plantings next to crops

Highbush blueberry was used as a model system to show the efficacy of using wildflower plantings adjacent to crop fields to increase the abundance of wild pollinators during crop bloom and enhance pollination and yield in the United States (Blaauw and Isaacs, 2014). Plantings were seeded with a mix of fifteen perennial wildflower species that provided season-long bloom. The effect of these plantings was on wild bee populations: honeybees visiting blueberry flowers had similar abundance in enhanced and control fields in all four years of this study, whereas wild bee and syrphid abundance increased annually in the fields adjacent to wildflower plantings. The enhanced presence of wild bees significantly increased the percentage of fruit set, berry weight and mature seeds per berry leading to higher crop yields; the associated increased revenue exceeded the cost of wildflower establishment and maintenance. More generalised guidance on promoting non-crop flowering plants in agroecosystems can be found in the upcoming publication (Gillespie *et al.* in Azzu and Gemmill-Herren, in press).



Shade trees and agroforestry benefits for pollinators

While flowering strips may 'pull' pollinators into servicing adjacent crops, the temporal availability of floral resources could be critical to facilitating the persistence of key pollinators in ecosystems. Since agricultural crops are in general seasonal, the pollinator(s) on which they depend may be supported only for a short period in any given year. Hence, it is important to consider the flora available in the same location or region to understand how the pollinator populations survive in the 'off season'.

In this respect, innovative systems of maintaining pollinator populations across time have been developed in the coffee and cardamom plantations of southern India. Both crops benefit from shade trees, and share common pollinators, but have relatively short blooming seasons at different times of the year. Farmers have developed managed agroforestry systems to create 'sequential blooms', planting a diversity of economically or domestically valuable trees to both provide shade and floral resources to pollinators in between the two crop blooming periods (Belavadi in Azzu and Gemmill-Herren, in press).

Managing pollinator resources across landscapes and regions

In many countries with a migratory beekeeping industry, colonies of managed honeybees are moved to farms during the pollination season. Outside the pollination season, beekeepers undertake practices that provide a honey flow, provide for colony build-up, or trap swarms to replace bees that abscond or die. These practices require a good availability and accessibility of forage resources for the pollinators across wide geographic regions – i.e. flowering plants supplying pollen (protein) and nectar (carbohydrates). Despite the importance of such resources to both crop and honey production, the assessment and deliberate management of these has rarely captured the attention of policy-makers or landowners. The partners of the Global Pollination Project in South Africa, the South Africa National Biodiversity Institute, have undertaken to raise awareness and document the seasonal and temporal importance of such resources, and the need to protect these for both wild and managed pollinators (Masehela *et al.* in Azzu and Gemmill-Herren, in press).

Respecting traditional knowledge

There is a long cultural tradition of honey hunting and domestication of other species of honeybees in Asia. The eastern honeybee, *Apis cerana* is kept by beekeepers in diverse mountainous areas, traditionally by building space in the walls of houses where bees can be maintained over cold winter months.

Assessing pesticide risks to wild pollinators

Increasing attention is being paid to the linkages between pesticide use and pollination services. Publications such as *Assessing the risk of pesticides to wild pollinators* (van der Valk *et al.*, 2013), and the companion guide on *Pollination safety in agriculture* (Roubik, 2014) are examples of how practitioners are concerned about the issue and have requested guidance material from the FAO.



CONCLUSION

The threats and risks that pollinators are facing under greater and greater agricultural intensification, less diversity in the field, and greater levels of disturbance or application of plant production products is not the only or inevitable pathway ahead. Other alternative trajectories in which the negative externalities of high input, high output, high pollution agriculture are minimised, and the positive externalities of ecosystem services are rewarded suggest a different pathway. This alternative trajectory is not a return to earlier, idealised eras, but rather proposes a transition process to agroecological systems that are acknowledged as complex, requiring changes in practices that result in greater diversification and the appreciation and support to the farmers' knowledge as they apply measures such as those described above.



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10

FARMER FIELD SCHOOLS FOR AGROECOLOGY IN CHINA: INSTITUTIONALISATION OF INTEGRATED PEST MANAGEMENT FARMER FIELD SCHOOLS FOR AGRICULTURAL GREEN DEVELOPMENT IN KUNMING CITY

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Abstract

Integrated Pest Management (IPM) Farmer Field Schools (FFS) promote agroecology within the context of a participatory and farmer-centred approach to extension, education and skill development. This case study analyses how IPM and the FFS approach to green development of periurban modern agriculture was institutionalised in Kunming city in Yunnan province. IPM-FFS was first introduced in Kunming by the Food and Agriculture Organization of the United Nations (FAO)/China Vegetable IPM Programme in 2003. At first there were nine core facilitators, who had received intensive training under the auspices of the FAO Regional IPM Programme, the IPM-FFS Programme in Yunnan was then quickly adapted to suit local conditions and needs and expanded to all the prefectures of Yunnan during the 2003–2016 period. Gradually, the IPM-FFS approach was also integrated into other national priority rural development programmes.

The Kunming Municipal Government also adopted the IPM-FFS system as an important approach to extension to improve productivity, increase farmers' income, secure food safety and protect the environment. IPM, and field-based learning about eco-friendly pest management were highlighted as the entry point for farmers to learn about broader agroecological concepts, and more sustainable crop production

practices, through active participation in a season-long FFS. Broader production issues, livelihood strategies and the sustainable management of ecosystem services are integrated into the FFS curriculum and learning activities. The IPM-FFS Programme fosters farmer organization and self-management and facilitates the design and implementation of local community action plans for pesticide risk reduction. Farmers and their rural communities took part in the collection of used pesticide packages/containers and disposal systems. Interventions in FFS communities include innovative demonstrations of IPM technology and work with various stakeholders on agribusiness and more efficient value chains, as part of public-private partnerships (PPPs). Results show that use of pesticides and fertilizers among FFS graduates was reduced by 20 to 35 percent and 20 percent respectively. Input costs were reduced by RMB 300 to 1 500 per ha and income was increased by RMB 675 to 3 450 per ha. The FFS programme has had a significant impact on improving productivity, increasing farmers' income, securing food safety and environmental protection. Lessons learned include the realisation of the importance of local ownership by various stakeholders, the quality implementation of FFS and follow-up training to promote and sustain adoption and adaptation of good practices to suit local farming conditions. The IPM-FFS programme also successfully capitalised on newly



emerging opportunities for scaling out, which included linking with development priorities, projects and investments from the municipality, local and national government.

Keywords: China/Yunnan, Integrated Pest Management, Farmers Field School, Institutionalization

BACKGROUND

China is the largest agricultural country in the world; with a population of 749 million farmers, which accounts for over 45 percent (NESDB, 2015) of the nation's total population. China is also one of the largest producers of agricultural products, such as cotton, oilseed, meat, aquatic products, vegetables and fruits. Apart from yield-reducing natural disasters, such as drought, over 1 600 species of pests including diseases, insects, weeds and rodents are recorded as having attacked crops, which has caused crop damage and yield losses of 10 to 20 percent have been reported annually. China is a major producer and exporter of agrochemicals. Currently, China produces the largest amount of pesticides in the world; production output in 2016 was 3.77 million tonnes of active ingredients.

Despite proactive pesticide regulatory action in recent years¹, pesticide abuse and overuse is still rampant. Intensive use of hazardous chemicals by smallholder farmers is causing a high incidence of poisoning of farmers, serious disruptions in ecosystems and a degraded environment. In China, farmers' fields are a greater source of water contamination than that caused by effluents from factories or industry (MEP *et al.*, 2010). Pesticide residues from crop production are also a major source of food contamination (Xu, 2015), raising concerns about food safety and jeopardising export potential.

However, China's national economy has entered a new normal, transforming from high-speed development to more balanced growth, including in the agricultural sector, where there is greater respect for sustainability, health and environmental protection and emphasises is being placed on higher quality and efficiency in agricultural value chains. China has implemented the new "innovative, open, coordinated, green, and shared" development concept. Innovation vitalises agriculture while green development harmonises agriculture development and protects the environment and ecosystem and produces safer food. The strategy ensures the improvement of rural livelihoods without compromising productive and sustainable agriculture development, reduces pressure on the environment, builds resilience and reduces vulnerability to climate change. The No.1 Central Government document released in 2017 (SCC, 2017) clearly stated

¹ The banning of the five key highly toxic organophosphorus pesticides and the label improvement regulations in 2008, new national food safety standard — Maximum Residue Limits for Pesticides in Food in 2012, pesticide and fertilizer zero increment initiative in 2015.



that China needs to strengthen the innovation-driven economy, promote agricultural supply side reform, and take the path of high efficiency, conservation of resources, produce safety and be friendly to the environment.

The present document also proposes to intensify the eradication of agricultural pollution and further implement Fertilizer and Pesticide Zero Increase Initiative. China released the renewed Pesticide Management Regulations in 2017 to provide a more solid law by which to regulate pesticide management and secure produce quality safety. The overall policies have created an enabling environment in China for IPM-FFS development to achieve successful agricultural transformation, and the mainstreaming of agroecological approaches.

OVERVIEW OF IPM-FFS DEVELOPMENT IN KUNMING CITY

After the Ministry of Agriculture proclaimed IPM to be a national long-term guiding principle of plant protection in 1976, with the subsequent minimally successful 10-year top-down IPM-related extension efforts, in 1988 China joined the FAO Inter-Country IPM Programme for Rice. Since then, China has been involved in the FAO Inter-Country IPM Programme for Rice (1994–2004), the EU/FAO Regional Cotton IPM Programme (2000–2005), the FAO Inter-Country IPM Programmes for Vegetables (2003–2008) and Pesticide Risk Reduction (2007–2016). Over the past 20 years, more than 50 Training-of-Trainers sessions (TOTs) have been conducted and around 1 500 facilitators have been trained. Several of these TOTs were season-long, 3 to 4 months, 5 to 6 days per week, which sought to develop a core group of master trainers.

These intensive TOTs helped build practical skills in IPM, ecofriendly knowledge of crop production and FFS facilitation. More than 6 000 IPM-FFSs were implemented in China, which were funded by the FAO and governments, about 180 000 farmers were trained. The IPM-FFS themes were extended to a wide variety of crop commodities, including rice, cotton, fruit trees, tea, cassava and vegetables. The China National IPM-FFS Programme is led by the National Agro-Technical Extension and Service Centre, Ministry of Agriculture (NATESC, MOA). At the provincial level, the key FFS implementing agencies are the provincial Plant Protection Stations (see <http://www.vegetableipmasia.org/countries/view/china> for more details).

Kunming is the capital city of Yunnan province (population around 6.5 million). The periurban modern agriculture focuses on efficient ecological agriculture and agritourism. The main agricultural industries include vegetables, flowers and mountain animal husbandry. The irrational use of pesticides has led to environmental pollution and issues related to the safety of agricultural products. Farmers lack the knowledge, technologies and organization to produce safe food and secure stable access to markets. Dianchi lake near Kunming city is the sixth largest freshwater lake in China, and the largest in Yunnan province. It is one of the important water resources for Kunming city, supplying water for drinking and irrigation. It also plays an important role in maintaining the ecological balance, shipping and fisheries. The lake, however, has been heavily polluted as a result of expansion of the city and the associated sewage discharged into the lake, often without treatment. The lake has been polluted by industrial development and the heavy use of pesticides and fertilizers on agricultural land surrounding the lake, which had



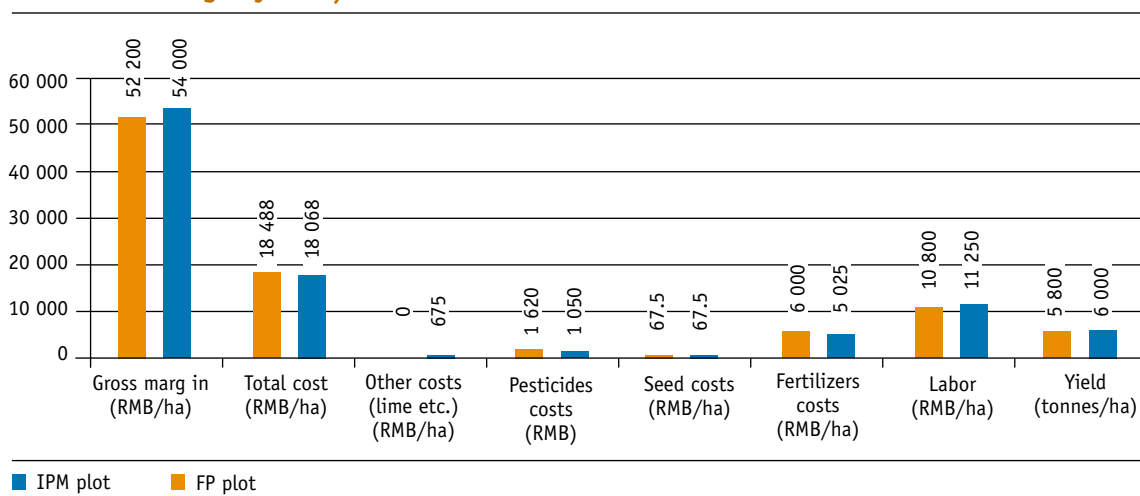
been converted from wetlands. How best to avoid the pollution of Dianchi lake has become one of the issues of greatest concern for environmental protection and green development of the city. Among the strategies used to eradicate agricultural pollution is IPM, which is one of the important initiatives promoted by the municipality.

IPM-FFS was first introduced to Kunming by the FAO/China Vegetable IPM Programme in 2003 with nine core facilitators who had graduated from the FAO-funded Training of Master Trainers (TOMT) and Training of Trainers courses. Upon graduation, these facilitators piloted the FAO-funded IPM-FFS and gradually developed the locally adapted FFS programmes. Following the FFS interventions, pesticide and fertilizer use were reduced by 20 to 35 percent and over 20 percent respectively. Input costs were reduced by RMB 300 to 1 500 per ha and the income was increased by RMB 675 to 3 450 per ha (Fu and Liu, 2006). The FFS programme has had a demonstrably significant impact on improving productivity, increasing farmers' income, securing food safety and environmental protection.

As can be seen in Figure 1, the net income from an IPM plot was RMB 1 800 higher than that from an FP plot, an increase of 3.5 percent, most significantly, the pesticide costs was 54.3 percent lower than that of an FP plot. The costs of time and labour increased slightly on an IPM plot, indicating that diversified efforts, including soil treatment, were employed to control plant diseases.

As per the impact assessment study on vegetable FFS carried out from 2003 to 2007 in the framework of the FAO vegetable IPM programme, IPM-FFS farmers gained significant knowledge about vegetable pests, natural enemies, insects and diseases, ecology and pest management (Yang P, Liu W, *et al.* 2008). After having observed and understood the ecological interactions through field based hands-on learning during the FFS, farmers became highly motivated in protecting their crops against natural enemies in their fields and avoiding the use of pesticides.

Figure 1. **The comparison of economic analysis in Chinese cabbage production on the IPM plot versus farmer practices (FP) plot in Kunming FFS (Liujiaying Village, Chenggong County, Kunming City 2006)**



Source: Individual FFS report by the facilitator



Because of the demonstrated impact of IPM-FFS and IPM villages, IPM-FFS has been integrated into other national programmes, for instance: Five One Project², Crops High Yield Creation Programme, Green Control Project, Dianchi Lake Environment Pollution Management Project and others. The FFS programme in Kunming has evolved from the initial pilot stage of the IPM-FFS, which was then gradually scaled out and institutionalised at the community level. Eventually, as of 2007, IPM-FFS was adopted by Kunming city as an important tool for farmer education and extension to empower farmers to make informed decisions to cut pesticide use, improve food safety and livelihoods and protect the environment. To meet the needs of IPM-FFS expansion, the Kunming municipal government funded two TOTs and one refresher TOT in 2008 and 2012 respectively to expand the network of IPM facilitators from 9 to 79, who have since then conducted IPM-FFS and facilitated community IPM development. To date, 152 IPM-FFS have been conducted and 152 IPM villages have been formed in Kunming municipality, covering rice, corn, flowers, vegetables, fruit trees, etc. A total of 4 560 farmers have been trained (45 % female) and 22 800 farmers have been reached through dissemination.

MAJOR ACTIONS TAKEN AND RESULTS OF IPM-FFS INSTITUTIONALISATION IN KUNMING

In this paper, institutionalisation means “to establish [something, typically a practice or activity] as convention or norm in an organization or culture” [Oxford English Dictionary]. In this case, it means that IPM-FFS is incorporated into and established in the agricultural extension system (Chuluunbaatar and Yoo, 2015) and has become part of the ‘norm’ (Jonfa and Waters-Bayer, 2005). In addition, IPM-FFS has also effectuated fundamental changes in the receiving entity at farm, community and city level.

IPM-FFS

Integrated Pest Management–Farmer Field Schools promote agroecology within the context of the approach to a participatory and farmer-centred extension, education and skills development. Participants are groups of men and women farmers with a common interest, who meet regularly over a long period of time and are guided by a ‘facilitator’, who does not lecture, but promotes learning by discovery through hands-on exercises (Gallagher, 2003). The FFS training approach is interactive, inspirational and interactive (Yang, 2008).

A participatory needs and opportunities assessment is conducted before IPM-FFS, which involves the community in the preparation process to identify and prioritise needs and problems and develop the curriculum: Training, ownership and commitment to the activity is fostered during the preparation process.

² Measures to produce safer vegetables: one light trap, one sticky trap, one FFS and one pack of biofertilizers



The overall topics should be discussed with the participants to meet their needs and solve the problems identified. FFS is not necessarily a tool for technology transfer, but is, foremost, a sharing platform on which to integrate outside and farmer's indigenous knowledge (Piao and Chen 2004, Duveskog *et al.*, 2011):

Normally, FFS participants meet on a weekly basis for rice and vegetable IPM-FFS. For other crops (such as fruit trees) or animal husbandry FFS modalities, if there is a longer growth period, farmers can meet regularly in the target commodities during critical growth stages.

