EVALUATION OF FLOWER-PLANT CULTIVATION'S IMPACTS

ON RURAL SOIL AND WATER

---- CASE STUDY IN WUJIN, MIDDLE-EAST PART OF CHINA

A Thesis

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ABSTRACT

The history of flower-plant (F-P) cultivation in China can be mainly divided into three periods: in 1980s, it existed with the style of small workshops with traditional planting skills, little scale, limited species and dispersed management. From 1991 to 1997, experienced the transforming from planned economy to market economy, this cultivation became basically suitable for industrial management. After 1998, it has been in the primary stage of management industrialization with sharply increased cultivation scale and species. China is in urbanization process and the market demand for F-P is huge and long lasting. The global F-P product demand is with big potential as well. Attracted by the huge market, plenty of districts over China start ornamental plants cultivation and till 2010, the national planting area came up to 918,000 ha from 70,000 ha in 1998 and sales value up to 86.21 billion Yuan from 9.9 billion in 1998. The output value also increased to 0.46 billion US$ from 3.2 million US$.

However, though F-P cultivation industry has brought much more economic benefits and job opportunities to local farmers than before and increased the regional greening coverage and beautified the environment, there are environmental problems emerging or being reported especially in the cultivation process which seems not to be sustainable. Firstly, with most farmers holding the misunderstanding that “more fertilizer and pesticide equals higher land productivity”, widely existed over-usage of chemical fertilizer and pesticide in cultivation (much more than in crops cultivation) are causing farmland soil and nearby water pollution seriously. Secondly, unlike traditional agriculture, it usually takes away a lot of land top-soil for distribution directly leading soil fertility decrease after years. So with the

hypothesis that “bringing rapid economic and societal development, F-P cultivation is threatening rural environment”, this research want to confirm and evaluate the impacts caused by F-P cultivation on rural environment mainly on soil and surface water. Wujin, honored with “Chinese Flowers & Plants Township” with more than 20 years flowers and plants planting history, was chosen as a typical case study area. Based on the DPSIR framework as logistic research guidance, we combined interview and structured questionnaire survey and field survey in order to figure out the driver, pressure, state, impacts of F-P cultivation, and then, based on the results, propose the well-targeted recommendations.

We face to face distributed more than 100 questionnaires to local farmers in traditional moving market and received 100 replies. Then, according to responders’ distribution map, we chose two sites (JiaZe and HuangLi town) for field work and finally collected 18 top-soil samples in 20 cm depth from F-P cultivated farmland (3 groups: control, > 10 years, and < 5 years) and 6 surface water samples from nearby-farmland stable water courses for analysis. The top-soil loss field survey was conducted on the main tree species in Wujin, which was divided into 3 categories (seedling, spherical shaped and up-growing trees) by us according to their separate calculating methods of top-soil loss.

According to the results of this research, the findings were as follows: 1) The low education level and no longer young are the internal limitations and the higher income from F-P than crops is the main external driver for the farmers to transfer to F-P from traditional agriculture cultivation; 2) The cultivation methods for farmers are mainly by self-learning and large chemical fertilizer usage (average 1623 Kg/ha/year) and low organic fertilizer usage (36% not use) is widely existed. Also the popular groundwater for irrigation (64% using) is a new

finding; 3) Usually the popular container seedlings of trees with a quicker financial feedback are taking away a larger amount of top-soil per km^2 and cause more serious soil fertility decrease than the up-growing and spherical trees. In addition, a linear relationship is expected and proved between tree's DBH (x) and soil ball's diameter (y) in up-growing trees (y = 4.5685x, R^2= 0.8526). Also an exponential relationship was found between each up-growing tree's age (x) and the yearly per unit amount of top-soil loss (y) (y = 14.219e-0.092x, R^2= 0.8747). So generally, according to the equation, the yearly top-soil loss situation by trees of different aged common specie in up-growing category can be predicted in a certain extent; 4) The surface water has very serious eutrophication problem after evaluation (100% hyper eutrophication). The obvious soil acidification tendency (pH 0.27-0.3 decrease) and TOC decreasing problem (2-3.6 g/Kg decrease) caused by F-P cultivation is also proved. The large amount of ground water for irrigation in F-P cultivation may lead to big possibility of land subsidence in rural area which needs more attention from the public and the government.

In reality, without external intervention to the farmers, if there is profit, there is cultivation. So, if the farmers continue to cultivate F-P and sell top-soil in current way, the vicious circle will be caused until the farmland fertility and safety is totally ruined. Then the rural economic development and society stability will break up. Currently the negative impacts caused by F-P cultivation haven not been paid enough attention to by academia, government and farmers. So we hope, through scientific data and logistic story, this research can somehow make contribution directly to stakeholders' better understanding and realization of F-P cultivation in a sustainable way.

Key Words: F-P, Sustainable agriculture, DPSIR, Top-soil loss, Water eutrophication

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LIST OF ABBREVIATIONS

AK	Available Potassium
AN	Available Nitrogen
AP	Available Phosphatase
CAM	Chinese Agriculture Ministry
CF	Chemical Fertilizer
DBH	Diameter at Breast Height
DPSIR	Driver-Pressure-State-Impact-Response
DSR	Driver-State-Response
EEA	European Environment Agency
EV/SV	Export Value / Sale's Value
F-P	Flower-Plant
GIWA	Global International Water Assessment
OECD	Organization for Economic Co-operation and Development
OF	Organic Fertilizer
PSR	Pressure-State-Response
TP	Total Phosphatase
TK	Total Potassium
TN	Total Nitrogen
UNEP	United Nations Environment Program

LIST OF UNITES OF MEASUREMENT

℃	degree Celsius
cm	centimeter
cm^3	cubic meters
g	gram
ha	hectares
kg	kilogram
km	kilometer
km^2	square kilometers
L	liter
m	meter
m^2	square meters
mg	milligram
mm	millimeter
Mu	2000/3 square meters (Chinese traditional area unit)
No.	number
US$	United States dollars
%	one hundred percent
‰	one thousand percent

CHAPTER-1 INTRODUCTION

1.1 Background

1.1.1 Definition of “flower-plant (F-P)” (花卉苗木)

In China, the narrow sense definition of “flower (花卉)” is “herbaceous plant with ornamental value” while the broad sense definition also includes “herbaceous or woody ground cover plants, flowering shrubs, blossom trees, bonsai, etc. Generally，Chinese people adopt the narrow sense definition of “flower” originally from “Chinese Agricultural Cyclopedia -Ornamental Horticulture Volume”. When in the application of statistic work for “F-P industry”, Chinese agriculture ministry gives the word “flower” the following explanation: Flowers include all the cultivated plants for ornamental, landscaping, greening or sweetening purposes belonging to the agricultural products. In this paper, in order to avoid the misunderstanding caused from the translation between two languages, the author adopts the narrow sense definition of “flower” and use “flower-plant” instead to indicate the same meaning with “flower” from Chinese agriculture ministry.

1.1.2 Flower-plant industry

F-P industry reflects the economic phenomena derived from traditional cultivation activity which was simply for individual ornamental purpose and from flower culture’s development. Nowadays, flowers and plants are treated as not only agricultural products but also commodities accompanied with exploring, cultivation, transporting, distributing, and trading activities in the market (Zehui JIANG, 2002). The features of the industry include high investment, high efficiency, and high risk (Kequan TAO, 2001), high dependence to natural resources and labor intensive industry (Xiaoyi MIN, 2007). This industry is usually with a certain scale and the initial investment for instrument or technology is much higher than traditional agriculture. Ornamental plants' consumption indicating people's pursuit of beauty and higher life quality also belongs to spiritual consumption which is temporal not liking traditional crops' or vegetables' consumption (Kequan TAO, 2001). In China, the abundant labor resource and Chinese farmers' extensive cultivation experience since ancient time can be obvious advantages for this industry's development.

1.1.3 History of flower-plant industry

China is one of earliest countries in the world in flower's application with at least 3000 years history. China also has abundant flower resources and flower culture. Since Tang and Song dynasties, China was in a leading position in the world referring to flower application, cultivation skills and new specie seeding selection theory & techniques. However, in the past 200 years, the development of F-P industry was totally behind the world's developed countries.

The F-P industry started since 1980s but it earned no obvious development taking a very little ratio in planting industry until 1986. So F-P industry's developing history can be mainly divided into three periods (Xiaoyi MIN, 2007):

1) The recovery period from 1986-1990: F-P industry was still a typical traditional industry mainly by the participation of family workshops with traditional cultivation skills, small scales, limited species and dispersed management. According to statistics from Chines agriculture ministry, national F-P cultivation area was around 200 km^2 and the output value was 0.7 billion Yuan in 1986. However, the two items respectively increased to 330 km^2 and 1.1 billion Yuan in 1990. Though the cultivated area and industrial output value had a certain increase, the F-P industry was still in recovery period.

2) Rapid developing period from 1991 to 1997: Experienced from the transformation from planned economy to market economy, F-P industry became basically suitable for industrial management. During this period, national economic development, cities' growing greening projects and people's increasing life quality actively lifted up the F-P demand and encouraged the industry' s fast development. In general, the typical character in this period was the better situation of F-P products shortage. For instance, in 1997, national cultivated area came up to 865 km^2 with output value 9.377 billion Yuan offering 1.889 billion fresh cut flowers, 1 billion potted flowers, etc. So, till the end of 1997, Chinese F-P industry had the basic conditions for industrial management.

3) Initial stage for industrialization from 1998 till now: it has been in the primary stage of scalization, marketization and industrialization in aspects of cultivation, circulation and research. In 2007, national F-P markets increased to 2,485 and companies increased to 54,651. The public participation in the unit of family in F-P cultivation reached 1,194,385 supporting 3,675,408 jobholders. In addition, professional technical staffs' number increased to 132,214 (Table 1). China is in the urbanization process and the market demanding for F-P is huge and continuous for a long time. With the economic development, people's daily consumption for

ornamental plants is also increasing. The global ornamental product demanding is still with big potential as well. Attracted and pulled by the big market demanding, plenty of districts over China started F-P cultivation and, till 2010, the national planting area came up to 9,176 km^2 from 698 km^2 in 1998 (Fig. 1) and sales value up to 86.21 billion Yuan from 0.99 billion in 1998 (Fig. 2). Though taking a small ratio to total sales value (Fig. 3), the export value increased to 0.46 billion US$ from 32 million US$ (Fig.2) during 12 years. Currently, the top 5 provinces in total cultivation area are JiangSu, HeNan, ZheJiang, SiChuan and HuNan province. Besides, JiangSu, ZheJiang and HeNan province rank the top three in the ornamental trees planting part respectively with the ratio of 84.3%, 80.2% and 68.9% (CAM, 2011).

Table 1. National F-P market information from 1998 to 2007

Year	No. of F-P Market	No. of F-P Company	No. of Family Participation	No. of Jobholder	No. of Technical Staff
1998	1564	67840	319894	1022867	30318
1999	2066	21273	403931	1197481	35499
2000	2002	21975	422764	1458832	46490
2001	2018	31747	673599	1909109	57001
2002	2397	52022	864006	2470165	85145
2003	2185	60244	954660	2934064	97267
2004	2354	53452	1136928	3270586	122851
2005	2586	64908	1251313	4401095	132318
2006	2547	56383	1417266	3588447	136412
2007	2485	54651	1194385	3675408	132214

Source: CAM, 2008, http://zzys.agri.gov.cn/huahui.aspx

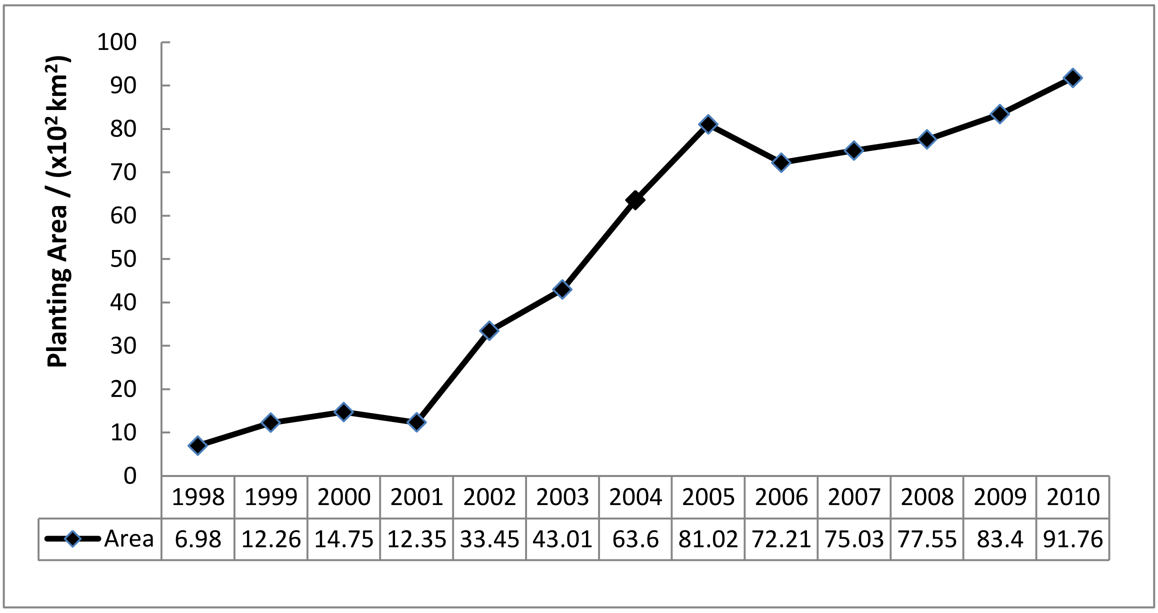

Figure 1. Changes of Chinese national yearly F-P cultivation area
Source: CAM, 2011

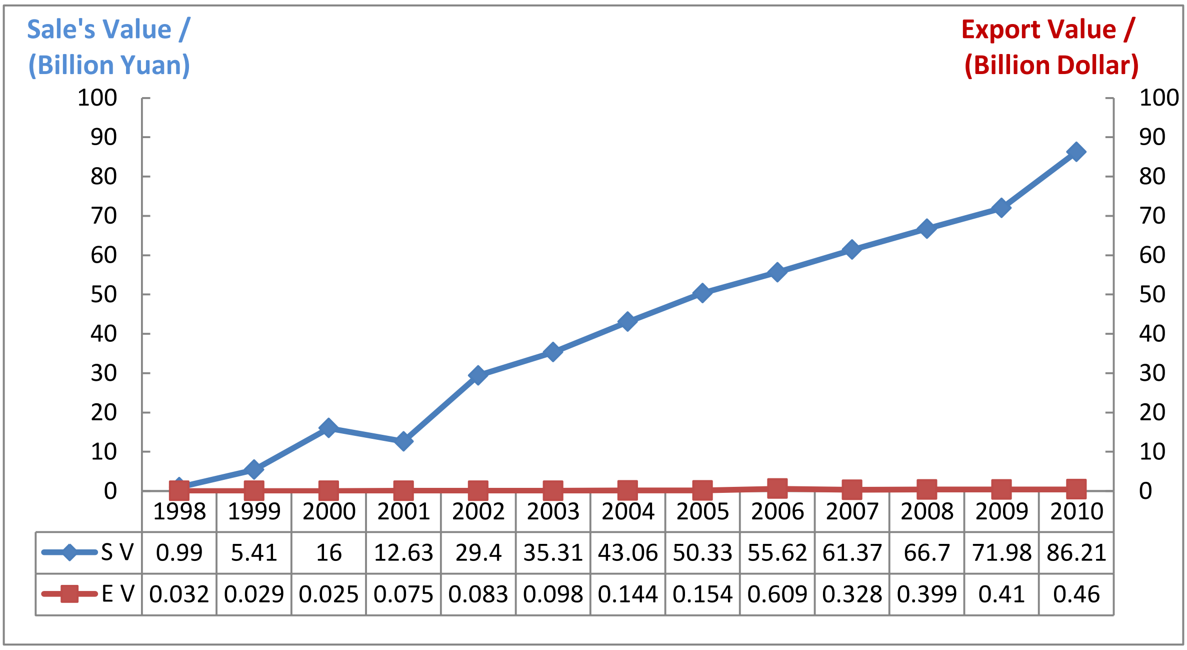

Figure 2. Changes of national yearly F-P sale's value (S V) and export value (E V)
Source: CAM, 2011

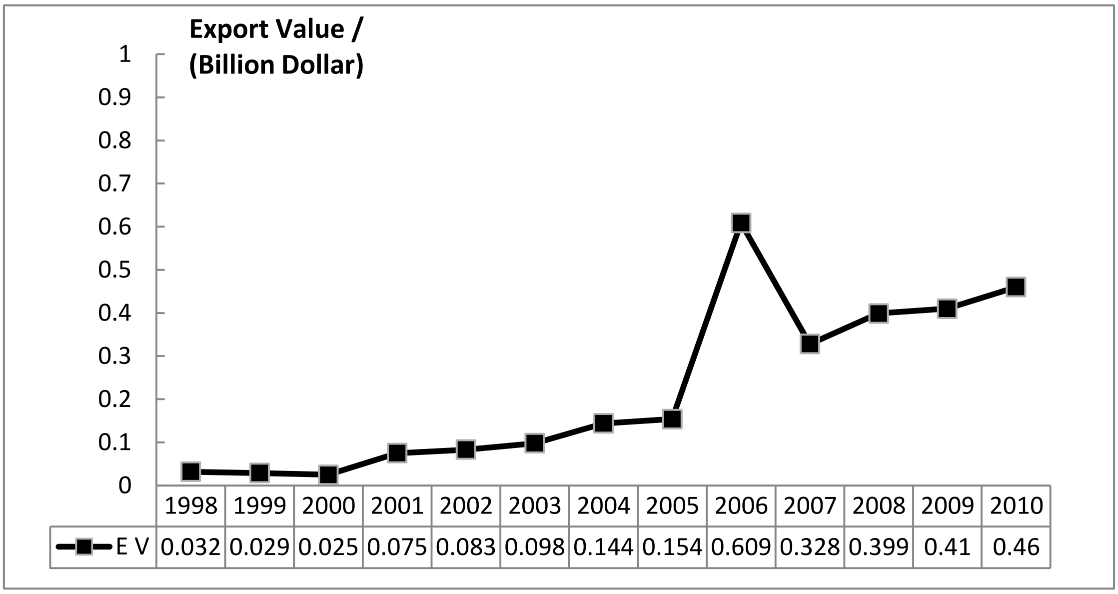

Figure 3. Changes of national yearly F-P export value (EV)
Source: CAM, 2011

1.2 Problems Statement

However, accompanied by F-P cultivation's quick spreading over China, some environmental problems are emerging gradually.

Firstly, over-usage of chemical fertilizer (CF) and pesticide causing soil and water contamination potential are widely existed. China only has 7% the world's farmland but needs to support 22% the world's population, so the farming activities must be very intensive and the land productivity for food or plants should be increased. Chinese farmers, mostly without high education level, usually hold the opinion that using more pesticides, herbicides and CF equals higher productivity and more economic benefits. But a lot of research has proved the diminishing marginal returns between productivity and CF's usage after over a certain amount. In 2008, the 7% of global farmland cost 31.4% of global CF quantity (FAO 2008). Table 2 shows the Chinese national yearly usage of various CFs. After 20 years from 1980 to 2008, the total amount of various CF usages increased more than 4 times. In 2008, the national cultivated area was around 120 million ha and the average CF was round 430 Kg /ha, but the upper safe limit of CF for avoiding water pollution in developed countries is around 225Kg/ha (Jiakang Li *et al.*, 2001) and China used almost two times amount. In F-P cultivation, usually the usage is much higher than in traditional agriculture. However, accompanied with high fertilizer usage is the low efficiency. Affected by facts of fertilizing methods and different nutrition ration, the efficiencies of nitrogenous, phosphate and potash fertilizer are 30-35%, 10-20% and 35-50% respectively (Kui PENG, 2001) which are 15-20% lower than developed countries. The farmland yearly loss ratio in China is 33.3-73.6% and average ration is around 60% (Fudao ZHANG, 1985). Abusing and unreasonable fertilizing can cause soil acidification, structure crust and fertility decreasing in cultivated farmland (Guilan ZHANG *et al.*, 1999). The extra nutrition elements like N and P, except absorbed by plants and remained in soil, through surface runoff or eluviation, may lead to surface water eutrophication and ground water contamination problems. So blindly increase the fertilizing density can only cause more loss ratio and more serious agricultural no-point source pollution.

Table 2. National chemical fertilizer usage in cultivated area

Year	Cultivated Area	Chemical Fertilizer	CF / Area	Nitrogenous Fertilizer	Phosphate Fertilizer	Potash Fertilizer	Compound Fertilizer
	$*10^8$ ha	$*10^4$ tons	Kg/ha	tons	tons	tons	tons
1980	0.99	1269.4	128.2	934.2	273.3	34.6	27.2
1985		1775.8		1204.9	310.9	80.4	179.6
1990		2590.3		1638.4	462.4	147.9	341.6
1995		3593.7		2021.9	632.4	268.5	670.8
2000		4146.4		2161.5	690.5	376.5	917.9
2005		4766.2		2229.3	743.8	489.5	1303.2
2006		4927.7		2262.5	769.5	509.7	1385.9
2007		5107.8		2297.2	773	533.6	1503.0
2008	1.217	5239.0	430.4	2302.9	780.1	545.2	1608.6

Source: Chinese statistical yearbook, 2009

China started to use organochlorine agrochemicals in 1940s. According to “Chinese Economic Yearbook”, the national agrochemicals’ usage was doubled to 1.46 million tons in 2005 from 0.733 million tons in 1990 and the categories increased to more than 2,000 from 100. After using them in farmland, the chemicals can go into and exist in surface/ground water, soil, plants and air. High toxic and high efficient pesticides and herbicides have gradually caused serious chemical remaining and ecological balance problems. In 2003, the average usage of agrochemicals was around 75 Kg/ha equaling more than 2 times the amount in developed countries but with almost 70% loss into environment. These chemicals are pushed into the eco-environment system circulation threatening eco-environmental safety, agricultural products quality and human health (Zhiwen F, 2010).

Secondly, selling plants with a big amount of local soil in order to improve survival rate is leading to urgent farmland top-soil quick loss problem. The farmland cultivated horizon with fertility is usually around 15-20 cm depth from ground. Figure 4 is a common soil profile: the soil has many layers with various characters.

