SUSTAINABILITY ANALYSIS OF FARMING SYSTEMS IN DAFANG COUNTY, GUIZHOU PROVINCE, PEOPLE'S REPUBLIC OF CHINA

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Gu Ming : การวิเคราะห์ความยั่งยืนของระบบการทำฟาร์มในเมือง DAFANG จังหวัด GUIZHOU สาธารณรัฐประชาชนจีน (SUSTAINABILITY ANALYSIS OF FARMING SYSTEM IN DAFANG COUNTY, GUIZHOU PROVINCE, PEOPLE'S REPUBLIC OF CHINA) อ.ที่ปรึกษา : ผศ.ดร.หัสไชย บุญจูง, 132 หน้า. ISBN 974 – 533 – 258 –5

ความยั่งยืนไม่ใช่แนวคิดใหม่ แต่ค่อนข้างจะเป็นแนวคิดที่โดดเด่นในปัจจุบัน นับตั้งแต่การเกษตรยั่งยืนได้กลายเป็นหลักสำคัญของสังคมที่ต้องการดำรงทรัพยากรธรรมชาติสำหรับอนุชนในอนาคต ประเด็นที่สำคัญประการหนึ่ง คือมีข้อโต้แย้งเกี่ยวกับวิธีการที่จะใช้เป็นข้อกำหนดและมาตรวัดระบบการเกษตรอย่างยั่งยืน การพัฒนาการเกษตรอย่างยั่งยืนคือความต้องการของประชาชนโดยปราศจากการลดลงของทรัพยากรธรรมชาติ เป็นที่เข้าใจกันในปัจจุบันว่าความยั่งยืนมีความแตกต่างกันในสองมิติ อันได้แก่ มิติความยั่งยืนในทางชีวฟิสิคส์ และมิติความยั่งยืนในทางเศรษฐกิจและสังคม มิติความยั่งยืนในทางชีวฟิสิคส์จะเกี่ยวข้องกับการดำรงไว้หรือการเพิ่มพูนในระยะยาวของความสามารถในเชิงการผลิต อันอยู่บนพื้นฐานของทรัพยากร ในขณะที่ มิติความยั่งยืนในทางเศรษฐกิจและสังคม จะเกี่ยวข้องกับความอยู่รอดในเชิงเศรษฐกิจของระบบการทำฟาร์มและสังคมเกษตรชนบท

ได้ทำการศึกษาโดยใช้วิธีการสำรวจเก็บข้อมูล โดยการสัมภาษณ์ครัวเรือนในตำบล Xiaotun , Zhuyuan และ Liulong จำนวน 78, 65 และ 57 ครัวเรือน ตามลำดับ ซึ่งใช้เป็นตัวแทนของพื้นที่ทำการเกษตรใน 3 ระดับความสูงจากระดับน้ำทะเลของเมือง Dafang แบบสอบถามที่ใช้อยู่บนพื้นฐานข้อกำหนดของดัชนีสำหรับการประเมินการเข้าสู่ความยั่งยืน การเกษตรอย่างยั่งยืนที่เมือง Dafang จังหวัด Guizhou นำมาวิเคราะห์ในด้าน ความยั่งยืนในเชิงนิเวศวิทยา ความอยู่รอดในเชิงเศรษฐกิจ และการยอมรับของสังคม ข้อมูลขั้นปฐมภูมิและทุติยภูมิจะถูกรวบรวมรวมทั้งข้อกำหนดของดัชนีชี้วัดสำหรับการประเมิน โดยการสัมภาษณ์ การสำรวจภาคสนาม และการจัดกลุ่มวิจารณ์สำหรับรายละเอียดหลักที่สำคัญ ทำการวิเคราะห์ความยั่งยืนในระดับมหภาคของแต่ละพื้นที่ตัวแทน และ 5 ตัวแทนครัวเรือนของแต่ละ พื้นที่ตัวแทน ทั้ง 3พื้นที่ จะบันทึกการทำฟาร์มเป็นเวลา 1 ปี จากนั้นนำมาวิเคราะห์ในระดับจุลภาคต่อไป

ผลการศึกษาพบว่าความยั่งยืนที่ Liulong ค่อยๆ เกิดขึ้นดีกว่า Xiaotun และ Zhuyuan ในด้านของความอยู่รอดในเชิงเศรษฐกิจและการยอมรับของสังคม ในเชิงเศรษฐศาสตร์ที่ดีคือก่อให้เกิดรายได้ของฟาร์มและผลตอบแทนจากการเลี้ยงสัตว์ แม้ว่าพื้นที่ศึกษาทั้งหมดมีความยั่งยืนในระบบการทำฟาร์มพอสมควรก็ตาม แต่ยังคงมีความต้องการที่จะเพิ่มการนำไปสู่ความยั่งยืนโดยการลดการใช้ปุ๋ยเคมีและสารเคมีกำจัดศัตรูพืช แต่เพิ่มการใช้ปุ๋ยอินทรีย์และการจัดการในเรื่องธาตุอาหาร ในขณะที่การให้บริการการส่งเสริม และการสนับสนุนในด้านอื่นๆรวมทั้งนโยบายของรัฐบาลก็เป็นสิ่งจำเป็นที่ควรได้รับการปรับปรุงด้วยเช่นกัน

สาขาวิชาเทคโนโลยีการผลิตพืช	**ลายมือชื่อนักศึกษา…………………….. ….**
ปีการศึกษา 2546	**ลายมือชื่ออาจารย์ที่ปรึกษา…………………**
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม……………..

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Sustainability is not a new concept but rather a prominent concept at the present. Since sustainable agriculture became the watchword for capturing society's desire to better preserve the natural resource base for future generations, there have been debates about how to define and measure sustainable agricultural systems. Sustainable agricultural development is to meet the people's requirement without degrading natural resources. Sustainable agriculture is not only worth pursuing, but also it is inevitable. It is now widely agreed that there are different dimensions of sustainability ranging from the biophysical dimensions to economic and social dimensions. The biophysical dimensions of sustainability relate to the long-term maintenance or enhancement of the productive capacity of the resource base. Economic and social dimensions relate to the long-term economic viability of farming and rural communities.

Sustainable agriculture at Dafang county, Guizhou province was analyzed in terms of ecological sustainability, economic viability and social acceptability. Xiaotun, Zhuyuan and Liulong were selected as representatives of lower-middle, middle and middle-high agricultural areas of Dafang county. Primary and secondary data were collected according to requirements of indicator evaluation. Household survey was collected through interview, field observations and group discussion for the key information. Numbers of households interviewed were 78, 65 and 57 for Xiaotun, Zhuyuan and Liulong respectively. The data were analyzed for sustainability indices at the macro-level of each representative site. Five households of each of three representative sites were placed a farm record for one year. Then the data were analyzed for sustainability at micro-level of each representative site.

The overall sustainability at Liulong is found to be slightly better than the other two sites in terms of economic viability and social acceptability. Good economy is due to high off-farm income and returns from animal raising. The results are supported by analyzing farm records. Even though, all sites are considered as moderate sustainability farming systems. They are still needed to increase sustainability by reduce use of chemical fertilizers and pesticides, but increase by use of organic fertilizers and integrated plant nutrient management. Meanwhile, extension service and some other supporting systems including government policy are also needed to be improved.

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CHAPTER I

INTRODUCTION

1.1 Background of the Study

The People's Republic of China (PRC), located between 73° E and 135°E and stretches from 18°20'N to 53°52' N, is the world's most populated country with 1,248.1 million people, making up 21.5% of the world's total population in the year 2001. Although China is named as one of the largest agricultural countries but only 6.9% of the world's arable land is found in the country (Gardener and Zhao, 1999). Meanwhile this land base is shrinking sharply due to natural degradation and the building of thousands of factories, warehouses, new residential areas and access roads. With the rapid increase of population in China, demand for food has outpaced growth of grain production since the 1970s (Zhang, 1999). By 2010, China will have a total grain demand of 560-590 million metric tons (MT), as compared to 480 million MT in 1998. Though the annual grain yield per capita increased from 358kg in 1988 to 384 kg in 1998, the largest amount was lower than the international average of about 500kg, and was much lower than that in developed countries (Xie, 1998). This implies that the demand for food is increasing with population growth. But the natural resource for agricultural production is very limited. Per capita water resource owned is only 28 %, cultivation land 32 %, forestland 14% and grassland 32 % of those of the world's averages respectively. Meanwhile, these resources are not distributed evenly, 90% of water resource, for instance, is distributed in the Eastern part of the country where only 30 % of cultivation land is located. Lester (1994) pointed out that "China could neither support herself, nor could the world afford China in the future. A potentially large food deficit might have strong implications for the global food balance". Though his forecasting lacks knowledge of China's conditions, he is alarming a valuable bell for China's food production.