Daily FFS meetings include an introduction to the activities of the day (10-15 minutes) and agro-ecosystem analysis (AESA) (about 90 minutes). AESA is conducted during each session of the FFS, and has been developed and adapted for a range of commodities because it is the key to improving farmers' ecologically based decision-making skills.

Farmers are expected to conduct their own AESA upon graduation, not necessarily by drawing pictures but by regularly observing their fields and making informed decisions. There are also activities covering special topics lasting 30 to 60 minutes, which are mostly in the form of lectures. It is important that structured-learning exercises are developed and conducted in support of the special topics.

A group dynamics exercise can last 10 to 20 minutes, and may vary from meeting to meeting, serving different purposes including the enhancement of team spirit, creating an enlightening atmosphere and addressing sensitive topics. Experimental observation, and the presentation of results, lasts around 30 to 45 minutes, and finally there is evaluation and planning for the next meeting, which takes 10 to 25 minutes.

AGROECOSYSTEM ANALYSIS

Agroecosystem analysis is a field-based analysis of the interactions observed between crop and livestock and other biotic and abiotic factors coexisting in the crop and livestock field. The purpose of the AESA is that FFS participants learn to analyse ecosystem developments in the field and improve their decision-making skills regarding farm management.

The general steps in the analysis of agroecosystems include:

- **Field observations** – FFS farmer groups go to the field to make observations, based on a range of monitoring indicators. Emphasis is on observing the interactions between various factors in the agroecosystem, farmer groups also take notes and collect specimens as needed.
- **Analysing and recording findings** – The FFS participants make drawings on newsprint to better visualise agroecosystem interactions. Upon acquiring a better understanding of the interactions in the system, the participants then decide on follow-up actions.
- **Presentation and feedback** – There is a group presentation for plenary discussions and feedback.
- **Discussing future actions** – The participants synthesise the presentations and collectively decide on which actions to implement in a plenary based on their decisions, which are implemented in the weeks that follow.

Source: FAO, 2016. Farmer Field School guidance document, planning for quality programmes



IPM-FFSs facilitate experiential learning (Bartlett, 2008; Edward *et al.*, 2012; Anandajayasekeram *et al.*, 2007) during experiments set up in the FFS, which is one of the main areas where innovations arise. It is the role of the FFS to help farmers create experiments to solve the problems they face, to demonstrate their indigenous knowledge and to introduce, test and adapt to new technologies. In follow-up FFS activities, farmers may continue to conduct experiments in their own fields, such as variety and fertilization trials and monocropping versus intercropping.

Comparative experimentation is also an indispensable part of the FFS. During IPM-FFS learning plots are set up and comparative experiments are conducted such as IPM versus farmer practices. While the FP plot is managed as per local conventional practices, the FFS farmers work together to carry out AESA and manage the IPM plot based on commonly agreed management decisions.

From IPM-FFS to IPM villages: Innovations, scaling up and out

FFS alumni are not only able to apply IPM principles in their own fields but individual activities may also evolve into collective action in their communities to institutionalise pesticide risk reduction, including the application of IPM. The learning process in the FFS enhances team building and group collaboration.

The main activities taken in IPM villages include:

- » **Enhancing the organization and self-management by the farmers** – The existing village committee plays a leading role in FFS programme development with regard to promotion of the IPM-FFS programme and organization of the activities, and in particular, at the initial stage of the programme. With the intervention of the IPM-FFS programme, village farmers take ownership and commit to community development to evolve towards a self-management group. The FFS empowers farmers with critical thinking, problem solving and informed decision-making skills. Participatory and experiential learning facilitates the FFS farmers to identify problems in the village and to take collective action in the development and implementation of action plans to improve their livelihoods. In Kunming IPM-FFS, the participants developed action plans to develop brands for their agricultural products, to protect their farmland environment, improve farmland sanitation, conserve water resources and manage pesticide disposal. The action plan also included the application of protective equipment for the use of pesticides, and the use of low-risk storage of pesticides and sprayers.
- » **Setting up a pesticide regulatory and disposal system** – ‘Quality assured pesticide sales shops’ are set up where inspection software has been developed and the equivalents provided. The use of fake and highly toxic pesticides is prohibited and strictly monitored. Village farmers also take collective action in the management of pesticide disposal. Waste pesticide containers and collection tanks are built in villages and some pesticide shops also encourage farmers, using a small incentive, to return their empty containers.



- » **Setting up a farm waste recycling system** – Crop debris and animal dung are used as resources in the development of organic fertilizers, which are applied to the field to improve field fertility and limit the use of chemical fertilizers. This practice has greatly improved the application of organic fertilizers, contributing to better health of the living soil and crop.
- » **Establishing an IPM technology demonstration and extension system** – In addition to using IPM-FFS as a powerful extension and learning platform, other methods are applied to experiment on and extend IPM technologies. Village-level pest forecasting and management information is displayed on village bulletin boards, which are updated regularly. IPM demonstrations include the integration of light and pheromone traps, use of biodiversity to manage pest populations, biopesticides, etc. As a result, IPM practice is deeply rooted in the communities.
- » **Developing agribusiness and value chain** – IPM technologies have helped farmers to cut inputs, produce safer food and generate more income. However, it does not necessarily mean that farmers gain a more equitable share of these improvements along the value chain. How can there be better assurances that farmers obtain an equitable share from the value chain? One option could be to organize farmers from the cooperatives to work together to develop premium quality products that can be certified and marketed as part of modern value chains. In IPM villages, farmers extend the industry chain to add value to their produce, for example, processing the products and linking to markets. Farmers also develop their own certified products. Farmers have improved solidarity within the group and make better use of collective bargaining power to demand a better deal as part of the entire value chain process. In this way, FFS farmers generate a higher income from their farming enterprises.
- » **Building public-private partnerships (PPPs)** – Innovation is a key driver for productivity growth and value addition. Cooperation between the government and the private sector is beneficial in promoting innovation, supporting investment and responding to farmers' needs for better and more stable prices and market access. To respond to farmers' needs, the private sector could contribute through technology creation, adaptation and transfer (FAO 2013) and by investing in research and skills development. IPM demonstration villages build linkages with companies supplying novel options for pest control. These companies demonstrate and provide alternatives and innovations that include biopesticides, light traps, insect pheromone traps and yellow sticky boards.

The novel options are introduced and tested by farmers at the FFS and further applied to their fields. The success and far reaching benefits of these partnerships may easily be seen. PPPs enhance farmers' access to technology and markets, leverage public funds, enhance efficiency, and improve the adaptation of innovation to demand so as to foster wider and faster diffusion (Moreddu, 2016; Hartwich *et al.*, 2007). PPPs also enable partners to draw from complementary resources and profit from synergy and joint learning (Hartwich, 2007). However, not all partnerships are necessarily 'good' – from an ecological viewpoint, these partnerships need to be assessed for their potential effects and their support for the transition towards more sustainable agriculture should be ensured.



LESSONS LEARNED

Lessons learned as a result of the success of the Kunming IPM-FFS programme, where the IPM-FFS and agroecology have been taken up by local government can contribute to agricultural green development. It is important that an FFS project is designed carefully from the beginning to enhance the likelihood of success and sustainability. Lessons learned include:

- » **Ownership by the stakeholders** – In this case, farmers and local programme development workers have strong ownership of the IPM-FFS programme. The farmers are the owners of the IPM-FFS programme and community development. IPM-FFS apply a participatory and discovery-based learning approach; farmers are empowered to work together with the facilitators to identify problems and opportunities, formulate action plans and take action to improve their livelihoods. Transformative change then takes place towards sustainable and inclusive community development. FFS alumni take the lead in disseminating IPM technologies and the other farmers are encouraged to take a greater role in community development, which also includes challenging the norm of the top-down approach of community governance to a bottom-up approach. Farmers have a say in how best to improve their lives. Farmers who take ownership of programme development play a key role in sustaining the IPM-FFS. Rather than taking an initial pilot FFS as a requested job task, the local extension and village administration took the FAO-funded pilot IPM-FFS as their opportunity to experiment on innovative ways to reduce pesticide risk and engage in rural development. When the experiment results were demonstrated as impressive and effective, more local drivers and efforts were added to the IPM-FFS programme at a later stage to ensure their greater effectiveness.
- » **Quality implementation of FFS programmes** is the basis of the FFS programme, to ensure its survival through the initial stage when funding is normally from an external source, such as the FAO in this case. It is important that pilot FFS programmes lay a solid foundation so as to demonstrate the value of adopting and institutionalising FFS. Poor quality IPM-FFS will only damage the reputation of the FFS resulting in their not being valued by the potential adopters.
- » **Promotion of FFS** – When implementing FFS, it is important that the approach is observed by the policy-makers. Policy-makers can be invited to the site, watch news reports on FFS, etc.. It is impossible to mainstream the FFS if nothing is known of the important results and impacts.
- » **Linking FFS programmes with the priorities for agricultural development** – It is important to demonstrate to stakeholders, including the government, the linkage between IPM-FFS and agricultural development priorities and innovations. For instance, enhancement of food safety has been high on the government agenda for years. In 2012 the No. 1 document of the Central Government emphasised the promotion of Agricultural Science and Technology Innovation and Enhancing Agriproduce Supply. In 2016 the No. 1 document of the Central Government specified intensifying agricultural non-point source pollution treatment and conducting a fertilizer and pesticide zero increase initiative. All these initiatives could serve as linkages between IPM-FFS and government priorities.



- » **Adaptation of the IPM-FFS programme to local situations** – IPM-FFS was first conceived and implemented in the late 1980s in the rice paddies of Indonesia as a way of training farmers to apply the principles of IPM in dealing with outbreaks of the brown planthopper in rice. This approach turned out to be very successful (Kenmore, 1991). The IPM-FFS programme cannot be sustained if local development workers do not take ownership of the programme and tailor it to the local situation in Kunming, for instance, ‘peri-urban’, ‘Dianchi lake control of non-point pollution’.
- » **Implementing FFS follow-up activities** – An FFS closing ceremony is a rare event at the end of the IPM-FFS. It is important that the FFS alumni are organized into an association or cooperative, the facilitators may continue monitoring and evaluation after the FFS to help farmers build on the mechanism and maintain a core group. The facilitators are also expected to provide assistance on produce certification, market development and testing and extension of novel IPM options. It would be better if facilitators employed a gradual exit strategy rather than suddenly ending the programme.
- » **Building the basis for FFS expansion from the initial stage** – It is important that FFS expansion is considered at the start of an IPM-FFS programme. In Kunming city, locations were selected in priority areas so that IPM-FFS could be implemented in combination with other projects to expedite rapid diffusion of IPM-FFS.

When selecting FFS participants, potential farmer leaders such as large growers in the villages were selected, so that they could lead other participants during training and in the FFS follow-up activities to sustain practices. FFS farmers may possibly swing from IPM to their previous practice under the influence of their neighbours and pesticide sellers. Critical mass can be reached by involving leading farmers and staging farmer-to-farmer dissemination so that the community can undergo transformative change.

DISCUSSIONS

Kunming city is the most advanced city in mostly underdeveloped Yunnan province. It has a strong local financial basis, great geographical advantages for the development of peri-urban agriculture, as compared to other prefectures in Yunnan. For other places in Yunnan, IPM-FFS institutionalisation faces various challenges. Location specific innovation and adaptation are required to sustain and develop IPM-FFS programmes.

The IPM-FFS programme has been implemented successfully in China. The programme has increasingly become a government-led activity rather than a project-led activity supported by international donors and resource partners. After years of pilot IPM-FFS programmes, implemented by NATESC/PPSs, with the FAO financial and technical support, the impact of the FFS has been experienced by farmers and observed by stakeholders, most notably by the government at various levels.

The farmer-led FFS approach has generated much interest in China, and has developed very quickly on diversified topics, including professional farmer training, poverty alleviation and rural development, environment protection, biodiversity conservation and utilisation. At the central



level, FFS has been adopted by the Ministry of Agriculture as an important approach to the reform of the agricultural technology extension system at the grassroots level and as a new type of professional farmer training.

During the Thirteenth Five-year Plan (2016-2020), The Ministry of Agriculture stated that 200 000 FFS would be conducted nationwide, covering major agriculture production industries. At the local level, several municipalities such as Beijing and Kunming have rapidly expanded FFS. It is believed, and has been verified, that this approach to agricultural extension could contribute greatly to the leap over “the last one kilometre”, which is the gap between agricultural technologies and farmers.

However, it is still challenging to maintain quality and improve on the emerging FFS, while scaling up and out. The fast growing demand for FFS programmes may cause “fast-food TOTs and FFS” (Chuluunbaatar and Yoo, 2015). The factors that influence FFS quality, for example, FFS managers who may emphasise quantity versus quality, and the facilitators who are busy with other job assignments and who are not fully trained. The baseline survey for curriculum development is insufficient; facilitators lack a sense of commitment; there is no system to monitor and evaluate FFS quality; there are no incentives to encourage facilitators to spend additional time and energy on FFS. As a result, the quality of the FFSs suffers, which may eventually damage their good reputation and the sustainability of the FFS programmes.

In the long term, the role of the FAO IPM-FFS Programme in China could provide FFS implementation guidelines to help countries assure FFS quality; provide a platform for the sharing of inter-country experiences; facilitate exchange visits among countries and pilot world innovations in China.

Originally, FFS were created for smallholder farmers who are resource-poor and often have limited access to education, information, extension services, market access and financial capital (FAO, 2016). In the context of promoting relative scale agriculture operations in China, the farmland is rotated and more concentrated among large land holders such as large growers, large family farms, leading agriculture enterprises, farmers’ cooperatives, etc. Consideration needs to be given to how best to develop the IPM-FFS model, based on the changing situation.

IPM-FFS has a profound impact on social capital. Based on the Sixth National Census Bulletin, which was released in 2015, there were 212 million who were 60 years old, accounting for 15.5 percent of the total population, while the number of those in rural areas was higher than the national average. The rural labour shortage has become a problem because the younger generation migrates to cities to make a living. Who will grow food in the future? This question is related to food security, the stable development of society and the creation of a prosperous society.

China has developed a national strategy to train more professional farmers, making agriculture a lucrative and attractive profession so as to retain the successors of the agriculture legacy. In the New professional farmer-training programme, FFS has become one of the powerful tools that empower farmers to become leading and expert farmers; the impact of FFS in China is achieving outreach and driving rural social change.



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11

DEVELOPMENT PRACTICES, EXISTING PROBLEMS AND GUIDANCE FOR PADDY FIELD AQUACULTURE IN CHINA¹

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Abstract

Paddy field aquaculture has a long history in China and has served as a source of food and income. Entering the New Century, great strides have been made in the diversity and scale as well as the area, yield, breeds and profits of paddy field aquaculture. Apart from support at the national level, different regions have provided policy support based on local conditions for technology extension, funds, government guidance, larvae bases, regulation, scale-up and industrialisation of paddy field aquaculture and the integration of primary, secondary and tertiary industries. The survey, however, reveals the problems of current paddy field aquaculture, including the lack of awareness, funds, infrastructure and

technology extension, undersupply of new breeds, non-organized farmer households, brand establishment and industrialised operations. The thesis suggests that relevant authorities should take the opportunity to advance the construction of standard paddy field aquaculture and larvae bases, provide technological services and training for technology extension personnel at the community level, encourage the development of specialised farmer cooperatives and family fishing grounds or farms, create local brands to add value to paddy field aquaculture, and conduct continuing studies on the development of the industry.

Keywords: paddy field aquaculture, improvement, local experience

Paddy field aquaculture is a farmer's 'rice bag', 'vegetable basket' and 'money clip'. In China, the comprehensive development of paddy field aquaculture is considered to have a positive impact on enhancing fishery modernisation, increasing farmers' incomes, alleviating poverty and enhancing the integration of production in rural areas. Further, paddy aquaculture can benefit from the new business model for ecological agriculture and the development of attractive villages. Paddy field aquaculture in China has a long history and mature technology. The local fishery culture has distinctive features and a robust development atmosphere. Fishery restructuring can be taken as a starting and turning point in the development of modern fisheries infrastructure and public services.

How can the opportunity for upgrading the fishery economic structure and ecological agriculture be seized? That is a big question, which is worth studying and summarising. It should also illustrate that the fishery industry is complying with supply side reform. If the Government of China could follow the tide of the times and make proper advancement, it can better take the initiative for the work and transform the growth model and economic structure of fisheries. Based on this understanding, the National Technology System for Conventional Freshwater Fish Industry organized 30 comprehensive test stations with experts. In 2016, from



August 22 to September 20, an economic model was researched covering rice field culture (fish, turtle, crab etc.) based on 160 questionnaires. This nationwide investigation focused on the current situation, revenue model, costs and problems of paddy field aquaculture. The present article summarises the experience and problems found in different areas related to providing technical support and advice for decision-making. The findings, judgment and main issues are hereby reported.

THE SUCCESS OF PADDY FIELD AQUACULTURE IN CHINA

In recent years, as industrialisation and urbanisation have developed, the phenomenon of rural migrant workers has become common. Given the low economic benefits of monocropping or single breeding, farmers are less willing to engage in planting and breeding, so that extensive planting has emerged, increasing double cropping has again transformed into monocropping, with the rapid development of monocropped rice. Guided by national policies, the agricultural sector plays a leading role in the wide-ranging technology of paddy fields farming, through hybrid breeding, and the reorganization and full use of resources. These measures have promoted the economic benefits of paddy yield per unit and have been welcomed by new business entities.

In 2005, the Ministry of Agriculture led the demonstration to allow households access to agricultural science and technology. The Ministry also integrated and expanded the techniques of paddy field aquaculture. In 2012, the Ministry carried out a new round of nationwide demonstrations of integrated rice-breeding technology, which is based on the premise of not reducing food production and improving the environmental protection aspects of aquaculture, reducing pollution of plants and realising the overall benefits of rice and aquatic production. Based on the natural conditions, combined with labour, capital and technology reserves and other production factors, aquaculture farmers have explored paddy farming patterns having local characteristics such as 'rice-crab symbiosis', 'rice-turtle symbiosis', 'rice-fish-duck intergrowth' and 'rice-loach symbiosis' (Xiaofang, 2017). Aquaculture technology has been improved the integration of technology, rice cultivation, fertilizer management and pest control (Wang, 2009). New business entities and rice and aquatic product brands have been created, thus improving food and fishery output. Economic, social and ecological benefits have been obtained (Zhu *et al*, 2016).