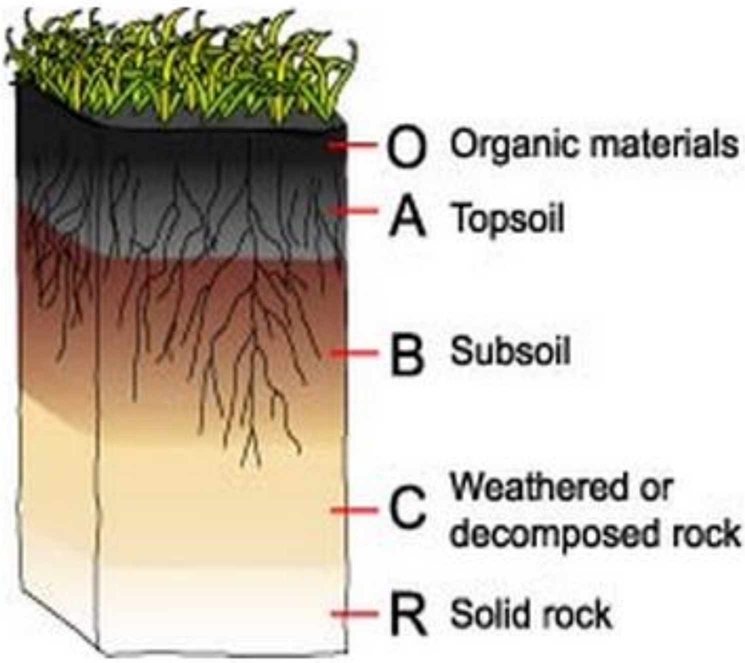

Figure 4. Typical simplified main soil profile
Source: GRILLO SERVICES, 2011/05/23
http://grilloservices.com/grillo-blog/determining-the-right-type-of-soil-for-your-project/

The "O" stands for organic. It is a surface layer, dominated by the presence of large amounts of organic material in varying stages of decomposition. This black line shows the real soil surface. The "A" horizon is usually called "topsoil". This layer has a layer of dark decomposed organic materials, which is called "humus". In farmland, the cultivated horizon is mostly in this layer. "A" Horizons may be darker in color than deeper layers and contain more organic material, or they may be lighter but contain less clay or sesquioxides. The "A" is also known as the zone in which most biological activity occurs. Soil organisms such as earthworms, pot worms and many species of bacteria are concentrated here, often in close association with plant roots. Thus the A horizon may be referred to as the bio-mantle. The depth of this layer is usually from 10-25cm. The "B" horizon is commonly referred to as "subsoil", and consists of mineral layers which may contain concentrations of clay or minerals. Accordingly, this layer is also known as the "illuviation" horizon or the "zone of accumulation". In addition it is defined by having a distinctly different structure or consistency to the "A" horizon above and the horizons below. They may also have stronger colors than the "A" horizon. The "C" Horizon may contain lumps or more likely large shelves of un-weathered rock, rather than being made up solely of small fragments as in the solum. The "R" horizons denote the layer of partially weathered bedrock at the base of the soil profile. Unlike the above layers, "R" horizons largely comprise continuous masses (as opposed to boulders) of hard rock that cannot be excavated by hand. Soils formed in situ will exhibit strong similarities to this bedrock layer (Johnson et al., 2005; Wilkinson et al., 2005; World Reference Base for Soil Resources).

In order to improve plants' survival rate during transplanting, selling plants usually means selling plants and local soil. The container's volume decides how much soil will be carried out with container seeding. The spherical trees' crown diameter and up-growing trees' trunk diameter determine the accompanied soil spherical or hemispherical diameter. An example is the SiMing mountain area in Ningbo city, Zhejiang province where F-P cultivation is very popular in recent years. In 2011, SiMing mountain area sold out 30 million plants taking away at least 0.75 million tons soil.[1] SiMing mountain area includes 9 towns and 2 state-owned forest farms and, in 2009, the remote sensing image from Ningbo water conservancy bureau indicated 129.81 ha area having water and soil erosion problem in SiMing mountain area taking 25.85% of the total erosion area 502.10 ha in Ningbo city (Jianyue H, 2012). [2]

1.3 Sustainable Agriculture

"Sustainable agriculture" was addressed by US Congress in the 1990 "Farm Bill". Under that law, "the term sustainable agriculture means an integrated system of plant and animal production practices having a site-specific application that will, over the long term":[3]

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1 Statistical data from Ningbo Forestry Ministration

2 Jianyue, H. 2012.03.12. Though bringing wealth, F-P cultivation affects the ecology. Ningbo Evening. http://nb.ifeng.com/qtwz/detail_2012_03/12/165697_0.shtml

3 Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA), Public Law 101-624, Title XVI, Subtitle A, Section 1603 (Government Printing Office, Washington, DC, 1990) NAL Call # KF1692.A31 1990

1) Satisfy human food and fiber needs;

2) Enhance environmental quality and the natural resource base upon which the agricultural economy depends;

3) Make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;

4) Sustain the economic viability of farm operations; and

5) Enhance the quality of life for farmers and society as a whole.

Sustainable agriculture always integrates three main goals: environmental health, economic profitability, and social and economic equity. A variety of philosophies, policies and practices have contributed to these goals. People in many different capacities, from farmers to consumers, have shared this vision and contributed to it. Sustainability rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, stewardship of both natural and human resources is of prime importance. Stewardship of human resources includes consideration of social responsibilities such as working and living conditions of laborers, the needs of rural communities, and consumer health and safety both in the present and the future. Stewardship of land and natural resources involves maintaining or enhancing this vital resource base for the long term.[4]

[4] http://www.sarep.ucdavis.edu/sarep/about/def

Sustainable agriculture refers to a system capable of maintaining productivity and usefulness to society, indefinitely, at the same time as conserving resources and environmental health, being economically profitable and supporting social needs.[5]

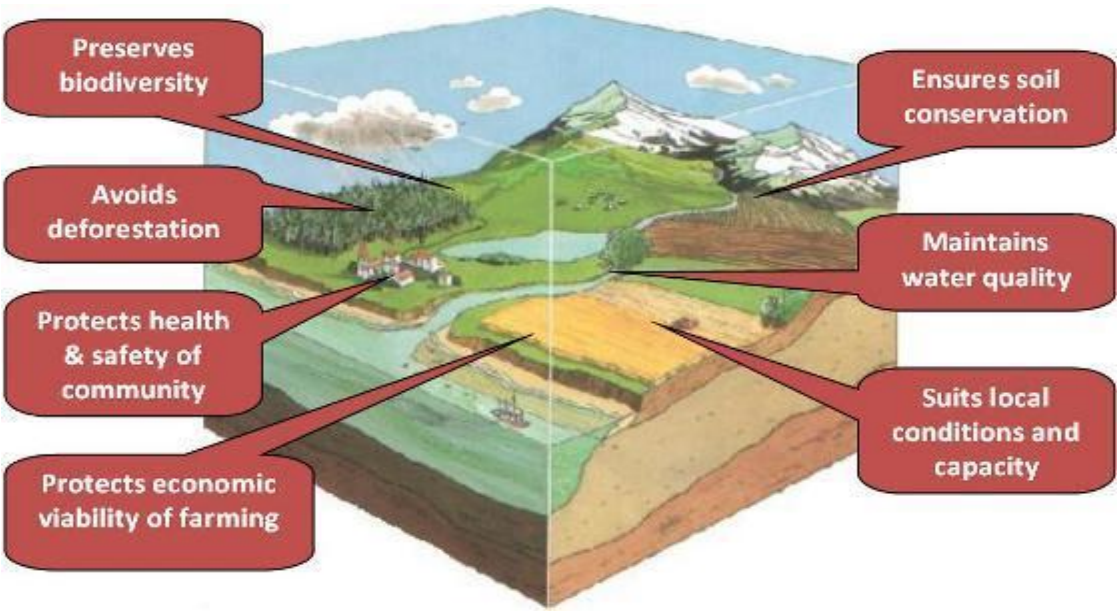

Figure 5. Stewardship of both natural and human resources is of prime importance

Source： http://www.stewardshipcommunity.com/stewardship-in-practice/challenges-of-modern-agriculture/sustainable-agriculture.html

1.4 Research Hypothesis

As part of agriculture, F-P cultivation has brought much more economic benefits and social improvement like more job opportunities and better life quality in rural area than before. However, there are environmental problems emerging and reported in cultivation activities

[5] http://www.stewardshipcommunity.com/stewardship-in-practice/challenges-of-modern-agriculture/sustainable-agriculture.html

but without being paid enough attention from public and academia which makes F-P cultivation seems not that sustainable. Unlike traditional agriculture, F-P always takes away a tidy of land top-soil for transplantation. Soil nutrients including total organic carbon erosion accompanied by transplantation activities will lead farmers to use more chemical fertilizers to ensure the F-P output from the land if the profits are still attractive enough. In return, continuous over-usage of chemical fertilizer and pesticide are causing soil acidification, structure deterioration and water pollution potentials. So after times, the F-P industry is making an unsustainable vicious circle.

So the basic hypothesis of this research is that: though bringing rapid economic and societal development, the F-P cultivation activities are threatening rural environment.

1.5 Research Objective & Questions

Because the impacts on environment are not being paid attention by academia, based on the research hypothesis, the objective of this research is to confirm and evaluate the impacts caused by F-P cultivation on rural environment mainly on soil and surface water.

After the main research objective, combined with the DPSIR (which will be introduced in details in methodology chapter) research flow, there are 5 research questions:

Q1: What’s the main driver for local farmers’ transformation from traditional crops’ to F-P cultivation? (Driver)

Q2: What activities have they done during cultivation and transplantation? (Pressure)

Q3: What's current state of local rural environment including soil quality and quantity & farmland-nearby surface water quality? (State)

Q4: What impacts F-P cultivation is causing to sustainable agriculture and sustainable social and economic development? (Impact)

Q5: What kinds of suggestions can be provided to stakeholders to reduce the negative impacts? (Response)

1.6 Significance and Structure of this Thesis

Currently the negative impacts caused by F-P cultivation haven't been paid enough attention to by academia, government and farmers. But the problems brought by F-P cultivation are with high urgency. So we hope this research, through scientific data and logistic story, can somehow contribute directly to stakeholders' better understanding and realization of F-P cultivation in a sustainable way. After finding out the problems and make it known to the public, the problems then can be solved by stakeholders. Well-targeted recommendations will be proposed in the end of research for public reference.

The structure of this thesis is as follows: Chapter 1 is mainly the background introduction of F-P industry in China and what is sustainable agriculture, the emerging problems statement, the research hypothesis, objective and 5 main research questions, also the significance of this research. Chapter 2 is mainly introducing the case study area Wujin in three aspects: geographic and climate information, social and economic information, and local F-P industry information. Chapter 3 is the methodology part for the research: firstly the research flow guidance of DPSIR framework, then the social survey methods including interview and detailed information of questionnaire part, then the field survey conducting methodology including qualitative and quantitative survey: the top-soil loss calculation and water/soil quality analysis. Chapter 4 shows the results corresponding to the questionnaire and the field surveys. In this chapter, the shown up results including lots of tables and figures are after general conclusion and data analysis software analyzing. Chapter 5 is the discussion and conclusion parts. This chapter is respectively answering the 5 research questions proposed in Chapter 1 based on DPSIR framework and the final conclusion is shown in a flow chart. Chapter 6 is the well-targeted recommendations to stakeholders based on the research findings.

CHAPTER-2 CASE STUDY AREA

Wujin in Changzhou city in Jiangsu province having more than 20 years flowers and plants planting history, which is honored with “Chinese Flowers & Plants Township” by Chinese forestry ministration in Nov. 2007, is chosen as a typical case study area in this research.

2.1 Geographic and Climate Information

Wujin is in Changzhou City, Jiangsu Province, China (Fig.6). It is located at the northwest of Tai Lake Plain in Yangtze River Delta with the geographic information of 31°20'-31°54′ N, 119°40′~120°12′ E. The total area is plain around 1245.8 km^2 with 27.4% (341 km^2) water area and 33.2% (414 km^2) cultivated area. Wujin belongs to sub-tropical with enough sunshine, suitable water, fertile soil and abundant products including plant species. In 2010, the average temperature was 16.5 ℃, 0.7 ℃ higher than past annual average temperature. The extreme maximum temperature was 38.6 ℃ happened in 13th August and extreme minimum was -5.8 ℃ happened in 14th January 2010. The average precipitation was 1085.1 mm, 6.3 mm less than past annual precipitation. The average sunshine duration was 2158.5 hours, 218.3 hours longer than past annual duration.[6]

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[6] Wujin Yearbook 2011 http://www.honet.cn/wjnianjian2011/profiles.asp?id=383

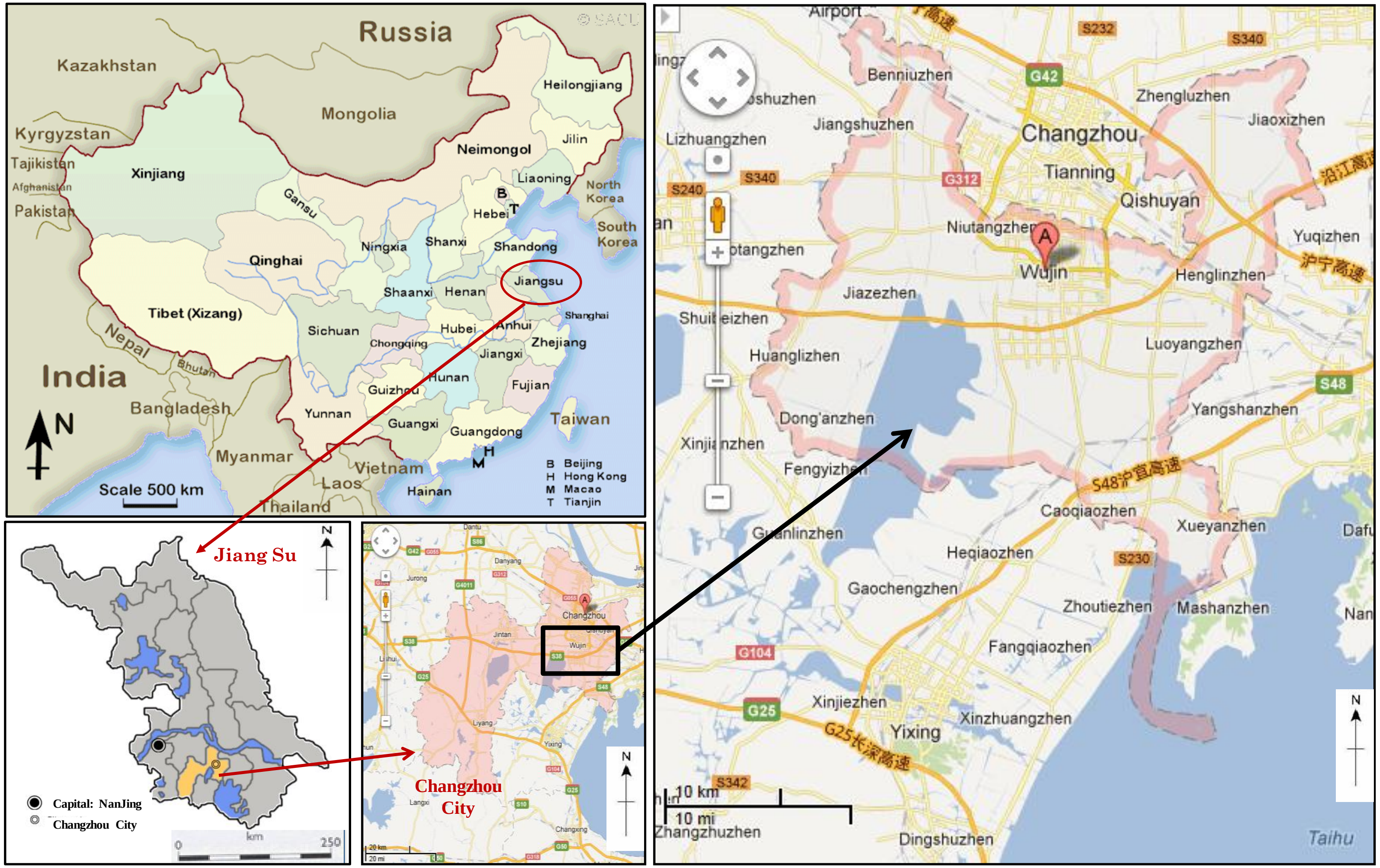

Figure 6. Study area: Wujin district in Changzhou city, Jiangsu province, China

Source: 1. Google Map; 2. http://en.wikipedia.org/wiki/Changzhou; 3. http://www.sacu.org/provmap.html

2.2 Social and Economic Information

In the end of 2010, the household population in Wujin was 1,002,977 with 362,654 households and the population density is around 805 per km^2. Natural growth rate of population was 0.23 ‰. Currently, Wujin district includes 14 towns, 2 streets, 2 Provincial-level development zones, 269 administrative villages and 98 communities. [7]

In 2010, the district GDP was 116.39 billion Yuan, increased by 20.6% from 2009. In addition, the primary, secondary and tertiary industry respectively contributed 3.698, 74.436 and 38.256 billion Yuan added value with 8.1%, 17.9% and 27.8% yearly increase correspondingly. Calculated with household population, local GDP per capital was 116.8 thousand Yuan increased by 1.89 from last year. The per-capita disposable income of urban residents was 27.2 thousand Yuan while 14 thousand Yuan of rural residents .Both of them had a bigger than 10% yearly growth. For farming, forestry, animal husbandry, side-line production and fishery industry, the total output value came up to 5.95 billion Yuan with 5.6% yearly growth. Besides, the farming industry brought 3.775 billion Yuan output value.

2.3 F-P Industry Information

F-P cultivation in Wujin was started in 1970s and till now, has been more than 20 years. Wujin was honored with “Chinese Flowers & Plants Township” by Chinese forestry

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[7] Wujin Yearbook 2011 http://www.honet.cn/wjnianjian2011/profiles.asp?id=383

ministration in Nov. 2007. According to the statistics from "Wujin Local Chronicles (1986-2007)", till the end of 2007, the entire F-P cultivation area reached 95 km^2 mainly distributed over the western part of Wujin including JiaZe (combined by former JiaZe, ChengZhang and XiaXi), Huang Li (combined by former HuangLi and DongAn), ZouQu (combined by former ZouQu and BoYi), and BenNiu town. Figure 7 shows the increasing of F-P cultivation area in Wujin district since 1986. In the beginning 14 years before year 2000, the changing rate was low and unobvious. After 2000, the cultivation area had a sharp increase and till 2005, the area was extended to more than 90 km^2. After 2005, the cultivation area increasing rate became smaller and the area kept gradual increase. Figure 8 indicates local participating households changing from 1986. In1986, the household number was around 14000 and in 2005, this number gradually increased to 34000 after 20 years. During 2005 and 2007, the numbers didn't change a lot and had kept stable. Currently, there area

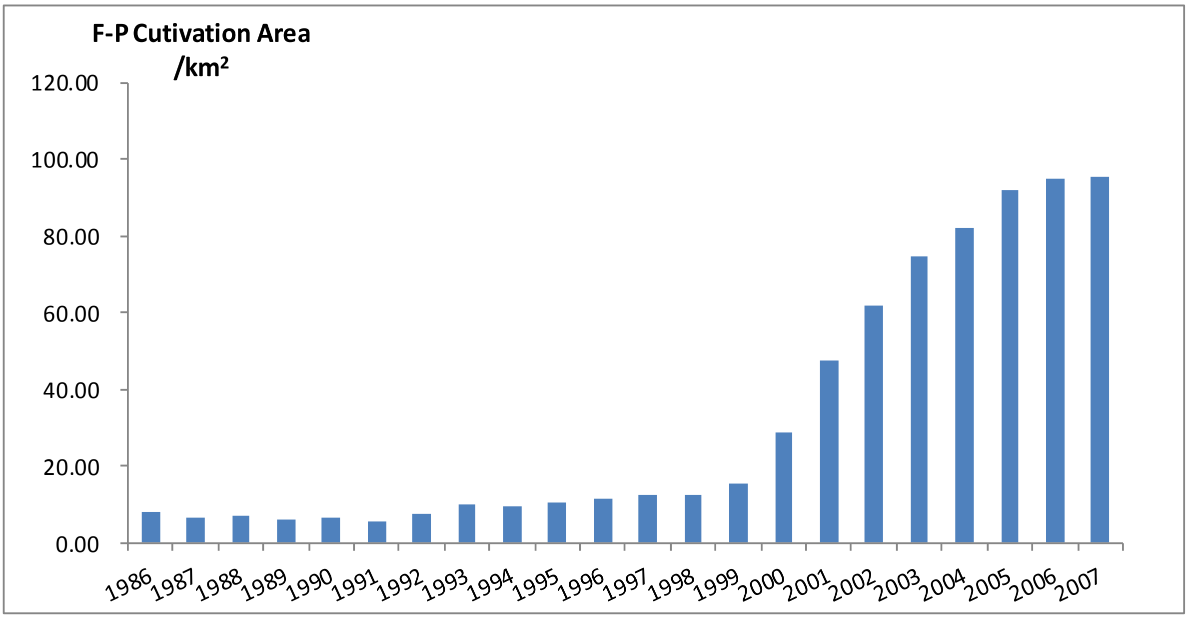

Figure 7. F-P cultivation area in Wujin since 1986
Source: WuJin local chronicles (1986-2007)

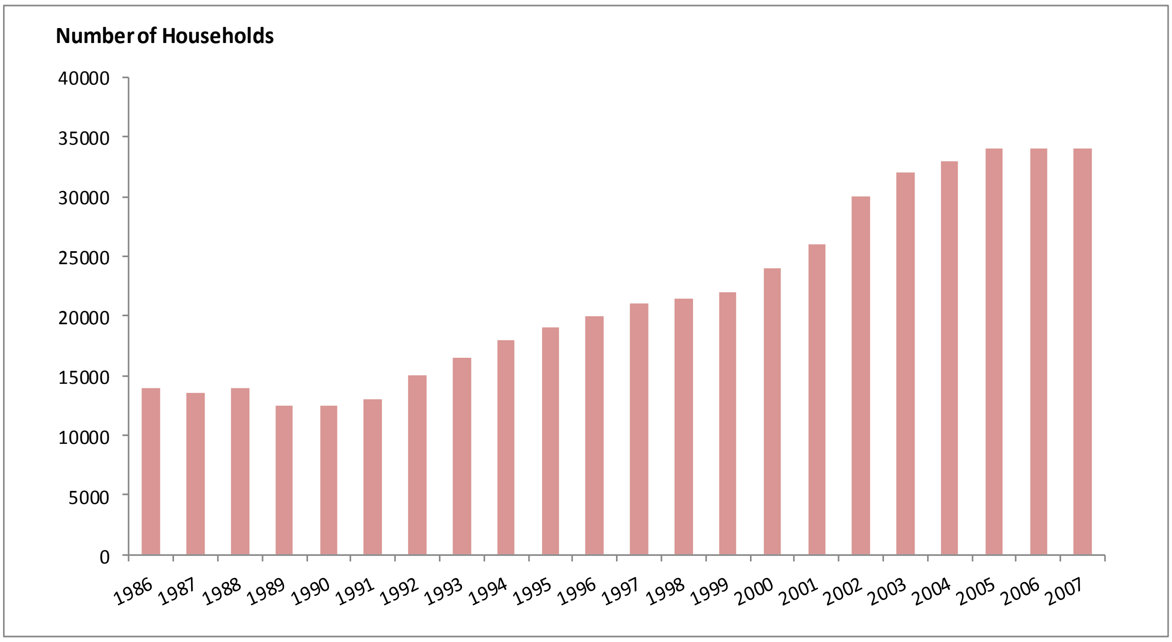

Figure 8. F-P cultivation participating households' number in Wujin since 1986
Source: WuJin local chronicles (1986-2007)

In 2006, the output of trees and flower plants came up to 0.16 billion. Besides, the output of bonsai, grass and fresh cutting flower respectively reached 0.6 million basins, 20 km^2 and 4 million pieces (Xiaoyi MIN, 2007). Figure 9 shows the four type (Grass, bonsai, flowers, and trees) F-P respective cultivation area variations and ratio to total F-P cultivation area changing since 2001. From figure 9, its' easy to tell that tree is the main specie cultivated. In 2007, trees cultivation area was 71.47 km^2 contributing a rate of 74.5 %. Grass area was 17.73 km^2 taking 18.5%. Besides, Flowers took 3.4% (3.27 km^2) and bonsai 3.5% (3.4 km^2). In addition, Figure 10 reflects the respective output value of the four types of F-P. In 2007, trees output value was around 536 million Yuan taking 55% of total. Bonsai, which was taking only 3.5% cultivation area, contributed 14% of output value. Besides, Grass (18.5% area) contributed 14% output value and flower (3.4%) contributed 5%. Meanwhile, in 2007, the output value per unit area for the 4 types were 16 Yuan/m^2 (tree), 15 Yuan/m^2 (flower), 75 Yuan/m^2 (bonsai) and 7.5 Yuan/m^2 (grass) correspondingly.