Clearly, there is a need to improve the management and use of limited land, water, and other natural resources to feed the ever growth population and protect the environment in order to meet the needs of next generations (Wen and David, 1992). However, the growing pressure on the land has made many of the traditional land-use practices increasingly difficult to sustain, particularly in locations with high population concentrations. To meet the intense pressure for increased food consumption, China has over the past three decades adopted yield-increasing, external input-requiring production technologies from the West. In 1949, for instance, farmers almost did not use manufactured fertilizers. In 1952, the total amount of fertilizers used was about 78,000 MT. This figure increased dramatically, and reached 8.84 million MT in 1978, with an annual increase of 30.9% over 26 years. In 1998, the total amount of fertilizers applied in the country was 40.85 million MT. China is now the world's largest consumer of manufactured fertilizers (Agricultural Information Network of China, 2000).

Apart from the increased use of chemical fertilizers, pesticide is also widely used. In 1997, the total amount of pesticide applied by farmers reached 0.9 million MT. High yield varieties (HYVs) have been increasingly used in China. By late 1980s, about 95% of rice, 70% of wheat, 90% of maize and sorghum planted areas were under HYVs. Total irrigation areas also increased rapidly over the past decades.

In 1949, the total irrigated area was 15.93 million ha, it increased to 44.97 million ha in 1978, and reached 50.3 million ha in 1998 (Agricultural Information Network of China, 2000).

Increased use of HYVs, chemical fertilizers, pesticides, irrigation and machinery have serious impacts on farmlands, especially in the areas where farmers have sufficient income to purchase these inputs. In the economically poor areas, however, the inputs to agricultural production are always inadequate due to limited access to input services and insufficient financial support. For instance, some soils in these areas have very low productivity due to less addition of fertilizer. Inadequate levels of inputs in these areas degrade resources through exhaustion.

External input based farming activities have serious impacts on soil and water quality. Twenty-four percentage of the total cropland, for example, is polluted by pesticide. The total area of land degradation is 1.6 million ha that is 16.6 % of the total land area of the country. Soil erosion is becoming a serious problem. The average area of soil erosion of arable land is 40 million ha. The total amount of soil erosion is 1 billion MT per year. Desertificated arable land is 0.33 million ha. Salinized land is 37 million ha (Agricultural Information Network of China, 2000).

These problems also exist in the micro level. For instance in Guizhou province, the population increased from 32.68 million to 37.6 million during 1990-2000. The total number of people increased annually was 0.49 million during this period (Guizhou Daily, 2001). On the other hand, the area of arable land decreased at a rate of 7,600 ha yearly, and average land area per capita decreased from 0.15 ha in 1957 to 0.059 ha in 1988 (Li, 1990), and to 0.047 ha in 2000 (Guizhou Agricultural Yearbook of Statistics, 2001). To feed the increasing population, the land is overused and not managed and maintained properly. Land degradation is widely spread across in the province; the total area of soil erosion is more than 5 million ha, which is about 1/3 of the total land area of the province. Among which, 33 counties are very serious in soil erosion (Li, 1990). Desertification is also becoming serious in recent years. Besides, water resource is very limited and used inefficiently. The effectively irrigated land is only 23.7% of the total arable land in the province. Water use efficiency of irrigation is only 40% (Guizhou Agricultural Yearbook of Statistics, 2001).

Irrational use of chemical fertilizer and pesticide results in waste of inputs, water pollution, soil pollution and the accumulation of chemical residues in the products. Inadequate knowledge and technology support from the government, low capability of the researchers, and poor education of the farmers all are the factors influencing sustainable farming practices in the area. As an important factor for economic development, market prices and marketing facilities influence directly the farming activities in the area.

To be sustainable, a farm system must generate a level of production that satisfies the productivity and social needs of the farm household within certain margins of security without long-term resource depletion. As the objectives of security, continuity and identity usually compete with an optimal productivity instead of maximum level of productivity. It has to ensure sustainability of the farming system. Therefore the relative effort is needed to find the new balance for sustainable farming system. The existing farming techniques must be assessed in term of their economics, ecological and sociopolitical sustainability, and available alternative must be assessed in the same way. In this process, the level of decision making concerned at the family level will be recognized the extent to which their specific objectives and ways of achieving them can be matched with current technical opportunities and limitations. Research to increase the sustainability of Chinese agriculture thus becomes a very pressing topic.

1.2 Rationale of the Study

Chinese government in 1992 has adopted the concept of sustainable development, the year when the UN had the conference on World's Environment and Development in Brussels. On March 25 of 1992, sustainable development was firstly included in "White Paper of China Agenda 21-Population, Resources and Environment". Sustainable development was considered as the most important component of the blueprint for domestic economy and social development. The President of China made a statement on the population and the environment in 1992 entitled 'Critical Relationships in the Modernization of Socialism'. He said that one should consider sustainable development as the major strategy, and put population control and environmental conservation in the most important place in the development processes in order to coordinate the development of population with social productivity, and economic development with environment development. This statement was a major part of commitment by the government towards environment conservation, and in taking an important role in developing strategies for sustainable resource management (Agricultural Information Network of China, 2000). It is addressed that sustainable development deals with sustainable agriculture development. If there is no sustainable agriculture, there is no sustainable modernization, and no modernization of the society as a whole.

Several laws and regulations have been formulated in response to these statements, including “Law of Agriculture”, “Law of Agricultural Environmental Protection”, “Law of Environmental and Resource Protection”, “ Law of Soil and Water Conservation”, “ Law of Land Management”, etc. The main components of these laws are the warning of the importance of environmental and natural resource protection, the regulations of natural resource protection, the role of the government and people in the process of environment protection, etc. Most of all, it is mentioned that two aspects should be taken into consideration for the sustainable agricultural development: first, development should be sustainable; second, development should be smooth and steady.

In line with this concern, sustainable agriculture has become a popular issue in China. The government and populace have realized both from the theoretical point of view and the practical point of view, that sustainable agriculture can increase profitable and efficient production with an emphasis on integrated farm management, and the conservation of soil, water, energy and biological resources, and other productive resources. It can meet subsistence needs and improve agricultural resource management systems. Likewise, it can minimize variable costs in using of external inputs. From social point of view, it can increase self-reliance among farmers and rural people through the better use of knowledge and skills of farmers.

Some of the research institutions have conducted research related to sustainable agricultural development in China. However, many studies at present are concentrated only on the very broad aspects. The contents of these researches can be summarized into two categories: (1) Macro-level studies, which normally cover the concepts and theory of sustainable agricultural development, overview of the sustainability of Chinese agriculture, the problems, potentials, challenges and hopes of sustainable agricultural systems based on the social survey. Most of these researches are strongly theoretical and fundamental in focus, without concrete analysis about farming sustainability in the context of Chinese situation. (2) Subject oriented research. The related researches done in the past are mostly the analysis of crop productivity, soil fertility, analysis, bio-diversification studies, land carrying capacity analysis, etc. Most of these researches are academic oriented, and insolated from each other. In depth research on sustainable agricultural development has not yet been conducted.

This study follows interdisciplinary approach including environmental, social and economic aspects. It focuses on the sustainability analysis of current farming systems in the selected county of P.R. China. Therefore, it is a site-specific micro level study on agricultural sustainability. It identifies a number of important insights about the issue of sustainable agricultural development and natural resource conservation and management, and makes sustainability analysis of farming practices more concrete through the application of indicators. So, the study is very useful for the decision-makers, academicians and researchers, and also aid for decision-making by farmers for their production activities in order to increase the production without compromising the sustainability.