In some places, the multiple uses of water, field and villages have been achieved. Local governments have established a few local brands, promoted rural tourism, increased the effect of the paddy farming economy, attracting farmers to join in comprehensive rice breeding. This has become the basis on which local governments promote the integration of industries and target poverty alleviation. Generally speaking, the new century has witnessed the diversified patterns of paddy field aquaculture on a large scale. The changes can be listed under the characteristics of an area, yield, range and income.

First, the area, output and yield of rice has steadily increased – In the new century, aquaculture production in the rice fields of China maintains about 5 percent of all fresh-water aquaculture. But the scale of the cultivated area, output and yield has increased significantly.



In 2015, China's fish farming in paddy fields covered 1 501 600 ha, the yield totalled 1 558 200 tonnes, and a new level of yield hit 69 kg/mu fish yield in paddy (1 ha = 15 mu). Compared to that of 2010, the national rice output, area and yield under rice aquaculture in 2015 have increased by 25.38 percent, 13.24 percent and 10.73 percent respectively, showing that the economic model of rice aquaculture is robust.

Second, a new model of paddy farming emerged – A new and upgraded model has been expanded. The paddy field aquaculture has considerable value. The survey found a dozen models, including 'rice-fish symbiosis', 'rice-crayfish symbiosis', 'rice-freshwater-shrimp symbiosis', 'rice-eel symbiosis', 'rice-loach symbiosis', 'rice-crab symbiosis', 'rice-duck symbiosis', altogether eight composite models. Furthermore, there are intergrowth models, such as rice-fish-shrimp, rice-shrimp-loach and rice-eel-loach.

Among them, the breeds for 'rice-fish symbiosis' include black carp, grass carp, silver carp, bighead carp, common carp, Crucian carp, bream and tilapia. From the survey, the 'rice-crawfish symbiosis' output value per mu increased by RMB 1 456.28, an increase of 258 percent over that of single rice cropping; 'rice-loach symbiosis' output value per mu increased by RMB 1 762.89, an increase of 901 percent over that of single rice cropping; 'rice-turtle symbiosis' output value per mu increased by RMB 13 744.94, an increase of 5 549 percent over that of single rice cropping; 'rice-crab symbiosis', an increase of RMB 2 484.33, an increase of 351 percent over that of single rice cropping; 'rice-fish symbiosis' output value per mu increased by RMB 524.76, an increase of 90 percent over that of single rice cropping. The new patterns of paddy farming show that urban and rural demand for distinctive, diversified and high-quality aquatic products remain strong; The paddy field aquaculture economy has contributed to the transformation of China's modern fishery, agricultural restructuring and consumption structure.

Third, the economic model of paddy field aquaculture has gradually expanded throughout most of the country – Since the 1990s, paddy field aquaculture extended from the ethnic ghetto areas to multi-ethnic areas and throughout most of the country. We have seen the development of paddy field aquaculture from mountainous regions to the plains or suburbs, from the southwest, mid-south, east China to the northeast, north and northwestern regions (Bao, 2012). The dual driving forces of the agricultural sector and market demand have caused the comprehensive paddy field aquaculture technology to become rapidly widespread nationally. This economic model is ubiquitous in other provinces and municipalities except for some remote and high-altitude areas such as Tibet and Qinghai.

Currently, rice aquaculture areas are mainly distributed in southwest, central and east China, where mainly paddy field aquaculture can be found. Measured by the area of fish farming in paddy, Sichuan province with 308.9 thousand ha, ranked first in the country; Hubei province with 200 900 ha ranked second; Hunan province with 171.4 thousand ha ranked third. The provinces of fish farming in paddy exceeded 100 000 ha include Jiangsu, Guizhou and Yunnan provinces. They are 109 800 ha, 153 100 ha and 111 400 ha respectively. Measured by the output of fish production in the paddy fields, Zhejiang province totalled 331 000 tonnes, ranking first in the country; Sichuan province with 339 200 tonnes ranked second; Hubei province with 256 600 tonnes ranked third; Jiangsu Province with 197 900 tonnes ranked fourth.



Fourth, we have seen noticeable benefits to the ecological economy from integrated paddy field aquaculture – We regard it as the new way to promote agricultural efficiency and increase farmers' incomes. The integrated cultivation of rice fields has increased productivity by tapping into resource potential and improving the productivity of paddy fields, thus increasing farmers' motivation. Liaoning Province, Panjin City has realised RMB 870 to 1 220 per mu of 'rice-crab symbiosis'. Crab farming has seen incomes increase by RMB 580 to 720 per mu. It has been possible to reduce fertilizer and pesticide consumption in paddy field aquaculture, which has reduced costs by RMB 50 to 60 per mu; rice purchase orders have increased output value by RMB 240 to 500 per mu.

Panjin's crab farming has become the main driving force for 'rice-crab-symbiosis' in northeastern and northwestern areas. In Panjin City, the system has a water surface circulation area of 45 acres, accounting for 60 percent of paddy fields. Crab farmers in Panjin have undertaken water surface crab farming on more than a million mu in the provinces of Jilin, Heilongjiang, Ningxia and the autonomous regions of Inner Mongolia, and Xinjiang Uygur. In 2015, in Bao Di District in Tianjin, Huanxi 'rice-crab symbiosis' Cooperatives and Hong Teng Aquatic Products Technology Development Co., Ltd. rice were certified by organic institutions. Rice prices have more than doubled compared to the local market. In Guangdong, paddy fields, fish in Liannan County fetch RMB 35 to 40/kg, which is 5 to 6 times more than that for pond carps. Agricultural products grown in rice fields are eco and environmental-friendly. They can attract new consumers, boost efficiency and increase the income of farmers. In Liannan County, a 'rice-crab symbiosis' demonstration park covers two towns and five villages, covering an area of 3 005 mu, benefiting nearly 3 000 households. This park has helped lift nearly 20 000 farmers out of poverty. Farmers called this symbiosis 'the Four 'Small' Projects', namely small granary, small bank, small reservoir, and small fertilizer plant.

In Yuanyang County, Yunnan Province, the intergrowth of rice-fish-duck in Hani terraced fields supports Haney villagers. Industrial progress helps protect the terraces and the traditional cultural landscape, enabling this world cultural heritage to survive in a living form. The 'rice-fish symbiosis' (shrimp, crab, loach, etc.) has a positive affects on weed, pest and disease control. Fish faeces fertilizes the soil, which is loosened by the fish, the temperature is increased along with oxygen, soil aeration and root vigour (Hong, 2017). In these fields, rice is harvested with taller spikes, more granules and full seeds. Environmentally friendly agricultural technology can greatly reduce the use of chemical fertilizers and pesticides, controlling agricultural source pollution. By doing so, costs can be reduced, quality improved and soil and water ecology maintained. Fertile rice fields and good rural ecology are important for leisure related to agriculture and rural tourism, and the introduction of new consumption patterns brings higher market value to the integrative cultivation of rice fields.

Overall, the integrative model of paddy field aquaculture conforms to the general requirements of modern eco-agriculture development. It is an important entry point for establishing ecological and green brands, and is also an important part of industrial integration in rural areas.



LOCAL PRACTICES AND EXPERIENCE

In addition to national-level policies, local governments have introduced supportive policies based on the local conditions. These policies, in general, cover the following:

First, strengthening promotion of paddy field aquaculture techniques – Skills and techniques that are used in paddy field aquaculture, such as paddy field engineering, variety selection, breeding management, disease control, fishing, as well as certification and branding of rice products, are transferred and promoted mainly through training, brochure, experts and technicians.

For instance, within the last three years, Fujian Province has organized 53 training courses on rice-aquaculture farming, with a total of 3 180 attendances.

According to the 'Six One Millions' project, one of whose aims is to develop one million *mu* of paddy-fish or lotus-fish farming fields, southeast Qian County, Guizhou Province, has built ditches, raised and strengthened ridges, set up independent water systems and standardised larvae size and quantity to build model fields that simultaneously cultivate lotus and fish or rice and fish/loach/shrimp/crab or rice or fish and duck. Such practices have substantially improved the productivity of local paddy fields.

Another example involves the Xing'an League of Inner Mongolia. Since 2009, local aquatic workstations have been offering free larvae and organizing annual technical training for farmers. Larvae are provided directly to the farmlands. Workers at the workstations have visited villages and towns to organize training and give technical instructions during production. They have also established communication platforms and have been assisting farmers on a regular basis.

According to the authors' survey, 62 percent of farmers were trained in related techniques and skills by the government technical department, 8 percent by other farmers, 19 percent became skilled on their own, and 11 percent by other means (aquatic stations, company's innovation projects, technical staff or study tour). The result indicates that the government has played a pivotal role in spreading and promoting paddy field aquaculture techniques.

Second, increasing financial support – For example, in order to promote crab culture in Panjin City, Liaoning Province, the City provides special support to projects that aim to improve crab larvae quality, set up demonstration areas, and promote brand-building strategies. The city also offers favourable financial, tax and credit policies to motivate farmers' and help local producers build brands. At the same time, the city rewards export companies, large crab sellers, model farmer households and outstanding instructors; it supplies crab larvae, crab feed, medicine and machines (rice transplanters); and waives tax on agricultural specialty products, utility fees, irrigation worker fees and voluntary labour service fees. The city advertises its natural large crabs, trademarks and brand image while strengthening the management and protection of its geographical indications and collective trademarks. A number of crab product brands are now influential within the province or nationwide.

Anhui Provincial Agricultural Commission has been executing a promotion plan that sets the goal of having one million *mu* of paddy fields and increasing yield by 1 000 *jin*¹/*mu* and

¹ 1 kg = 2 jin



RMB 1 000/*mu* of income. With the adjustment of a fuel subsidy fund for fishing boats, used in the past, the province has been building modern fishing infrastructure and providing financial support (RMB 500 per *mu*) to households with more than 100 *mu* of paddy fields. Anhui province is now integrating funds from several agricultural projects to develop paddy field aquaculture.

Ningxia Hui Autonomous Region has introduced supportive policies for rice-crab farming. The province assigned a special fund of RMB 200 million to assist large crab farming households, leading enterprises and cooperative organizations.

Third, strengthening the regulative and guiding role of the government – Take Panjin City, Liaoning Province for example. The City has established five separate systems that assign tasks respectively to Mayors, County/District Chiefs, Township Magistrates, Village Chiefs and Directors of the Fishery Bureau. Under the systems, officials are guided and coordinated by the city government every year. In cities, counties (districts) and townships, there are crab-farming panels that guide the construction of the pilot, demonstration and experimental fields. Counties (districts) have incorporated the development of the crab farming industry into their rural economic development plans. To achieve the goal, specific tasks are assigned to townships and are linked to the annual evaluation of the heads of local governments; thus motivating local governments to develop the crab farming industry.

Fourth, promoting the establishment of larvae breeding stations – In Hunan Province, the establishment of local fish breeding is encouraged. In 2014, the Hangxi Special Aquaculture Hatchery built the Zixing Rice Flower Fish Breeding Station on 20 *mu*. The station now supplies 5 million rice flower fish every year to the entire city.

In Hebei Province, the 2006 Qianjiang Provincial Rice-Crawfish Culture Conference inspired the development of paddy field aquaculture. Within the last ten years, the provincial government has held several meetings and arranged a specialty fund to support crawfish breeding, promotion of technique, R&D projects and selective breeding centres.

Fifth, promoting normalisation, scaling up and industrialisation – In 2013, within the project of ‘stabilising crop yield and increasing income through fishery’, Zhejiang Province set up more than 25 demonstration counties with 200 000 *mu* of paddy fields and more than 60 standardised new types of rice-fish farming demonstration sites. As a result of the demonstration counties, the province now holds 400 thousand *mu* of rice-fish farming fields. The province has also standardised techniques for rice-turtle farming and has unified the production process to ensure every *mu* of field can yield a hundred *jin* of fish, a thousand *jin* of rice and raise RMB 10 000 of income. The province has also created five product brands for quality rice.

In 2016, Jiangsu Province made use of RMB 10 million from the High Yield Specialty Fund to support 10 pilot counties in rice-fish farming. Every pilot county set up two concentrated areas, each comprising more than 200 *mu* of rice-fish farming demonstration fields. As for non-pilot cities and counties, demonstration fields were established in coordination with eco-farming and high yield projects. Jiangsu Provincial Agriculture Commission, together with Jiangsu Provincial Oceanic and Fishery Bureau, set up a rice-fish farming panel to spread agricultural techniques and guide farmers to better management of planting and breeding, improving their products’ marketability, and scaling up and industrialising their production.



In Guangdong, supported by the Fishery Demonstration Park project initiated by the Guangdong Provincial Ocean and Fishery Bureau, Liannan County a 3 005 *mu* demonstration park is up and running. More than 30 000 m of field ridges have been raised and strengthened. About 50 *mu* of fish breeding demonstration sites have been built or transformed. The average unit yield in the transformed demonstration parks is now 30 to 40 kg, an increase of 20 *jin*, and the output value per *mu* is now RMB 1 800 to 2 400.

Sixth, propelling the development of recreational fishing and ecological breeding and planting while promoting the integration of the three economic sectors – For example, Guangdong Province has introduced a number of policies that encourage rice-fish culture, which have successfully promoted the integration of the rice-fish farming system and organic rice farming. The rice and fish produced in the system are of better quality and greater competitiveness in the market. At the same time, the Province has integrated tourism into the rice-fish farming industry. The initiative of farmhouse tours has injected new blood and brought added value to traditional rice-fish farming. In Liannan County, the new mode of ‘tourism plus rice-fish farming’ has driven the development of both industries. The County has held a Rice-Fish Festival for three consecutive years. During the festival, people can go fishing and grill the fish they catch. The festival has attracted the media and tourists from Guangdong Province. From 2014 to 2016, the festival was reported by CCTV 7 ‘Xiangtu’ program, CCTV Qingyuan, Ocean and Fishery magazine, Yangcheng Evening News, the Southern Daily, QYBTv and other media in the form of publications, WeChat articles and television documentaries. Now, fish raised in the rice fields of Liannan have become an eco-aquatic brand and its name is known in thousands of households.



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PROBLEMS

Though China's history of paddy field aquaculture can be traced back to 400 BCE, such farming systems only existed in remote mountainous areas as a low-skill and less-productive production activity. After the reform and opening up, in order to increase fish supply, the Chinese Government encouraged paddy field aquaculture. Rice-fish farming fields covered 836.6 million *mu* in 1984; however, because of the popularisation of intensive pond aquaculture and the limited unit yield of rice-fish farming, its development was rather slow. In recent years, because of the new types of agricultural resources and changes in the consumer market, paddy field aquaculture has begun to prosper. Nevertheless, there are still some prominent problems waiting to be solved.

Unstable area for paddy field aquaculture

Influenced by economic or geographic environments, several regions are now witnessing shrinkage of the area for paddy field aquaculture. For economic reasons, a number of areas have been requisitioned as urban or rural construction land, among which 81 percent were once used as paddy fields or other types of arable land. Such practices have constrained the development of paddy-aquaculture farming. Take Jingxi rice for example, because of the decrease in paddy fields in Beijing, Jingxi rice is hardly ever planted but is stored in archive. Regions like Gansu have to reduce paddy fields because of the arid climate. In Gansu, the cultivation of water-hogging crops has been discouraged, in order to protect the discharge from the Heihe river, resulting in a huge loss of paddy fields along the river's upstream reaches, where only a small amount of land is used for paddy field aquaculture.

Lack of knowledge

First, China's traditional paddy field aquaculture is dominated by rice-fish (carp species) farming. Compared with intensive pond culture, the unit yield is no more than 100 *jīn* and is thereby less efficient. Therefore, rice-fish culture is described as a low-return activity. Second, traditional rice-fish farming is usually extensive; thus, technical personnel often regard it as a low-productive way of farming. Third, farmers are still content with being self-sufficient. Fourth, in some regions, rice-fish farming is believed to be the cause of non-point source pollution and greenhouse gas emissions. Fifth, because paddy field aquaculture is carried out in paddy fields, a considerable number of fishery technicians take it for granted that the development of the industry should fall under the responsibility of the farming sector. As a result, they lack the knowledge and understanding of paddy field aquaculture and lack the knowledge of the technical needs and challenges. Technical support is unable to match the needs as the methods of paddy field aquaculture have diversified.



Insufficient funds and infrastructure

The survey shows that if the costs of land contracting and seedlings are set aside, the average cost to farmer households for ditch construction is RMB 1 095 000. Ditch construction is costly in terms of field engineering, as ditches require annual maintenance and repair, raising the threshold of paddy field aquaculture. Farmers, however, show a strong demand for infrastructure. A total of 46, 28 and 23 percent of farmer households complain about ponds, roads and electricity, respectively. Fish protection infrastructure is not in place since the survey has also shown the gaps in fish protection such as from mice and birds and to prevent fish escaping.

Well-functioning infrastructure is often necessary for paddy field aquaculture. It, however, requires the cooperation of farmer households and government support because the costs cannot be borne by a single household. In this survey, the costs of land contracting, fertilizers, feed, seed, seedlings, labour, and machines takes up a large portion of total production costs, demonstrating the high inputs in the early phase of paddy field aquaculture. Government support for paddy field aquaculture, however, is rather limited and government-led demonstration and outreach initiatives need to be reinforced.

Insufficient technology extension and undersupply of new breeds

There is insufficient technology extension and supply of improved varieties. On the question as to whether new varieties are needed, 64.2 percent of participants select yes, but believe improved new breeds that yield well, and are disease resistant, fast growing and suited for local conditions are needed, including rice, crayfish, river crabs, loach and carp. But surveys show that traditional local varieties are often used in paddy field aquaculture, where purification and rejuvenation are lagging behind.