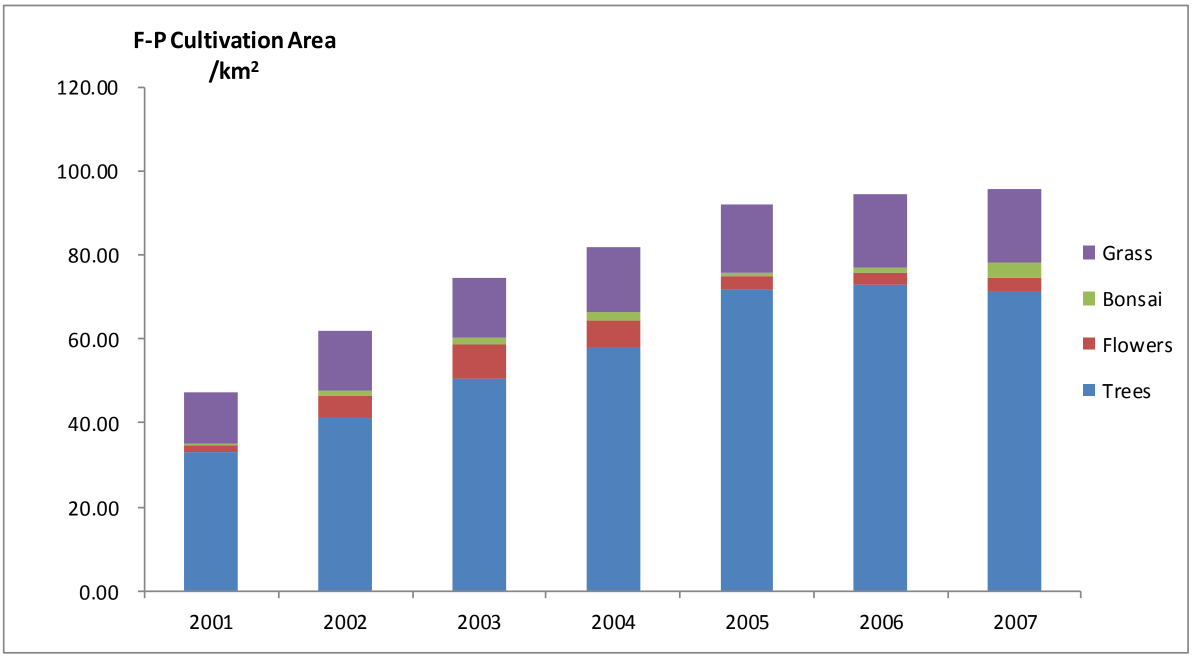

Figure 9. Respective cultivation area of different F-P types in Wujin since 2001
Source: WuJin local chronicles (1986-2007)

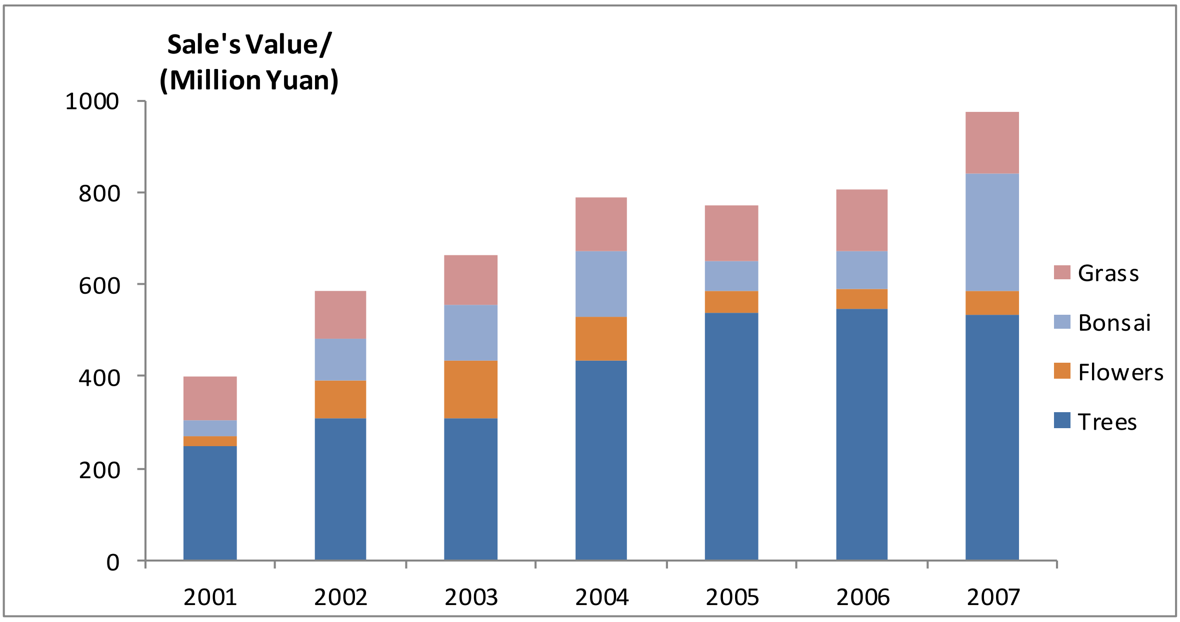

Figure 10. Respective output value of different F-P types in Wujin since 2001
Source: WuJin local chronicles (1986-2007)

In Wujin, a national key F-P trading market called XiaXi trading market is located here which has brought a very positive impact to the development of local F-P industry. In 1999, XiaXi market was founded with the support from Wujin government. In 2002, the first-phase market was extended 12 ha area by "Wujin XiaXi F-P Market Development Co., Ltd." and, currently, has increased to 23.5 ha. In 2010, the second-phase market construction was started with an extra 21 ha area. As described in Figure 11, the trading volume of XiaXi market earned a rapid increase during the past 11 years. The trading volume in 2000 was 0.12 billion Yuan while, in 2011, the number sharply went up to 9.88 billion Yuan which was more than 80 times the value in 2000. In 2006, the trading volume exceeded 2 billion Yuan and the seedling trees' trading volume ranked No.1 compared other F-P trading market in China. At the same time, the total trading volume was the biggest in east China area.

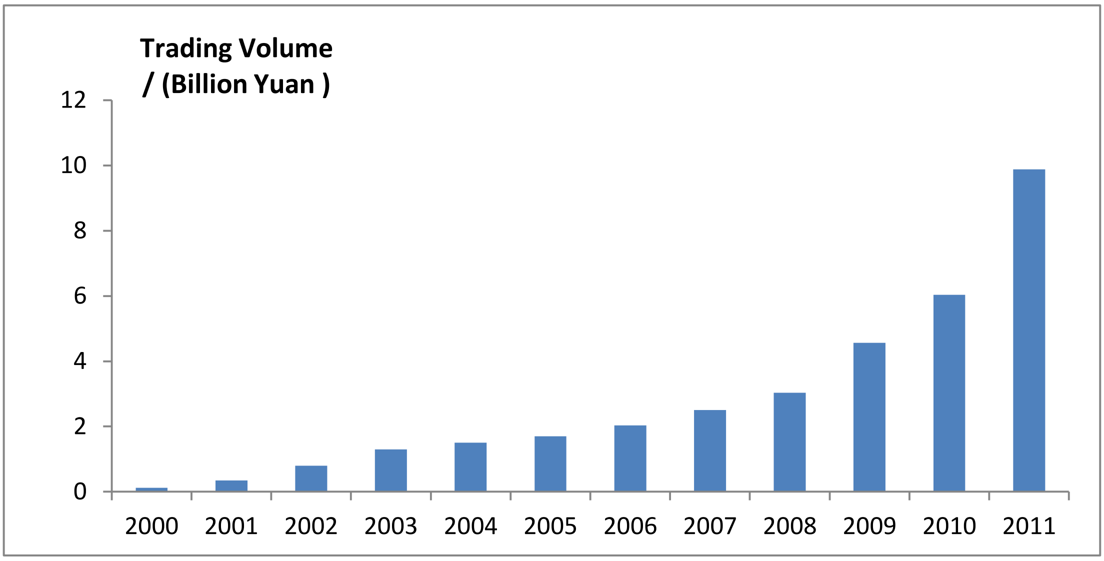

Figure 11. Trading volume in XiaXi F-P market in Wujin since 2000
Source: 1. WuJin local chronicles (1986-2007); 2. http://baike.baidu.com/view/3916915.htm

In Wujin district, JiaZe and HuangLi are two representative and famous towns in F-P cultivation. JiaZe town has a total area of 102.17 km^2 with 88.2 thousands permanent population. F-P cultivated area is around 64 km^2 taking more than 90% of the total cultivated farmland area by 21,500 households. More than 6000 F-P agent people are from JiaZe. In 2010, the GDP was 3.36 billion Yuan and farmers' average net income reached to 13,855 Yuan. HuangLi town has a total area of 86.08 km^2 with 72 thousands permanent population. In 2011, the GDP of HuangLi was 7.8 billion Yuan.[8] F-P cultivated area is around 29 km^2 (trees & flowers11.7km^2, grass 17.4km^2) taking 92.9% of total cultivated farmland area. The F-P sales value in 2011 was 0.425 billion Yuan.[9] The total F-P cultivation area from HuangLi and JiaZe has reached 93 km^2 taking more than 90% of the entire F-P cultivation area in Wujin district.

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[8] Wujin Government Homepage http://www.wj.gov.cn/web2010/zjwj/xzqhFlash/385532.shtml

[9] Report on the work of government in the first meeting of the second people's congress of Rulin town. 2011.12.26. http://wenku.baidu.com/view/bd202c8e6529647d27285235.html

CHAPTER-3 METHODOLOGY

3.1 Research Flow Guidance: Driver- Pressure- State- Impact- Response (DPSIR)

In order to systematically evaluate ornamental plants cultivation's impacts on environment in Wujin, this research is referring to DPSIR framework which can logistically and practically figure out the current local environment state through relevant indicators and formalize the cause-effect relationships between various sectors of human activity and the environment for better understanding.

In response to the challenge of linking scale issues with political objectives, the ''Pressure-State-Response'' (PSR) model was one of the first models that aimed to integrate scientific and political aspects of indicators. Historically, the original form of the PSR model was developed by the OECD in collaboration with the UNEP and Statistics Canada (Bakkes *et al.*, 1994; Hammond *et al.*, 1995). Basically, the PSR model puts various factors into a causal chain framework. The stream of factors presents the relationships between the indicators in a clear and structured manner. Since the PSR Model was introduced by the OECD in the 1990s, there has been a surge in the use of environmental indicators for reporting in various institutions, such as by the European Environment Agency (EEA), US Environmental Protection Agency (EPA), United Nations Environment Program (UNEP), World Resources Institute (WRI), and the CBD (Niemeijer and de Groot, 2008a, b). Over time, certain modifications were made to the original PSR framework as it lacked behavioral elements, and the focus shifted to human-induced pressures and responses (Lin *et al.*, 2009); thus, the frame-work integrated the drivers with the DPSIR models (Fig. 12).

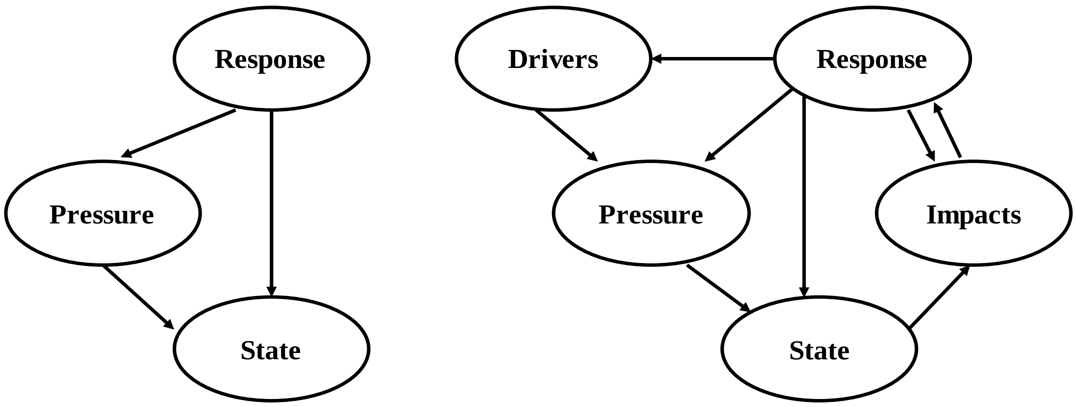

Figure 12. PSR and DPSIR models

The Driver-Pressure-State-Impact-Response (DPSIR) frame-work was developed in the late 1990s and proposed by the Organization of Economic Co-operation and Development (OECD, 2003) as a means of structuring and organizing indicators in a way that is meaningful to decision makers. Built on previous environmental frameworks, such as the Pressure-State-Response (PSR) (OECD, 1993) and the Driver-State-Response (DSR) (UN,1996), DPSIR was adopted as a conceptual framework by the European Environmental Agency (EEA) in 1995 (Gabrielson and Bosch, 2003). DPSIR was promoted to show the cause–effect relationships between environmental and human systems. The framework was introduced in a report by Smeets and Weterings (1999) to help policy makers to understand the meaning of the information in indicator reports. Drivers, which may be social, economic or environmental developments, exert Pressures on a certain environment. As a result of “Pressure”, the “State” of the environment changes. This then leads to an Impact (social, economic or environmental), which may lead to a societal Response. The response may feedback to Drivers, Pressures, States or Impacts (Smeets and Weterings, 1999).

Figure 13 well explains the detailed DPSIR framework in application. Driving forces are the underlying causes, which lead to environmental pressures. Examples are the human demands for agricultural land, energy, industry, transport and housing. These driving forces lead to Pressures on the environment, for example the exploitation of resources (land, water, minerals, fuels, etc.) and the emission of pollution. The pressures in turn affect the State of the environment. This refers to the quality of the various environmental media (air, soil, water, etc.) and their consequent ability to support the demands placed on them (e.g. supporting human and non-human life, supplying resources, etc.). Changes in the state may have an Impact on human health, ecosystems, biodiversity, amenity value, financial value, etc. Impact may be expressed in terms of the level of environmental harm. The Responses demonstrate the efforts by society (e.g. politicians and decision makers) to solve the problems identified by the assessed impacts, e.g. policy measures, and planning actions.

With DPSIR as the research flow guidance, the first step is social survey includes interview and questionnaire for “Driver” part (e.g., motivation to start F-P cultivation) and “Pressure” part (e.g., human activities during cultivation process causing threatens to environment). The second step of this research is field survey for “State” and “Impact” parts includes top-soil loss survey and surface-water and farmland soil quality analysis. The final

“Response” part based on the previous survey results will be proposed with the form of recommendation to relevant stakeholders to correct public misunderstanding in planting, to make regulations or policy for the government rightly leading the public farming behavior and balancing the local social & economic development with the environmental cost, etc.

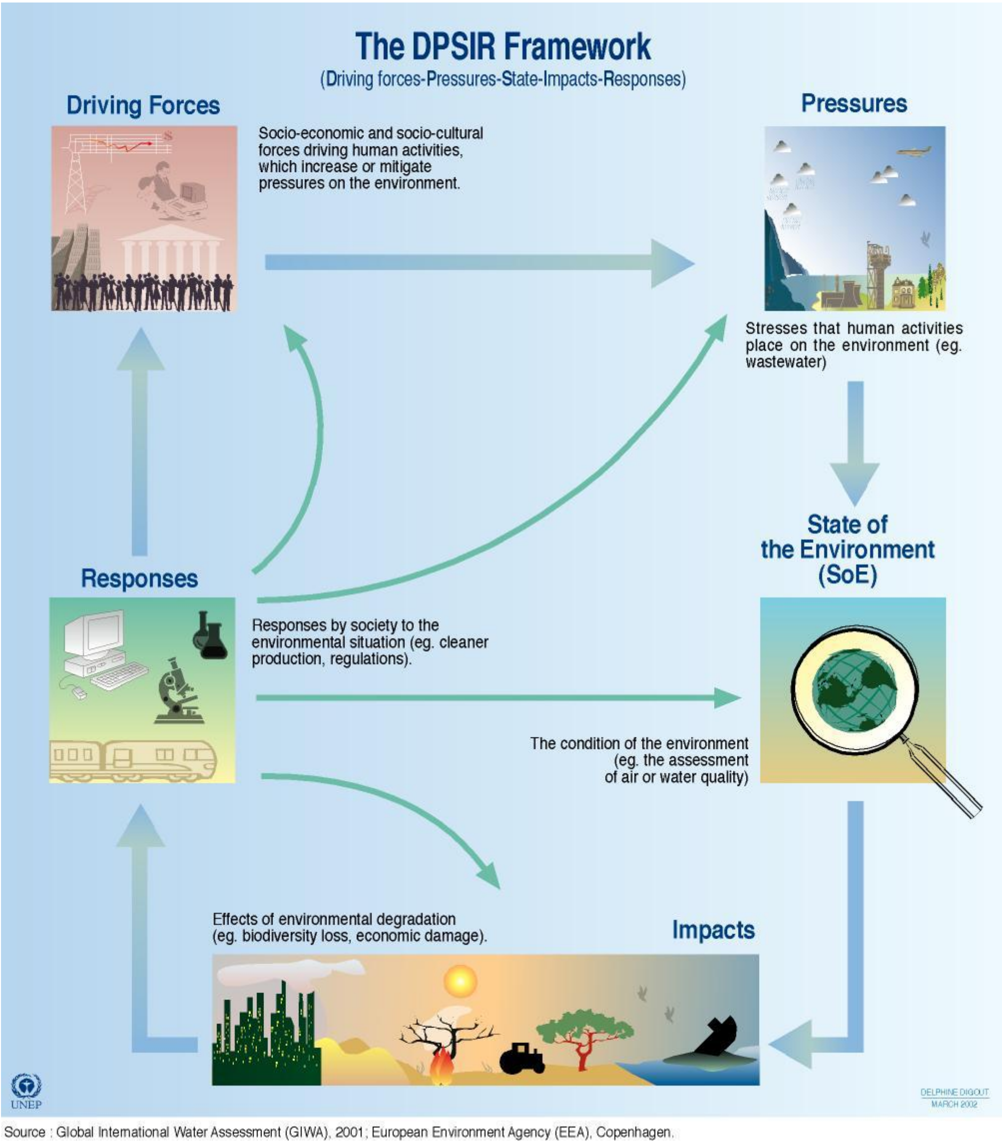

Figure 13. DPSIR framework with detailed information in application
Source: Global international water assessment (GIWA). 2001. EEA, Copenhagen.

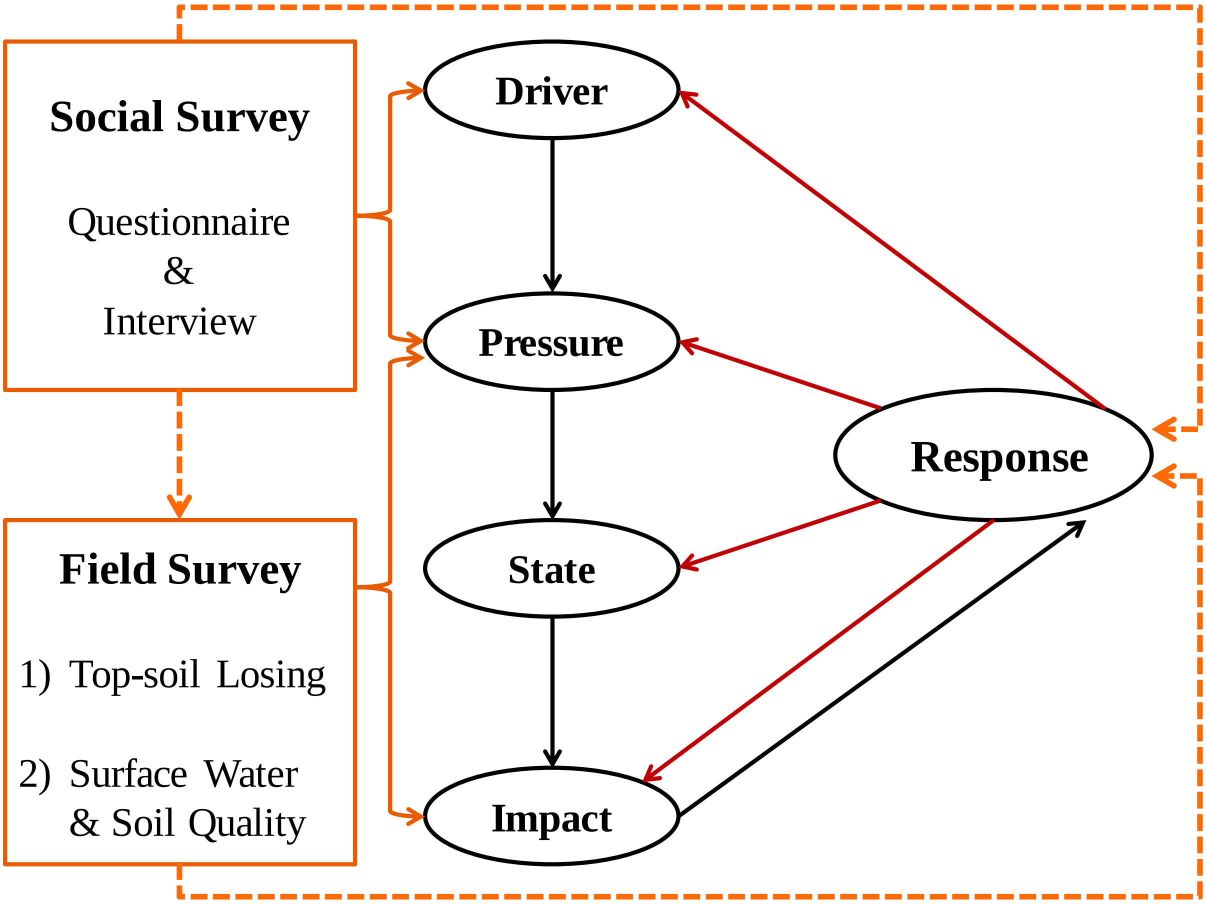

Figure 14. Research flow applying DPSIR

3.2 Social Survey: Questionnaire together with Interview (2011.03-2012.02)

From pre-survey, the author finds that individual farmers are still the basic unit in F-P cultivation in Wujin, so the questionnaire is targeted on individual farmers who are the key players in cultivation process in which the human activities are directly influencing local environment. As shown in Table 4, the questionnaire with 30 detailed questions is mainly divided into three parts: basic information, environmental aspect and economic & social aspect. In the first part, farmers' basic information including age, education level, cultivated area & history and initial motivation to transfer from traditional crops cultivation etc. . In the second part, questions are mainly about how they are cultivating F-P, what they have done to local environment and what feelings now they have to local environment (soil, water, climate, and air quality). In the third part, questions are about the economic investment and feedback, the increased job opportunities brought by F-P cultivation in rural area and their various information resources like for distribution channel, market information, cultivation skills etc.