1.3 Research Objectives

The objectives of this study in sustainable farming systems on the mountainous agricultural land in Dafang county, Guizhou province are as the following:

1). to analyze the existing farming systems of 3 agro-ecological zones in Dafang county for sustainability,

2). to identify the opportunities and limitations for developing sustainable farming systems, and

3). to develop strategies of sustainable agriculture in each agro-ecological zone.

1.4 Scope and the Limitation of the Study

Dafang county is selected as the study area for analyzing sustainability of current farming systems. Due to its mountainous topography with the height ranges between 1400 and 1900 meters above sea level, different environmental conditions and farming practices, therefore three towns were selected as the representative sites for three different agro-ecological zones. Xiaotun, Zhuyuan and Liulong towns are represented a lower agricultural area (<1400m), a middle agricultural area (1400 – 1700 m), and high agricultural area (>1700 m) respectively. Thus, the scope of sustainable agriculture will focus on these three towns that represent the Dafang county.

CHAPTER II

LITERATURE REVIEW

2.1 Sustainable Development

2.1.1 Definitions of Sustainable Development

Defining sustainability and sustainable development in operational terms has proved problematic and no universal consensus has yet emerged (Crabtree and Bayfield, 1998). The report of the World Conference on Environment and Development (WCED) (1987) addresses the growing tensions between environment and the economy, and advocates "sustainable development as the only viable route to world political and ecological stability". The report also defined that "sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts: the concept of needs and the idea of limitations." Its central concerns are with intra- and inter-generational equity: the intra-generational equity is concerned with activities and their impacts that occur at different geographical locations, and the inter-generational equity with activities and their impacts that occur on different scales (Cowell and Stuart, 2003).

The concept of sustainable development is social rather than fundamentally scientific. It relates to the management of a natural resource for a human purpose and is therefore opened to different interpretations (Tait and Morris, 2000). To make the concept more pragmatic and attainable many authors present a variety of definitions from different perspectives. Conway (1986) provided the best-known definition of sustainability as the ability of a system to maintain productivity when subjected to a major disturbing force (stress or shock). Conway's concept of sustainability of any agricultural system relies on the ability of that system to recover, in terms of levels of productivity, from environment shocks. Rees (1989) provided the working definition of sustainable development on a society-wide basis and mentioned that sustainable development requires both society as well as individual economic activities.

Smith and McDonald (1998) mentioned two approaches of sustainable development: wealth approach and mosaic approach. The wealth is concerned with the capital to be inherited to next generation thereby maintaining "inter-generational equity".

On the other hand, Hart (2000) claimed that sustainability has become one of those terms that will probably need to be abandoned because of its multiple meanings to different people. Most people who use the term are suggesting that long-term environmental costs need to be taken into consideration when evaluating short-term economic benefits. Tait and Morris (2000) stated that the concept of sustainable development is in danger of becoming discredited because it appears vaguer and ill defined and cannot readily be measured in a manner, which is precise, repeatable and value-free.

The definitions may vary in terms of their degrees of detail and the extents to which they are explicitly incorporated, internationally structural as well as natural dimensions, geographical scales of importance and inter-temporal effects. In review of the definitions it can be defined that sustainability is the ability of a system to 'continue'.

2.1.2 Components of Sustainable Development

Some scholars addressed that there are always three distinct development processes under-way at the local level as far as sustainable development is concerned. These three processes are economic development, community development, and ecological development. Sustainable development is a process of bringing these three development processes into balance with each other (Lo and Xing, 1999). Simon (1989) highlighted political process as one of the processes for the sustainable development.

Iclei (1996) described that the development imperative of the current economic system favors market expansion, externalization of costs, and sustained private profit. The current imperatives of community development are to meet basic human needs, increase economic and social equity, guarantee participation, and create community self-reliance. The imperatives of ecological development are established in natural order. Humans can support ecological development by limiting the consumption of natural resources to a rate that allows nature to regenerate resources and by reducing the production of wastes to levels that can be absorbed by natural process.

It is now widely agreed that there are different dimensions of sustainability ranging from the biophysical dimensions to economic and social dimensions. The biophysical dimensions of sustainability relate to the long-term maintenance or enhancement of the productive capacity of the resource base. Economic and social dimensions relate to the long-term economic viability of farming and rural communities (Byerlee and Murgai, 2001).

The above discussion has provided the basic understanding about the concept of sustainable development. It is a location and time specific concept. To keep development process sustainable, one must take into consideration of ecological sustainability, economic sustainability and social sustainability as a whole. The components of each aspect vary according to the situation of different cases.

2.2 Definitions and Components of Sustainable Agriculture

2.2.1 Definitions of Sustainable Agriculture

Sustainable agriculture has been described as an umbrella term encompassing several ideological approaches to agriculture, including organic farming, biological agriculture, alternative agriculture, ecological agriculture, low input agriculture, and resource-conserving (Tisdell, 1996). For simplicity, the term sustainable is commonly used by most of the researchers.

During the past 10-15 years, sustainable agriculture has progressed from a focus primarily on a low-input, organic farming approach with an emphasis on small fruit or vegetable production farms, often described as Low Input Sustainable Agriculture, to the current situation where sustainability is an important part of mainstream animal and plant production units (Wagner, 1999). Sustainable agriculture is now a frequently used term that has different interpretations depending upon one's background. All of us must be concerned that agriculture is sustainable but we must also realize that no single definition of sustainable agriculture exists. Sustainable agriculture satisfies many demands in addition to food and fiber production that society places on modern agriculture. Worldwide, sustainable agriculture has multiple goals that are conditioned by how agriculture fits the economic needs of individual countries (Runge, 2001).

Though there are many ways to define sustainable agriculture, sustainability is not yet a well-defined, specific term. It has a time dimension, and few activities are sustainable without limits. Issues concerning the environmental impacts and sustainability of agriculture involve a judgment of benefits and costs, where the balance depends on circumstances. Nevertheless, sustainability is an important and useful concept that embraces all forms of human activities, but it is used with various meanings. Even though, there is a general consensus that agricultural systems must approach sustainability. To become sustainable, in general, then, agricultural systems of the world ought to transition towards ones that are characterized by favorable economics, conservation of resources, preservation of ecology, and promotion of social justice (Payne et al., 2001).

Precise and absolute definitions of sustainability, and therefore of sustainable agriculture, are impossible (Jules, 1995). Sustainability itself is a complex and contested concept. To some it implies persistence and the capacity of something to continue for a long time. To others, it implies resilience and the ability to bounce back after unexpected difficulties. With regard to the environment protection, it involves not damaging or degrading natural resources (Pretty and Hine, 2000). Hansen (1996) addressed that sustainability is an approach and a property to agriculture. It is the ability to satisfy a diverse set of goals or an ability to continue through time. Jules (1995) explained that it is important to clarify what is being sustained, for how long, for whose benefit and at whose cost, over what area and measured by what criteria. ATTRA (1997) defined sustainable farming is a management-intensive method of growing crops as a profit while concurrently minimizing negative impact on the environment, improving soil health, increasing biological diversity, and controlling pests.

Although there are literally hundreds of definitions of sustainable agriculture, one of the more widely accepted definitions, developed by the US Department of Agriculture (USDA), is "an integrated system of plant and animal production practices having a site-specific application that will, over the long-term: (1) satisfy human food and fiber needs; (2) enhance environmental equality and the natural resource base upon which the agricultural economy depends; (3) make the most efficient use of non-renewable 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. A truly sustainable agriculture is one that is economically profitable for farmers, preserves and enhances environmental quality, contributes to the well-being of farm households and nurtures local community development. Sustainable agriculture denotes as holistic systems oriented approach to farming that focuses on the interrelationships of social, economic and environmental processes (Lyson, 2002).

Another meaningful definition of sustainable agriculture, proposed by Jules (1995), is any system of food or fiber production that systematically pursues the following goals:

- A more through incorporation of natural processes such as nutrient cycling, nitrogen fixation and pest-predator relationships into agricultural producing processes;
- A reduction in the use of those off-farm, external and non-renewable inputs with the greatest potential to damage the environment or harm the health of farmers

and consumers, and a more targeted use of the remaining inputs used with a view to minimizing variable costs;

- A more equal access to productive resources and opportunities, and progress towards more socially just forms of agriculture;
- A greater productive use of local knowledge and practices, including innovative approaches not yet fully understood by scientists or widely adopted by farmers;
- An increase in self-reliance among farmers and rural people through the better use of the knowledge and skills of farmers;
- An improvement in the match between cropping patterns and the productive potential and environmental constraints of climate and landscape to ensure long-term sustainability of current production levels, and
- Profitable and efficient production with an emphasis on integrated farm management, and the conservation of soil, water, energy and biological resources.