On the question as to whether training is needed, 96.2 percent of respondents said yes. When asked what training is needed, the frequently chosen options are seed breeding, breed improvement, scientific feeding, pest control, ditch design and renovation, water quality improvement and aquaculture management technologies. Apart from this, most farmers need to find markets on their own without a guarantee because they do not possess the technologies for paddy field fishing and control of drug use.

Regarding what information or services are required, 67.5 percent of respondents tick two, three or four options for market price information, technology training, on-site guidance and pest control. This demonstrates that technologies, training, and services should be in place so as to extend the economic model for paddy field aquaculture since the outreach of farming technology and improved breeds cannot meet the fundamental requirements for the development of paddy field aquaculture.



Small-scale and non-organized farmer households

A total of 15, 7, 15, 11, 15, 18 and 20 percent of participants possess average rice growing areas of under 10, 11-20, 21-50, 51-100, 101-200, 201-500, and over 500 *mu*, respectively. The median for land transfer is 120.5 *mu* and an average of 502.6 *mu* land is transferred. This shows that large-scale households make up a large portion of all respondents, which may be because of the choice of samples and industrialised operation of paddy field aquaculture (12 enterprises among the participants represent 7.55 percent of all samples). The survey shows that 87.5 percent of farmers were not members of cooperatives or associations because such organizations do not exist in their communities. Only five households attend, and 15 did not attend, although such organizations exist. Small-scale and a low level of organization mean that farming resources are scattered, making it difficult to foster synergy in production and marketing, which hinders regional development, standard-based production, industrialised operation and social services.

Brand establishment and industrialised operation

Apart from the low level of organization and small-scale, practitioners' lack of operational ability also impedes the industrialised development of rice field aquaculture. The average age of respondents is 47. The respondents have worked in rice farming for 17 years on average, and in rice field aquaculture for 6 years on average. Half have achieved senior high school education, 25 percent have gone to college for professional training. They tend to accept the new knowledge, information and technology. The survey shows that apart from enterprises and certain cooperatives operating as companies, the unit price of rice in paddy field aquaculture does not reflect its high added value featuring eco-friendliness. The unit price of rice in most regions is just slightly higher than for ordinary rice.

Today, no standard-based system for rice field aquaculture is in place. Many farmers have recognised the value of their rice and aquatic products but cannot raise prices because of immature mechanisms and obstructed distribution channel.

SEIZING THE OPPORTUNITY TO STRENGTHEN INFRASTRUCTURE AND PROVIDE PUBLIC SERVICES

Rice field aquaculture farming integrates rice farming with aquaculture by drawing upon the symbiosis between rice and aquatic animals. Rice farming and rural economic activities reinforce each other to form a new and multi-dimensional ecological system and improve the circulation of materials and energy transformation. The development of this model has bright prospects because it will facilitate double harvests of rice and aquaculture farming, enrich farmers and rural areas and improve the rural environment. The model also witnesses market potential as it serves people's demand to upgrade their diets and consumption, and develop the concept of ecological safety.



The 2016 No. 1 Central Document of the Central Committee of the Communist Party of China (CCCPC) and the State Council indicate that it is essential to advance the modernisation of agricultural, and establish a modern agricultural industrial, production and operational system. The focus will be shifted to land farming and technology development to promote the integrated development of food, cash crops and feed, agriculture, forestry, animal husbandry and fishery, cropping, livestock farming and processing, and primary, secondary and tertiary industries. It is sought to turn agriculture into a promising industry.

Rice field aquaculture is a multi-dimensional ecological farming pattern that is favourable to the sustainable development of agriculture, integration of the three industries, and improvement of the rural environment. The key to unleashing the potential of this model lies in scaled production and operation, encouragement of moderately sized operations and the cultivation of new business entities. Against such a backdrop, the present thesis suggests the following:

First, seizing the opportunity to build standard bases of larvae and paddy field aquaculture – Improving the infrastructure of paddy field aquaculture includes standardised facilities such as field roads and the upgrading of the power grid. Special funds should be set up to support the construction of infrastructure, with subsidies for larvae and the purchase of machinery. The application and administration of approval procedures should be simplified to facilitate farmers' access to financial support. Poor and under-developed regions should be assisted in building demonstration parks and larvae bases founded on local conditions in order to leverage the role of demonstration and outreach for paddy field aquaculture farming.

Second, providing technology services and training for community-level technology outreach personnel – Support should be given to technology extension personnel at community-level aquaculture stations, such as raising the ceiling of expenses and providing professional training. Technology and information should be integrated to encourage and guide research at universities and research institutes on breeds and techniques used in paddy field aquaculture farming. Standard-based systems should be established and improved to provide system and technological support for product verification. A technology and experience-sharing platform should be created to promote exchange and teaching of aquaculture techniques, drug use and larvae, etc.

Third, encouraging the development of professional cooperatives and family fishing grounds or farms – The participation of new types of agricultural businesses will help overcome weaknesses in the scale and specialisation of paddy field aquaculture and improve the application of technology and extension and strengthening of infrastructure. Currently the southwest and poor mountain areas show the greatest demand for paddy field aquaculture, where farmers have little awareness of organization. Training for professional cooperatives and family farms, therefore, should be provided along with technology assistance, with a view to enhancing trainees' abilities in operation and management.

Fourth, creating regional brands, developing leisure fisheries and raising added value of paddy field aquaculture – Specialty brands should be increasingly nurtured and publicised to improve public acknowledgement and influence of those brands. Social capital should be attracted into rural investment and leisure fisheries and unused resources in paddy field aquaculture should be activated for job creation and development of related industries in the communities.



Fifth, ensuring continuous study – Low profits, climate and rise in temperature are crucial for the habitual choice of paddy rice aquaculture in different regions. Currently, single-cropping rice growers are the majority of paddy field aquaculture farmers, and account for 89 percent of all rice farmers in this survey. Paddy field aquaculture has mushroomed since the beginning of the new century and 61.3 percent of respondents started their farming activities after 2001.

When asked about the preferences of paddy field aquaculture in the neighbourhood, 96 percent of farmers prefer to develop aquaculture in their rice fields. This reflects that this model appeals to ordinary rice growers. It also indicates that farmers choose a comprehensive model on their own initiative when profits of either cropping or aquaculture lower in order to increase unit yield. This is a result of market choices and rational decisions made by farmers.

This is the reason why the relevant agencies should follow market rules and create enabling conditions and provide sound services to keep up with this trend. It is necessary to stress that over the past few years freshwater fish prices have been volatile, but paddy field aquaculture shows a strong momentum, which suggests that China's aquaculture is entering a significant period of transformation and restructuring of the development model. Infrastructure and public services, therefore, need to be strengthened whether from the viewpoint of fisheries' authorities or paddy field aquaculture. Meanwhile, quality, safety, moderate scale and the market should be prioritised in our work, which calls for the continued study and investment in the industrial development of fisheries authorities.



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12

COMPARATIVE ANALYSIS OF THE POLICY FRAMEWORKS IN PLACE IN CAMBODIA, LAOS, MYANMAR AND VIET NAM IN REGARDS TO SUPPORT TO AGROECOLOGY

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Abstract

This article builds upon four national studies conducted between October 2015 and February 2016 in the Kingdom of Cambodia, the Lao People's Democratic Republic, the Republic of the Union of Myanmar and Viet Nam and maps the agroecology stakeholders and

reviews the national agriculture policy frameworks. An analysis is provided of the general trend across these countries and, more broadly across the Mekong Region, for policies supporting agroecology and recommendations for moving towards an agroecological transition.

INTRODUCTION¹

As a polysemic concept, agroecology is understood in many different ways according to one's background and experience. It can imply a scientific discipline, an agricultural practice, or a social or political movement (Wezel *et al.*, 2009). Though agroecology initially dealt primarily with aspects of crop production and protection, in recent decades new dimensions are becoming relevant such as environmental, social, economic, ethical and development issues (Wezel *et al.*, 2009). Agroecology is an applied science, adapting ecological concepts and principles to the design and management of sustainable agroecosystems and providing a framework to assess the performance of agroecosystems (Altieri, 2002).

When fully developed, agroecology does more than inform the selection and use of alternative practices; it helps farmers fashion and maintain agroecosystems that have minimal dependence on expensive chemical and energy inputs. Agricultural systems are supported by interactions and synergies between and among biological components that enable these systems to sponsor their own soil fertility, productivity enhancement and crop protection (Altieri, 2002).

Relying on four national studies² that mapped agroecology stakeholders and reviewed agriculture policy framework in the Kingdom of Cambodia, Lao People's Democratic Republic, the Republic of the Union of Myanmar and Viet Nam, this article provides an analysis of the general trend across these four countries and, more broadly, across the Mekong³ Region involving policies in support of agroecology.

¹ This analysis has been carried out in the framework of the Agroecology Learning Alliance in Southeast Asia (ALiSEA, <https://ali-sea.org>), a regional platform coordinated by GRET and aiming at networking all initiatives supporting the agroecology movement in the Mekong Region as well as feeding public policies and supporting wider dissemination of successful alternative agricultural practices.

² The full country report can be accessed at the ALiSEA online library (<https://ali-sea.org/online-library/>)

³ The article mostly refers to the Mekong Region while relying on data from the four studied countries (the Kingdom of Cambodia, the Lao People's Democratic Republic, the Republic of the Union of Myanmar and Viet Nam).



The policy review focuses specifically on the agriculture development policy framework at the country or subcountry level, mostly on national plans, existing laws, decrees and regulations. It addresses the promotion or support of the six most commonly found set of agroecological practices (System of rice Intensification (SRI); conservation agriculture (CA); integrated pest management (IPM); integrated farming/VAC (Vuon-Ao-Chuong meaning garden-pond-pigpen); agroforestry and organic agriculture); support to small-scale farming; food security; sustainable agriculture; preservation of biodiversity; development of rural/agricultural tourism; support to climate friendly agriculture/climate-smart agriculture; green growth and the promotion of marks of quality such as geographic indications (GI); organic certification, participatory guaranty system (PGS) and good agriculture practices (GAP).

COMPARATIVE ANALYSIS

From subsistence and agroecologically based farming to Green Revolution led agriculture policies

Farmers in the Mekong Region have historically practiced subsistence-based integrated farming, which combines crops, livestock and trees in a complex landscape mosaic. Paddy rice grown in the lowlands and upland rice produced as part of long-term rotational agriculture have long been the main staple food throughout Southeast Asia. Agricultural practices rely on strong ecological knowledge that has been built up over many generations by subsistence farmers. Shifting cultivation systems involving an integrated fallow period for restoring soil nutrients, home gardens characterised by high biodiversity, the practice of agroforestry based on nitrogen-fixing trees are all based on agroecology principles. However, shifting cultivation, once widely practiced by upland farmers throughout the region, has largely vanished as a result of increased population pressure, combined with government policies that convert temporary land use to permanent (Castella *et al.*, 2015).

Over the past decades, the main objective of agricultural policies in the region has been to increase production and productivity, in order to improve food security and autonomy in the context of population growth, but also, more recently, to increase exports to the world market. As a result, all countries in the Mekong Region have engaged in a process of ‘modernisation’ of agriculture by applying the agricultural practices of the Green Revolution: monocropping, hybrid seeds and the intensive use of chemical inputs (Castella *et al.*, 2015).

This has been especially the case for Viet Nam, as soon as it opened to the outside world in 1986, following the Doi Moi Policy. Agriculture has been restructured with crop diversification, increased production of cash crops (vegetables and fruit crops), development of international trade in agricultural inputs and products, and the increasing application of agrochemical inputs. Directed by commercial demand, more monocrop systems have been promoted with increased intensification of land and water use (Pham Van Hoi and Ngo The An, 2016). The Doi Moi Policy has contributed to the expansion of rice production by improving the efficiency of marketing sectors and strengthening individual land use rights and the autonomy of farm management (Tran Thi Ut and Kei Kajisa, 2006). Impacts on the environment (deforestation, contaminations,



loss of biodiversity, etc.), on long-term sustainability (soil fertility, water resources, etc.) and human health were not really taken into account. Green Revolution practices have been prioritised by Governments and promoted through public policies (Pham Van Hoi and Ngo The An, 2016).

A late shift towards sustainable agriculture and agroecology

In the 2000s, 'modern agroecology' initiatives (combining traditional know how, agriculture practices and scientific knowledge) in the Mekong countries were largely pushed by national and international non-governmental organizations (NGO) as part of a global movement that spread across the region (Castella *et al.*, 2015). This counter-movement to the global trend of agricultural intensification promotes more sustainable land uses, production of healthier food, and conservation of traditional knowledge and practices. More recently, these practices have been valorised as part of 'climate smart' agricultural strategies.

At the same time, and specifically over the past 10 years (to the notable exception of the Kingdom of Thailand where the alternative agriculture network started in the 1970s), the issue of sustainability has been climbing up in the political agenda and agroecological principles have been progressively included in public policies in the four countries, to varying degrees and at differing paces according to the country.

When observing policies that have been implemented in the four countries, it appears that Viet Nam first initiated a movement towards the more agroecological. Directed by significant commercial demands, early on Viet Nam strongly developed monocrop systems with increased intensification of land and water use (i.e. through a higher cropping index), with more forestlands converted into agricultural production, together with increased illegal logging and other forest by-product harvests for sale. These brought Viet Nam to a state of serious environmental pollution and resource degradation, with serious impact on people health and welfare⁴. This may have led the Vietnamese government to realise the negative consequences of Green Revolution practices.

After privatisation of agricultural production, which was officially endorsed by the central government with its Open-door Policy (Doi Moi) of 1986, the government stopped subsidising supplies of chemical inputs. This marked a shift to private pesticide imports, formulation, distribution and use in Viet Nam (Pham Van Hoi *et al.*, 2013). The Vietnamese Government began to adopt agroecological policies in the early 1990s through the implementation of the Vietnamese national integrated pest management (IPM) programme by the Plant Protection Department (Ministry of Agriculture and Rural Development), with the support of the Food and Agriculture Organization of the United Nations (FAO). However, despite many activities being promoted that were related to IPM in the 1990s and 2000s such as farmer field schools (FFS), the '3 Reductions', the '1 Must and 5 Reductions' or the '4 Rights', IPM was only officially

⁴ Pesticides take up a major place among the food safety issues in Viet Nam. For instance, 81 percent of consumers interviewed in Hanoi mentioned concerns about food risk associated with pesticide use on vegetables (Figuíé, 2003)



institutionalised at the central level in 2013 under the Law on Plants Protection and Quarantine (Pham Van Hoi and Ngo The An, 2016).

On the contrary, in Myanmar, although the policy of subsidising supplies of chemical inputs to farmers and purchasing the produce at fixed prices (quotas policy) practiced during the socialist period was stopped, encouragement of the use of chemicals for increasing production was practiced until the early 2010s, when the country began to open up to the world (San Thein and Aung Thin, 2016). Myanmar, therefore, has just started revising its policy framework. As can be noted, many reforms have been passed over the years and one might anticipate that Myanmar could quickly catch up with neighbouring countries.

Thus, several reasons can be identified to explain this shift towards more sustainable agriculture practices:

- » A growing awareness of policy-makers regarding the negative impacts of this agricultural model on the environment and human health, but also its 'limits'. Indeed, the degradation of soil fertility and the potential of ecosystems has been generating yield decreases (or at least lower increases or stagnation), higher costs for inputs and increased vulnerability to climate variations.
- » A combined influence of international organizations (specifically the FAO, which has promoted large-scale integrated pest management programmes), research centres (the Agricultural Research Centre for International Development [CIRAD] for conservation agriculture and the World Agroforestry Centre [ICRAF] for agroforestry), financial partners, civil society organizations and the private sector (especially for organic agriculture in Cambodia and Laos), have been disseminating agroecological principles, often reinforced by the results of existing experimentation or pilot projects and programmes and through a better appreciation of traditional knowledge and agroecological traditional practices.
- » Increasing impacts of climate change leading primarily to a need for adaptation (a priority for countries in the Mekong Region), combined with international negotiations that address the issue of mitigation.
- » Growing opportunities on the world market for safe and organic products, mostly driven by the private sector.
- » Consumers' growing concern about the safety of agriculture products, which has led to increasing pressure on governments to change public policies (for example Viet Nam).

Different levels of agroecology inclusion in public policies across the region

Analysing the policy framework evolution in the four countries over the past decades, the authors of this article identified four different levels of inclusion for agroecology in public policies.

The **first level of inclusion** is when sustainable agriculture principles are part of the governments' framework documents such as national strategies and policies together with the laws and regulations developed.

This demonstrates a certain awareness of the government of the negative impacts and limitations of the conventional agriculture model that they have been promoting for years.



These documents show the government's willingness to promote more sustainable agriculture particularly in Cambodia (Agricultural Strategic Development Plan (ASDP) 2014-2018) and Lao PDR (Decision of the Minister of Agriculture and Forestry on Organic Agriculture Standards in Laos, September 2011).

The **second level of inclusion** is when agroecological experimentation, pilot projects, or projects and programmes have been implemented in specific territories (not for the entire country or for all farmers).

Such initiatives are mostly led by, or with the full participation of, public institutions with technical and financial support from international institutions and donors. These types of projects and programmes have been implemented in the four countries, for example the Project to Support Agricultural Development in Cambodia (PADAC) on conservation agriculture supported by CIRAD and the French Government or Integrated Pest Management (IPM) supported by the FAO in Myanmar, Cambodia and Viet Nam. As part of this latter, over two million rice farmers in Asia and Southeast Asia participated in rice IPM farmer field schools (FFS) between early 1990, when the first FFS was conducted in Indonesia, and the end of 1999. During those ten years, farmers and field workers for agriculture extension, plant protection and NGOs learned to facilitate the FFS approach and conducted over 75 000 FFSs (Pontius *et al.*, 2002). These projects and programmes contributed to the increasing awareness of the need for policies supporting sustainable agriculture.