The location to distribute the questionnaire was in traditional moving market along the main street every time in one of the following 4 towns by turns each month (Table 3). Generally, each town will hold a moving market in the morning time every five days. So, almost every day in each month, there's a gathering opportunity for individual planters from different towns or villages in or near Wujin district. Farmers bring their product samples and show them along the street. Most of them make a simple poster with all his products information like the species, quality and quantities standards. From the moving market, the planters can get information like the price level, current species with shortage or over-capacity, marketing demanding etc. Also a lot of agent people, greening project contractors and other buyers will come to the market looking for proper products. Moving market was chosen to distribute questionnaires mainly because planters from every district over Wujin can be found and then, the analysis result from questionnaire can better represent and reflect the real developing situation in Wujin area. The distribution of questionnaire was through random sampling method in September and October 2011, and finally 100 effective copies were reclaimed. Figure 15 shows the questionnaire responders' distribution map. Responders from

JiaZe and HuangLi town take 91% which reflects the same cultivation situation introduced in sector 2.3 that the cultivation area in both JiaZe and HuangLi takes more than 90% F-P cultivation area in Wujin. Besides, 2 responders are from BoYi town and 7 responders are outside Wujin area including XinBei district, nearby JinTan area etc.

Table 3. Traditional moving market location and time schedule

Moving market	**Date in Each Month**
Street in JiaZe	2,7,12,17,22,27th
Street in XiaXi	3,8,13,18,23,28th
Street in ChengZhang	1,6,11,16,21,26,31th
Street in HuangLi	5,10,15,20,25,30th

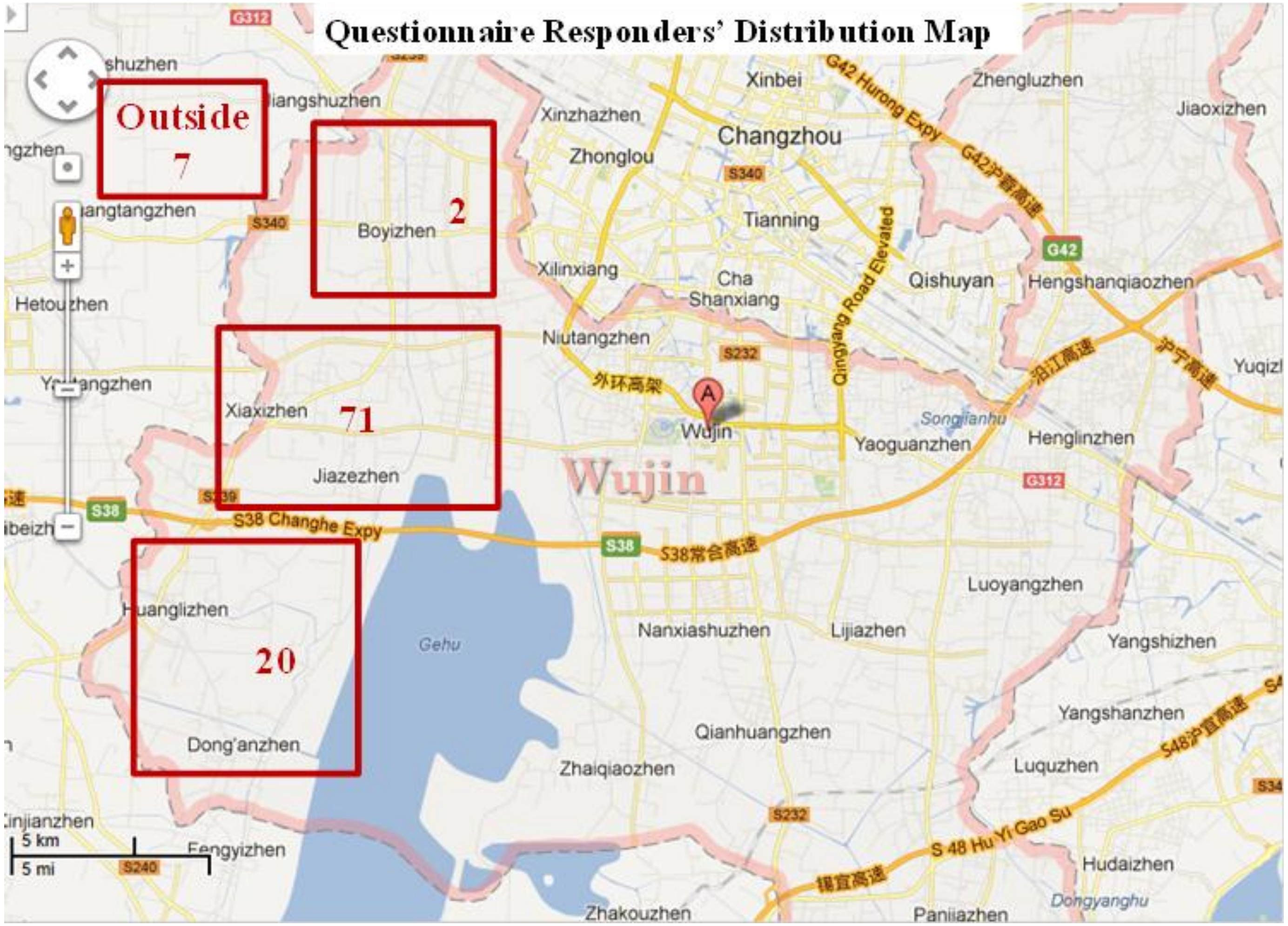

Figure 15. Questionnaire responders' distribution map

Table 4. Questionnaire to farmers for social survey[10]

Basic Information	
1. Name	
2. Age	
3. Education Level	
4. Local / Migrant	
5. Family Member	Male: Female:
6. Planting Area	A.<1 Mu B.1-5 Mu C.5-10 Mu D.> 10 Mu
7. Planting History	A.<1 year B. 1-3 Years C.3-5 Years D.5-10 Years E. >10 Years
8. Crops Planting Area	A.<1 Mu B.1-5 Mu C.5-10 Mu D.> 10 Mu
9. Working Hours / Day	A.<1 hour B.1-3 hours C.3-5 hours D.5-8 hours E.> 8 hours
10. Initial Motivation	A. Government Encouragement B. Follow Friends or Neighbours C. Crops' Low Output Value
11. Main Species	
Environmental Aspect	
12. Chemical Manure Usage	Times / Amount
13. Pesticide Usage	Times / Amount
14. Organic Fertilizer Using	Times / Amount
15. Irrigation Resource	A. Only Ground Water B.Ground Water & River Water C. Only River Water
16. Feeling to Local Water Quality	A. Very Good B. Good C. Mean D. Bad E. Very Bad
17.Felling to Local Micro-Climate	A. Very Good B. Good C. Mean D. Bad E. Very Bad
18. Feeling to Local Soil Quality	A. Very Good B. Good C. Mean D. Bad E. Very Bad
19. Feeling to Local Air Quality	A. Very Good B. Good C. Mean D. Bad E. Very Bad
Economic & Social Aspect	
20. Yearly Investment	**a. Seeding/Seedling** **c. Fertilizer & Pesticide** **b. Tools** **d. Labor Resource**
21. F-P Suvival Rate	A. <10% B. 10-30% C. 30-50% D. 50-80% E. 80%-100%
22. Yearly Income	A.<10^4 Yuan B: 1-3*10^4 Yuan C. 3-5*10^4 Yuan D. 5-8*10^4 Yuan E. 8-10*10^4Yuan F. >10^5 Yuan
23. Part-time Job Offering	**a. Man-days / Year** **b. Price / Man-day**
24. Subside from Government	
25. Off-spring's Willing to Continue	
26. Degree of Saticfaction to Life	A. Very Satisfied B. Satisfied C.Just So So D. Un-satisfied E. Badly un-satisfied
27. Resources for Market Information	A. Agent People B.XiaXi Market C. Moving Market D. Internet E.Other Farmers F.Government G.Corporatives
28. Resources for Cultivation Skills	A. Agent People B.XiaXi Market C. Moving Market D. Internet E.Other Farmers F.Government G.Corporatives
29. Resources for Distribution	A. Agent People B.XiaXi Market C. Moving Market D. Internet E. Greening Company F. Corporatives
30. Resources for Price Setting	A. Agent People B.XiaXi Market C. Moving Market D. Internet E.Other Farmers F.Government G.Corporatives

[10] Q 20 (b): Tools include: the traditional farming tools like hoe and iron-toothed rake, the black gauze cover used to protect plants from over sunshine, the containers for the container seedlings, etc.

3.3 Field Survey (2012.03-2012.05)

3.3.1 Survey of top-soil loss

As introduced before, trees are the main type taking 74.5% of total F-P cultivated area in Wujin (2007). In top-soil loss survey in this research, trees are picked out as typical cases. In order to ensure trees' survival rate after transplantation, a big amount of farmland top-soil will be taken way with plants' roots in distribution. Based on personal observation and talk with farmers, trees can be divided into three categories according to respectively different calculating method of top-soil loss: seedling (ground seedling, container seedling), spherical trees and up-growing trees (Fig.16).

For ground seedling, the taking-away soil can be directly weighted. For container seedling, the container's size decides the soil volume. Generally, the cylinder container has three sizes: 10cm (caliber)* 10cm (height), 12cm*10cm, 21cm*17cm and the soil inside is around half the container volume. So the soil loss by container seedling can be calculated with the container volume and soil density with the following formula:

$$M(soil)= 1/2* \pi *(Caliber*Caliber*Height)*Soil\ Density$$

(M(soil): Top-soil weight of loss)

For spherical trees, the cone shape (cone diameter usually equals cone height) of soil body is very common. Usually the diameter of soil cone has a close relationship with the tree crown's diameter. In the survey, both the cone diameter and tree crown diameter were directly measured in different aged trees ranging from 1 year to 6 years old. So the soil loss by spherical trees can be calculated with the cone volume and soil density with the following formula:

$$M(soil)= 1/3*\pi*(Diameter*Diameter*Diameter)*Soil\ Density$$

(M(soil): Top-soil weight of loss)

For up-growing trees, the hemi-spheroid shape of soil body is very common. Similar with spherical trees, the diameter of the soil ball has a close relationship with up-growing tree's trunk diameter (DBH). In the survey, both the spherical diameter and tree's DBH were directly measured. Besides, the cone shape, spheroid shape and cylinder shape with different upper and below circle area are also existed. All the necessary lengths of factors to calculate the soil body volume were measured. 28 different aged trees with various species were measured ranging from 2 years to 45 years old. The soil loss by up-growing trees can be calculated with the soil ball's volume and soil density with the following formula:

1) Hemi-spheroid Soil: M(soil)= 2/3* π *(Diameter*Diameter*Diameter)*Soil Density;

2) Cone Soil: M(soil)= 1/3* π *(Diameter*Diameter*Diameter)*Soil Density;

3) Spheroid Soil: M(soil)= 4/3* π *(Diameter*Diameter*Diameter)*Soil Density;

4) Cylinder (different upper and below circle area) Soil:

$$M(soil)= 1/3* \pi *Height*(Diameter_{upper}*Diameter_{upper} + Diameter_{upper}*Diameter_{below} + Diameter_{below}*Diameter_{below})*Soil\ Density$$

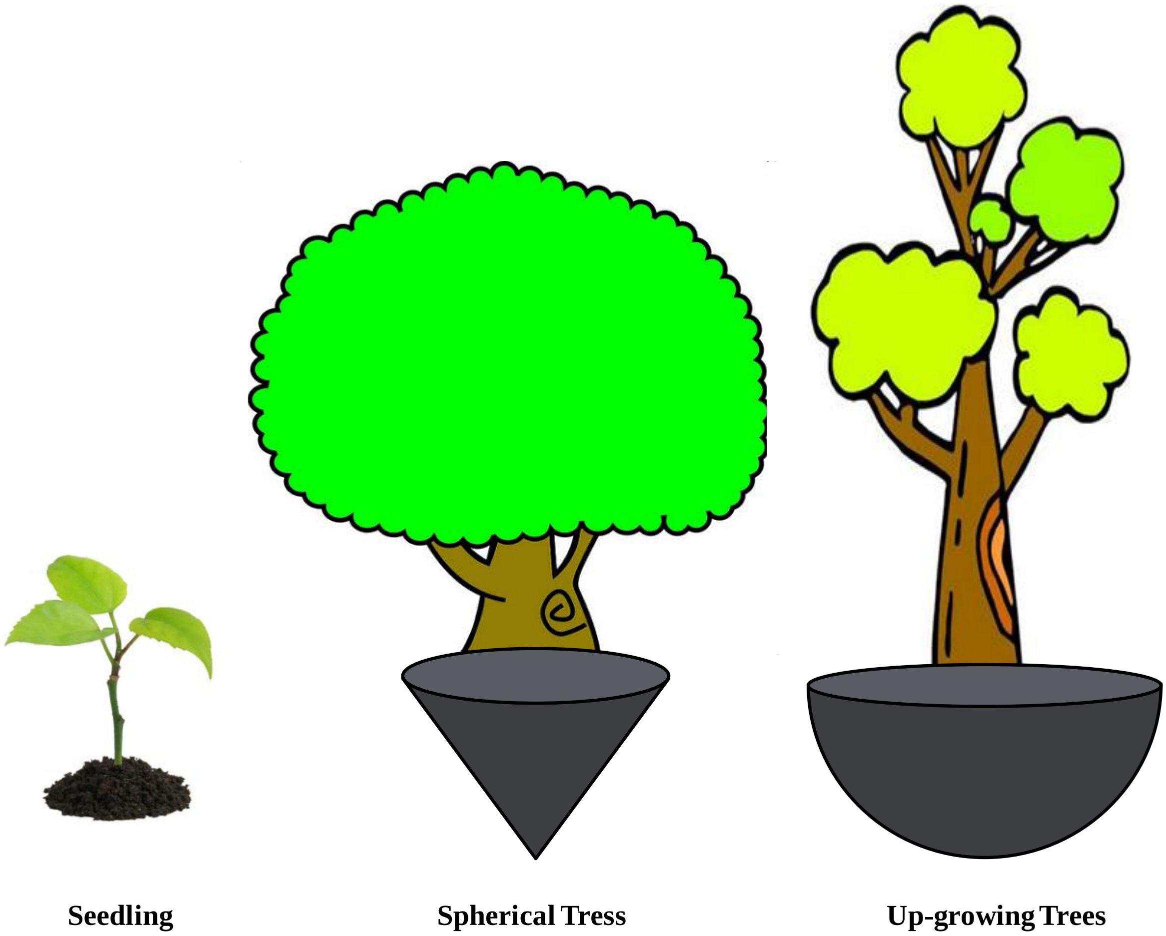

Figure 16. Three categories of trees

About the soil density, the parent material of soil in Wuijn is lacustrine deposit (Mao XU, 2006) and the soil bulk density in this area is around 1.2 g/cm^3（Ruwei YANG *et al.* ,2006）.

3.3.2 Water & Soil Quality Survey

After finishing the questionnaire, responders' location distribution was sorted out. Just as predicted, the main responders are in JiaZe and HuangLi in the western part of Wujin. Human cultivation activities and leaded pressures can be reflected from the questionnaire result analysis, so JiaZe and HuangLi are chosen as sampling sites for water and soil quality survey to show current local environment state and impacts in order to formalize the cause-effect relationships between various sectors of human activity and the environment for better understanding. In JiaZe (Site A) and HuangLi (Site B), 3 water samples and 9 soil samples (3 groups and 3 samples for each group) were selected.

3.3.2.1 Water Sampling and Quality Analysis

About the water sampling, the sampling location was in rural watercourses either in wetland, pools or small rivers. They are no-flowing or slow-flowing water body and from the satellite image, some of them are pool-sized and some are a bit long but not so long without up-stream pollution influences. Each water area is entirely surrounded (5 samples) or semi-surrounded (1sample: No.4) by farmland. Figure 17 and Figure 18 show the location of the 6 water samples (Sample No.1- No.3 in JiaZe and Sample No. 4- No.6 in HuangLi).

Tiao Lake and Ge Lake are separately in the left and right side of JiaZe and HuangLi town. The main flow direction in China is from west to east. So in the left, the nearest outlet river form Tiao Lake near sampling location is HuangLi River to which the nearest distance is around 1.95 km (measured in Google Earth with tools). And the main nearest input rivers to Ge Lake to my sampling location are HuangLi River and XiaXi River (around 2.37 km distance to sampling location) (measured in Google Earth with tools). [11] So the pollutants in the water area from up-stream possibility can be avoided.

In addition, during the sampling period, no industry was found located along or near the water area. Most of the water areas are entirely blocked by farmland except Sample No.4 water area blocked by farmland and house. So, the main pollutants in the river can be insured from agriculture. At the same time, rice and vegetable planting take a very small ratio (less than 10%) which has been introduced in Sector 2.3, so the main pollutants to the environment can be regarded from F-P cultivation.

About water sampling method, this research is referring to the sampling standards of Chinese National Water Quality Monitoring from the forth version book “Water and Wastewater Monitoring and Analyzing Methods”. All the targeted watercourse area is less than 50m wide and less than 5m depth, so one sample from each water course was collected. Besides, the sampling depth is around 50cm from water surface and if the total water depth is

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[11] www.jiangsutaihu.com/newsList.aspx?fmenu=7&menuid=45

less than 0.5m, the sampling depth is around half the water depth.[12] Following is the geographic location of all the 6 water samples (blue wavy signs in Fig. 17 and Fig. 18):

No.1: N 31° 40′ 49.10″， E 119° 44′ 36.35″

No.2: N 31° 40′ 44.61″， E 119° 44′ 43.08″

No.2: N 31° 40′ 33.22″， E 119° 44′ 40.35″

No.4: N 31° 39′ 21.88″， E 119° 43′ 29.11″

No.5: N 31° 39′ 19.46″， E 119° 43′ 23.16″

No.6: N 31° 39′ 13.78″， E 119° 43′ 28.73″

About the water analysis part, 7 main indicators for eutrophication evaluation are picked out for analysis: pH, Dissolved Oxygen (DO), Total Phosphorus (TP), Total Nitrogen (TN), Chemical Oxygen Demand (COD_{Mn}), Chlorophyll a (Chl a), Transparency (SD). The analyzing step was done in the laboratory of School of Environment in Nanjing University. The detailed analyzing methods are all referring to the book with fourth version “Water and Wastewater Monitoring and Analyzing Methods” as follows:

1) pH: Portable METTLER pH meter method;
2) DO: Portable dissolved Oxygen analyzer method (Analyzer Model No.: YHA-2310);
3) TP: Ammonium molybdate spectrophotometric method (GB11893-89);

[12] State environmental protection administration of china & “Monitoring and analysis methods of water and wastewater” editorial board. 2002. Monitoring and analysis methods of water and wastewater (fourth version). China Environmental Science Press.

4) TN: UV spectrophotometric method-Alkaline potassium persulfate digestion method (HJ 636—2012);

5) COD_{Mn}: Permanganate index method;

6) Chl a: Spectrophotometry method;

7) SD: Cross determination method of water transparency.

3.3.2.2 Soil Sampling and Quality Analysis

In the soil sampling step, three groups of soil were collected and each has 6 samples (3 from Site A and 3 from Site B):

1) Control Group: control group samples are from house-surrounding areas where there are plants naturally growing in the soil without external chemical fertilizer and pesticide.

2) < 5 years Group: samples in this group are from farmland which has a less than 5 years F-P cultivation history.

3) > 10 years Group: samples in this group are from farmland which has a more than 10 years F-P cultivation history.

As introduced before, the soil with fertility in cultivated farmland is usually in top-soil layer with a depth from 15cm to 20 cm. In the sampling process, firstly, get off the soil surface leaves and other organic materials. Secondly, a cylinder plastic tube with 20 cm height was used to dig a 29 cm high cylinder soil. Then collect all the soil from the container and mixed them together. And then send them to the laboratory. These samples are also analyzed in the laboratory of School of Environment in Nanjing University. Following is the geographic location of all the 6 water samples (blue wavy signs in Fig. 17 and Fig. 18):

1) “Control Group” No.1: N 31° 40′ 45.15″， E 119° 44′ 36.73″

No.2: N 31° 40′ 42.44″， E 119° 44′ 37.94″

No.3: N 31° 40′ 36.80″， E 119° 44′ 39.40″

No.4: N 31° 39′ 23.03″， E 119° 43′ 28.76″

No.5: N 31° 39′ 17.11″， E 119° 43′ 25.30″

No.6: N 31° 39′ 16.47″， E 119° 43′ 22.97″

2) “< 5 years Group” No.1: N 31° 40′ 47.57″， E 119° 44′ 38.36″

No.2: N 31° 40′ 38.79″， E 119° 44′ 38.47″

No.3: N 31° 40′ 33.95″， E 119° 44′ 38.85″

No.4: N 31° 39′ 24.21″， E 119° 43′ 28.73″

No.5: N 31° 39′ 24.84″， E 119° 43′ 30.95″

No.6: N 31° 39′ 23.87″， E 119° 43′ 25.37″

3) “>10 years Group” No.1: N 31° 40′ 49.33″， E 119° 44′ 30.85″

No.2: N 31° 40′ 45.60″， E 119° 44′ 31.89″

No.3: N 31° 40′ 35.35″， E 119° 44′ 43.98″

No.4: N 31° 39′ 23.71″， E 119° 43′ 30.21″

No.5: N 31° 39′ 18.16″， E 119° 43′ 28.01″

No.6: N 31° 39′ 15.01″， E 119° 43′ 30.72″

For the soil analysis, sorts of indicators were chosen out to reflect soil quality (fertility): pH, Total Organic Carbon (TOC), Total Nitrogen (TN), Available Nitrogen (AN), Total Phosphorus (TP), Available Phosphorus (AP), Total Potassium (TK), Available Potassium (AK), Water Contents (Original Soil Samples and Air Dried Samples). The detailed analyzing methods are as follows:

1) pH: Glass electrode method (GB7859-87);
2) TOC: Potassium dichromate volumetric method(GB7857-87);
3) TN: Kjeldahl determination(GB7173-87);
4) AN: Alkaline hydrolysis diffusion method;
5) TP: Alkali fusion–Mo-Sb Anti spectrophotometric method;
6) AP: Hydrochloric acid -ammonium fluoride extraction method;
7) TK: Alkali fusion-Atomic absorption spectrometry method;
8) AK: Ammonium acetate extraction method (GB7856-87).

Figure 17. Satellite image of water and soil sampling site A (in JiaZe)

Source: 1. Google Earth & Google Map; 2. http://www.sacu.org/provmap.html

Figure 18. Satellite image of water and soil sampling site B (in HuangLi)
Source: 1. Google Earth & Google Map; 2. http://www.sacu.org/provmap.html

Figure 19. Relative location of sampling to Tiao Lake and Ge Lake

Source: Google Earth

CHAPTER-4 RESULTS

4.1 Questionnaire Results (100 farmer responders)

100 farmers: 71 from JiaZe, 20 from HuangLi, 2 from ZouQu, 7 from outside Wujin.

4.1.1 Basic Information:

As introduced in Chapter 3, the responders home location distribution is as follows: 71 from JiaZe (38 from former XiaXi, 24 from former ChengZhang, 9 from former JiaZe), 20 from HuangLi, 2 from ZouQu (2 from former BoYi), 7 from outside Wujin.

Q2: Farmers Age?

Figure 20 indicates the famers' age structure in Wujin. In 100 responders, only 1% (1 farmer) is below 30 years old and 14% (14 farmers) are more than 60 years old. Middle-aged farmers between 40 to 60 years old are taking the dominant part taking 75%.