When these goals combine together, agriculture becomes sustainable (Jules, 1995). As such, farming and research are not concerned with high yields of a particular commodity, but rather with the optimization of the system as a whole.

FAO (1995) also proposed that a system which involves the management and conservation of the natural resource base, and the orientation of technical and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable agriculture and rural development: 1) meet the basic nutritional requirements of present and future generations, qualitatively and quantitatively while provide a number of other agricultural products; 2) provide durable employment, sufficient income, and decent living and working conditions for all those engaged in agricultural production; 3) maintain and, where possible, enhance the productive capacity of the natural resource base as a whole, and the regenerative capacity of renewable resources, without disrupting the functioning of basic ecological cycles and natural balances, destroying the socio-cultural attributes of rural communities, or causing contamination of the environment; and 4) reduce the vulnerability of the agricultural sector to adverse natural and socio-economic factors and other risks, and strengthen self-reliance.

The definition of Dhaliwal et al. (1999), on the other hand, is very concrete and summarized: sustainable agriculture refers to the farming systems that meet rising demands over the indefinite period at economic, environmental and social costs consistent with the rising income. Therefore, sustainable agriculture should involve the successful management of resources for agriculture to satisfy the changing human needs while maintaining or enhancing the quality of environment and conserving natural resources.

2.2.2 Components of Sustainable Agriculture

To make the concept of sustainable development more pragmatic and attainable, many authors presented the components from different perspectives. Douglas (1984, quoted in Smith and McDonald, 1998) identified three different views. The first view is called “sustainability as food sufficiency” which seeks to maximize food production within the constraints of profitability; the second view is “sustainability as stewardship” which seeks to minimize environmental damage; the third view is “sustainability as community “ which seeks to maintain and restructure economically viable rural systems.

Farshad and Zinck (1993) mentioned that the term agricultural sustainability involves agronomic, ecological, economic, social and ethical considerations. Cai and Smith (1994) summarized that the development of Chinese agriculture has been seriously shaped by its biological, sociopolitical and techno-economic environments. Tisdell (1996) pointed out that sustainability normally involves at least three dimensions; the biophysical, the social and the economic. Sustainable land management combines technologies, policies and activities aimed at integrating socio-economic principles with environment concerns so as to simultaneously fulfill productivity, security, protection, viability and acceptability. ATTRA (1997) addressed that "… a truly sustainable farm system must be sustainable economically, ecologically and socially". Smith and McDonald addressed (1998) agricultural sustainability encompasses biophysical economic and social factors operating at the field, farm, watershed, regional and national scales.

Jules (1995) has classified agriculture into three: industrialized agriculture, Green Revolution agriculture, and the diverse and complex lands (resource poor) agriculture. He summarized that all successes have three elements in common: resource-conserving technologies, local institutions and groups, enabling external institutions. Therefore, according to Pretty, agriculture can only be persistent and sustainable when resource-conserving technologies are developed and used by local institutions and groups, who are supported by external research, extension and development institutions acting in an enabling way.

In general, the concept of sustainable agriculture, as Thrupp (2001) stated, refers broadly to the form of agricultural development that is environmentally sound, socially equitable and responsible, as well as economically viable and productive

(Figure 2.1). This concept includes aims to achieve long-term food security for all people, while conserving and soundly using the resource base.

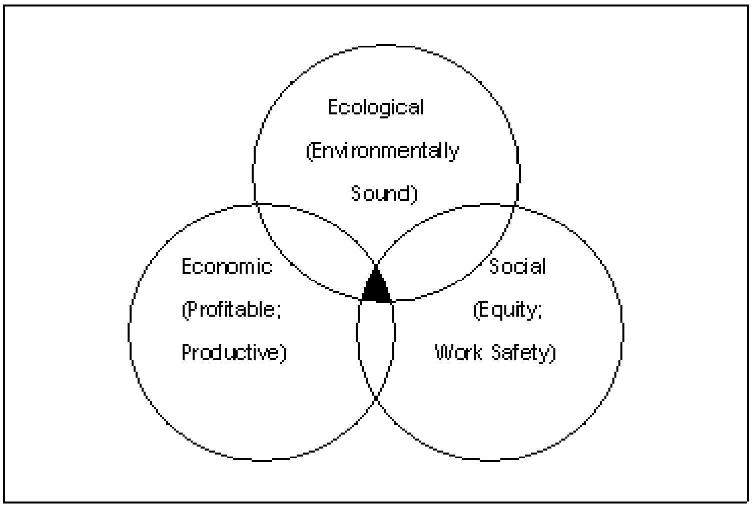

Figure2.1 Elements in the concept of sustainable agricultural development.
(Source: Thrupp, 2001)

2.3 Factors Influencing Sustainable Agricultural Development

2.3.1 Environmental Factors

The main purpose of sustainable agriculture is to seek to optimize the use of locally available resources by combining the different components of the farm systems. It also seeks to use external inputs only to the extent that they are needed to provide elements that are deficient in the ecosystems and to enhance available biological, physical and human resources. On the importance of existing farming and natural conditions, Webster (1997) stated that the major determinants of change at farm level are the existing farm systems, the soil types, climate and topography, and the surrounding natural ecology. Where farming systems already depend on a diversified crop and livestock complex, and where there is integration of natural processes, there will be less needed for change.

Developing resource management is essential to the sustainable agriculture of China. Ellis and Wang (1997) have addressed the importance of traditional farm management to ecologically sustainable agriculture. Therefore, ecological development of sustainable agricultural systems deals with the conservation of natural resources on which agriculture depends. There is a wider range of technologies and practices applied in related areas. Land management practices and the levels of external input application are the dominant factors influencing ecological agricultural development.

Environment sustainability includes the existing natural conditions that farming systems are dependent on, use of internal and external inputs, cropping pattern, and the use of appropriate technology.

2.3.2 Economic Factors

Tisdell (1996) mentioned that any types of conservation farming are unlikely to be adopted and be used sustainably unless it is economically viable. A sustainable farming practice must be profitable. Profitability depends upon the level of yields or productivity as well as on price levels and their trend and the degree of uncertainty and instability of income involved. He summarized that the factors influencing the economics of farming operations in market economics can in the first instance be classified into two sets: production related factors and market related factors.

Barbier (1987) pointed out that sustainable development is directly concerned with increasing the material standard of living of the poor at the ‘grassroot’ level, which can be quantitatively measured in terms of increased food, real income, emergency stocks of food and cash, etc.

2.3.3 Social Factors

Attitudinal and institutional changes are required to ensure sustainability at all scales, and facilitate the coordinated delivery of appropriate services, inputs, and expertise, for local development initiatives around individual countries. Therefore, a flexible blends of “bottom up “ and “top down “ approach is required. ATTRA (1997) addressed that “to be socially sustainable, agriculture should promote the physical, spiritual, cultural and economic health of farm families and communities.“

Social challenges refer to the population pressure and food sufficiency (Cai and Smith, 1994). It is very important whether the current food production is sufficient to support the existing population. Besides, equity is also important for is t is one of the important social aspects of sustainable development (Lo and Xing 1999). It emphasizes not only inter-generation equity but also intra-generation equity. It means the sustainable development should ensure minimum needs of each individual satisfied.

A necessary condition for sustainable agriculture is the motivations, skills and knowledge of individual farmer’s household, as well as farmer’s groups or communities as a whole (Jules, 1995). Simon (1989) has undertaken many case studies and stated that the many supposedly sustainable projects that have been implemented in recent years have turned out to be totally unsustainable, one of the main reasons is the inadequate provision for participation.

As an important party of social factors, research and extension services of farming systems represent a formidable set of constraints to the intensification of agricultural and adoption of an alternative cropping systems, based on input intensive, permanent farming. As identified by many scholars, agricultural research, extension and training are important for farmers' adoption of new technology.