The **third level of inclusion** is when governments have effectively integrated agroecological principles into a few specific policies and regulations to address issues of sustainability.

Many policies are relatively favourable to agroecological principles in the different countries. For example, in Myanmar, the fertilizer laws⁵ are noted to be friendly to agroecology principles. In Cambodia, specific policies concerning systems of rice intensification (SRI) can be found⁶, while in Viet Nam policies supporting VAC⁷ promotion⁸ and IPM were institutionalised in 2013. In Laos, several laws, decrees and regulations have been adopted in support of such policies, e.g. the law on agriculture, forestry law, land law, the decision of the Ministry of Agriculture and Forestry (MAF) on Organic Agriculture Standards, the regulation to control pesticides. In some cases, however, there are setbacks; for example, in Cambodia, IPM was a priority during the 2006-2013 period, but no longer from 2014 to 2018.

⁵ Fertilizer Law, October, 2002 (SPDC Law No. 7/2002) and Fertilizer Law Amended, March 2015 (The Pyidaungsu Hluttaw Law No. 15/2015).

⁶ Ministry of Agriculture, Forestry and Fisheries (MAFF) officially endorsed SRI in 2005, and subsequently SRI was included in the MAFF's Agricultural Strategic Development Plan (ASDP 2006-2010), in the National Strategic Development Plan (NSDP 2006-2010) and in the Strategic Framework for Food Security and Nutrition in Cambodia (2008-2012). In January 2005, the SRI Secretariat was established and hosted at the Department of Agronomy and Agricultural Land Improvement (now GDA) of MAFF.

⁷ Integrated farming system in Viet Nam: Vuon = garden, Ao = pond, and Chuong = pigpen.

⁸ Decision 31-BT: Establishment of Viet Nam Gardening Association, 2/1986, Promoting VAC practices for household income and nutrition improvement, poverty reduction which contribute to sustainable agriculture development.



In such a context, public or private certification is found to be recognised and promoted by the government, especially for organic agriculture and good agriculture practices, which is the case for organic agriculture in Laos. Although there are no regulations for organic agriculture in Viet Nam, the government acknowledges and supports the participatory guarantee system (PGS) process that certifies organic products.

In many cases, there is limited implementation and these policies have little impact. For example, in Laos it is noted that the government's policies, strategies, laws and regulations regarding the agriculture sector and agroecology were not well disseminated, implemented and enforced at both the central and local levels (Manivong, 2016). In Viet Nam, despite strong government support to VietGAP⁹ (although, one could argue whether VietGAP is really part of agroecology) only 0.4 percent of the vegetable area is currently GAP certified (MARD, 2015).

The **final level of inclusion** is when the government supports and enforces policies that aim to fully mainstream agroecological principles, by disseminating these principles to all farmers and effectively integrating them into all policy measures. Currently, none of the countries in the Region are implementing such a policy.

However, it is worth mentioning that, in some cases, there is more engagement at the subnational level than at the national level. For instance, in Viet Nam, there are no legal documents at the national level concerning SRI, but there are in several provinces. For example, the Decision 2745/QĐ-UBND (Approval of project: Agriculture development applying advanced technology in Thanh Hoa Province until 2020), 8/2012, which supports application of SRI on a large production area to achieve 30 000 ha of high-quality rice production.

Several common hindrances to promoting agroecology across the Mekong Region

Despite clear changes in agricultural policies, mainstreaming agroecology is constrained by the fact that conventional intensification practices, based on the intensive use of chemical fertilizers and pesticides and specialisation, are still considered to be the best way to increase production and exports (especially in Myanmar, Laos and Viet Nam). For example, this can be observed in the different policies adopted at the Association of Southeast Asian Nations, (ASEAN) level, which do not take agroenvironmental or socio-economic challenges seriously enough (Nelles, 2017).

The recently launched ASEAN Economic Community (AEC) includes food, agriculture and forestry as 'priority integration sectors' (ASEAN Secretariat, January 2008), yet agroecological approaches, and more specifically organic agriculture, remain weakly promoted in *ASEAN's Integrated Food Security (AIFS) Framework and Strategic Plan of Action (SPA-FS) 2015-2020* (Nelles *et al.*, 2014; Nelles, 2017).

⁹ The Ministry of Agriculture and Rural Development (MARD) issued Decision No. 379/QĐ-BNN-KHCN on the 28 January 2008, that established Vietnamese Good Agricultural Practices (in short: VietGAP) as the main standards and guidelines for production of safe fruit and vegetables.



There may be a conflict of interest between the two different policies, for example in Laos or in Cambodia, while the national and agriculture development strategy includes the promotion of agroecological practices, the foreign investment law (Manivong, 2016) and State Land Lease and concessions decree (Ly and Sar, 2016) promote industrial crops such as rubber on extensive community land where agroecological practices are applied.

In addition, there is little regulation or control of chemical pesticides. Agrochemical companies' intensive advertising campaigns can be seen on television and in public and private news journals and magazines; it is difficult to avoid prohibited pesticides that are illegally imported and sold to farmers at a low price (Pham Van Hoi, 2013; San Thein and Aung Tin, 2016).

Finally, there is the issue of effective coordination and cooperation between ministries in different sectors because of the way government departments are structured.



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Some recommendations for moving forward

Public awareness and support for capacity-building are essential. One important priority should be the introduction and integration of agroecological principles and concepts into the basic educational system. The pertinent curriculum should be integrated into technical vocational education and training (TVET) and at universities, technical colleges and relevant research programmes. The approach to national extension should be reviewed so that there is real support for the shift from Green Revolution to agroecological practices.

Since there is a growing concern about the safety of agriculture products, especially in Viet Nam, Laos and Cambodia, consumers are becoming increasingly involved in expressing their views about public policies (safer food versus more food), which could also help speed this transition.

At the regional level, more emphasis could be placed on the 'green economy' and on the market opportunities offered by organic products, for example the ASEAN Economic Community alone represents a common market of 620 million people. Promotion of agroecological principles in agriculture policies requires better coordination and a regional approach for the entire agricultural sector (ASEAN level support) so that the public and private sectors could unite to promote one clear vision and goal.

CONCLUSION

Since the beginning of the twenty-first century agricultural policies in the region have been increasingly integrating a few agroecological principles. However, to a large extent, mainly public policies and regulations are still promoting Green Revolution agriculture, which is based on monocropping, hybrid seeds and the intensive use of chemical fertilizers and inputs, despite the limits to sustainability and the negative impacts on the environment and human health. Fully mainstreaming agroecological principles into agriculture policies would imply the removal of all the policies and regulations that are inconsistent with such principles, so as to plan the agroecological transition for the entire agricultural sector and to refocus the various political measures and regulations on this goal.



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FAO'S REGIONAL RICE INITIATIVE: LANDSCAPE MANAGEMENT APPROACHES FOR SUSTAINABLE INTENSIFICATION AND DIVERSIFICATION OF RICE-BASED FARMING SYSTEMS IN ASIA

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Abstract

The Food and Agriculture Organization of the United Nations (FAO) estimates that farmers will have to produce nearly twice as much food as they do today to feed the 9.2 billion global population by 2050. The challenge will be for farmers to sustainably intensify agricultural production by producing “more with less” while adapting to a changing climate. In Asia, FAO is promoting the concept and good practices associated with sustainable intensification of rice production within the context of its Regional Rice Initiative (RRI). Pilot activities involving thousands of rice farmers in the Republic of Indonesia, the Lao People’s Democratic Republic (PDR) and the Republic of the Philippines – including farmer training by means of innovative Farmer Field Schools on *Save and Grow* for Sustainable Intensification of Rice Production (SIRP). The success of

the training is demonstrated by the significant increase in resource-use efficiencies, land productivity and net incomes achieved by farmers who have adopted SIRP practices while diversifying their farming systems and making optimal use of the multiple goods and services provided by Asian rice production ecosystems and landscapes. This paper outlines the RRI implementation progress and results to date and argues the case for increased policy support and investments for up-scaling of resource use efficiency and agroecology-based literacy training involving smallholder farmers so as to formulate agricultural landscapes that are more resilient and climate-smart. This will be essential for the responsible and environmentally sound management of rice-based landscapes and to ensure food security and nutrition for present and future rural and urban generations in Asia.

INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) estimates that the global population will reach about 9.2 billion by 2050; nearly all the increase in population will be in developing countries where about 795 million people remain undernourished. Urbanisation, is at 49 percent today, is expected to continue, and will reach about 70 percent by 2050. As cities and income levels grow, land use and consumption patterns also change. While acknowledging that there is tremendous scope for reduction of the current globally estimated 30 percent food waste and losses (including those resulting from poor post-harvest management), there is general recognition that food production will have to be increased by about 70 to 100 percent to feed the world’s population of both humans and livestock. The FAO has estimated that, by



2050, annual global cereal demand will reach almost 3.3 billion tonnes (FAO, 2016a). Around 80 percent of future growth in crop production in developing countries will need to come from intensification. Agricultural growth will rely more than ever before on productivity gains through increased crop yields (Fisher *et al.*, 2014). Growth in the productivity of major cereal crops has been declining steadily from 3.2 percent in 1960 to 1.5 percent in 2000 (FAO, 2009). Rice yield growth has declined from 3.3 percent per year during 1976 to 1985 to 0.7 percent during 1998 to 2007 while global annual rice demand will increase to 114 million tonnes by 2035 (IRRI, 2010). Furthermore, farmers will have to contend with other yield reducing challenges induced by climate change such as drought, floods, pests and disease.

Asia produces and consumes 90 percent of the world's rice. It is also home to nearly two-thirds (64 percent) of the world's food insecure population; the majority eat rice as a staple food and are dependent on rice production for their livelihoods (FAO *et al.*, 2015). These producers are mostly resource poor, smallholder farmers; many have less than 1 ha of landholdings. These farmers hold a key role in protecting and enhancing the vital ecosystem services provided by natural biological processes, e.g. biological control, pollination and nutrient cycles if they are to intensify crop production sustainably (FAO, 2010). Unfortunately, the push for intensification of agricultural production has driven farmers to increase the use of chemical inputs such as fertilizers and pesticides in efforts to increase their yields. The intensive use of pesticides harms vital ecosystem services, particularly aquatic fauna such as fish and waterfowl in wetland areas (Ramsar Convention, 2012) and compromises the substantial potential of raising rural incomes through production of fish in rice-landscapes (FAO, 2016a).

Pesticide use also raises food safety concerns and jeopardises the export potential of agriculture produce, causes frequent poisoning and chronic health problems and exposes the most vulnerable – women and children – directly or indirectly to toxic substances. These concerns have led governments to promote the more efficient use of diminishing natural resources and better management and use of agroecological processes for the sustainable intensification of agricultural production, which is promoted by the FAO under the banner of *Save and Grow* (FAO, 2011 and 2016a).

Ecosystem-literacy training for smallholder farmers is, therefore, essential if they are to acquire the required agroecological knowledge and skills to achieve sustainable intensification of production (Ketelaar and Abubakar, 2012).

Other global phenomena such as climate change, the 'greying' and 'feminisation' of agriculture, vanishing rice cultures and heritages, the lessons from the 2008 rice price crisis, and enhanced awareness of the need to raise the contribution of rice production landscapes to poverty reduction and food and nutrition security of millions of farmers has led governments to examine and re-design policies and strategies to support the sustainable intensification of rice production.

This paper, illustrated with case studies from the region, outlines the progress made in RRI implementation and the results to date and argues the case for increased policy support for – and investments in – agroecology-literacy training for smallholder farmers, which is essential for ensuring *sustainable* intensification of crop production as well as food and nutrition security for future rural and urban generations in Asia.



THE REGIONAL RICE INITIATIVE

The Regional Rice Initiative

An FAO response to the urgent call for action and support from the Association of Southeast Asian Nations (ASEAN) Member Countries

Farmers are faced with the challenge of intensifying agricultural production to feed the world's growing population in the face of declining availability of labour, water and agricultural land, lower productivity and changing consumer patterns. It was against this background that government representatives, at the thirty-first Session of the FAO Regional Conference for Asia and the Pacific (APRC) held in Hanoi in March 2012, requested FAO to: strengthen the capacities of the Member Countries for rice production; and develop a regional rice strategy to harmonise the diverse rice-related issues. The subsequently formulated/published document is intended to provide evidence-based guidelines to member nations to help them develop and adjust their rice sector strategies in light of broader regional and global trends and national priorities; and choose among key strategic options while considering the implied trade-offs (or consequences) with the end view of assisting countries to achieve sustainable food security (FAO, 2014). In December 2012, the 145th Session of the FAO Council endorsed the formulation and implementation of a regional initiative to strengthen rice-based production systems in Asia as part of its new Strategic Objective 2: *Make agriculture, forestry and fisheries more productive and sustainable*. Since 2013 the Regional Rice Initiative has supported three pilot projects – in Indonesia, Lao PDR and the Philippines by: focusing on goods and services produced by and available from rice ecosystems and landscapes; and identifying and undertaking sustainable rice production practices to enhance resilience and increase efficiencies in rice production to improve food security.

Indonesia and the Philippines were chosen as the pilot countries because they are major rice importing countries but are strongly committed to improving food security by reducing their dependency on rice imports and increasing food production. Lao PDR was selected as it suffered from the second highest prevalence of undernourished in the region in terms of the proportion of undernourished in the total population at that time (FAO *et al.*, 2012). The sustainable increase of rice production in Lao PDR was considered critical for reducing hunger and malnutrition and improving the livelihoods of impoverished farmers, especially smallholders.

Concepts and approaches to the Regional Rice Initiative

The Regional Rice Initiative foresees long-term impact on improved food and nutrition security through effective provision and utilisation of ecosystem services and goods derived from rice-based farming systems and landscapes; and poverty reduction through increased productivity and income-generating opportunities and improved access to markets in the rice sector. This can be achieved through: adopting innovative and sustainable rice farming practices, i.e. based



on Save and Grow Sustainable Intensification of Rice Production, which allows rice farmers and producers to sustainably increase productivity and improve rice quality despite there being fewer agricultural and labour inputs; generating more knowledge and evidence concerning the sustainability and efficiency of resource use in order to substantiate the effectiveness of the Regional Rice Initiative approach; and formulating and implementing national rice policies or strategies that draw on the vision and strategic options laid out by the Regional Rice Strategy for Sustainable Food Security in Asia and the Pacific, while contributing to regional and global policy processes such as the Convention on Biological Diversity.

A two-pronged approach is employed while implementing the RRI with practical work at the field level involving farmers that provides empirical evidence for policy reform in support of the implementation and scaling out of innovative and more sustainable rice farming practices at the field level. At the same time, the Initiative contributes to global policy processes and helps the governments of Member Countries deliver on their contributions towards implementation of relevant international treaties such as the Convention on Biological Diversity and the Ramsar Wetlands Convention.

The Regional Rice Initiative offers farmers the opportunity, within the context of field-based training, to experiment with an array of options that are more productive, sustainable and efficient in resource use. These include exploration of more diversified farming systems: rice-fish, rice-livestock and rice-vegetables. It also includes testing good practices for adoption of integrated pest management (IPM), promoting soil health, better water management, understanding ecosystem functions of trees outside forest (TOF) in rice-landscapes and raising awareness about climate-smart agriculture. All these approaches are integrated into the overarching Save and Grow paradigm that espouses the use of multiple agroecological approaches for sustainable intensification of production.

Save and Grow Farmer Field Schools (FFS) are the main vehicles employed for increasing the knowledge and skills of farmer groups and communities on good agricultural practices to achieve the objective of increasing rice productivity; cost reducing technologies (to achieve the objective of increasing cost efficiencies and reducing production costs); and diversification through integrated rice-fish/livestock and multi-cropping systems to achieve the objective of increasing farm incomes.

FFSs employ discovery-based group learning processes. Usually, a group of 25-30 farmers meet one morning weekly for an entire crop-growing season and engage in experiential learning activities to gain an ecological perspective for managing ecosystems and to strengthen skills for informed decision-making based on location-specific conditions. The learning process is facilitated by extension workers or trained farmers. Non-formal education methods are employed and the field is used as the primary resource for discovery-based learning. FFS trains groups of farmers to work together to address agriculture and broader community concerns (FAO, 2016b). In this way, communities can identify multiple goods and services in the rice ecosystem and landscapes and employ the most suitable Save and Grow best practices to be enhanced and utilised for sustainable management.



Case studies:

Save and Grow Farmer Field Schools (FFS) to promote sustainable management of the multiple goods and services derived from rice production landscapes in Asia

Save and Grow Farmer Field Schools (FFS) in the Republic of the Philippines

In Northern Mindanao, the Republic of the Philippines, 643 rice farmers taking part in 20 Save and Grow FFSs established field studies to compare Save and Grow and conventional farmers' practices. A summary is provided in Table 1 of the practices applied during the 2013 wet season.

Many practices in the Save and Grow fields had existed for a long time (e.g. transplanting fewer seedlings at 1 to 2 seedlings per mound) while some were new and recent technological advances (e.g. the use of IRRI's site specific nutrient management (SSNM) based on mobile smart phone applications). The use of natural biological control, employed under the Save and Grow practices, included generalist predators including spiders and aquatic predators, such as water bugs, which are the dominant population regulators for many rice insect pests, including the Brown Plant Hopper (BPH-*Nilaparvata lugens*). The populations of these generalist predators are boosted early in the season by the availability of alternative, semi-aquatic, prey resources for example chironomid midges and ephydrid flies go through an aquatic larval stage and terrestrial adult stage. The strong generalist predator populations have already established by the time the first potential rice pest species arrive, thus they reduce the chance of survival of subsequent pests and are also key to the unfolding of the seasonal pest dynamics (Settle *et al.*, 1996).