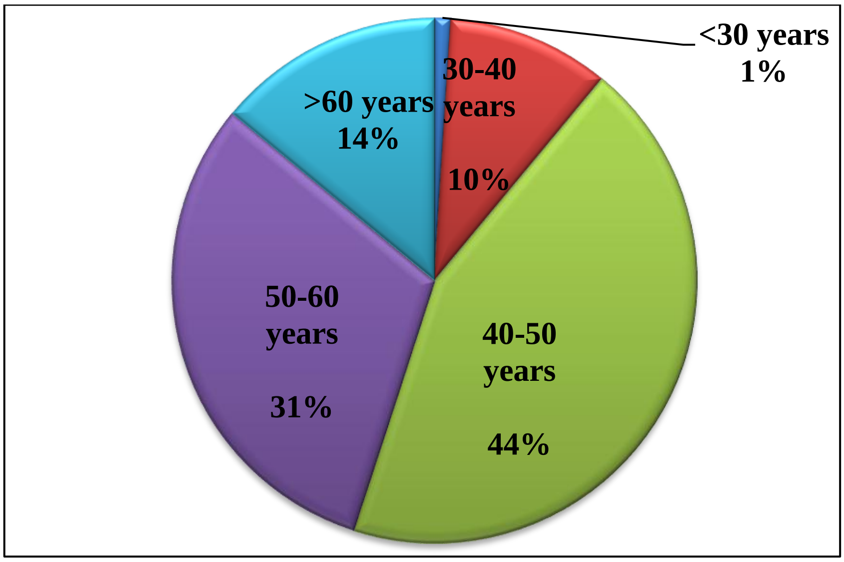


Figure 20. Responders' age distribution

Q 3: Farmers' Education Level?

About farmers' education background, only 1 % (1 farmer) is of university or upper degree. 23% of them are primary school degree. Most of them (76%) are middle school or high school degree. In general, most of the farmers are without high education level.

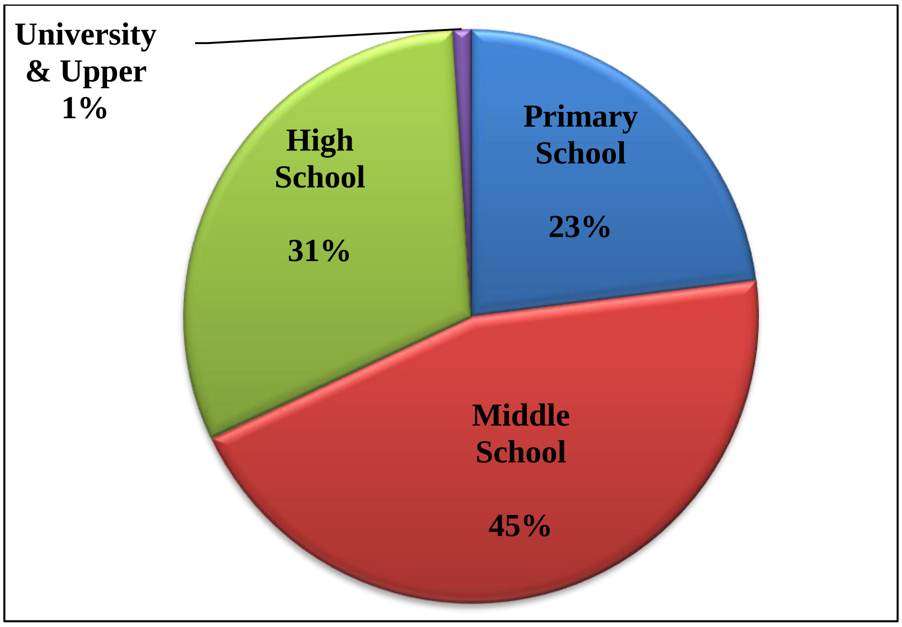


Figure 21. Responders' education level distribution

Q 6 & Q 8: Farmers F-P Cultivation Area VS Crops Cultivation Area?

"Mu" is the Chinese traditional area unit and 1 Mu equals 666.67(2000/3) m^2. From Fig. 22, 97% responders are not planting crops any more or just plant less than 1 Mu area but only 1% is planting F-P for less than 1Mu. For F-P cultivation, more than half (52%) the responders cultivated 1-5 Mu. 31% are cultivating 5-10 Mu and 16% are cultivating more than 10 Mu. It's obvious that almost all the responders have transferred most of their farmland from crops to F-P cultivation.

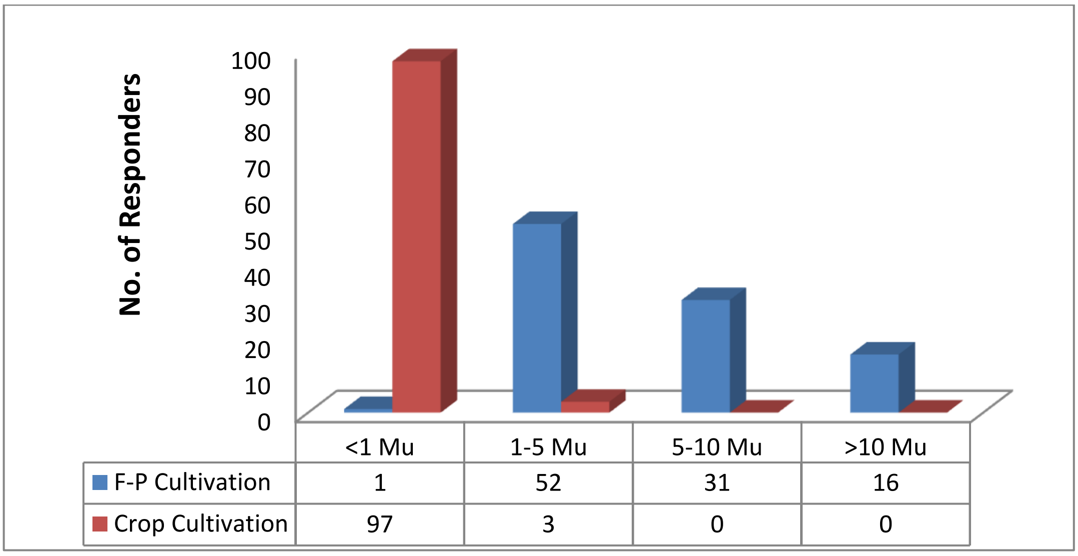


Figure 22. Responders’ F-P and crop cultivation area distribution

Q 7: Responders F-P Cultivation History?

42% farmers have F-P cultivation history between 5 to 10 years. Only 1% just starts F-P cultivation less than 1 year ago. 34% of farmers have cultivated F-P for less than 5 years and 24% more than 10 years. The dominant farmers already have 5 to 10 years cultivation period.

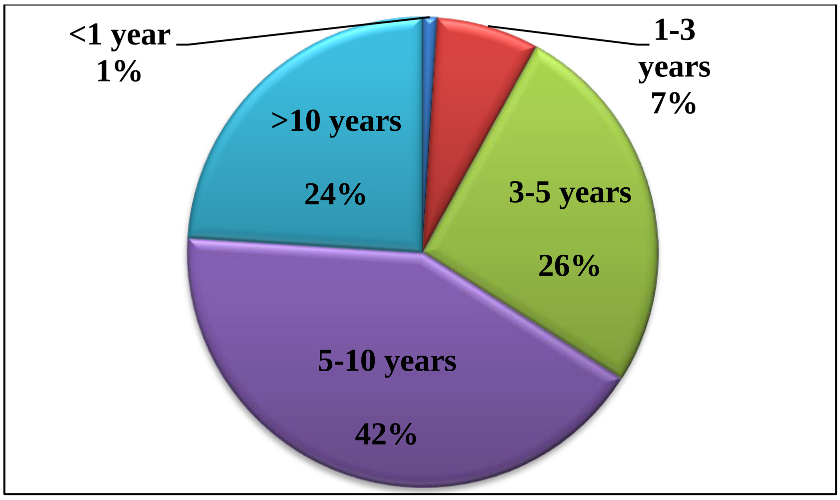


Figure 23. Responders’ F-P cultivation history distribution

Q 10: Farmers' Initial Motivation to Transfer to F-P cultivation (multiple choices)?

82% of responders think that their initial motivation is the more output value from F-P than crops which is the main external driver. 31% were also influenced by friends or neighbors and only 16% were encouraged by government.

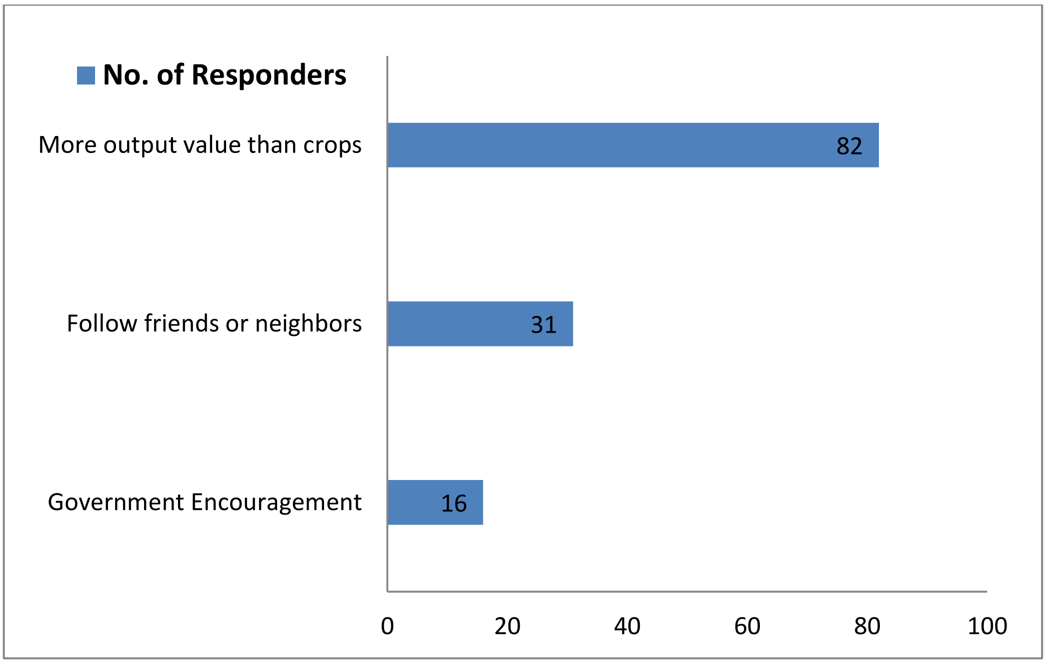


Figure 24. Farmers' motivation to start F-P cultivation

4.1.2 Environmental Aspect

Q 12: Chemical Fertilizer (CF) Usage in F-P Cultivation?

The average of CF usage of 100 responders is 1623 Kg/ha/Year, more than 6 times the amount 225 Kg/ha/Year which is suggested by developed countries to avoid rural water pollution problems (Chapter 1). In 2010, the cultivated farmland area was 161,500 ha and the total CF usage in agriculture was 69,000 tons (*Changzhou Statistics Website*).[13] So the average CF usage was around 430 Kg/ha/Year in 2010 in Changzhou area. It's obvious that CF usage in F-P cultivation is around 3 times more than the average.

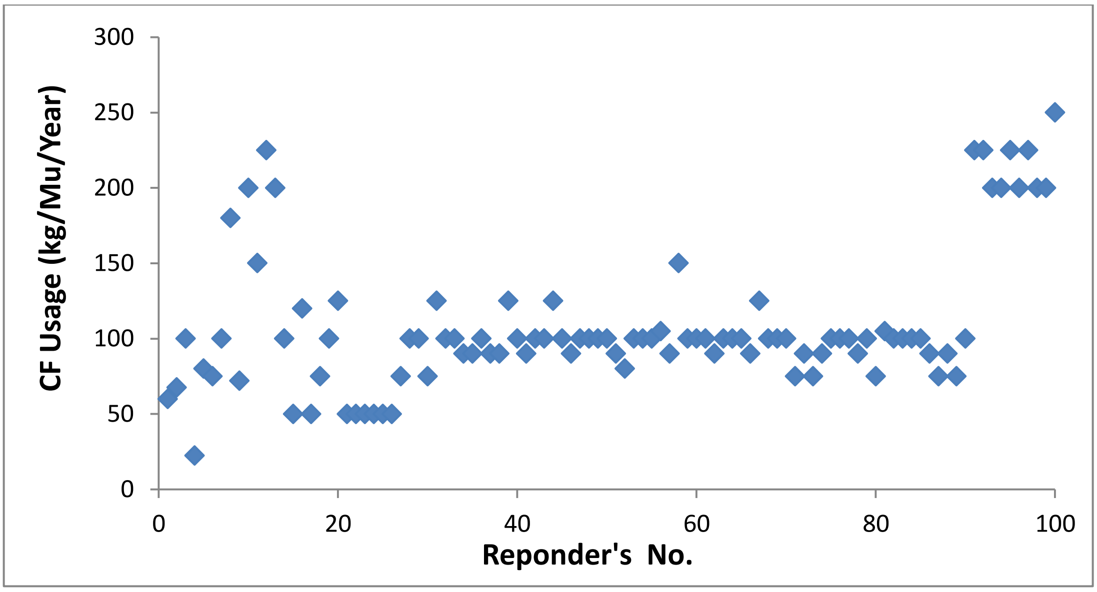


Figure 25. Chemical fertilizer usage in F-P cultivation

Q 14: Organic Fertilizer (OF) Usage in F-P cultivation?

In 100 responders, 36% are not using organic fertilizer at all in F-P cultivation. And in the other 64% responders, the average usage is 3798 Kg/ha/Year. Figure 25 shows the CF and OF respective usage for each farmer and there's no obvious relationship found between CF and OF usage. From Figure 26, with the ascending order of CF usage as the values in X axis, the first 20 samples are with a relatively low CF usage and high OF usage and the last 15 samples are with a relatively high CF usage and low OF usage.

[13] http://www.cztjj.gov.cn/node/ztbd_115/2011-10-12/1110121629436688173.html

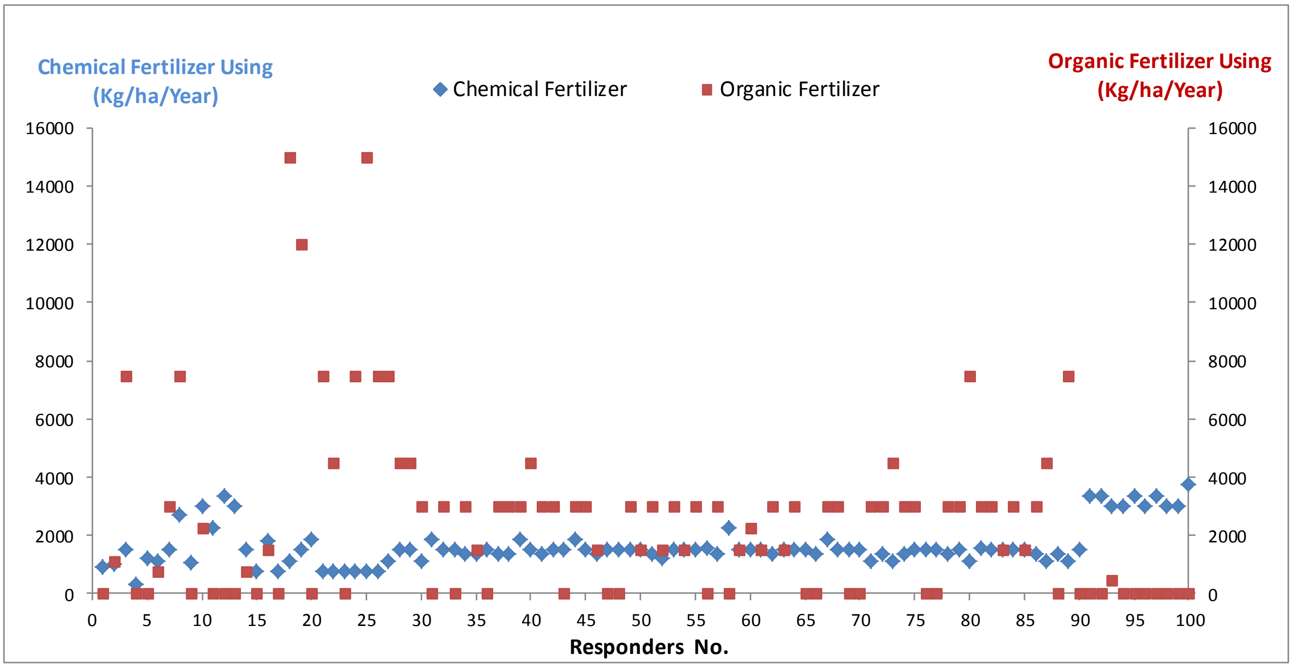


Figure 26. CF usage VS OF usage in F-P cultivation

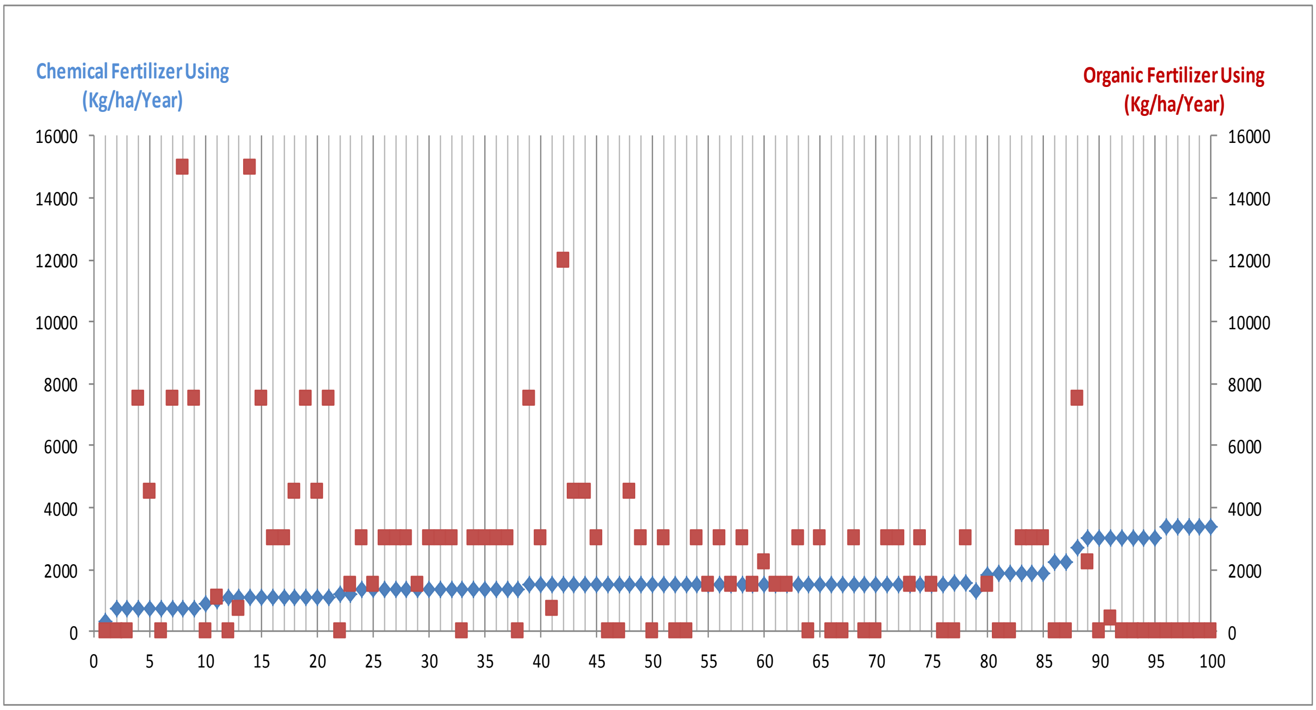


Figure 27. CF usage VS OF usage in F-P cultivation (ascending order for CF usage)

Q 15: Irrigation Water Resource?

The irrigation resources include ground water (GW) and river water (RW). From the 100 responders, 4% are only use GW, 60% are using both GW and RW, and 36% are only us RW. The ground water for irrigation is popular in Wujin.

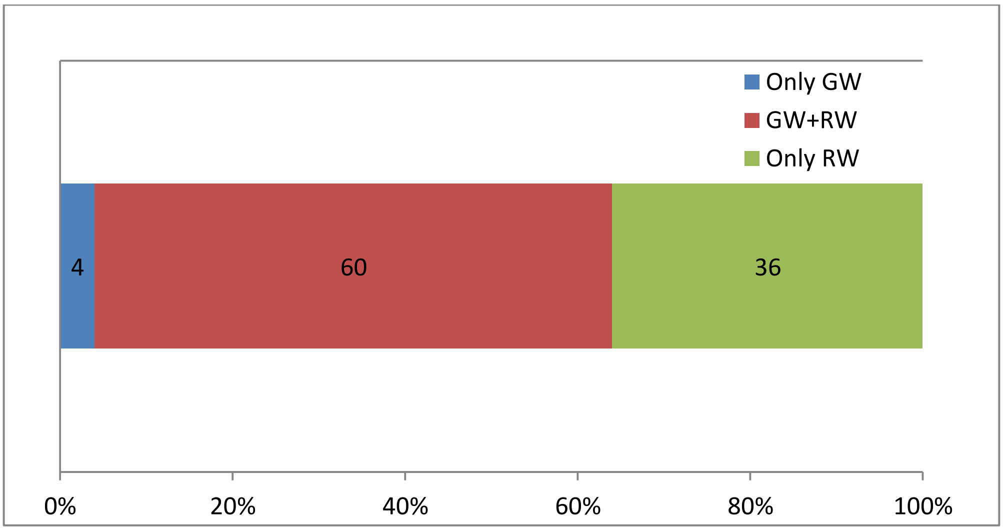
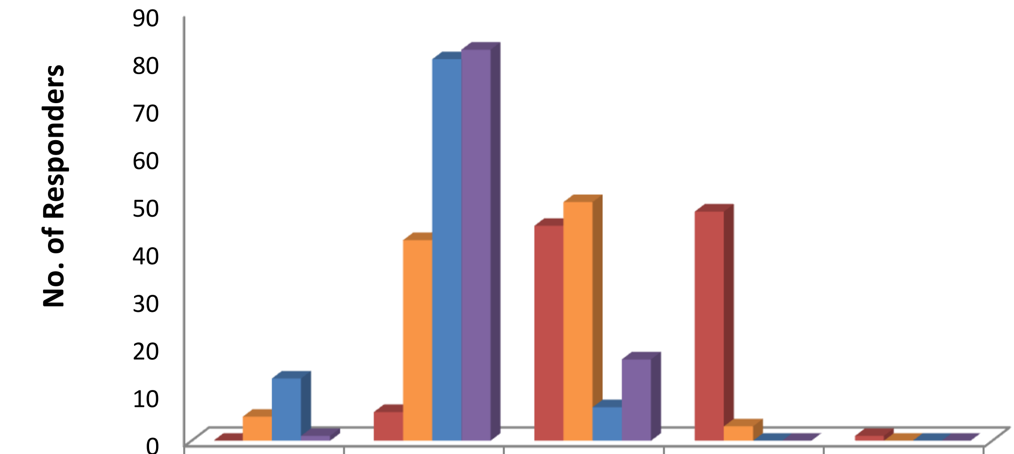


Figure 28. Farmers' irrigation resource in F-P cultivation

Q 16-19: Personal Feeling to Local Micro-climate, Water, Soil, and Air Quality?

Among the four kinds of environmental media, water and soil have a more serious problem from farmers' opinion. For water quality, only 6% think "good" and 45% think "medium". About half of the responders (49%) hold the opinion that the water quality was "bad" or "very bad". For soil quality, though 47% choose "very good" or "good", 50% are thinking soil quality is "medium" and 3% are even "bad". For air quality and local micro-climate, respectively 93% and 83% are thinking "very good" or "good". Only 7% and 17% are thinking "medium" and no responder choose "bad" or "very bad" option. It seems that farmers already have gotten a direct feeling to and some personal consideration of local environmental quality.