The supportive role of government policies in sustainable agricultural development has been widely accepted. The problem here is that the concept of sustainable agricultural development requires redistribution of wealth and resources. But these are not usually equitably distributed within or between societies. This implies that considerable political commitment will be required, together with the establishment and enforcement of appropriate mechanisms and procedures (Jules, 1995, Pretty and Hine, 2000). Governments must facilitate the process with an appropriate range and mix of policy instruments and measure. They can either offer incentives to encourage resource conservation, and /or penalize those polluting the environment. A more sustainable agriculture can only be achieved by integrated action at farm, community and national levels (Jules, 1995).

Altieri (1987) and Tisdell (1996) addressed that many current policies, including subsidies (inputs, clearing of tree cover, draining of wetlands and the extension of agricultural onto marginal land), price, taxes, and market interventions can strongly influence cropping patterns and land use, and result in serious resource degradation.

2.4. Sustainable Agricultural Development

Sustainable agriculture is multi-functional within landscapes and economies – it produces food, range of public goods and many unique non-food functions that cannot be produced by other sectors (Pretty and Hine, 2000). Thus, it is seen that agriculture growth is not only an instrument of maintaining an effective national food security system but also a catalyst of income and employment generation in rural areas.

However, in most of the developing countries, agriculture sector was "squeezed" or "milked" (Schiff and Valdes, 1995). Policymakers believed that promoting industry at the expense of agriculture would sacrifice little in output. Thus agriculture sector received a relatively small share of national investment. As a result, agriculture stagnated in some countries, and in others failed to grow fast enough to meet the good needs of rapidly increasing population. This, in turn, brought food deficits, malnutrition, and widespread rural poverty that have characterized the developing world to this day.

It was recognized that the food deficits could be reduced, the incomes of the rural poor increased, and the economics of rural regions strengthened only by raising agriculture productivity and creating new sources of off-farm employment. There was a strong conviction that agriculture, rather than urban industrialization, was the key to both economic growth and reduction of poverty in the vast majority of developing countries (Rondinelli, 1986). The development in predominantly rural economics should not depend on "squeezing" or "milking" agriculture for capital to be invested in export oriented manufacturing, but on increasing agricultural productivity and rural household income.

Sustainable agricultural development has become a key issue because of widespread and growing concern about the severity of the depletion of the world's natural resource base and an ever-increasing population pressure on these resources (Liu and Lu, 1992). The main threat to agriculture is twofold, depletion and contamination of resources. Both problems have impacts beyond agriculture, resulting in loss of food production and environmental degradation, which ultimately affect our quality of life. If the current trends are allowed to continue unabated, they are grim (quoted by Poincelot, 1986). We have a moral obligation for future generations. It has been estimated that by the year 2050, the world will have to feed an additional 3.2 billion people (Pookpakdi, 1993). Agricultural sustainability is an important objective to be considered in deciding whether to introduce new agricultural techniques or systems, while the debate continues about whether unlimited economic growth can be sustained or not (Conway, 1991). It is evident that the present trend of economic growth is geared towards short-term benefits, thus ignoring any long-term environmental consequences (Regmi and Weber, 1996).

The concept of sustainable agricultural development differs in its meaning between developed and less developed countries. In developed countries, sustainable agricultural development focuses on issues like organic farming, pollution from agricultural activities, and the like. In the case of less developed countries, the focus is on unsustainable resource use leading to soil erosion, declining crop yields and loss of soil productivity.

There is general consensus about the importance of agricultural sustainability, as expressed in different terminologies encompassing several ideologically loaded approaches to agriculture, including organic farming, biological agriculture, alternative agriculture, ecological agriculture, ecofarming, conservation farming, permaculture or agroecology.

2.5. Measurements of Sustainable Agriculture.

The current momentum for the development of sustainability indicators arose from the 1992 Rio Earth Summit where the Commission on Sustainable Development

(CSD) was established to monitor the progress of sustainable development using standards or indictors of sustainable development. This has received additional impetus in preparations for the 'Rio + 10' conference in 2002. As a consequence, there is now a rapidly developing literature on the use of sustainability indicators alongside indicators development programmes being undertaken by national governments as well as organizatoins (Rigby et al., 2001). An indicator is a quantitative measure against which some aspects of policy performance or management strategy can be assessed. Indicators have three functions; simplification, quantification and communication (Briggs and Harrison, 1993, quoted in Glenn and Pannell, 1998). As for the application of indicators, Jules (1995) pointed out that when specific parameters or criteria are selected, it is possible to say whether certain trends are steady, going up or going down. For example, practices causing soil to erode can be considered to be unsustainable relative to those that conserve soil. Practices that remove the habitats of insect predators or kill them directly are unsustainable compared with those that do not. Forming a local group as a forum for more effectively collective action is likely to be more sustainable than individual trying to act alone.

Approaches commonly known by researchers in monitoring sustainability include environmental or extended cost-benefit analysis (ECBA), multi-criteria decision mechanisms (MCDM), and sustainability indicator analysis (Mueller, 1997). Among them, the sustainability indicator analysis is considered as the least formal approach. It simply aggregates and integrates diverse information into a meaningful form. With less data and analytical skills required, a sustainability indicator becomes a significant tool for sustainability assessment. Further, it is considered as a flexible analytical tool when applied to any country with given specific economic, environmental, and social conditions (Praneetvatakul et al., 2001).

Nowadays, Sustainability Indicator Analysis (SIA) is widely applied in assessing the sustainability of agriculture in the world, as the result, different kinds of indicators are developed. We cannot wait 50 years to decide if a system is sustainable, Hart (2000) claims, the possible indicators of 'sustainability' are currently being explored by many different institutions and these include:

- Measuring all inputs and outputs and calculating changes in system efficiency (the total factor productivity approach);
- Monitoring indicators of natural resource productivity and modeling the probable future impact of these changes, such as soil erosion; and
- Setting up benchmark sites where many factors can be measured. In order to identify minimum data sets (indicators) for use by researchers working in similar environments.

Hair (1991) categorized indicators into four types, there are:

- Direct indicators: direct measurements of the result, e.g., actual crop yield, etc.;
- Qualitative indicators: dealing with perceptions, e.g., assessment of the extent of erosion;
- Proxy or surrogate indicators: in the absence of previous measurements, proxy indicators are used, e.g., the exposure of root of trees; and
- Crypto indicators: which have connection to a process, revealing significant changes in a systems over a long period of time, e.g., the replacement of cattle with small ruminants (sheep, goats) may be indicative of degradation of grazing land.

For sustainable agriculture a major requirement is sustainable management of land and related resources. An International Working Group (Smyth and Dumanski, 1993) has developed the following 5 criteria (also called 5 pillars) for sustainable land management.

· Maintain or enhance production service (productivity);

· Reduce the level of production risk (stability);

· Protect the potential of natural resources (protection);

· Be economically viable; and

· Be socially acceptable (acceptability).

During the international workshop on " Sustainable land management for the 21st Century" held at Lethbridge, Canada, in June 1993, twelve focus groups addressed the issue of indicators for specific land uses in five major climatic regions of the world. Dumanski (1996) in his summary pointed out that a number of indicators were common for many of the focus groups. He suggested these standards for evaluation and monitoring of sustainable land management. The indicators identified were:

· Crop yield (trend and variability)

· Nutrient balance

· Maintenance of soil cover

· Soil quality / quantity

· Water quality / quantity

· Net farm profitability

· Participation in conservation practices

2.5.1. Ecological Sustainability

In groundnut-based cropping systems, Ghosh et al. (2003) developed five indicators to evaluate the sustainability of nutrient management practices. The five indicators are total systems productivity (TSP), sustainable yield index (SYI), agronomic efficiency (AE), partial factor productivity (PFP) and soil organic carbon (SOC).

Rigby et al. (2001) constructed seed sourcing, soil fertility, pest/disease control, weed control and crop management as indicators to assess sustainability of agricultural practice at farm level in the United Kingdom. The paper serves to highlight some of the conceptual issues, examines some of the technical issues and choices associated with indicator construction, and informs discussion of the relationship between organic production and agricultural sustainability.