Table 1. **Save and Grow Practices and Conventional Rice Farmers' Practices in Northern Mindanao, the Philippines, Wet Season 2013**

SAVE AND GROW PRACTICES	CONVENTIONAL FARMERS' PRACTICES
Thorough land preparation (ploughing, 1 st & 2 nd harrowing and final levelling)	Farmers' local practice - not well levelled
Best inbred seeds in the location either purified or certified/hybrid	Good seeds or certified seeds
Planting distance of 20 x 20 cm, 25 x 25 cm and 30 x 30 cm	Planting distance of 20 x 20 cm
Transplanting 1-2 seedlings/hill	Transplanting 4-7 seedlings/hill
Age of seedling 12-14 days	20-25 days
Soil analysis and Site Specific Nutrient Management (SSNM)	No soil analysis; no basal fertilizer application
Use of IRRI phone application Nutrient Manager ¹	Farmers' local practice based on experience
Application of organic fertilizer (Vermicast)	No organic fertilizer
Alternate wet and dry water management (1-2 cm)	Constantly flooded fields (3-5 cm)
Timely use of rotary weeder	Hand weeding
Integrated pest management including use of natural biological control such as predators and parasitoids	Integrated pest management
Planting of vegetables (e.g. eggplant) and climbing herbaceous legume crop (<i>pole sitaw</i>) on the bunds	Not applied
Introduction of ducks to enhance biodiversity and provide food	Not applied



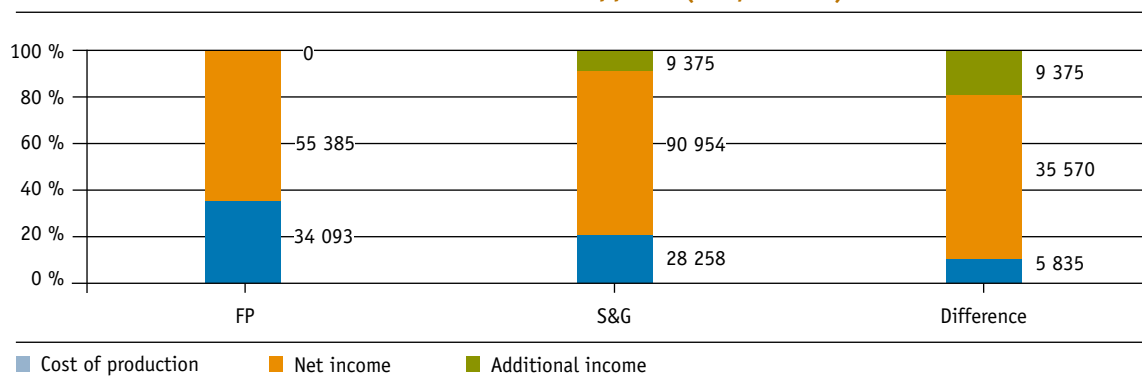
At the end of the rice production season, farmers reported an average rice yield of 6.7 tonne/ha on Save and Grow plots compared with 5.27 tonne/ha on Farmers' Practice plots or a difference of 1.43 tonne/ha, an average yield increase of 27.2 percent. On Save and Grow FFS plots, the average cost of production was reduced by, on average, 17 percent or the actual money value saved was USD 132 per ha. The net income, which had resulted from higher yields and lower input costs, had increased by about USD 803. The average production cost using Farmers Practices was USD 769 while on Save and Grow plots it was only USD 638 (Figure 1). The reduced cost of production was attributed to the application of improved management practices (e.g. use of younger seedlings, wider spacing, organic fertilizer and alternate wet and dry water management). In addition, informed decision-making for management was based on the analysis of the agroecosystem, the use of ecosystem services such as natural pest control to avoid the unnecessary use of chemical pesticides and the use of biological control agents, which also contributed to effective and sustainable pest management.

The 72 percent increase in net income generated by the application of Save and Grow practices was attributed to higher yields, benefit derived from the smart use of enhanced agrobiodiversity through multiple cropping as well as introducing ducks into rice production, and utilising existing aquatic biodiversity. Savings from the reduced cost of production, resulting from improved management practices, such as the reduced number of seedlings per hill, also contributed to the increased net income.

Planting vegetables on the bunds maximises use of the production area and, at the same time, provides habitat for *natural enemies* thus enhancing natural biological control. Where ducks were introduced into the rice fields these provided additional supporting ecosystem services by eating the insect pests found at the stem and base of the rice plants.

Enhancing aquatic biodiversity in rice-based cropping systems provided an average additional income of USD 209 per ha. For example, duck egg production alone became a source of additional income and nutrition. Information about existing aquatic biodiversity was unavailable until local agricultural schools, as part of the interventions supported by the RRI project, carried out assessments to determine the existing species of inland fish (e.g. catfish and mudfish) and molluscs (e.g. *kuhol* and another local snail species known as *pongok*).

Figure 1. Comparison of cost of production, net income and additional income using Save and Grow and Conventional Farmers' Practices, Philippines (PHP/hectare)



Source: Based on FAO (2015a)



These aquatic inland species had disappeared from farmers' fields as a result of high chemical use for rice production. Their return to the rice landscape is a result of reduced use of chemicals by farmers trained in IPM-FFS under the Philippine National IPM Programme that started in 1994 (FAO, 2015). The process of involving agricultural secondary schools and colleges was necessary to raise awareness among children (of farmers) and other stakeholders in the community (e.g. teachers and local leaders) as to the importance of aquatic biodiversity to sustainable rice production and its contribution to food security.

Save and Grow Farmer Field Schools (FFS) in Viet Nam

In response to the RRI results and interest showed in other countries, pilot Save and Grow activities implemented in Viet Nam in 2014. The pilot activities in Viet Nam were carried out in partnership with civil society organizations (CSOs) at the regional and national levels. The regional CSO, Field Alliance/Thai Education Foundation and the local CSO, Centre for Initiatives on Community Empowerment and Rural Development (The International Convention on the Elimination of All Forms of Racial Discrimination ICERD) carried out the training on aquatic (including rice-fish) and agrobiodiversity and pesticide impact assessment in rural communities. The FAO-supported National IPM Programme, as part of the process of community education on pesticide risk reduction, assisted rural communities in the formulation of Community Action Plans and trained farmers in FFS to reduce pesticide risk, including making better use of biological control options for pest management.

A group of 105 FFS alumni (55 women) applied rice intensification practices learned from FFS to 34 ha. Farmers applied efficient management, growing healthy, high-yielding crops with fewer and more sustainable production inputs. Farmers explored making optimal use of multiple goods and services of paddy-based farming systems – including conservation and management of aquatic biodiversity (both captured and cultured fish species), in combination with improved agronomic practices such as wider plant spacing/reduced seeding rates, improved water management, and reduced chemical pesticides through the application of ecologically-sound IPM. This included the use of biological control agents such as *Metarhizium anisopliae* as an alternative to chemicals for the management of the BPH and other hoppers and natural biological control provided by ecosystem services.

The average gross income from integrated rice-fish-aquatic production was USD 7 751/ha compared to USD 1 892/ha obtained from producing only rice (Table 2). The employment of integrated rice-fish-aquatic biodiversity production practices resulted in an increased average gross income ranging from 211 to 551 percent, compared with producing rice only (Figure 2). Farmers' experience and the aquatic biodiversity species and numbers, especially fish, accounted for the big difference in benefits. Informed management decision-making, based on analysis of the agroecosystem analysis, the use of ecosystem services such as natural pest control to avoid the unnecessary use of chemical pesticides and the use of biological control agents also contributed to effective and sustainable pest management. The fish provided regulating services for the ecosystem by eating insect pests (e.g. hoppers) found at the stem and base of the rice plants and those that fell into the water (FAO, 2015b).

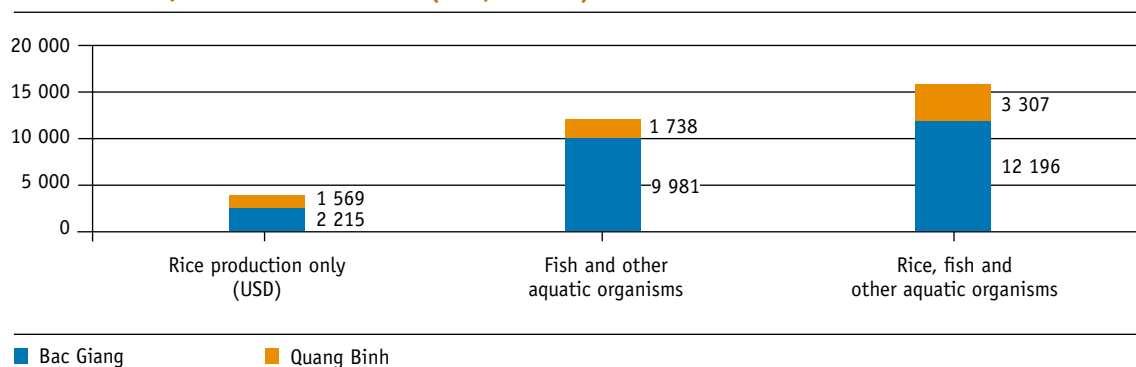


Table 2. **Yields and Benefits from Rice Only and Integrated Rice-Aquatic Biodiversity Production Systems, Viet Nam**

PARAMETERS	TOTAL BAC GIANG	TOTAL QUANG BINH	AVERAGE
A. Rice yields (kg/ha)	6 120	5 417	5 768.5
B. Gross income from rice production only (USD/ha)	2 215	1 569	1 892
C. Yields of fish and other aquatic organisms (kg/ha)	7 913	1 860	4 886
D. Gross income from fish and other aquatic organisms (USD /ha)	9 981	1 738	5 860
E. Gross income from rice, fish and other aquatic organisms [B + D] (USD /ha)	12 196	3 307	7 751
F. Input costs (USD /ha)	4 547	1 402	2 975
G. Profits [E - F] (USD /ha)	7 649	1 905	4 776
H. Difference in gross income between rice production only and integrated rice-fish-aquatic biodiversity production (% increased)	551 %	211 %	381 %

Source: Based on FAO (2015b)

Figure 2. **Gross income from rice only and integrated rice-aquatic biodiversity production systems in two provinces in Viet Nam (USD/hectare)**



Source: Based on FAO (2015)

Similar and very successful capacity-building work with farmers in their rice fields and with policy-makers at the local and national level was also accomplished in Lao PDR. Results of this RRI work had not been fully analysed at the time of writing this paper but will be documented in forthcoming papers to be published (Ketelaar *et al.*, 2018).

CONCLUSIONS AND RECOMMENDATIONS

In the Philippines, the RRI pilot was designed to support the generation of empirical evidence from the field in support of the overarching goals of the agriculture sector under the Philippine Development Plan (PDP) 2011-2016, namely attaining food security and raising incomes. The pilot project was in line with the Department of Agriculture's Food Staples Sufficiency Programme and met the key set policy targets. The positive results of the pilot activities in 2013 were used



to strengthen the Save and Grow curriculum for farmer training with the purpose of scaling out the FFS interventions so as to achieve rice self-sufficiency and raise rural incomes. The Government of the Philippines, under its National Rice Programme, is currently committed to the expansion of Save and Grow FFS under the second phase of the Regional Rice Initiative to which FAO had also committed technical assistance and additional funding support from 2014 to 2017.

Viet Nam, which was not included in the original set of RRI pilot countries, quickly picked up on lessons learned elsewhere in the region and developed its own Save and Grow SIRP Farmers Field Schools initiative with initial FAO technical and financial support. Impressed with the field results to date, the government is investing in scaling out the FFS work so that more Vietnamese farmers can benefit from training.

In Indonesia, the Government set a target of 1 million ha of rice-fish production, partly attributed to the results demonstrated by the pilot RRI. Some of the documented benefits of rice-fish production are: increased productivity from the paddy field (e.g. rice production increase by 10-20 percent, 6 to 7.5 tonnes/ha/crop; additional production of fish/aquatic animals: 1.2 to 1.5 tonnes/ha); symbiotic relationship between fish and rice (e.g. the paddy field provides fish with free food; the fish help in weeding and pest control in the paddy); sound ecological and environmental benefits (e.g. less of a negative impact on the environment as a result of the reduced use of chemicals, which contributes to food safety); and social and economic benefits from the sustainable management of natural resources and their application



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in crop management (e.g. net income increased by about USD 4 800 to 7 800/ha with reduced production costs for both rice and fish/freshwater prawn. Concerns were addressed about the 'greying' of agriculture because rice cultivation has become an attractive livelihood for the younger generation) (Soetrino, 2015).

Key lessons learned from the implementation of the Regional Rice Initiative for sustainable management of the multiple good and services derived from rice production landscapes in Asia include:

- » Sustainable intensification of rice production is location/site specific and requires smallholder farmers to test and adapt good practices based on a deep understanding of rice agroecosystems and landscapes and their responsible management.
- » Smallholder farmers, trained in season-long Farmer Field Schools, understand the concepts of agroecosystems and have gained the skills required for ecosystem-literacy to sustainably manage natural resources, which they effectively apply in crop management with good and profitable results.
- » Improved management practices and enhanced agrobiodiversity conservation and utilisation, as shown by the RRI in several Asian countries, significantly increases yields, benefits and net income while allowing farmers to conserve and make optimal use of the multiple goods and services provided by rice-based ecosystems and landscapes.
- » Supportive policies and renewed investments are required so that agriculture can continue to maintain rice production at its core and promote more integrated farming systems that can help generate significantly higher incomes and meet multiple development objectives.
- » Increasing the profitability of rice-based farming systems and reducing labour-intensive practices will be particularly important when providing incentives to the younger generation of farmers who are willing to become engaged in rice production and take up farming in the future.



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CHARCOAL APPLICATION FARMING WITH LIVESTOCK FOR SMALL SCALE FARMERS IN CENTRAL VIET NAM

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Abstract

The application of agrowaste charcoal is expected to increase technical options for small-scale farmers who cannot access affordable agricultural inputs. For example, charcoal is commonly used as a soil amendment and growing media. Our project team introduced the lessons of Japanese farmers and practitioners who applied charcoal in agriculture and animal husbandry but the results of agricultural extension, however, were still limited, compared to the number of research projects. For further agricultural extension activities, we aimed to review the challenges and constraints of charcoal application farming with livestock for small-scale farmers in Thua Thien Hue Province, central Viet Nam.

Bach Ma Charcoal Project was implemented by the Japan International Cooperation Agency (JICA) Partnership Program from 2009 to 2013. The objective was to introduce the multipurpose use of charcoal in agriculture and animal husbandry by small-scale farmers in the buffer zone villages of Bach Ma National Park (Viet Nam). During the project, more than 150 participants were trained in workshops covering *Charcoal-applied environmentally-friendly farming with livestock (CEFL) model*.

In order to observe the challenges and constraints faced by smallholder farmers in charcoal application farming in the post-project activities, a questionnaire was designed to survey 36 farmers, who had been certified as model farmers

by the project. During the past year, 30 of the 36 model farmers made rice husk charcoal (RHC), was used as a soil amendment in vegetable gardens and on field crops. Among the model farmers were 16 out of 17 farmers who reared pigs and fed RHC to piglets. Households consumed most of the vegetables; only five farmers made charcoal organic fertilizer to grow vegetables and seven farmers individually sold organic vegetables. Most of the model farmers needed to buy the materials such as rice husk and rice bran to make charcoal compost and organic fertilizer.

Although the project tried to promote the CEFL Model as “easy to practice”, model farmers still needed simpler and more convenient methods of applying organic fertilizer as well as options to enable them to profit from an organic supply chain.

Charcoal application farming was introduced to farmers’ groups, farm enterprises and government institutions both within and outside the project area. Examples of farm enterprises that adopted the Project’s model of charcoal application farming indicate the potential of charcoal application farming with livestock. To reduce the costs of materials (manure, rice bran, etc.), stakeholders, such as livestock farms, slaughterhouses and rice mills need to cooperate. Small-scale farmers also need to cooperate when adopting charcoal application farming to ensure success and to develop efficient biomass flows and profitable supply chains.



INTRODUCTION

Farming systems combined with livestock have been sustaining small-scale farmers' livelihoods and nutrient cycling in agroecosystems. However, improved farming systems are expected to provide better options for small-scale farmers who are facing problems associated with rapid environmental and economic changes. Although recent agricultural changes in Asian countries have been strongly supported by conventional modern technologies, the organic farming boom has opened up other opportunities for producers, distributors and consumers. In general, small-scale farmers in tropical Asia have maintained integrated livestock systems in home gardens to provide sources of organic fertilizer. Therefore, strategies to utilise the available biomass are critical when promoting organic farming by small-scale farmers.

In central Viet Nam, small-scale farmers may hold less than 0.5 hectare (ha) of agricultural land and hesitate to apply agrochemicals for crop cultivation and antibiotics for livestock breeding because of the high cost and concerns about environmental and health risks. To respond to this situation, our group introduced the lessons of Japanese farmers and practitioners who have applied charcoal in agriculture.

Japanese farmers often add rice husk charcoal (RHC) as a conditioner when fermenting Bokashi organic fertilizer by mixing livestock manure, rice bran, and other materials. As recent research has revealed, when charcoal is applied as a soil amendment with fertilizers, it improves both crop growth and soil properties such as the pH and available nutrients (Ogawa and Okimori, 2010). In addition to charcoal, its by-product, wood vinegar (pyroligneous acid) is introduced to improve animal hygiene in livestock production through reducing the odour (Kishimoto, 1997). We attempted to transfer such practices as "charcoal application farming" to Vietnamese small-scale farmers who sought alternatives to conventional practices.

While many research papers have been published recently around the world on charcoal application, only a limited number of projects being implemented to spread the knowledge and technologies (Scholz *et al.*, 2014). Our project targeted small-scale farmers to improve their practices in agriculture and animal husbandry through the use of charcoal application farming. In this case study, we review the challenges and constraints of charcoal application farming with livestock in central Viet Nam so as to further agricultural extension targeting small-scale farmers in developing regions.