	Very Good	Good	Medium	Bad	Very Bad
Water Quality	0	6	45	48	1
Soil Quality	5	42	50	3	0
Air Quality	13	80	7	0	0
Micro-climate	1	82	17	0	0

Figure 29. Farmers' feeling to local environment (water, soil, air, micro-climate)

4.1.3 Economic & Social Aspects

Q 20: Yearly Investment (Seeding / Seedling, Fertilizer & Pesticide, Tools, Labor Resource)?

The yearly investment was mainly divided into four categories. From Figure 29, it's obvious that, for most of responders, seedling/seedling investment is the biggest part and then the labor resource investment (e.g. Hire people for temporal working). Fertilizer and pesticide investment rank the third and tools last. For seedling / seedling and labor resource parts, their separate average investment ratios are 61% and 25%. For fertilizer and pesticide category, the average ratio among 100 responders is around 14%. Besides, 14 responders have a more than

20% investment ratio for this part. As for the tools investment, the average ratio is about 0.5‰ which almost can be ignored.

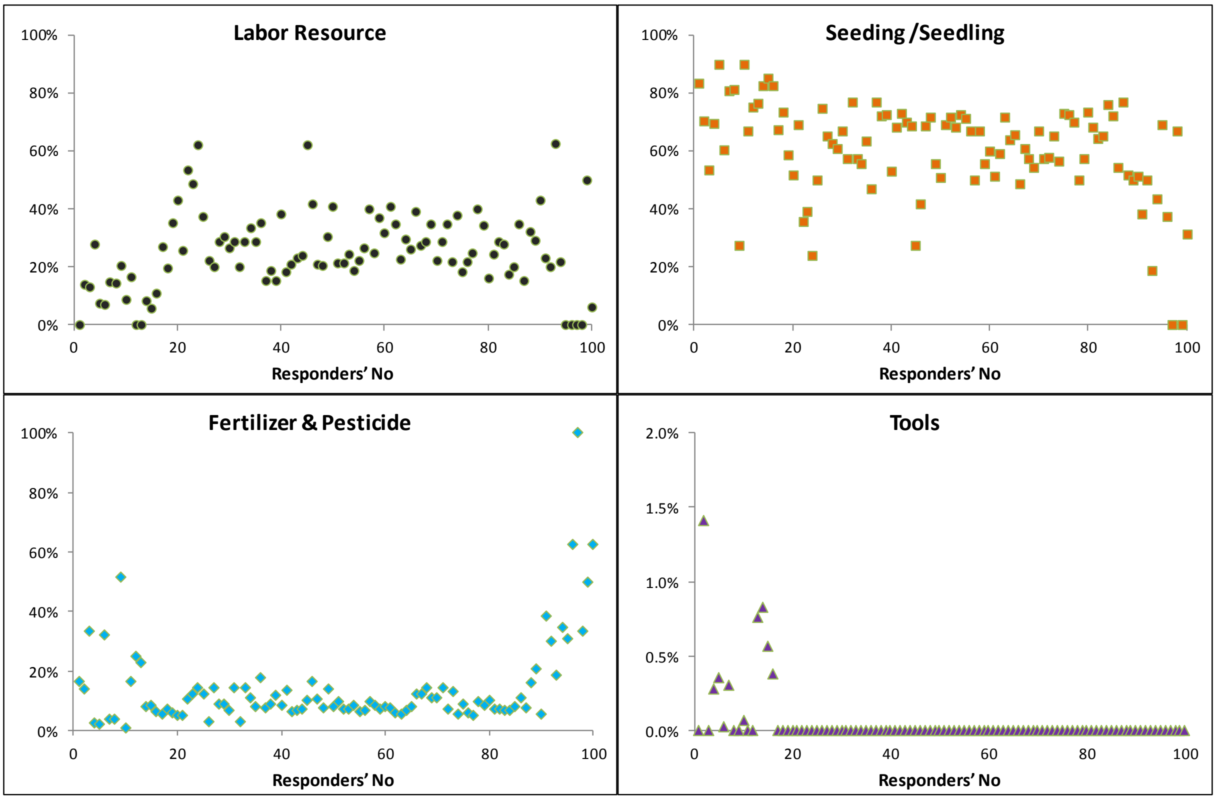


Figure 30. Farmers' yearly investment ratio to total investment for four categories

Q 21: F-P Survival Rate?

Among 100 responders, 90% can get the F-P survival rate with "80% -100%". Besides, except 1% is "10%-30%", the other 9% are all around "50%-80%". Generally, the F-P survival rate is in a good level. For the 1% "10%-30%" case, the reason for low survival rate is the irrigation water pollution by chemical plants.

Q 22: Yearly Income?

As shown in Figure 30, the income brought by F-P cultivation to farmers is very notable. 39% responders can get more than 100,000 Yuan per year and 22% can get 80,000 to 100,000 Yuan per year. In total, 84% can get more than 50,000 Yuan from F-P cultivation which is much better than traditional crops cultivation. The least income for 100 responders is still more than 10,000 Yuan.

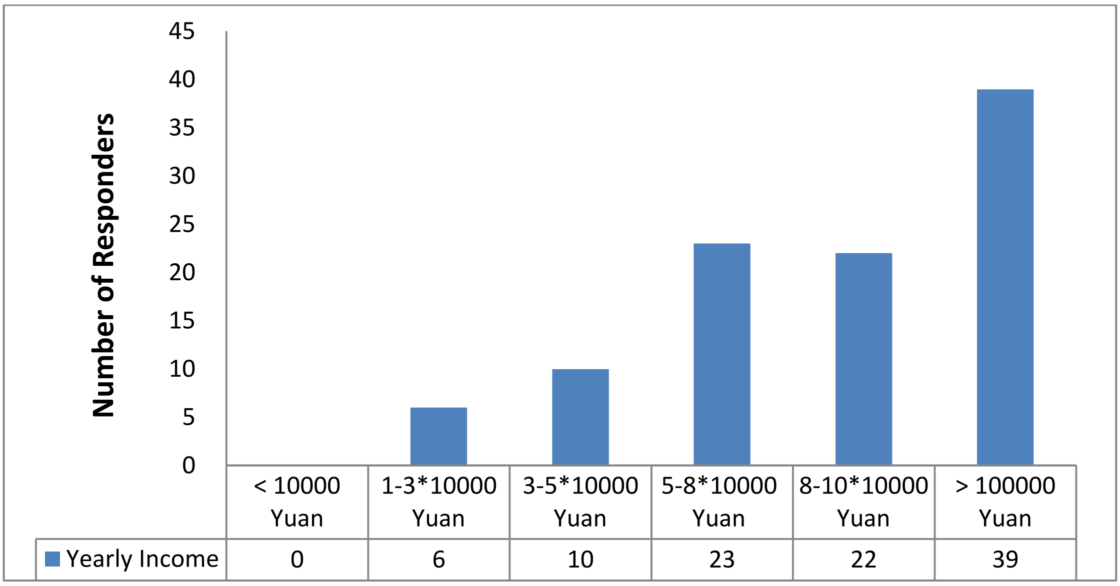


Figure 31. Farmers' yearly income distribution

Q 23: Part-time Job Opportunities Offered in F-P Cultivation and What Price?

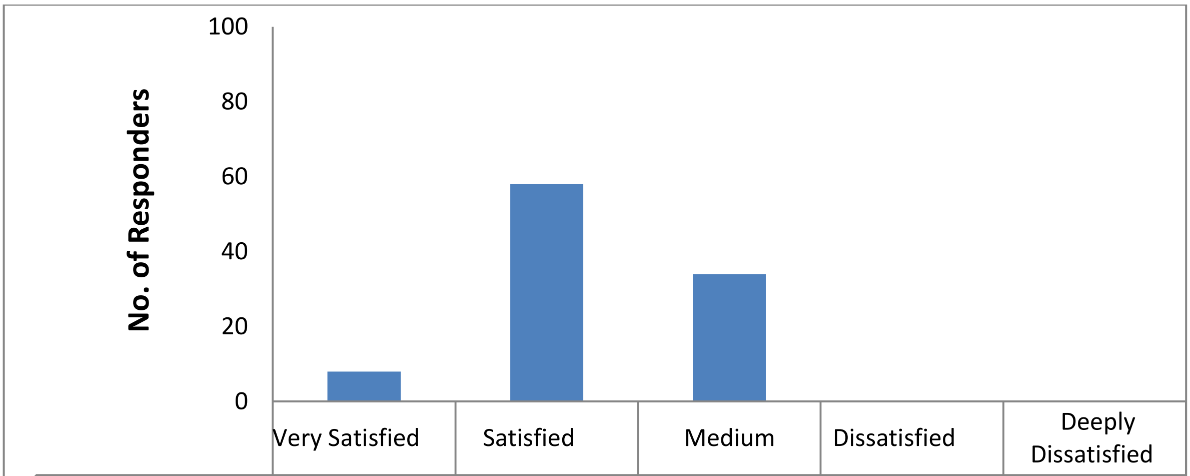
During 100 responders, only 8% don't hire people with payment for temporal working for them but only do F-P cultivation relative work all by their family members. 92% will hire other rural people for help because F-P cultivation usually needs intensive labor resources especially in planting and transplantation process. For the other 92% farmers, totally they will offer 13,540 man-days job opportunities and averagely each family offers 147 man-days job opportunities every year. Among the 92% responders, the average price they can provide is around 94 Yuan/Man-day. That means they need to pay 94 Yuan when they hire one person working one day for them.

Q 24: Subside from Government?

83% responders didn't received the subside money from the government.17% responders received subside and the amounts of money are 60 Yuan/Mu (10%) and 80Yuan/Mu (7%). Mu is the basic area unit in China and 1 Mu equals 2000/3 m^2 and 1/15 ha.

Q 25 -26: Farmers' Current Degree of Satisfaction to Life & Farmer's Off-spring's Willingness to Continue F-P cultivation?

66% of responders are satisfied or very satisfied with life and 34% are feeling medium to life. No one is dissatisfied or deeply dissatisfied with life. Generally, the farmers have a very positive attitude to current life state. As for their off-springs willingness to continue F-P cultivation, only 19% of them said their kids have the willing and 81% said no.



	Very Satisfied	Satisfied	Medium	Dissatisfied	Deeply Dissatisfied
Satisfaction to Life	8	58	34	0	0

Figure 32. Farmers' degree of satisfaction to life

Q 27-30: Farmers' resources of various kinds of information?

From Figure 32, for most farmers, "XiaXi Market" and especially "agent people" and "moving market" are the main information resources for their distribution channels, F-P demanding condition in market, and products price-setting standards. For the cultivation skills learning, self-learning is a common way for 99% responders. Also, agent people (26%) and other farmers (15%) sometimes can give some aid as well as trading market (XiaXi market 6%, moving market 10%), internet (3%), and cooperative (5%). Anyway, most of the farmers mainly can get cultivation skills by their own experience and personal practice.

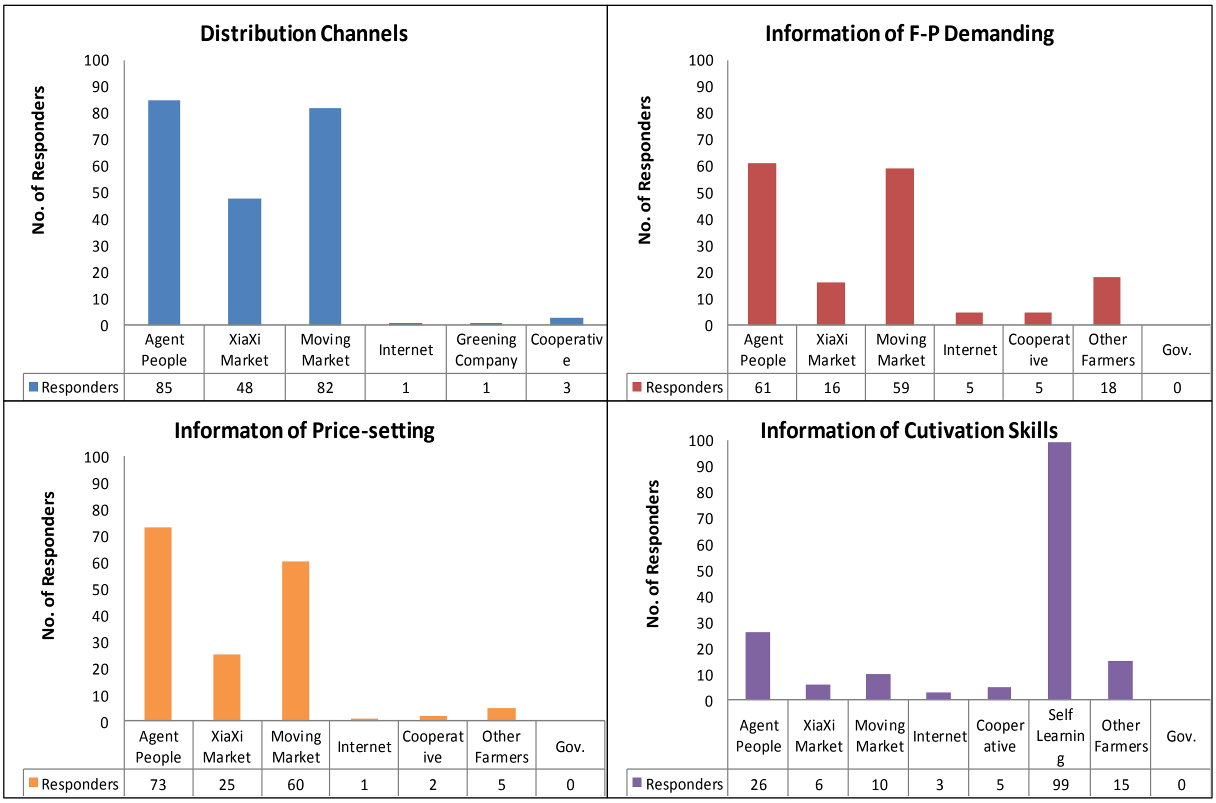


Figure 33. Farmers' resources of various kinds of information

4.2 Field Survey Results

4.2.1 Top-soil Loss Survey Results

As mentioned in methodology chapter, the main specie category tree is chosen as the targeted typical F-P product. According to respectively different calculating methods of top-soil loss, trees are divided into: seedling (container seedling, ground seedling), spherical trees and up-growing trees. In order to make comparison, we make a reasonable assumption that the height of top-soil is 20cm. So, with the soil bulk density 1.2 g/ cm^3, the weight of topsoil is around 240 million Kg/km^2 (240 Kg/m^2) (Top-soil weight=Soil density* (Topsoil depth*Area)).

1) Seedling

In Table 5, the plants density, the soil volume and weight taken away by each plant, by a certain area of plants at one time, and by a certain area of plants per year are all listed. The first item in the second row is referring to ground seedling and the next three rows are referring to three sized container seedling. For instance, the container size 12(cm)*10(cm), 12 means the caliber and 10 means the height. In seedling category, ground seedlings are taking away much less soil than container seedlings. In container seedlings, the "12*10" sized container seedlings are taking more soil away though with a lower density than "10*10". With the same container height, the container with a bigger caliber will cause more serious top-soil loss. For "21*17" sized containers which has a bigger height and caliber than "10*10" and "12*10", they take away the biggest amount of soil as expected. But since the "21*17" sized container seedlings usually need 2 years growth, the top-soil loss per year is lower than "12*10" but still higher than "10*10" sized container. As mentioned before, the total top-soil weight is 240 million Kg/km^2 or 240 Kg/m^2. For ground seedlings, every time / year they are generally taking away 1/24 of all. For "10*10" sized container seedling, every time / ear they are taking away more than 29%. For "12*10" sized, every time / year they are taking away more than 38%. For "21*17" sized, every time they are taking away more than 57% of total soil, and divided 2 years, every year they are taking away more than 28%. What do these numbers mean? They mean, it the farmers continue to cultivate container seedlings every year with whatever sized containers, at most, the cultivation activities can sustain 3 years. And after that time, the soil will lose almost all the fertility and can't be cultivated as farmland anymore if without other external top-soil replenishment.

Table 5. Top-soil loss situation of seedling

Type	Year	Soil V/plant	Soil M/plant	No./km^2	Soil M/km^2	Ratio of Total	M/km^2/Year (M/m^2/Year)	Ratio of Total
		cm^3	Kg	Million	Million Kg	Top-soil / Time	Million Kg (Kg)	Top-soil / Year
Ground	1		0.03	330	9.9	4.13%	9.9	4.13%
10*10	1	392.7	0.21	150	70.69	29.45%	70.69	29.45%
12*10	1	565.49	0.31	135	91.61	38.17%	91.61	38.17%
21*17	2	2944.07	1.61	39	137.78	57.41%	68.89	28.70%

2) Spherical Trees

In spherical trees category, the diameter of soil cone depends on the tree crown's diameter. In this part, "Seatung" *(Pittosporum tobira (Thunb.) Ait)* is chosen out as one representative specie and the data are mainly from direct measurement in farmland (Fig. 33). In Table 6, the crown & soil cone's diameter, trees' growth period, trees density, and the soil volume and weight taken away by each plant, by a certain area of plants at one time, and by a certain area of plants per year are all listed.

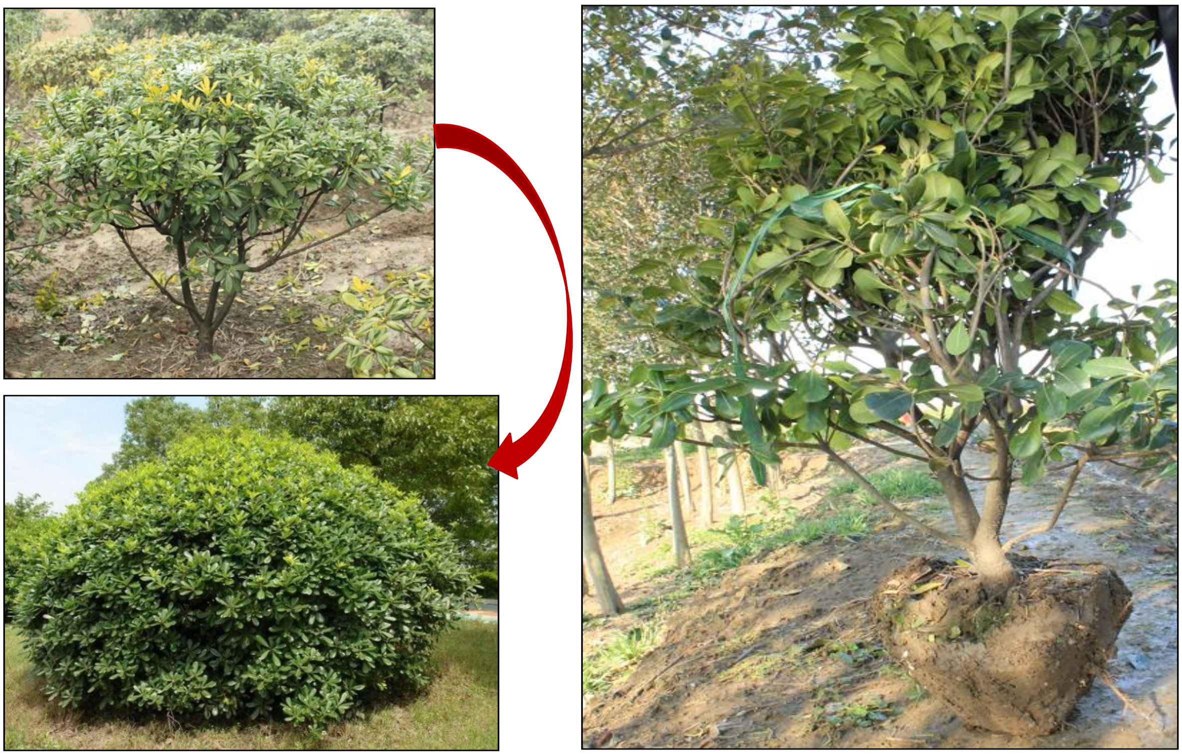


Figure 34. Typical spherical tree specie “Seatung”

Table 6. Top-soil loss situation of spherical “Seatung” trees

Crown DIA	Year	Cone DIA	Soil V/plant	Density	M/km^2	Ratio of Total Top-soil / Time	M/km^2/Year (M/m^2/Year)	Ratio of Total Top-soil / Year
cm		cm	cm^3	Million /km^2	Million Kg		Million Kg (Kg)	
30-50	1	17.5	5612	5.25	35.36	14.73%	35.36	14.73%
50-80	2	27.5	21778	2.4	62.72	26.14%	31.36	13.07%
80-100	3	32.5	35948	1.2	51.77	21.57%	17.26	7.19%
100-120	4	37.5	55223	0.675	44.73	18.64%	11.18	4.66%
120-160	5	45	95426	0.375	42.94	17.89%	8.59	3.58%
160-200	6	55	174227	0.225	47.04	19.60%	7.84	3.27%

From Table 6, the seatung trees with different cultivation period from 1 year to 6 years are taking different amount of soil away in one time or per year. Seatung trees with longer cultivation years as well as bigger crown diameter and bigger soil cone's diameter will have a lower products' density. The total amount of soil taken away by one-year old seatung in one time is around 35 million Kg/km^2, the least in all the trees, about 15% of entire top-soil. The soil taken away in one time by two-year old seatung with a crown diameter from 80cm to 100 cm is 62 million Kg/km^2, around 26% of entire top-soil in farmland. The number is still less than in container seedling case. Ranging from two-year old trees to five-year old trees, with a descending order of trees' density, the taking away top-soil in one time also has a descending tendency. When considering the per year loss soil amount, seatung trees from one-year to six-year old have an obvious decreasing tendency. So the six-year old seatung can cause the least, which is about 7.84 million Kg soil loss per km^2 per year, in the 6 different aged trees.

3) Up-growing Trees

For up-growing trees category, 28 trees with different species are measured aging from 2 years to 45 years in XiaXi trading market. In order to simplify the calculation, we made an assumption that all the trees have experienced only one time transplantation and they were living only in one place during the whole growth before dealing. In table 7, with an ascending order of tree's age, each tree's DBH, value of soil diameter to DBH, reasonable products density, weight of top-soil loss per area per year, and the ration of topsoil loss to total amount are all listed separately. In this research, a linear relationship is expected and proved between tree's DBH and soil ball's diameter. Based on the DBH column and corresponding soil ball DIA value, Figure 34 shows 2 curves fitting process with linear function of the two items. And the coefficient of determination r^2 (0.9187 or 0.8526) is very acceptable.