The ecological dimension of sustainability is fundamental to overall sustainability, as it is a prerequisite for the economic and social dimension. Based on these ideas, Hay and Petit (2002) used 12 indicators to evaluate environmental impact of agriculture at the farm level. The methods take into account a number of environmental objectives (e.g. soil erosion, water quality). The study concluded that the method should be validated with respect to (a) the appropriateness of its set of objectives relative to its purposes and (b) its indicators.

2.5.2. Ecological and Economic Sustainability

In Norway, Eltun et al. (2002) selected environmental, soil fertility, yield and economical effects to compare sustainability of six cropping systems based on an 8-year experiment. The experiment included conventional arable, integrated arable, ecological arable conventional forage, integrated forage and ecological forage cropping systems which were established on model farms of 0.2 ha. They concluded that, overall, integrated and ecological forage systems resulted in the least environmental harm, and based upon the present government subsidies, the forage systems also seem the most profitable, along with the ecological arable system.

2.5.3. Ecological, Economic and Social Sustainability

Based on farmer surveys, Lefroy et al. (2000) suggested five indicators in their study for evaluating sustainable land management in Vietnam, Indonesia and Thailand. They were:

- Productivity: yield, soil color (as an estimate of SOM), plant growth and leaf color;
- Security: average annual rainfall, residue management (% returned), drought frequency and income from livestock;
- Protection: topsoil eroded, cropping intensity and extent of protection, cropping patterns;
- Viability: net farm income, off-farm income, different between market and farm price, availability of farm labor, land holding size, availability of farm credit, percentage of farm produce sold in market; and
- Acceptability: tenurial status, access to extension services, access to primary schools, access to health center, access to agricultural inputs, subsidy for conservation practices, training in conservation practices and village road links to major roads.

In Mexico, some of the most common diagnostic criteria and indicators are used in the different case studies in which their framework applied (Table 2.1). The set of indicators derived in the evaluation of natural resource management Systems cover the seven sustainability attributes as well as the social, economic and environmental dimensions (Lopez-Ridaura et al., 2002).

Table 2.1. Common attributes, diagnostic criteria and indicators utilized in the MESMIS case studies (Lopez-Ridaura et al., 2002).

Attributes	Diagnostic criteria	Indicators
Productivity	Efficiency (yield and profits)	Yields, quality of products, cost/benefit ratio
	Return to labor	Economic return to labor
Stability, resilience, reliability	Degradation or conservation of resources,	Nutrient balances, erosion levels, biophysical characteristics of soils (i.e. compaction, percentage of organic matter), yield trends.
	Agrodiversity,	Number of species grown, income per species
	Crop damages,	Incidence of pests, diseases and weeds
	Variability of input/output prices	Variation of input and output prices (e.g. coefficient of variation of input/output)
Adaptability	Ability to change and to adopt new technology	Adoption of new alternatives and/or farmers permanence within a system, capacity building activities, proportion of area with an adopted technology
Equity	Distribution of costs and benefits	Initial investment costs Share of benefits by different farmer groups
Self-reliance	Organization and participation	Participation in the design/implementation, degree of participation in the decision-making process.
	Degree of dependency from external inputs	Cost of external inputs, use of external resources

In Scotland, Crabtree and Bayfield (1998) developed 18 sustainability indicators covering socio-economic, environmental and institutional themes to evaluate mountain ecosystems in the Cairngorms. The study concluded that to improve the use of indicators for sustainability assessment a greater understanding of economic-environmental processes is required, and performance indicators need to be developed which incorporate a comparison of current state with policy defined capacity criteria.

There are, of course, no universally accepted indicators. As Webster (1997) said that sustainability concept has yet to be made operational in many agricultural situations. It is difficult to develop precise and absolute indicators, which will be accepted by everybody and will be used in every society and every country.

2.6. Descriptions of Some Widely Used Indicators

2.6.1. Ecological Dimensions

Landuse Pattern:

Percentage of tree grown: As trees and vegetation have many positive impacts on soil. Trees can help restore fertility to tropical soils. They also help purify the air by assimilating a large quantity of CO_2. Trees, combined with undergrowth, and a little layer, provide strong protection against erosion (Troeh et al.,1999). So, relatively high proportion of land used for forestry indicates relatively sustainable farming systems.

Percentage of legumes under growing: Cultivation of legumes is chosen for evaluating sustainability of farming systems in the given sites because it is good for improving soil quality and productivity by enhancing organic matter and nitrogen contents in soils and controlling the depletion of phosphorous and potassium (Sharma and Sing, 1970).

Cropping Management

Use of organic fertilizers: It is well-known that additions of organic matter (OM), e.g. manures, composts, above-ground crop residues, or increases in soil organic matter (SOM), e.g. below-ground crop residues, microbial biomass, can improve soil properties (Loveland and Webb, 2003). Use of organic fertilizers is good for soil quality and improves its productivity. Therefore, the larger use of organic fertilizers the better management of soil fertility and higher the sustainability.

Use of crop residues: Crop residues are much too valuable to be ignored. To a soil conservationist, crop residue utilization means using residues either as mulch to protect the soil or as raw material for soil organic matter. Using the residues to protect the soil is important enough to claim priority. Enough residues should be left to control erosion and maintain satisfactory soil physical conditions (Troeh et al., 1999).

Application of chemical fertilizers: Large increase in crop production was due to the heavy use of chemical fertilizers, especially nitrogen fertilizer as well as the introduction of new varieties of rice that could use these heavy energy inputs. Therefore, chemical fertilizer use is an important index of resource utilization and sustainable (or perhaps, unsustainable) development (Tong et al., 2003). In general, agrochemical use is inversely proportional to agricultural sustainability for two main reasons: first because they are external inputs of a high relative cost, imposing a considerable capital drain to the farm, and second, because they are important environmental pollutants when inadequately used or overused.

2.6.2. Economic Viability

Economic viability is necessary for sustainable agricultural development. A system that lacks economic viability eventually sacrifices control over resources. If farmers cannot stay in business, their farming systems are not sustainable (John, 1996).

Benefits of Crop Production

Inputs self-sufficiency: One of the goals of sustainable agricultural systems is to increase self-reliance of farmers and rural people by optimizing the use of locally available resources and using external inputs only to the extent that they are needed to provide elements that are deficient in the ecosystems (Altieri, 2002). It relies more on internal resources and less on the external inputs to mitigate negative environmental impacts and maintain ecological sustainability of the agricultural systems (Jules, 1995). Sustainability should involve a reduction in external inputs and a move towards internal self-sufficiency (Tellarini and Caporali, 2000).

Benefit-cost ratio: Benefit-cost analysis refers to a basic set of “common principles and analytical techniques” that can be used to “appraise decision problems in the light of objectives chosen by the decision maker”. The approach has been proven useful at all levels of decision making from the individual farmer to the government policy maker (David et al., 1994).

Tendency of Crop Yield

Trend of yield: Dumanski (1996) used this indicator in his study. To measure the yield stability, farmers were asked whether crop yields were increasing, decreasing or remaining constantly. On the basis of farmers’ responses, the following formula was used to evaluate the trends of yields (Rasul, 1999).

$$ITY = \frac{fi * 1 + fd * (-1) + fc * 0}{N}$$

Where,

ITY = Index of Trend of Yields

fi = Frequency of responses indicating increasing yield

fd = Frequency of responses indicating decreasing yield

fc = Frequency of responses indicating constant yield

N = Total number of observations fi

Cropping diversification is an important means to maintain soil quality and to promote ecological sustainability through nutrient recycling and increasing bio-diversity. Moreover, it also helps to reduce risk of crop failure and ensures food supply to farmers. To see the differences in crop diversification among the sites, Thapa (1990) used the following formula in his study:

$$ICD = \frac{Pa + Pb + Pc + ... + Pn}{Nc}$$

Where:

ICD = Index of crop diversification

Pa = Proportion of sown area under crop a

Pb = Proportion of sown area under crop b

Pc = Proportion of sown area under crop c

Pn = Proportion of sown area under crop n

Nc = Number of crops

2.6.3. Social Acceptability

Women's participation in agriculture: Agricultural and rural development that is equitable, effective and sustainable cannot be pursued without an explicit recognition of the tremendous contribution of rural women to food and agricultural production and their crucial role in determining and guaranteeing food security and well-being for the entire household, because many women in the developing world work an average of 12-16 hours a day, and most of the agricultural work is done by women (Sinn, et al., 1999). Whatever the intention - efficiency, equity or empowerment - gender analysis provides a 'map' for identifying men's and women's roles and helps improve the choice and design of improved technologies (Feldstein, 2000).