Based on our experiences of agricultural extension activities in Thua Thien Hue Province, first, we reviewed how charcoal was applied to improve farming with livestock for small-scale farmers in the buffer zone of the Bach Ma National Park. Second, we observed the challenges and constraints of charcoal application two years after the project ended. Third, we surveyed how different types of farm enterprises learned from the Project and adopted the application of charcoal to produce charcoal organic fertilizer. During discussions, we characterised these cases to be able to better understand the potential and limitations of charcoal application farming with livestock for small-scale farmers. Mainly we reviewed the authors' previous reports that were published or presented at seminars and conferences (Oikawa, 2012; Oikawa *et al.*, 2013; 2014; 2016; Yamada *et al.*, 2014) and Tokyo University of Agriculture and Technology (2011).

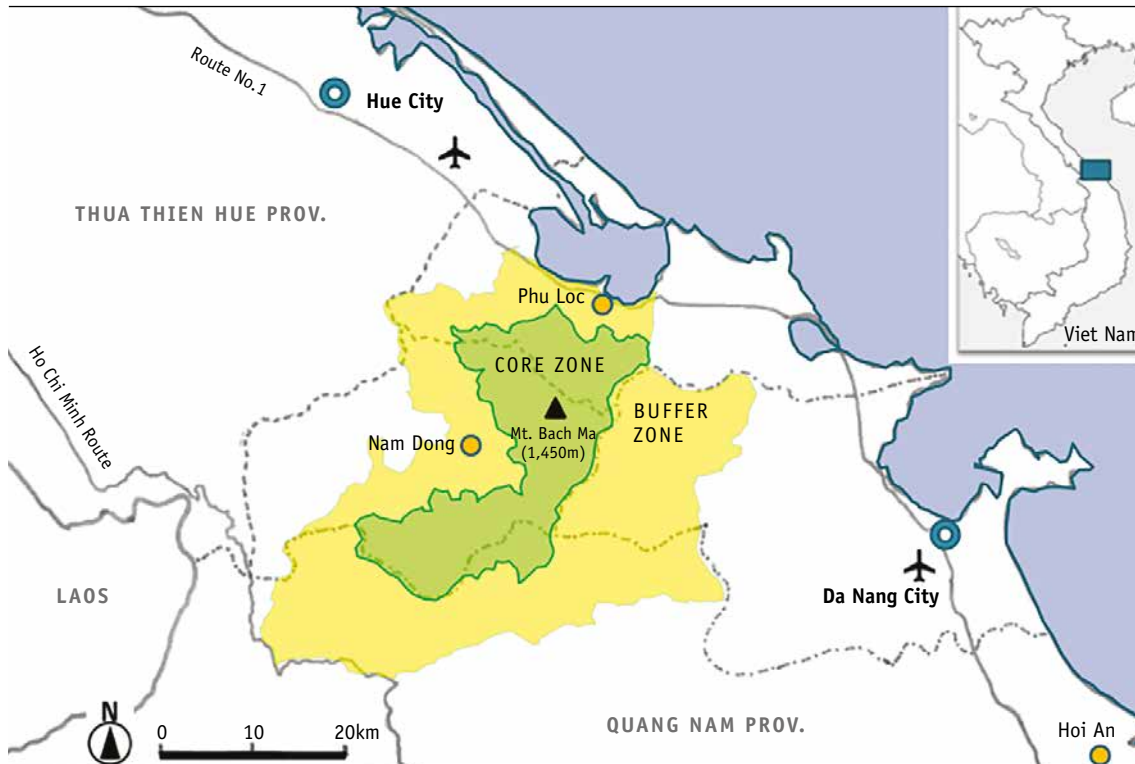


AGRICULTURAL EXTENSION ACTIVITIES THROUGH BACH MA CHARCOAL PROJECT

The Bach Ma Charcoal Project was implemented as a Japan International Cooperation Agency (JICA) Partnership Program from June 2008 to March 2013. The project aimed to introduce the multipurpose use of charcoal into agriculture and animal husbandry to small-scale farmers in the buffer zone villages of Bach Ma National Park, Viet Nam (Figure 1). By promoting organic practices using charcoal for use by farmers, we intended to improve environmental conservation and rural livelihoods in and around the national park (Nguyen, 2012).

At the early stage of the project in 2009, we intended to produce wood charcoal as well as agrowaste charcoal made from sawdust, twigs and the pruned branches of fruit trees in home gardens in a target village (Khe Su). We demonstrated wood charcoal making several times using a used 200-litre drum kiln. Local farmers could easily prepare *Acacia* timbers and biomass after forest thinning. However, it was not profitable to make wood charcoal because of the low market prices and no used drums were available in the rural areas to make the kilns. Then, we shifted to RHC since farmers could make it easily from rice husk, which was available in each household or from the local rice mills.

Figure 1. **Bach Ma National Park and Hue City, central Viet Nam**



The national park's core zone is indicated in green, the buffer zone is in yellow.



The project provided farm households with stainless chimney pipes to make RHC. A simple method was used: A short iron bar was set into the ground; embers or fuel were placed near the bar; a standing 1 to 1.5 m long stainless pipe was fixed to the bar using wire (as a chimney). The bottom of the pipe was set 5 to 10 cm away from the ground so that hot air could rise up through the pipe; after confirming that the fuel was burning well, the bottom of the pipe was covered with rice husk so that the smoke rose continuously and the rice husk gradually became RHC.

Workshop participants learned how to make charcoal from rice husk, and how to use charcoal as a soil amendment. By following our experiences in Japan, we first recommended 1 to 2 tonnes per hectare of RHC as an initial input for soil amendment. To attract the attention of the small-scale farmers to charcoal application, we demonstrated how to make charcoal organic fertilizer (aerobic Bokashi) using rice husks, RHC, rice bran and livestock manure by fermenting at 50 to 55 °C for about three weeks. We expected that vegetables grown using the charcoal organic fertilizer would improve farmers' home consumption and would become an additional source of income as well as an alternative to firewood gathered from the forest.

In April 2010, in order to demonstrate vegetable growing using charcoal organic fertilizer, six pilot farmers were selected, based on their motivation, the availability of a garden plot area of 200 m², livestock manure, access to a water source for growing and selling vegetables such as eggplant, leaf amaranth, water spinach, Indian spinach, cucumber and chillies (TUAT, 2011). The project provided them with the initial input of charcoal organic fertilizer, seeds, and a net to protect the crops from birds. Then the vegetable production and sales were monitored for a year.

Before participating in the project, the pilot farmers bought their vegetables at the market because few are grown in the village. After learning from the Project, they were able to produce vegetables both for home-consumption and for sale. While saving on the cost of buying vegetables, the farmers could earn extra income from selling their vegetables.

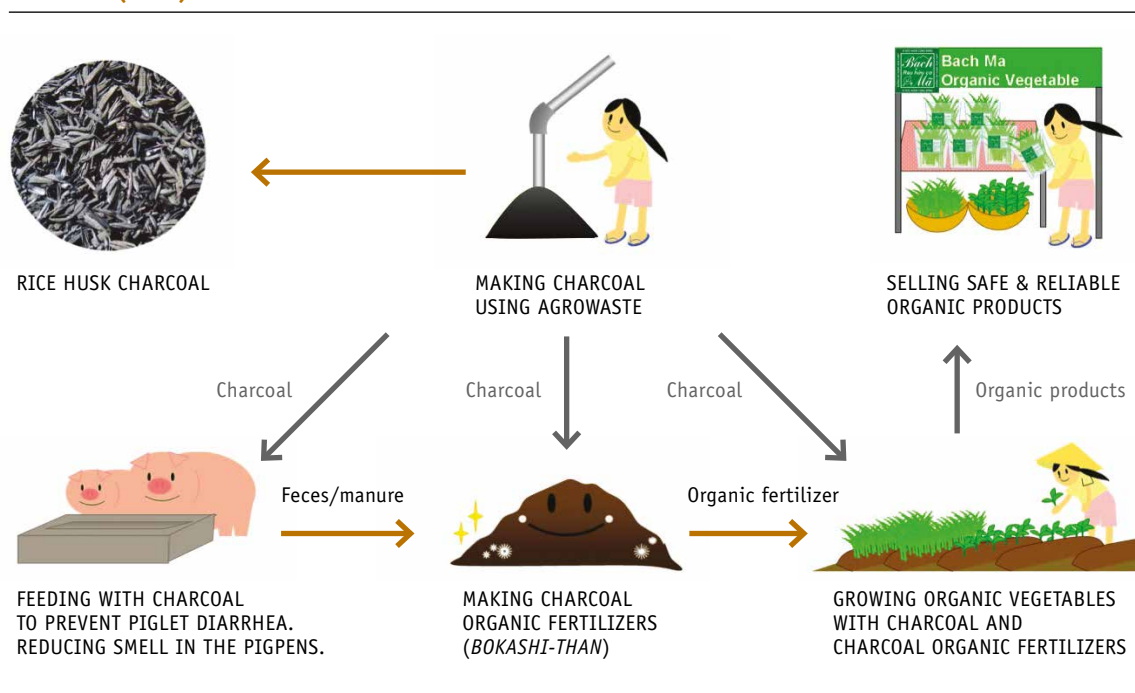
Since the pilot farmers understood and practiced charcoal application farming in the target village, in 2011, we started follow-up project activities to transfer charcoal application to farmers in other villages in the buffer zone. For further agricultural extension of farming with livestock through charcoal application, the project developed the *Charcoal-applied environmentally-friendly farming with livestock* (CEFL) Model. The faculty members and graduate students of TUAT and the Vietnamese collaborators studied the effects of charcoal application on soil, crop growth, and pig diarrhoea and growth, etc. to understand and improve this model practically and scientifically (TUAT, 2011).

This farming model comprised five steps: making charcoal from agrowaste, especially rice husk; mixing the charcoal powder with feed for piglets to prevent diarrhoea, without having to use antibiotics; making charcoal compost or charcoal organic fertilizer from rice husk charcoal, rice bran, and livestock manure, etc.; applying charcoal compost or Bokashi organic fertilizer to grow vegetables without the use of agrochemicals; selling vegetables grown after charcoal application to earn extra income (Figure 2).

From 2011 to 2013, more than 155 participants were trained in workshops demonstrating the CEFL Model (Yamada *et al.*, 2014). In each training workshop, 23 to 33 participants took part in the participative lectures and exercises. The project staff members and senior farmers, who had learned the farming model in advance, were the instructors and demonstrated the technical



Figure 2. Summary chart of Charcoal-applied Environmentally-friendly Farming with Livestock (CEFL) Model



Illustrated by A. Saito

options of the CEFL Model to the new participants. Some workshops targeted vegetable growing and others pig rearing.

Through the training workshops with local farmers, we emphasised the characteristics of this model as being easy to implement; better for health and the environment than conventional agrochemicals or use of antibiotics; money is saved as agrochemicals, antibiotics and growth promoter are no longer purchased; profits are increased because the money that would have been spent on buying vegetables and agrochemicals can now be saved. After conducting the training workshops, local project staff supported the participants in the practice of charcoal application farming on their own farms or garden plots.

The Project invited 36 motivated farm households (hereinafter model farmers), who were practicing charcoal application for the cultivation of vegetables and to raise pigs, to the senior-level training workshop in January 2013. At the final workshop for the Project in February 2013, participants were given the *Certificate of the CEFL Model Farmer* with a reference book on the CEFL Model. These model farmers were expected to continue vegetable and pig production and train and demonstrate the CEFL model to other farmers after the Project ended.



CHALLENGES AND IMPROVEMENTS TO CHARCOAL APPLICATION FARMING AFTER THE PROJECT

Since the Project was completed in March 2013, modifications of the farming model have been observed in and outside the Project target area. To observe the challenges and constraints related to the post-project activities, February to March 2015, two years after the project ended, a questionnaire was used to survey the 36 model farmers who had been certified by the Project. During observation of the model farmers' activities, we attempted to understand the benefits and difficulties faced by smallholder farmers employing charcoal application farming.

The 36 model farmers were 19 vegetable growers (without pig raising but six farmers raised water buffaloes), five farmers grew both vegetables and raised pigs, and 12 pig farmers (without vegetable growing) (Table 1).

Table 1. **The number of model farmers who practiced the CEFL Model in 2014 – 2015 among the 36 model farmers certified by the Project**

TYPE OF MODEL FARMER	PHU LOC DISTRICT		NAM DONG DISTRICT		TOTAL	
	As of 2013	Practiced 2014-2015	As of 2013	Practiced 2014-2015	As of 2013	Practiced 2014-2015
Vegetable growing	14	13	5	2	19	15
(with water buffalo)	(n.d.)	(5)	(n.d.)	(1)	(n.d.)	(6)
Vegetables and pig growing	4	4	1	1	5	5
Only pig growing	9	9	3	3	12	12
Total	27	26	9	6	36	32

Source: Interview survey in February to March 2015.

From March 2014 to February 2015, 30 of the 36 model farmers (83 %) made RHC and used for it for soil amendment or with piglets, specifically 16 of the 17 pig raisers (94 %) fed piglets with RHC and wood vinegar to prevent diarrhoea.

Twenty of the 24 vegetable growing model farmers (83 %) produced organic vegetables such as eggplant and okra. Thirteen of these 20 farmers (65 %) produced organic vegetables only for home-consumption while only seven households sold organic vegetables to local customers or at the local market.

The above-mentioned 13 farmers who grew vegetables for home-consumption applied RHC directly or RHC mixed with livestock manure compost to the garden plots. Only five farmers made charcoal organic fertilizer that had been introduced through the Project training workshops. All of the five farmers made the fertilizer to grow vegetables both for sale and home-consumption.

Thus, most model farmers still practiced charcoal application but did not make charcoal organic fertilizer. We asked the farmers the reason. The answer was that organic vegetable production using charcoal organic fertilizer takes time and labour to produce RHC, ferment materials, cultivate and sell vegetables. Particularly so when charcoal organic fertilizer is made,



as several materials (livestock manure, RHC, rice husk, rice bran, fermentation starter yeast) are needed for its preparation.

During the implementation of the project, however, we expected that small-scale farmers could easily practice this charcoal-farming model if they raised livestock as a source of manure. Table 2 shows the costs of making charcoal organic fertilizer for four model farmers. By forming a group the cost of making the fertilizer could be reduced, the finished charcoal organic fertilizer could then be shared.

Table 2. **Materials required for 8 m³ of charcoal organic fertilizer in Khe Su Village**

MATERIALS	AMOUNT	COST (VND)	COST (USD)
Cattle and buffalo manure	8 m ³	560 000	26.9
Transportation	5 trucks	1 250 000	60.0
Rice bran	240 kg	1 920 000	92.3
Rice husk	80 bags	320 000	15.4
Plastic bags for RH	80 bags	400 000	19.2
<i>Men ru'ou</i> (starter yeast)	4.8 kg	72 000	3.5
Total		4 522 000	217.3

Source: The budget estimate by the Project in April 2012

In reality, the farmers who continued to make charcoal organic fertilizer after the Project purchased rice bran at the local markets or rice mills for around VND 8 000 per kg to make the charcoal organic fertilizer. These farmers were actively selling organic vegetables even after the Project ended.

In addition, 24 of 30 model farmers, who made RHC needed to buy rice husk. Rice husk, which weigh about 7 to 10 kg per bag, cost VND 4 000 per bag in the rice growing villages (Phu Loc district) and VND 10 000 per bag in the inland remote villages (Nam Dong district).

Another reason there were fewer model farmers selling vegetables may be related to local prices. There was almost no price difference between organic and conventional vegetables at the Cau Hai local market in Phu Loc town. Some model farmers complained that organic vegetable production was not profitable, considering the labour and costs, especially for making charcoal organic fertilizer. This could be a reason why RHC was applied directly or in local compost.

Some successful cases of organic vegetable growers were, however, observed in the villages 5 km from the national highway. One model farmer sold a sufficient amount of organic products directly to the staff members at local government offices, instead of through intermediaries at the local market. While reviewing the handbook provided by the Project, one model farmer was growing organic crops using rice straw compost from straw mushroom for mixing with charcoal organic fertilizer. Another model farmer developed sprout cultivation under shaded conditions in a home garden and delivered the product to the market every day.

One senior model farmer introduced pot cultivation for ginger, garlic, and chilli using fertilizer bags in a home garden and expressed satisfaction with the easy handling of potted plants (Figure 3). The simple technologies, described above, were devised by the farmers. Most model farmers still follow the practices they had learned during the Project.



Figure 3. **Sprout growing with charcoal organic fertilizer (left) and pot cultivation of ginger using plastic bags (right) in home gardens.**



All photos: © Yosei Oikawa

In 2012 to 2013, the Project attempted to involve more farmers in the buffer zone of the National Park through training workshops in Nam Dong district, located in a mountainous area more than 20 km from the national park headquarters and the national highway. Nine households started charcoal application as model farmers. In 2015, two years after the project, they had no means of transportation to sell at the market and the price of rice husk was double that of Phu Loc district, their practices were obviously constrained compared to the model farmers in Phu Loc district. It was necessary to understand the farmers' limitations related to their production and market environment in the mountainous areas.

In this way we have observed some successful and unsuccessful examples of model farmers after the end of the Bach Ma Charcoal Project. Although the project tried to provide 'simple-and-easy' options for making charcoal organic fertilizer as well as providing sales channels for organic products, small-scale farmers still needed simpler and more convenient methods of applying organic farming and required further support in developing a profitable organic supply chain.

DIFFERENT EXAMPLES FROM THE PROJECT ON ADOPTION OF CHARCOAL APPLICATION

Our agricultural extension activities were formed as the CEFL Model by targeting small-scale farmers in the Project area. This model was originally designed for dissemination to small-scale farmers who were raising a small number of pigs, or other livestock, and for development of organic vegetable cultivation in the buffer zone villages. During the Project period, the Project members also introduced charcoal application farming to farmers' groups, farm enterprises, and governmental institutions in the Province of Thua Thien and others. After the Project ended, a few farm enterprises adopted charcoal application farming as a part of their activities. We surveyed how these farm enterprises adopted the practices of charcoal application farming, in order to identify the key to dissemination of charcoal application farming with livestock.