Table 7. Top-soil loss situation of up-growing trees

Species	Tree's DBH	Year	Soil DIA/ DBH	Density	M/km^2	Ratio of Top-soil / Time	$M/km^2/Year$ ($M/m^2/Year$)	Ratio of Top-soil / Year
	cm			$No./km^2$	Million Kg		Million Kg (Kg)	
Willow	2.8	2	5.4	141471	30	12.50%	15	6.25%
Japanese Maple	3	4	8.3	50930	50	20.83%	12.5	5.21%
Camphor Tree	6	5	3.3	79577	32	13.33%	6.4	2.67%
Walnut Tree	6.2	5	6.5	19894	64	26.67%	12.8	5.33%
Date Tree	7	6	5.7	19894	53.33	22.22%	8.89	3.70%
Red Plum	7.1	7	9.9	6496	80	33.33%	11.43	4.76%
Plum Tree	7	7	7.1	12732	57.14	23.81%	8.16	3.40%
Cherry Tree	11	8	4.5	12732	50.00	20.83%	6.25	2.60%
Hall Crabapple	10	8	7.0	6496	70.00	29.17%	8.75	3.65%
Persimmon Tree	8.8	9	5.7	12732	44.44	18.52%	4.94	2.06%
Cherry Blossom	8.5	10	6.5	10523	44.00	18.33%	4.40	1.83%
Loquat Tree	12	12	6.3	5659	50.00	20.83%	4.17	1.74%
Red Maple	10	12	6.5	7534	43.33	18.06%	3.61	1.50%
Lotus Magnolia	10	12	8.0	4974	53.33	22.22%	4.44	1.85%
Honey Locust	9.5	13	8.4	4974	49.23	20.51%	3.79	1.58%
Acer Palmatum	9	13	6.7	8842	36.92	15.38%	2.84	1.18%
Goldenrain Tree	40	15	4.8	882	101.33	42.22%	6.76	2.81%
Magnolia	18.5	15	6.8	2037	66.67	27.78%	4.44	1.85%
Ginkgo Tree	22	16	5.0	2631	55.00	22.92%	3.44	1.43%
Wolfberry	8	20	5.0	19894	16.00	6.67%	0.80	0.33%
Pomegranate	18	20	6.1	2631	44.00	18.33%	2.20	0.92%
Orange	34	22	4.1	1624	50.91	21.21%	2.31	0.96%
Flos Albiziae	32.2	25	3.4	2631	35.2	14.67%	1.41	0.59%
Waterelm	32	28	4.7	1415	14.28	5.95%	0.51	0.21%
Camphor	40	28	4	1243	45.71	19.05%	1.63	0.68%
Citron	31	30	4.2	1883	34.67	14.45%	1.16	0.48%
Waterelm	40	35	5	796	20.13	8.39%	0.58	0.24%
Camphor	57.5	45	4	602	15.33	6.39%	0.34	0.14%
Mean Value	**17.9**	**15.4**	**5.8**	**15847**	**45.82**	**19.09%**	**5.06**	**2.11%**

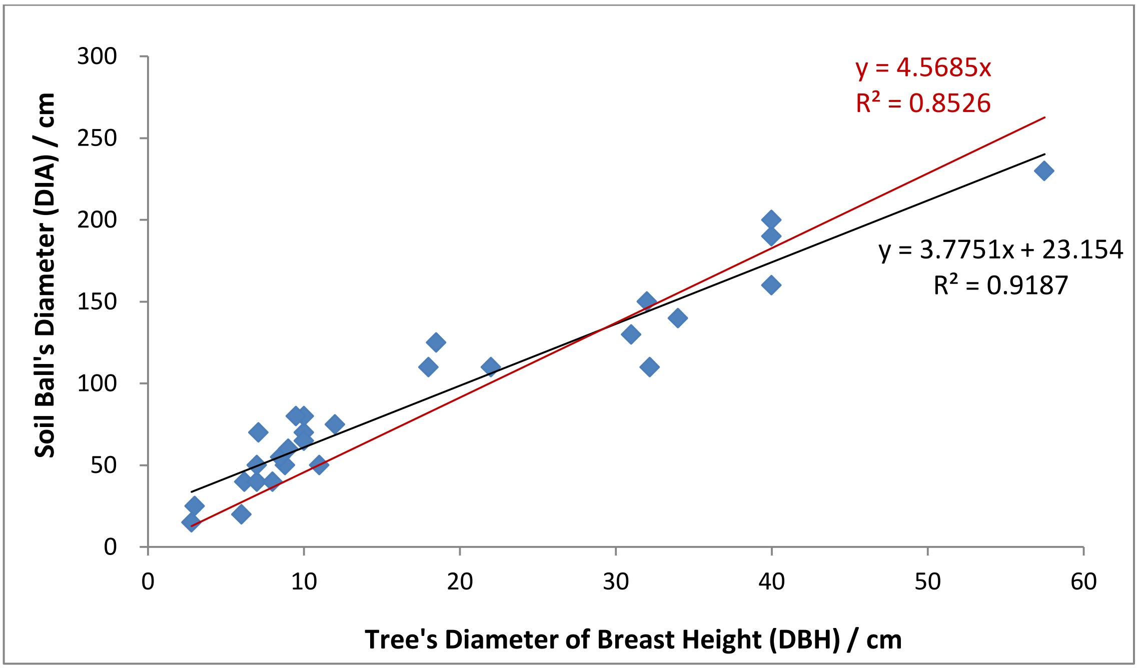


Figure 35. Linear fitting between tree's DBH and soil ball's DIA

From Table 7, the mean value of trees' DBH to soil DIA is around 6 which is consistent with reality and the mean value of topsoil loss by different species in one time is about 46 million Kg/km^2. With an ascending order of tree's age, though the total amount of soil taken by each specie in one time seems have no obvious regularity of change, the amount of top-soil loss by unit per year has a gradually decreasing tendency. Figure 35 shows the relationship between each tree's age and the yearly per unit top-soil loss amount. From the scatter diagram, the negative correlation between the two items is much apparent but the number in y axis in this paragraph will be always more than "0". It's understandable that, when a tree is very old with an enough big age, the amount of soil loss during transplantation is very large but after dividing the number of years, the yearly loss amount will be very small. Also a curve fitting with an exponential function is used in Figure 35 and the coefficient of determination r^2 (0.8747) is also good and acceptable. So generally, according to the equation, the yearly top-soil loss situation by different aged trees of common species of up-growing category can be predicted in a certain extent.

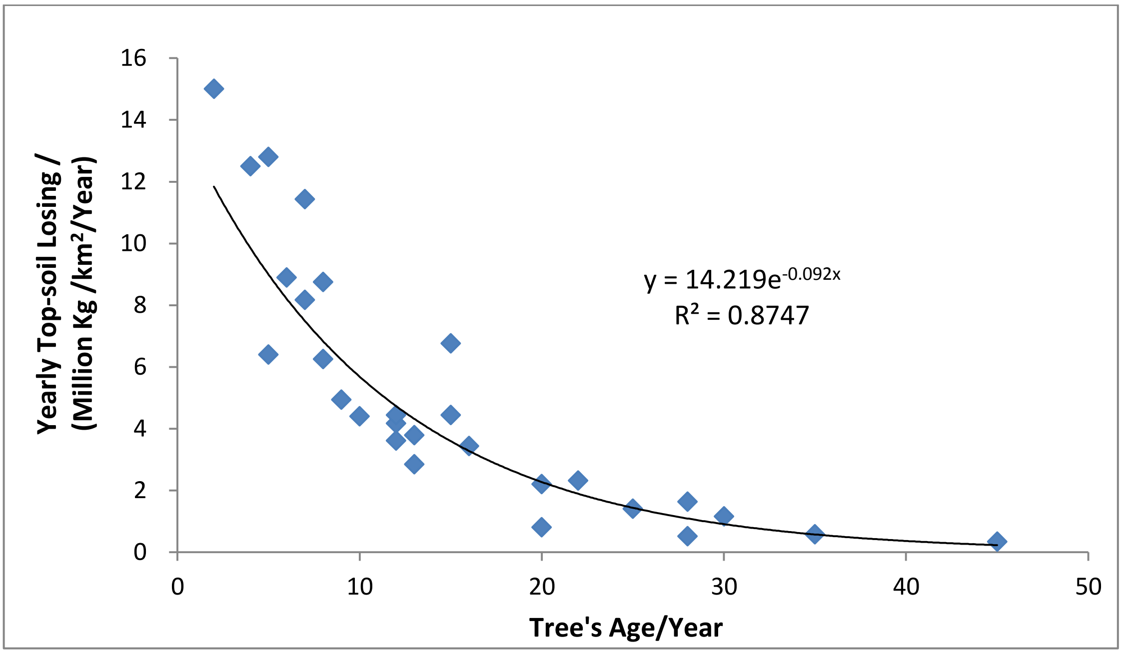


Figure 36. Exponential curve fitting between trees' age and yearly top-soil loss amount

4.2.2 Water and Soil Quality Survey Results

4.2.2.1 Water Quality Results

Table 8 shows the analysis results of 7 indicators for water quality mainly for eutrophication assessment. According to the trophic terminology proposed by OECD (Janus and Vollenweider, 1981; Kerekes, 1983; Mandaville, 2000; Vollenweider, 1976; Vollenweider and Kerekes, 1982)[14], there's a fixed boundary system for trophic category and this

[14] Eutrophication of Waters (Monitoring, Assessment and Control), Research of the Organization for Economic Cooperation and Development (OECD), http://www.chebucto.ns.ca/ccn/info/Science/SWCS/TPMODELS/OECD/oecd.html

assessment system can be applied in “pond-size lakes” or “great north American lakes”. In the category, each separate indicator has a limitation value for eutrophication evaluation. If the TP average concentration is between 35-100 mg/m^3 or more 100 mg/m^3, if the chlorophyll average concentration is between 8-25 mg/m^3 or more than 25 mg/m^3, and also if the average transparency degree is between 1.5-3 m or less than 1.5m, correspondingly the water can be regarded with eutrophic or hypertrophic problem. So applying this trophic terminology in this research, the water samples all have hypertrophic problems.

Table 8. Analysis results of water quality indicators

Sample No.	**pH**	**DO**	**TP**	**TN**	**COD_{Mn}**	**chl-a**	**SD**
		mg/L	**mg/m^3**	**mg/L**	**mg/L**	**mg/m^3**	**m**
1	7.35	9.29	144	2.185	14.634	31.6	0.31
2	7.46	9.33	123	6.191	4.878	48.3	0.26
3	7.56	8.24	72	5.458	39.024	18.4	0.42
4	7.67	8.39	144	4.425	29.237	27.6	0.36
5	7.37	6.80	134	3.299	24.390	29.3	0.25
6	7.53	5.50	82	3.626	24.390	18.9	0.28

Also there are many other methods to evaluate the eutrophication degree. When Chinese researchers evaluating water eutrophication degree, the Comprehensive Trophic Level Index (TLI（Σ）) is often referred to evaluate the lake and reservoir water eutrophication (*State Environmental Protection Administration of China*). The Trophic Level Index (TLI) is an indicator of lake water quality. Four parameters are combined to construct the TLI: total nitrogen, total phosphorus, clarity, chemical oxygen demand and chlorophyll a. Nitrogen and phosphorus are essential plant nutrients. In large quantities they can encourage the growth of nuisance aquatic plants such as algal blooms. Chlorophyll a is the green pigment in plants used for photosynthesis. It is a good indicator of the total quantity of algae in a lake. Algae are a natural part of any lake system, but large amounts of algae decrease water clarity, make the water look green, can form surface scums, reduce dissolved oxygen levels, can alter pH levels, and can produce unpleasant tastes and smells.

$$TLI(\Sigma) = \sum_{j=1}^{m} Wj \bullet TLI(j) \quad (1)$$

In equation (1): “TLI（Σ）” means the comprehensive trophic level index; “TLI (j)” means the trophic level index for indicator of No. j; “W_j” means the weight for indicator of No. j.

$$W_j = \frac{r_{ij}^{2}}{\sum_{j=1}^{m} r_{ij}^{2}} \quad (2)$$

With “chl-a” as the standard index, the normalized relevant weight of No. j can be calculated with equation (2). The value of “r_{ij}” means the correlation coefficient of indicator No. j with indicator “chl-a”; “m” means the number of total indicators in this trophic evaluation.

For lakes in China, according to the statistics from “Chinese Lake Environment” , the values of “r_{ij}” and “r_{ij}^2” calculated from the survey data in 26 main Chinese lakes are listed in Table 9 and the equations of “TLI (j)” are listed as follows (Xiangcan JING, 1995):

(1) TLI（chl-a）=10（2.5+1.086lnchl）(chl-a: mg/m3)

(2) TLI（TP）=10（9.436+1.624lnTP）(TP: mg/L)

(3) TLI（TN）=10（5.453+1.694lnTN）(TN: mg/L)

(4) TLI（SD）=10（5.118-1.94lnSD）(SD: m)

(5) TLI（COD_{Mn}）=10（0.109+2.661lnCOD）(COD: mg/L)

And according to the total equations and Table 8, the TLI(j) and TLI（Σ） for the 6 samples in this research are calculated and listed in Table 10.

Table 9. Water quality indicators' correlations with "chl-a"

Indicator	**chl-a**	**TP**	**TN**	**SD**	**COD_{Mn}**
r_{ij}	1	0.84	0.82	-0.83	0.83
r_{ij}2	1	0.7056	0.6724	0.6889	0.6889

Table 10. Water eutrophic level calculation results applying TLI

No.	**TLI （chl-a）**	**W (chl-a)**	**TLI （TP）**	**W (TP)**	**TLI (TN)**	**W (TN)**	**TLI (SD)**	**W (SD)**	**TLI (COD)**	**W (COD)**	**TLI()**
1	62.50	0.27	96.70	0.19	67.77	0.18	73.90	0.18	72.49	0.18	**73.79**
2	67.11	0.27	96.36	0.19	85.41	0.18	77.31	0.18	43.26	0.18	**73.38**
3	56.63	0.27	95.53	0.19	83.28	0.18	68.01	0.18	98.59	0.18	**78.49**
4	61.03	0.27	96.70	0.19	79.72	0.18	71.00	0.18	90.91	0.18	**78.39**
5	61.68	0.27	96.54	0.19	74.75	0.18	78.07	0.18	86.09	0.18	**78.05**
6	56.92	0.27	95.69	0.19	76.35	0.18	75.88	0.18	86.09	0.18	**76.51**

According to the value of TLI（Σ） ranging from 1 to 100, the eutrophic level can be divided into 6 categories:

1) TLI（Σ）＜30: Oligotrophic;
2) 30≤TLI（Σ）≤50: Mesotrophic;
3) TLI（Σ）>50: Eutrophic;
4) 50＜TLI（∑）≤60: Light eutrophic;
5) 60＜TLI（Σ）≤70: Middle eutrophic;
6) TLI（Σ）>70: Hyper eutrophic.

Referring to the TLI（Σ）values in the last line of Table 10, all of them are above 70, so all the 6 samples of water have hyper eutrophication problem.

4.2.2.2 Soil Quality Results

Before introducing the soil quality results, the species currently cultivated in 2 sample groups have an interesting condition: all the 6 samples in “<5 years group” are seedlings, and in “>10 years group”, except Sample 4, the other 5 samples are all big up-growing or spherical trees. About the sampling time in the end of March and in the beginning of April in 2012, it was before spring fertilizing time this year and it had been a few months since last fertilizing which was in the end of last autumn or in the beginning of last winter. In addition, all the analysis results of each indicator are based on the average value of three times group parallel determinations.

When it comes to the soil analysis result, firstly, Figure 36 shows the soil pH condition with 3 colored broken lines correspondingly referring to control, 5 year and 10 year groups. The range of pH value of pH is from 5.31 (in “<5 years” group) to 6.51 (in control group). It’s obvious that the control group PH value should be higher than other two groups. The mean pH value of control group is 6.28 which is 0.3 higher than the value of “<5 years group” and 0.27 higher than the value of “>10 years group” (Table 11). So the farming activities from human beings do have caused soil acidification tendency. When comparing the “<5 years” and “>10 years” groups, the mean value is 6.01 for the former group and5.98 for the later. It seems that the “<5 years” group has a more serious acidification tendency.

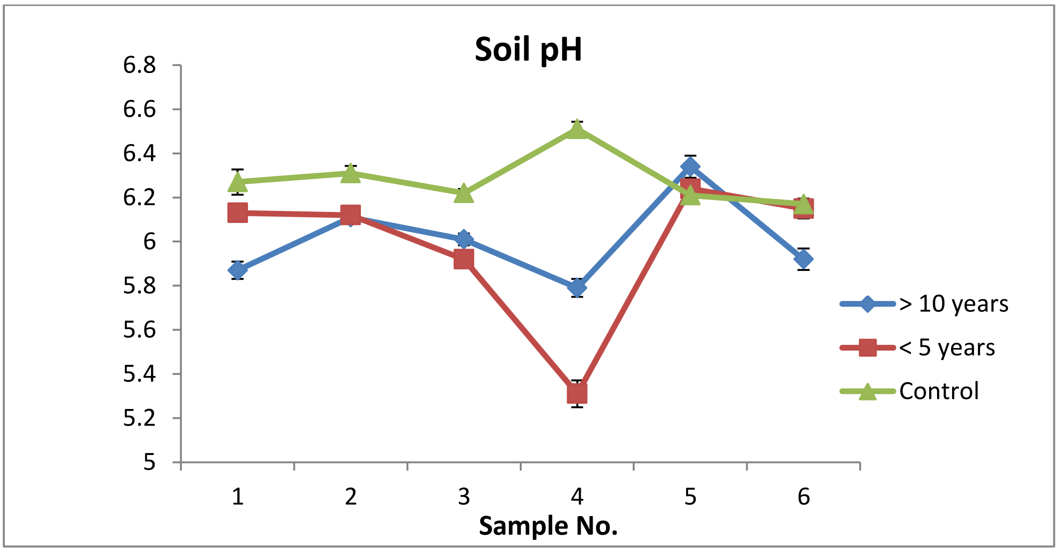


Figure 37. Comparison of soil pH between control and sample groups

Table 11. Soil quality results with various indicators’ mean value

Mean Value	pH	TOC	TN	AN	TP	AP	TK	AK
		g/Kg	g/Kg	mg/Kg	g/Kg	mg/Kg	g/Kg	mg/Kg
Control	6.28	20.8	1.22	181.40	0.67	3.21	13.26	126.95
<5years	5.98	17.2	1.57	213.07	0.68	3.66	11.89	115.68
>10years	6.01	18.8	1.41	196.33	0.72	4.43	13.12	109.25

Secondly, Figure 37 shows the soil total organic carbon condition which is also a key factor of soil fertility. The control group generally has a higher TOC content than two sample groups. The mean value of control group is 20.8 g/Kg which is 3.6 g/Kg higher than “<5 years” group and 2 g/Kg higher than “>10 years” group. For the 2 sample groups, generally the “>10 years” group has a higher value than “< 5 years” group. The range of TOC value in “< 5 years” group is from 13.2 g/Kg to 21.3 g/Kg and in “> 10 years” group is from 15.2 g/Kg to 21.8 g/Kg. The mean TOC values for them are 17.2 g/Kg and 18.8 g/Kg and the “<5 years” group seems have a more serious TOC decreasing situation than “> 10 years” group.

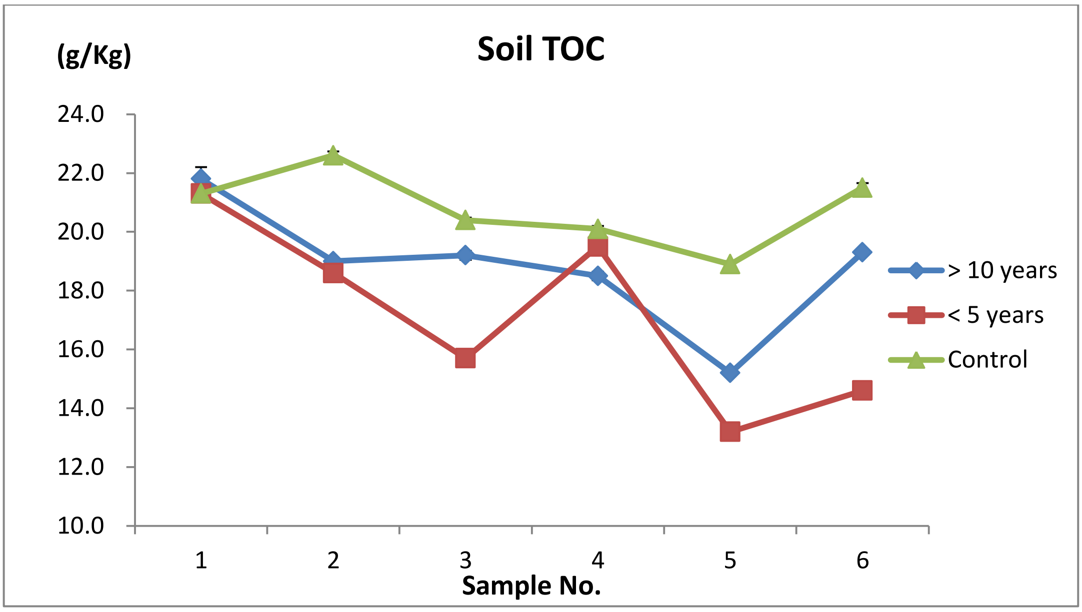


Figure 38. Comparison of soil TOC between control and sample groups

Thirdly, the contents of N, P and K elements are also the main indicators for soil fertility. As shown in Figure 38, the differences between groups are also apparent in the indicator of total nitrogen (TN) and available nitrogen (AN). The average values of TN and AN for control group are around 1.22 g/Kg and 181 mg/Kg which are both lower than the other two sample groups. For “< 5 years” group, the average values of TN and AN are 1.57 g/Kg and 213 mg/Kg both of which are higher than 1.41g/Kg and 196 mg/Kg of “>10 years” group.

Figure 39 shows the TP and AP situation in three groups. There’s no special finding between groups. The control group has a relatively more stable value changing than the other two groups. In the other two sample groups, TP and AP of various farmlands cultivated by different farmers have changeable values. The mean TP and AP values for “< 5 years” are 0.68 g/Kg and 3.66 mg/Kg and for “> 10 years” group are little higher with 0.72 g/Kg and 4.43 mg/Kg correspondingly.

Figure 40 indicates the TK and AK condition between groups. Also from the broken lines, there’s no special finding between groups. The mean TK and AK values of 6 samples in control group are 13.26 g/Kg and 127 mg/Kg, both of which are bigger than the other two groups. The mean TK and AK values for “< 5 years” group are 11.89 g/Kg and 116 mg/Kg and for “> 10 years” group are 13.12 g/Kg and 109 mg/Kg.

In a general conclusion of the mean values for different indicators, the control group has the highest pH, TOC, TK and AK contents; the “< 5 years” has the highest TN and AN contents; and the “> 10 years” group has the highest TK and AK contents. Also the “< 5 years” group has more serious soil acidification problem and TOC decreasing tendency than “> 10 years” group.