2.7. Scoring Systems

Part of the difficulty in assessing the sustainability of agricultural systems is the fact that both the units of measurement and the appropriate scales for measurement differ both within and across the commonly identified economic, biophysical and social dimensions of sustainability. How biophysical, economic and social information be combined? Some scholars use scoring systems to combine, such as, Rigby et al. (2001) used scoring system to evaluate farming practices on farm sustainability for their sample of 237 organic and conventional farms. Nambiar et al. (2001) developed an index, agricultural sustainability index (ASI) for assessing agricultural sustainability using the broad set of biophysical, chemical, economic and social indicators, each indicator is rated from low to high, with 100 as the maximum.

2.8. Sustainable Agricultural Development in China

The past few years have witnessed rapidly progress of the sustainable agricultural technology in China and great achievements have been made in the areas of crop breeding, plant protection, environmental protection, bioengineering, rural energy utilization, soil and water management (SAREP, 1999). The Chinese experience with agriculture has often cited as an example of sustainability of the land resources (John, 1994). For a long period, the Chinese farmers have been doing the agricultural work in such ways as rotation, intercropping, relay cropping, green manure, etc to maintain the land resources. But China underwent severe erosion in many regions in recent years. In China, agricultural policy is encouraging farmers to grow green manures in the rice fields. Green manures and plant residues are now used on 68% of the 22 million ha of rice fields (Jules, 1995).

Lo and Xing (1999) concerned that Chinese sustainable development is composed of three main objectives: maintaining economic growth and development, promoting equity, and preserving natural resources and the environment. The main concerns of sustainable development are the population, economic development, the costs of environment damage; natural resource and environment conditions; energy supply and demand; rural sustainability and population holding capacity; urbanization and changing patterns of consumption; and policy alternatives for sustainable development.

However, behind the great success lies the continuous decrease in cultivated land in the last two decades as a result of the encroachment of roads, townships and other industrial activities, and the serious ecological problems of land degradation, soil erosion, and agro-environmental deterioration. All these could be attributed to the irrational utilization of natural resources, especially through destruction of ecological environment and overuse of chemicals in agricultural production (Ye, et al., 2002).

2.8.1. Challenges to Sustainability of Chinese Agriculture

The growing number of population and the corresponding production activities to meet the food of the population will have a major impact on the environment, social and economics.

Environmental Challenges

Vegetative Destruction is the main impact of unsustainable agricultural activities. Nearly one-third of China's grassland is estimated to be over-gazed and degenerating due to expanded production activities. This results directly in desertification, vegetative destruction, drought and flooding disasters. The average area of the country affected by such disasters in the 1980s is estimated to be 68% more than that in the 1950s.

Cultivated land reduction. China has a vast cultivated land area, but in per capita terms the cultivated land on average is only 0.11 ha being 33.3% of the world average. It is even less than 0.05 ha per capita in the coastal provinces of southeast China (Ye et al., 2002). As a result of industrial development and farmhouse buildings, millions of hectares of cultivated land have been replaced by construction. It was reported that cultivated land disappeared at an average rate of 0.5 million ha annually during 1986-1996 in China (Ye, et al., 2002). Even more alarming is the fact that millions of ha of cultivated land with fertile soils are currently earmarked for industrial, township and road construction.

Soil erosion and land degradation is the further result of vegetative destruction. More and more forest and grassland in recent decades have been cleared and converted into cropland to compensate the shrinking cultivated land. At the same time, some effective traditional soil conservation techniques were abandoned. Thus soil erosion has become a serious problem. About 15% of the total land area of China suffers from soil erosion. An estimated 5 billion MT of soil are washed from the terrestrial highlands of China into the sea after long transportation by rivers (Agricultural Information Network of China, 2000). Mono-cropping and cultivation on slopes are also the essential reasons of soil erosion. In Sichuan province, for example, an estimated 44% of the land area is undergoing soil erosion, with 2 million ha of cultivated land on slopes losing an average of 110 tons of soil/ha/year. Soil organic matter is a good indicator of soil fertility (Agricultural Information Network, 2000). Due to intensive utilization and lack of soil fertility maintenance and improvement measures in the past years, soil organic matter has declined in most areas of the country. In South China, the area of green manure crops planted in paddy fields declined from more than 10 million ha 30 years ago to present 2-3million ha (Agricultural Information Network of China, 2000). The popular tradition of reusing straw by returning it back to the fields is also gradually being abandoned. Traditionally, animal manure served as a major source of fertilizer. However, the use of chemical fertilizer has become dominant since the early 1980s (Ye et al., 2002). As a result, the failure to maintain organic matter equilibrium in the field has contributed to an adverse decline in soil physical and chemical properties.

Desertification is also a serious problem in China. Presently, 3.3 million km^2 of land are suffering from desertification in China, which occupies 35% of the total territory. More than 0.4 billion people live under the environmental conditions of desertification. Desertification is still expanding at a rate of 2460 km^2 annually from north to south, particularly in northwest China (Zhou, 1999).

Water shortage and pollution is also a problem of high concern in China. On average, annually 2231 m^3 of water is available per capita in China, which is only 33% of the water resource per capita in the world (Zhang, 1999). Current total water consumption of the country is 450 billion m^3 per year, of which 400 billion m^3 is used for agriculture. Due to stress on water resources, the annual deficit of water for agriculture is as much as 30 billion m^3 (Zhang, 1999). Even areas with ample rainfall lack water resources. The overuse of groundwater is also an important problem. It is estimated that the potential available underground water resource is only 290 billion m^3 in China, of which 90 billion m^3 have already been exploited for human consumption and agricultural irrigation (Zhang, 1999). The increasingly serious problem of water stress also partially results from the widespread pollution and eutrophication of water. According to a survey conducted during 1989-1993, among 131 sample lakes in China, 51.2% are classified as excess-nutrient lakes and are no longer suitable as freshwater sources without pretreatment (Ye, et al., 2002).

Chemical pollution has become a serious problem all over China. Acidic precipitation, and water and cropland pollution are the major forms of environmental pollution that could ultimately threaten agricultural sustainability. For example, 24% of the total cropland is polluted by pesticide, depending on the measured residues. Overuse of chemical fertilizers and pesticides has significant impact on water quality. Between 1990 and 1994, agricultural chemical use increased by 28.1% to 33.2 million MT, agricultural plastic film by 84% to 887,000 MT, and farm chemicals by 33% to 979,000 MT (Ye et al., 2002).

Social Challenges

Population pressure and food sufficiency. The most important social impacts on sustainable agricultural development are population pressure and food sufficiency. In the past century, the Chinese population has increased exponentially, from about 400 million before 1900 to 1.248 billion in 2000 (Agricultural Information Network of China, 2000). Although the government has been taking severe measures to control population, the total population will inevitably increase and will reach 1.4 billion by year 2020 and 2.5 billion by year 2060. However, according to estimation, China’s food production can support only 1.66 billion populations. Therefore, food self-sufficiency will be a big problem in the coming years (Agricultural Information Network of China. 2000).

Urbanization is another factor affecting sustainable agricultural development. As major urban concentrations tend to be located on or near the areas of most productive agricultural land. Given the limited supply of arable land in China, it is generally held that the continued conversion of farmland into non-agricultural uses represents a threat to the prospects for agricultural sustainability.

Institutional and cultural aspects. Modern social attitudes tend to undervalue natural resources. The price of products form natural resource use is kept low in China by public policy. The result is that, on the one hand, enterprises engaged in agricultural land use have a meager income, which prevent them from making investment in basic inputs; on the other hand, the cheap resources are used wastefully. Meanwhile, the present land in rural China is owned by collectives and contracted to farmers. Therefore, farmers are not interested in land investment but tend to use the land for short-term exploitation. So, it seems that agriculture based on these attitudes and tenure system may not be sustainable.