The *Thanh Thien* Pig Farm, located in Phu Loc district, is part of the buffer zone in Bach Ma National Park, had excess manure and sewage from a few hundred pigs. In 2013, the farm manger learned to use this waste to make charcoal organic fertilizer by mixing with rice husks, RHC and rice bran. The charcoal organic fertilizer was tested for crop cultivation on the farm.

A slaughterhouse in Hue city also had excess manure that caused a bad odour. In 2013, the same concept of making charcoal organic fertilizer from excess manure was introduced. The slaughterhouse staff learned how to make and apply RHC to produce charcoal organic fertilizer from manure. Then, the smell of manure and wastewater from the slaughterhouse were reduced by producing charcoal organic fertilizer. The next challenge would be the appropriate use and distribution of organic fertilizer to respond to the demands from organic producers.

Contrary to the above examples, Xong Garden was developed as an organic farm without its own livestock manure but adopted charcoal application farming from the Project.

Xong Garden belongs to Duc Son Pagoda in Thuy Bang Commune, Huong Thuy district, which is about 4 km south of Hue City, where organic farming using RHC has been practiced since 2011. According to the interview of the chief gardener in March 2014, Duc Son Pagoda and Orphanage established the 0.8 ha Xong Garden in 2010 to supply vegetables to the nuns and orphans.

In July to August 2011, the application of organic fertilizer mixed with RHC was introduced to the chief gardener. Since then, charcoal organic fertilizer has been applied to the garden without the use of agrochemicals.

As of 2014, the chief gardener has grown 20 different crops including cucurbits, celery, lettuce, cucumber, amaranth, Indian spinach, sweet potato, carrot, corn and tea. The staff member followed the guidelines for making charcoal organic fertilizer as learned from the Bach Ma Charcoal Project.

Xong Garden needed to purchase materials for charcoal organic fertilizer, since the garden did not have rice fields or livestock. The Duc Son Pagoda and Orphanage supported the purchase of the materials, including transportation costs. To make 30 to 40 m³ of charcoal organic fertilizer, Xong Garden purchased cattle and buffalo dung from farmers at the An Truyen Commune, Phu Vang district, which is 15 km from the garden; rice husks and bran from the rice mills in Thuy Phuong Commune, Huong Thuy district, which is 12 km from the garden; and rice wine yeast, to start fermentation, was purchased at the local market (Table 3). After making RHC, these materials were mixed so that they could ferment for 25 days.

Table 3. **Materials required for 40 m³ of charcoal organic fertilizer at the Xong Garden**

MATERIALS	AMOUNT	COST (VND)	COST (USD)
Cattle and buffalo manure including transportation	40 m ³	15 000 000	714
Rice bran	200 kg	900 000	43
Rice husk	400 kg	?*	?*
<i>Men ru'ou</i> (starter yeast)	2 kg	44 000	2.1
Total		15 944 000	759.1

* Rice husk is given from a rice mill and transported with rice bran to the garden.

Source: Interview in May 2014



The chief gardener reported problems with pests from January to February and June to July, including fruit fly, *Phyllostreta vittata*, *Agrotis ypsilon*, leaf insects and aphids. To prevent crop damage, he used odour and pheromone traps, herbal pesticides and hand capture. He also removed tree crops that had been damaged by rot fungi, which developed every May and June. Despite seasonal pest and disease damage, various vegetables were harvested to supply the members of the Pagoda and Orphanage throughout the year.

This garden needed to buy manure and rice bran to practice charcoal application farming, which was supported by the Pagoda and Orphanage. If the garden staff had access to excess manure from pig farms and slaughterhouses, and sufficient rice husk and rice bran from rice mills and rice enterprises, they could reduce the cost of materials. The example of Xong Garden indicates charcoal application farming is possible for the development of the organic supply chain.

DISCUSSION

Here we characterise the CEFL model and other practices to better understand the potential and limitations of disseminating charcoal application farming with livestock to other developing regions.

The challenge of charcoal application farming (the CEFL Model) in Bach Ma National Park was related to the provision of alternative options for small-scale farmers who had noted the negative impacts of conventional farming. We combined RHC with livestock manure to promote organic vegetable cultivation on garden plots and promoted the technical package as the CEFL Model. During observation of the farmers' practices, after the project demonstrations and training workshops, several challenges and constraints were recognised such as materials; cost; the effort involved in making charcoal organic fertilizer and the low price of local vegetables that discouraged the farmers. Simpler and easier options for charcoal application and alternative sales channels for organic products may need to be researched and studied.

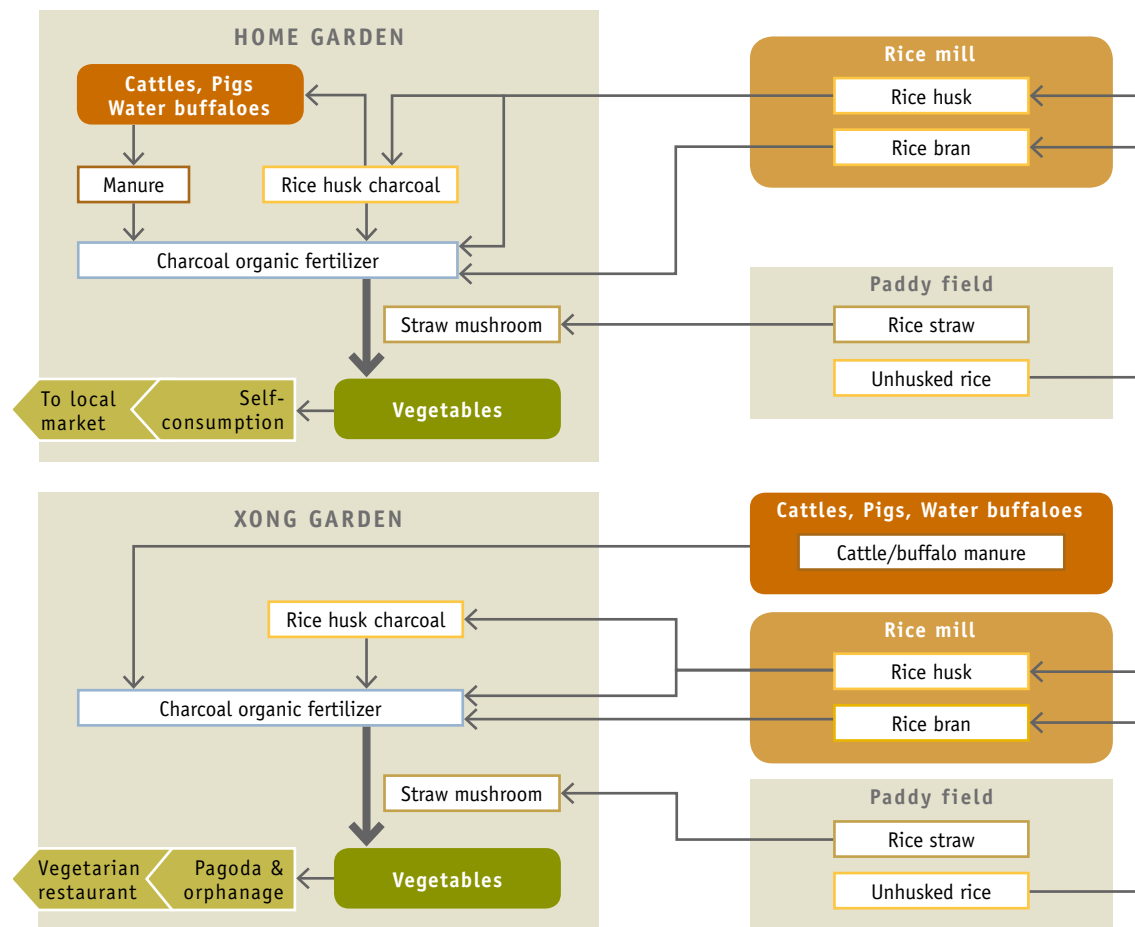
Farm enterprises in the Province have demonstrated the potential of the charcoal application farming with and without livestock. The producers who have excess manure, or agrowaste such as rice husks, could provide the materials or the organic fertilizer to those who need them.

Xong Garden needed to purchase most materials for organic fertilizer, while the model farmers, who had taken part in the Charcoal Project could prepare the materials for charcoal organic fertilizer in and around the village (even though many farmers had to buy some of the materials). As shown in Table 2 and 3, the high cost of organic fertilizer materials seems to be a constraint to charcoal application farming with livestock, especially for small-scale farmers who do not possess sufficient funds. The cost, however, may be reduced through cooperation with neighbouring livestock raisers or rice mills. Farmers cooperate with each other for the required labour involved in making a certain amount of organic fertilizer to share.

Both the garden and model farmers were producing organic vegetables mainly for their own consumption. Considering the biomass flows for both examples (Figure 4), these farming models could be developed to supply organic vegetables to consumers.



Figure 4. Biomass flows in a small-scale farmer's home garden with livestock and paddy fields (upper) and in the Xong Garden without livestock or paddy fields (lower)



These farming models could be improved, they could become more sustainable and profitable systems if stakeholders such as livestock farms, slaughterhouses, rice growers and rice mills cooperated, which would reduce the costs. Small-scale farmers without livestock and without paddy fields could participate in the organic supply chain by adopting charcoal application farming.

In this study, the challenges and constraints were reviewed related to charcoal application farming with livestock, which was promoted by the Bach Ma Charcoal Project in central Viet Nam. Although the project attempted to promote the “easy to practice” farming model as an alternative option, farmers still need simpler and more convenient methods of obtaining organic fertilizers. While confirming that there was less of an environmental impact with lower costs and higher profits with use of the farming models, we need to improve charcoal application farming with livestock by encouraging the stakeholders to cooperation to reduce the costs of materials. Small-scale farmers also need to cooperate to ensure the successful adoption of charcoal application farming, the development of efficient biomass flows and a profitable supply chain.



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LINKING SMALL-SCALE AGROECOLOGICAL PRODUCERS TO MARKETS IN SIEM REAP PROVINCE, CAMBODIA

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Keywords: agroecology, family farming, local collectors, market access.



INTRODUCTION

Development of Sustainable Agriculture for Small-scale Farmers

Since 2010 Professionals for Fair Development (GRET) has been working in partnership with the local non-governmental organization (NGO), Cambodian Institute for Research and Development (CIRD), and Siem Reap Provincial Department of Agriculture on a project to increase incomes and improve the livelihood of smallholder farmers through the development of sustainable agriculture based on low inputs and diversification. The Project, which is funded by the General Council of the Hauts de Seine département of France, and named *Development of Sustainable Agriculture for Small-scale Farmers*, currently targets 2 000 farmers in 50 villages in the districts of Prasat Bakong and Sotr Nikum in Siem Reap Province near Tonle Sap Lake.

GRET and CIRD assist farmers to take up the challenge of initiating an agroecological transition towards a sustainable farming system that is intended to produce in a healthier way by maintaining or improving soil fertility, the yield and growth of the crops and reducing costs by lowering chemical inputs. The successful promotion and dissemination of agroecology practices is strongly linked to the improvement of market access.

In Cambodia, smallholder farmers face difficulties in adapting their local production to the rapidly increasing population of Siem Reap Province and recent consumer trends towards a preference for healthy and safe food. This situation has led to the development of efficient supply chains that are mainly based on imported produce from other provinces and neighbouring countries such as Vietnam and Thailand (Brun, 2012), which strongly impacts variations in the price of vegetables.

In addition, consumers today have a heightened awareness of the use of pesticides in vegetable production and, as a result of media information, the health consequences. The inability of farmers to adapt their local production can be explained by difficult natural conditions, for example flooded land in the wet season and a lack of available water in the dry; producers' poor technical skills; limited investment potential and little or no information feedback to producers about market demand. This situation has led to the development of efficient supply chains that are mainly based on imported produce, which has had a strong impact on fluctuating vegetable prices.

APPROACH

Support to agroecological farmers' organizations and local collectors

The approach, developed by GRET and CIRD, relies on supporting the setting-up of agroecological farmers' organizations and facilitating the business development of local collectors. GRET and CIRD focus their support on the businesses of existing local collectors, who are living in the same community of producers, without providing any direct financial support to their capital.



Within this market system, collectors play a key role in linking the local production area with urban markets, using two distribution patterns that are based on short food supply chains such as restaurants and canteens, but also wider local markets that are managed by wholesalers. Generally, the market in Cambodia perceives locally produced vegetables as safe. Markets, however, do not pay a premium price for safe products.

Local collectors in this vegetable chain are key players in improving rural and urban linkages, as the production area of the two districts is located 30 km from urban markets. Collective action allows for having a better answer to market demand for regular, large and diversified production offers. Pre and postharvest training has been provided to farmer groups and local collectors, including 4-step courses on harvesting techniques, quality classification of vegetables, storage and the calculation of production costs. In addition, eight market notice boards have been installed at the collectors' farmgate to inform all farmers of the kinds of vegetables they buy and at what price. These boards are updated every 2 or 3 days and have the advantage of creating transparency by providing price references.

The project team targeted two stakeholders: producers and local collectors. GRET and CIRD facilitated the setting-up of 15 agroecological vegetable producer groups by helping farmers become organized at the village level, by electing representatives, setting up internal rules and creating an action plan, which is a key strategy to having a large, diversified and regular supply. Within this market system, 290 farmers, including 243 women, now have better access to urban markets and have seen their incomes rise. In total, all vegetable producer groups are able to grow 43 different kinds of vegetables on 52 ha. Producers, on average, are able to produce only 7 to 8 months a year, because of the difficult natural conditions such as drought and flood. Before the creation of producer groups, and the link with the local collector, most farmers sold their surplus to outside traders who visited their villages. Farmers were unable to negotiate because they had no price reference.

The 18 local collectors are business-oriented farmers with complementary business activities, including collection and transportation. Each day, collectors spend around 5 hours collecting, transporting and selling their products. Farmers need this crucial time to take care of their production. Collectors link rural and urban areas by contributing to increasing agricultural product flows to urban markets through their daily supply of vegetables. On the other hand, collectors provide flows of information to producers on market mechanisms, including price fluctuations and consumer preferences.

Local collectors build trust with farmers as they perform four functions: provide advice on agroecology practices; collect and transport products to markets; share market information as regular traders, and ensure social contact as they live in the same community. Through their collaboration with local collectors, farmers have learned how to adapt their vegetable production to meet urban market demand. In 2016, the 18 local collectors provide on average, 80 tonnes of vegetables to markets in Siem Reap. Of this, 70 percent of the total comes from vegetable producer groups, during specific months vegetable production decreased mainly because water was scarce.

The Project has developed initiatives with farmer groups and collectors in supplying the mainstream markets of Siem Reap with a strategy of targeting domestic markets. Phsar Leu and Phsar Samaki markets are the two largest wholesale vegetable markets in the city of Siem Reap.



They play an important role in supplying large amounts of vegetables to many district markets. Getting involved in this distribution pattern, local collectors are able to sell their production on a large scale. Provincial and district markets represent 97 percent of purchases. There are still limits to the ability of small-scale farmers to adapt their production to the broader needs of local markets. Among the customers, local collectors count 8 wholesalers, 23 retailers, 3 restaurants and 1 children's canteen. The market demand for local products is so high that collectors have no problem in finding customers.

CONCLUSION

To conclude, the role of the collector is crucial in linking urban demand with rural supply. The flow of information between the market and the producers helps them negotiate good prices with the collectors, and helps the collector explain urban demand in terms of price and quality, improving their own performance at the same time as that of the farmers.

To move forward, GRET and CIRD wish to continue to support the development of new business relations for local collectors through two distribution patterns; improve the promotion and visibility of local vegetable products on the domestic market; assist 50 to 60 interested farmers among 290 vegetable producer groups to first achieve agroecology production standards, and then to set up an internal control system to guarantee the traceability and quality of the vegetables.



EXAMPLES OF SHORT SUPPLY CHAINS WHERE GRET AND CIRD HAVE BEEN WORKING

GRET and CIRD have been implementing an agroecological dissemination strategy for small-scale farmers. A total of 290 vegetable producers have joined producer groups, which were established to supply products to local and Siem Reap markets. On average 90 tonnes per month are sold to the markets in Siem Reap and to local markets. Some short supply chains, described below, have also been developed.

Senteurs d'Angkor – is a shop and a member of the Angkor Handicraft Association (AHA), where local handicraft products are sold such as soaps, candles, incense and spices, which are delivered by different suppliers. The shop began to collaborate with the Project in September 2014. The shop sets a fixed price for two weeks, there are four deliveries per week at 8:00 am and producers are paid every 2 weeks.



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Bayon School – To respond to and fulfil market demands, one of the collectors has been collaborating with a project to supply vegetables, fruit, rice and local meat (chicken, pork, beef, etc.) to the Bayon School, to provide nutritious food for children in the Siem Reap Province education programme.

Since 1997 Bayon School has been educating children in need. In 2014, a canteen was built to provide healthy meals for up to 200 students, five days a week. Collaboration with the Project began in November 2014. The price for produce is fixed for 2 weeks and delivery takes place from Monday to Friday at 7:00 am. Producers are paid every 2 weeks.

Molopor restaurant – In order to deliver agroecological products produced by small-scale farmers, and improve their recognition; the Project has been collaborating with restaurants in Siem Reap City, Siem Reap Province. Vegetables and fruit are purchased on a regular basis.

Molopor is a Thai food restaurant that opened in 2014 and is located near Siem Reap's river. Collaboration with the Project began in January 2015. Fixed prices are set for 1 week and there are 2 to 3 deliveries per week at 8:00 am. Payment to various suppliers takes place every week.



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The International Symposium on Agroecology in China provided a forum for representatives of governments, academia, the private sector and civil society organizations, including peasants, fisherfolks, pastoralists, urban communities, indigenous peoples, women's organizations, youth and others, to share experiences and showcase successful examples of agroecological approaches to agriculture in China and the region. The discussion and debate focused on the challenges linked to food system transformation, climate change, natural resources, social innovation and the necessary responses from public policies.

The present Proceedings collects the lessons learned from the symposium, as well as the knowledge, scientific research and case studies of agroecology in practice, both at the global level and those specifically focusing on China and Asian countries.



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