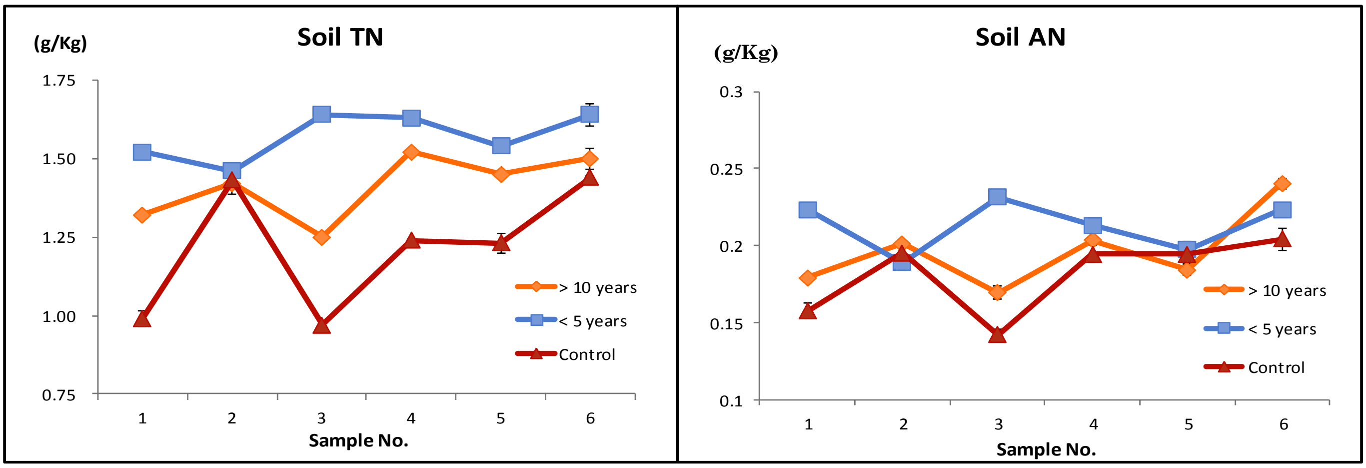


Figure 39. Comparison of soil TN & AN between control and sample groups

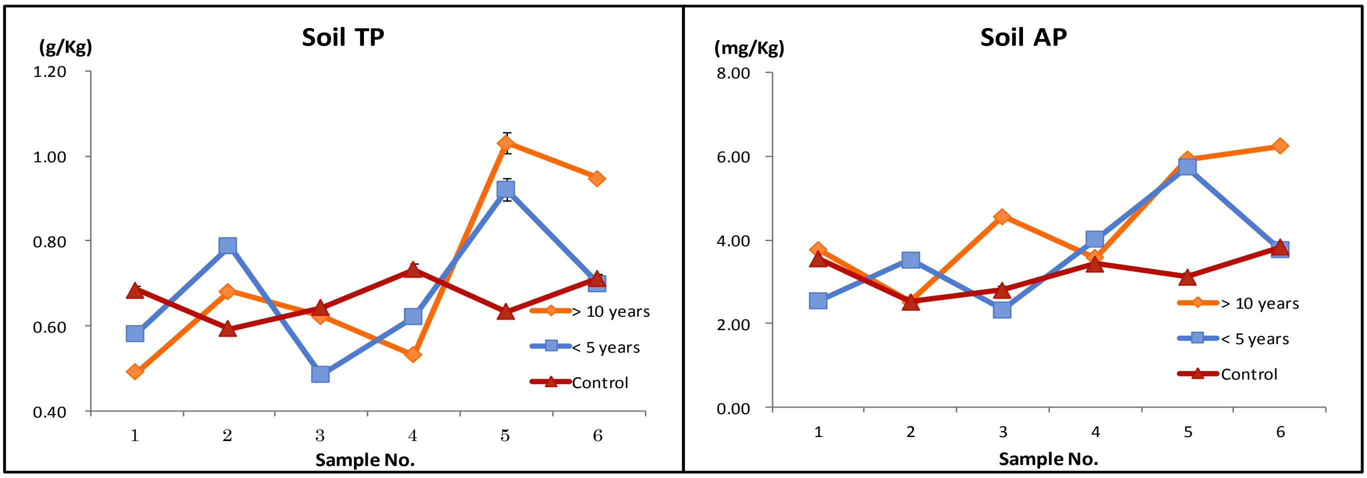


Figure 40. Comparison of soil TP & AP between control and sample groups

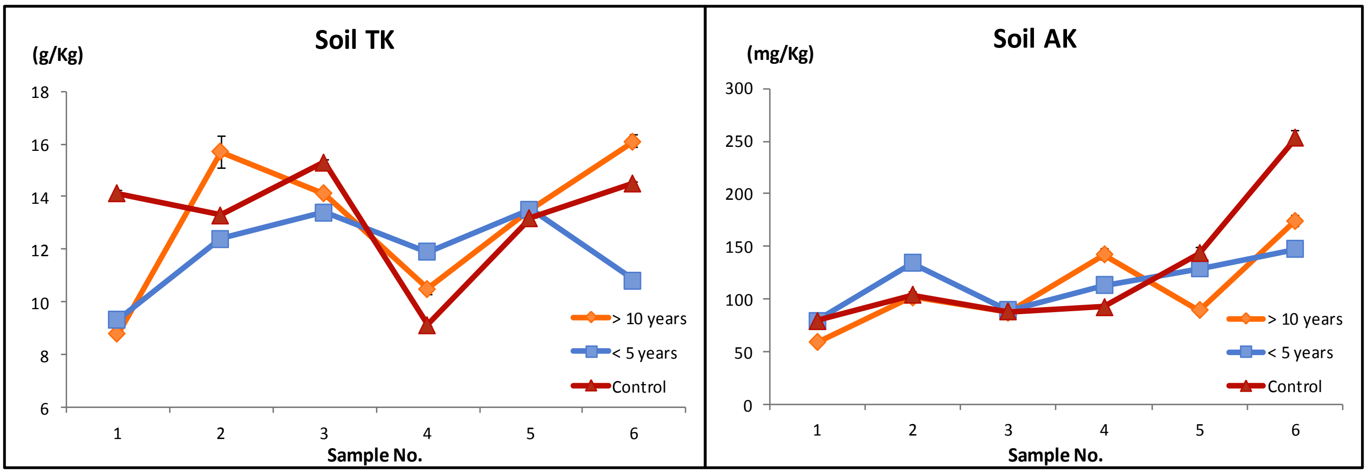


Figure 41. Comparison of soil TK & AK between control and sample groups

According to the classification standards for soil nutrition after Chinese second national general soil survey, Table 12 lists the 6 levels of nutrition contents. And combing Table 11 and Table 12, the soil nutrition individual levels are calculated in Table 13. From Table 13, all the nutrition in the two sample groups are below medium level though it had been several months after last fertilizing time in last year.

Table 12. Classification standards for soil nutrition

Indicators / Nutrition Level	TOC	TN	TP	TK	AN	AP (P_2O_5)	AK (K_2O)
	g/Kg	g/Kg	g/Kg	g/Kg	mg/Kg	mg/Kg	mg/Kg
Level 6: Very Low	<6	<0.5	<0.2	<5	<30	<3	<30
Level 5: Low	6-10	0.5-0.75	0.2-0.4	5-10	30-6-	3-5	30-50
Level 4: Medium	10-20	0.75-1	0.4-0.6	10-15	60-90	5-10	50-100
Level 3: High	20-30	1-1.5	0.6-0.8	15-20	90-120	10-20	100-150
Level 2: Very High	30-40	1.5-2	0.8-1	20-25	120-150	20-40	150-200
Level 1: Extreme High	>40	>2	>1	>25	>150	>40	>200

Source: Chinese second national general soil survey

Table 13. Nutrition separate levels of control and sample groups

Indicators / Soil Group	TOC	TN	TP	TK	AN	AP (P_2O_5)	AK (K_2O)
Control Group	L3	L3	L3	L4	L1	L4	L2
< 5 Years Group	L4	L2	L3	L4	L1	L4	L3
> 10 Years Group	L4	L3	L3	L4	L1	L3	L3

CHAPTER-5 DISSCUSSION & CONCLUSION

As introduced in Chapter 3, the framework for this whole research is based on DPSIR model. This chapter based on the research results is mainly in order to ask the main questions extended by this framework:

Q1: What's the main driver for local farmers' transformation from traditional crops' to F-P cultivation? (Driver)

Q2: What activities have they done during cultivation and transplantation? (Pressure)

Q3: What's current state of local rural environment including soil quality and quantity & farmland-nearby surface water quality? (State)

Q4: What impacts F-P are causing to sustainable agriculture and sustainable social and economic development? (Impacts)

Q5: What kinds of suggestions can be provided to stakeholders to reduce the negative impacts? (Response)(This question will be discussed in details in Chapter 6.)

Q1 and Q 2 are mainly based on social survey including questionnaire and interview and part of field survey (top-soil loss survey) while Q3 and Q4 are mainly based on field survey results and literature review. Q5 are based on both the social and field survey findings.

To answer Q1: For most of farmers, they don't have high education level (99% below university degree). Besides, about half of them (45%) are more than 50 years old and no longer young. In reality, except farming, they don't have many job alternatives to get a respectable income. Since there's an alternative choice of farming contents which can bring more financial benefits than before, they must have strong willing to try as much as possible. That's why they transferred most of their cultivated agriculture species to F-P which has been proved by questionnaire and the statistics from government. From questionnaire, 97% are panting crops less than 1 Mu area or have stopped crops cultivation. From the government statistics, the F-P cultivation area in JiaZe and HuangLi towns has extended 90% of all the local cultivated farmland area. So for Q1 the "Driver" part, the higher income from F-P cultivation than crops is the main external economic driver (82%).

For Q2 the "Pressure" part: 92% farmers from the questionnaire have more than 3 years cultivation history (66% more than 5 years history) but the cultivation skills or methods are mainly from self-learning and own cultivation experience for 99% farmers. About the CF, the usage per unit per year does extend too much than our expected: the mean value of usage is around 1623 Kg/ha/Year which has been more than 7 times the amount of 225 Kg/ha/Year which was proposed by developed countries to avoid farmland nearby water eutrophication problems. Besides, the average CF usage for agriculture in Changzhou area was around 430 Kg/ha/Year in 2010. It's obvious that CF usage in F-P cultivation is around 3 times more than the average usage in agriculture. For organic fertilizer usage, 36% farmers don't use organic fertilizer at all. In addition, 64% farmers use ground water for irrigation (4% only use ground water, 36% only use river water and 60% use both for irrigation) which is a very big consumption for ground water and deep wells are very common in rural families. At the same time, Changzhou in Yangtze River delta area has serious land subsidence problem and in city area, the ground water consumption is with strict limitation while in rural area, these situation hasn't attracted enough attention from government. Just as previous research indicated, the land subsidence in China is with a tendency from city to rural area mainly because of ground water irrigation for rural agriculture. For top-soil loss problem, the situation is more serious than expected especially for the container seedling species. Generally, if the cultivation of container seedling continues for three times in the same farmland, there will be no top-soil with fertility left in farmland (Each time of selling container seedling will take away about 30% of total top-soil per year amount in farmland.). For instance, as for the 21*12 sized container seedling cultivation, it will cause more than 57% top-soil loss after each selling time and cause around 28.7% top-soil per year loss. One-year ground seedling takes only a small ratio of top-soil, but the price of ground seedling is much lower than container seedlings mainly because of the low survival rate after transplantation. Since container seedling cultivation can have quick financial feedback, usually farmers without too much circulating money prefer to plant seedlings than big trees. In the soil samples of "< 5 years" group in field survey, all the 6 samples are from seedling cultivation farmland and in fact, farmers have already realized that container seedling cultivation can't be frequent in same farmland and that's why there are five samples are from big trees cultivation farmland in "> 10 years" cultivation history group. As for the 6 level sized trees in spherical category, trees with a crown diameter around 50 to 80 cm will take away the biggest top-soil (26.14% of top-soil loss) each time during selling while the trees with a crown diameter around 30 to 50 cm will take away the biggest top-soil per year (yearly 14.73% of top-soil loss). Though the mean amount of each time top-soil loss by spherical trees are still around 20% of total top-soil, the yearly top-soil loss situation is much better than container seedlings. When it comes to up-growing trees category, the soil ball's diameter was found has a linear relationship with the tree's DBH. According to the curve's fitting formula "$y = 4.5685x$ ($r^2=0.8526$)", soil ball's diameter (y) can be predicted after knowing the tree's DBH(x). Besides, after analyzing the data form 28 sample trees, an exponential correlation was found between the yearly top-soil loss amount (y) and tree's age (x): $y = 14.219e^{-0.092x}$ ($R^2 = 0.8747$). The negative correlation between the two items is much apparent (the older the tree is, the less the yearly top-soil will lose) but the number of “y” will always be positive number. It’s understandable that, when a tree is becoming very mature with an old enough age, the amount of soil loss during transplantation is very large but after dividing the number of years, the yearly loss amount will be very small. So generally, according to the equation, the yearly top-soil loss situation by different aged trees of common up-growing species can be predicted in a certain extent. The mean value of top-soil loss by up-growing trees is around 20% which is similar with the mean value of spherical trees. Among the 28 up-growing trees, only 4 trees will take away more than 25% of total top-soil each time after transplanting but all of them are 5 years old or even much older. All the other 24 trees, aging from 2 years to 45 years old, each time they will take less than 25% of total local top-soil away. In addition, the biggest yearly top-soil loss among these 28 trees is around 6.25% of total top-soil which seems much better than spherical trees.

For Q3 the “State” part: From the questionnaire, respectively, more than 90% and more than 50% of farmers are thinking the water quality and soil quality decreasing. From personal feelings to scientific experimental analyzing results: firstly about the farmland nearby water quality, 100% of the water samples are found with hyper-eutrophication problems after applying Comprehensive Trophic Level Index (TLI（Σ）) and the fixed boundary system for trophic category (proposed by OECD) for eutrophication assessment. As introduced before, the F-P is the main cultivated specie of agriculture in JiaZe and HuangLi towns and there’s no direct industry pollutants and household wastewater emission to the water area. So fertilizer over-usage in F-P cultivation is the main cause to nearby water hyper-eutrophication. About the soil quality, both the “< 5 years” (mean pH 5.98) and “> 10 years” (mean pH 6.01) F-P cultivation history groups has soil acidification tendency compared with control samples (mean pH 6.28). In natural condition without external human interruption, the soil pH changes very slowly and it takes hundreds of or even one thousand years for soil pH to decrease 1 unit. In the past 20 years, the high intensive farming activities and the high CF usage (especially the nitrogenous fertilizer) have rapidly shortened the soil acidification progress. At the same time, the soil TOC also decreased by 3.6 g/Kg and 2 g/Kg with "< 5 years" group (17.2 g/Kg) and "> 10 years" (18.8 g/Kg) group than control group (20.8 g/Kg). It seems that "< 5 years" group has a more serious TOC decreasing problem than ">10 years" group. As mentioned before, the current species cultivated in "< 5 years" group are all container seedlings while only 1 sample in "> 10 years" group is from container seedling cultivation farmland (the other 5 are from big trees cultivated farmland) and container seeding cultivation usually takes a huge amount of top-soil. The large amount of top-soil loss by plants during transplantation is an important reason for TOC decreasing. When considering the N, P and K contents in soil, their nutrition level at that time can somehow reflect something. According to the "Classification Standards for Soil Nutrition" proposed after Chinese second national general soil survey, the TN is in Level 2 (very high) for "< 5 years" group and in Level 3 (high) for "> 10 years" group and AN is in Level 1 (extreme high) for both groups. The TK and TK are respectively in Level 4 (medium) and in Level 3 (high) for both "< 5 years" and "> 10 years" groups. The AP is in Level 4 (medium) and Level 3 (high) respectively for "< 5 years" and "> 10 years" groups and TP is in Level 3 (high) for both groups. From the separated levels, the P and K elements are in a suitable level and the N element is much abundant and enough for plants. In addition, the soil sampling time was in 2010.03-2012.04 before the spring fertilizing this year when it had been a few months since previous fertilizing in the end of last autumn or in the beginning of last winter. From another aspect, farmers didn't fertilizer with a good balance of N/P/K elements and they have used too more Nitrogenous fertilizer than Phosphate and Potash fertilizer.

For Q4 the “Impacts” part: From the research results till now, the F-P do have caused soil acidification accelerating, serious top-soil loss accompanied with soil TOC decrease, and water hyper-eutrophication problems. Current the F-P cultivation is not in a sustainable way. But if there’s still F-P demanding in market and the profit is still attractive, the cultivation activity will be continued by the farmers. Because of the serious top-soil loss, in order to promise the product growth, they need to use more CF and continue to sell plants with soil. So, if without any external positive intervention and any change in cultivation ways, these human activities will turn into more pressure to local environment and form a vicious circle until the farmland quality and safety are totally ruined. At that time, neither F-P nor traditional agriculture can sustain anymore. The farmers will lose their farmland they live by and lose the economic income or job opportunities brought by the farmland. So in long term, current F-P cultivation mode will threaten the environment quality, rural economic development and societal justice / stability.

In order to make the conclusion visible and easily understanding, Figure 41 shows a research flow fulfilled with research results.

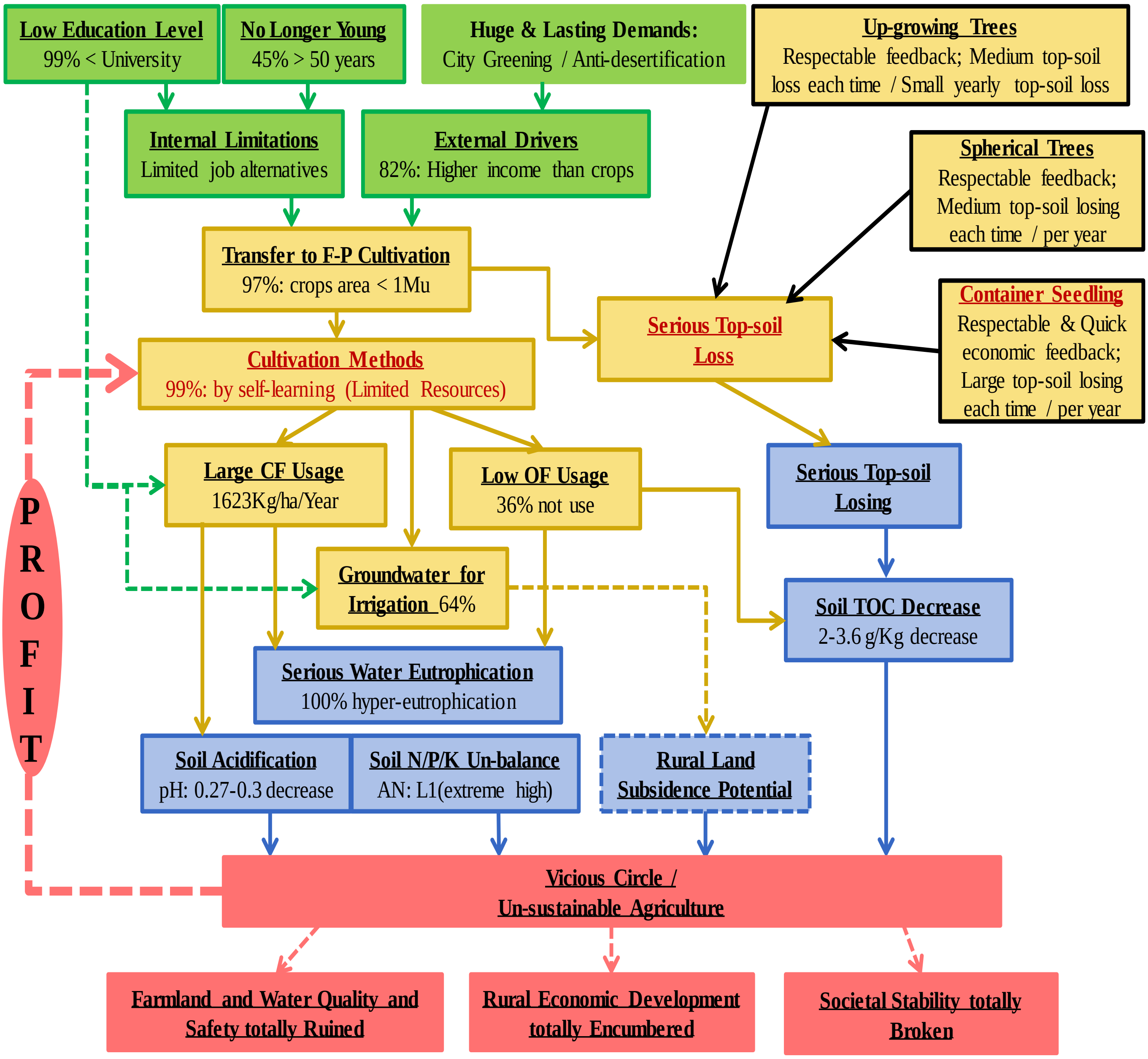


Figure 42: Research conclusion based on DPSIR framework
(Description of different colors: Driver, Pressure, State, Impacts)

CHAPTER-6 RECOMMENDATION

This chapter is in order to answer Q5 the "Response" part. Based on the previous 4 parts of DPSIR framework, the recommendations to different stakeholders corresponding to the limitations, gaps and shortages in DPSI steps are as follows:

Firstly, to solve the information gap. The government can bridge the collaborations between academic institute or agricultural universities and rural farmers in the form of holding free lectures, using moving posters, conduct yearly small scale water and soil quality survey and public the results to farmers to guide them how to fertilizer and irrigate. Besides, the cooperatives between greening company and farmers should be encouraged. Taking the farmland as their cultivation base, the company can give market information and support technical supporting to farmers by technical staff. Meanwhile, the government should strengthen public education to increase sustainable awareness and set irrigation regulations. Certainly, the agent people, trading market and internet can also be information resource choice.

1) Strengthen publicity and education of scientific and sustainable F-P cultivation: most farmers without enough scientific knowledge have the misunderstanding that higher CF equals higher productivity and the farmers having very limited cultivation methods information resources mainly can earn F-P cultivation skills through personal experience. So the government can offer opportunities to bridge the collaborations between academic institute or agricultural universities and rural farmers. They can help to organize some free lectures by experts and offer moving promotion posters in rural area to introduce F-P cultivation skills of different species and to guide farmers fertilizing CF efficiently in order to

save unnecessary investment and to avoid serious environment pollution. At the same time, the government can do small scale survey to collect soil samples for fertility analysis every year and timely public the soil quality data to farmers guiding them to fertilize in a more scientific way. Also the government should improve the rural public education to increase the sustainable awareness and minimize the ground water over-usage for irrigation by setting strict regulations and strengthening effective monitoring system.

2) In some villages, there're already some cooperatives founded and have corporations with some greening companies forming the "Greening company-Cooperatives" mode. These farmer's F-P cultivation farmlands are regarded as the cultivation base of the greening companies and the greening company can offer market demanding information and cultivation skills supporting to the farmers and also can regularly help them sell their products. This is a typical "win-win" mode and should be popularized with the help form government as a bridge. In that case, the current problem of some farmers' somehow blindly specie choosing for cultivation because of can be solved in a certain extent. The local government should try to give more accesses for farmers to market information.

3) Encourage more farmers to use organic fertilizer and increase the organic fertilizer ratio and minimize the chemical fertilizer usage for each farmer. Also when using either CF or OF, they should pay more attention to the nutrition balance like N, P and K.

Then serious choose cultivation species. This includes specie choice and cultivation period decision. About the specie choice: container seedling is badly un-recommended, spherical and up-growing trees with acceptable soil loss are recommended. Since containers seedling can bring quick and satisfied financial feedback, after the cultivation, promise years of intermission with proper species. As introduced in research results, the container seedling with high survival rate during transplantation, respective price, short growth period and quick economic feedback are very popular in Wujin. But the container seedlings cause more serious top-soil loss either by time or by year than spherical or up-growing trees, container seedlings are not encouraged to farmers. However, because most farmers are without much money for circulation, they can cultivate container seedlings but not in a dis-continuous way. For instance, in the first year they can choose cultivate seedlings, and in the second year, they can change to cultivate up-growing or spherical trees for more than 3 years to giving the farmland enough recovering time. Certainly, among the years, the organic fertilizer is a good choice to resupply the soil total organic carbon. Then after years, they can again cultivate container seedlings. However, big trees with low yearly top-soil loss and by time medium or low top-soil loss are strongly encouraged. Also the amounts of top-soil loss per year or per time by 3 tree categories can be generally predicted with the formulas or tables conclude in this research. For cultivation period decision, after up-growing tree's age, the yearly soil loss can be predicted. For spherical trees, crown diameter more than 80cm is recommended to take acceptable amount of soil. Surely, when trees become bigger, the transplantation becomes harder. The survival rate after transplantation also needs to be considered. Also the greening policy should pay attention to the container seedling serious harm to topsoil and make restriction.

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