Economic Challenges

In private market where environmental land and social costs remain external to the pricing system, emphasis is put on the short-term economic benefit, and the environment and resource sustainability are often ignored. Meanwhile, under the present pricing system in China, the price of farming products is so low that some farmers abandon agricultural activities for commercial enterprises and also leads much cropland to be converted to other uses. Naturally, it will be increasingly difficult for farms to remain in agricultural production without adequate economic rewards for producers.

2.8.2 Sustainable Practices in China

Rising pressures of population and resource use in China make the establishment and maintenance of more productive yet sustainable agricultural systems ever more necessary. According to Altieri (2002), farmers can improve the biological stability of the system by choosing more suitable crops, or developing methods of cultivation that improve yields. The land can be irrigated, mulched, manured or rotated, or cops can be grown in mixtures to improve the resilience of the system. Pesticide can be replaced by biological and mechanical methods for controlling pests, weeds, and diseases; inorganic fertilizers can be substituted by livestock manure, composts and nitrogen fixing crops. Range of agricultural practices that can improve output on a sustained basis are already well recognized. These include more effective fallow-management, fertilization and manuring, improving tillage practices and intercropping.

In the 1980s, a new mode of agricultural production and rural development, called Chinese ecological agriculture (CEA), emerged in China's rural areas. Guided by the combined principles of ecology and economics, this mode of production takes agriculture as a holistic system engineering project, which incorporates various sectors of agriculture. It aims to establish an agricultural production structure in which various sectors are promoted mutually to enable conducive recycling of production factors, and to develop technologies, which combine proper traditional agricultural techniques with modern ones. These, then, ensure a sustainable development of agriculture with optimized ecological, economic and social benefits. The development and practices of CEA over the last two decades have achieved remarkable success in promoting sustainable agricultural development. With these new achievements, CEA has been accepted by Chinese scientific community and later endorsed by related government departments at all levels. A CEA movement, with strong government support, has been successfully carried out nationwide (Ye et al., 2002).

CHAPTER III

RESEARCH METHODOLOGY

3.1. Site Selection

The study focused on Dafang county, Guizhou province, Southwestern China. Agricultural production is the dominant economic activities of the county and the main source of farmer's income. Based on the reconnaissance survey and secondary data on biophysical, socioeconomic and topography, Dafang's agriculture can be divided into three parts as (1) lower-middle agricultural area, (2) middle agricultural area, and (3) middle-high agricultural area (Dafang Comprehensive Agricultural Division, 2000). Correspondingly, Xiaotun, Zhuyuan and Liulong towns were selected as representatives of those three parts.

3.2. Site Description

3.2.1. Administration Levels in China

China's administration is hierarchically divided into six levels. Directly under the Central Government are the provinces, autonomous regions and municipalities, Guizhou is at this level. The provinces are in turn subdivided into prefectures. In Guizhou, there are 9 prefectures. The forth level is the counties. A county is again divided into towns. The lowest level is the village (Figure 3.1).

3.2.2. Basic Site Description

Dafang county (marked as an oval in the map, Figure 3.2), 184 km far from Guiyang - the capital city of Guizhou province, is located in northwest Guizhou

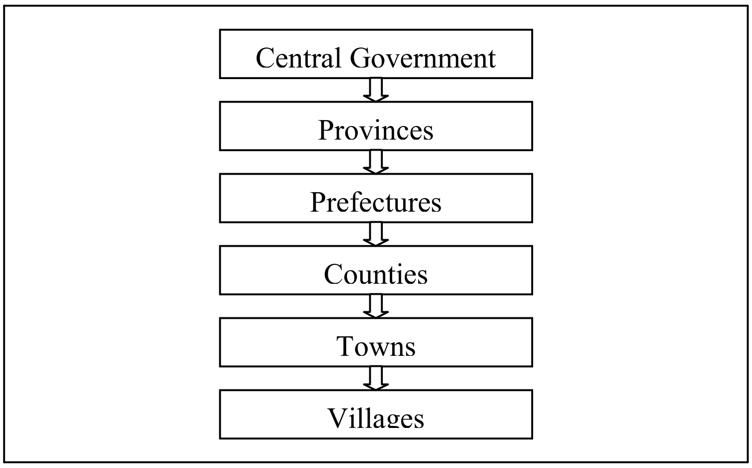

Figure 3.1 Hierarchical structure of administration systems in China

province between 105°15'47" and 106°08'04" E, 26°51'02" and 27°36'04" N. The county covers an area of 3,504.551 km². It has a varied topography and most of its area is on the average 1400-1900 meters above sea level in the middle part, gradually it slopes towards the south and north. Officially, Dafang is made of 36 towns with 233,644 households and population of 947,363 in the year 2000. It is one of the biggest counties in Guizhou province in terms of its population, of which, 95.68% is engaged in agriculture. Population density is 270.3/km² compared to Guizhou's 204.4/km² and China's 130/km². Dafang is a multi-cultural county with 23 national minorities living in the region accounting for 29.62% of the total population. Agriculture dominates Dafang county, which accounted for 47.86% of total economy in the year 2000. Within the agricultural sector, crop share was 74.12%, forestry 2.17%, livestock 23.57% and fishery 0.14% respectively. Within the crop sub-sector, food crops were 42.64% of total crop value, cash crops and other crops were 36.38% and 20.98% respectively. Among food crops, corn is the most important both in terms of its sowing area and total yield which accounted for 59.44% of total arable area and

50.47% total food crop output. So, corn occupies a pivotal position in crop production in Dafang (Dafang Statistics, 2001).

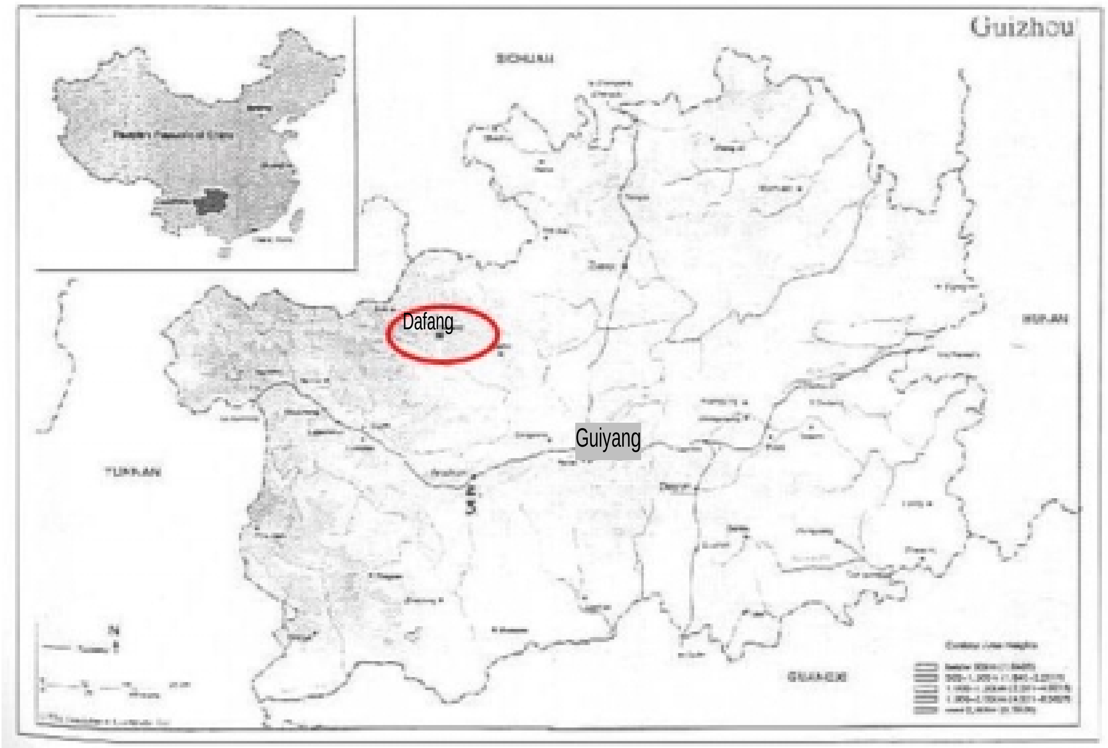

Figure 3.2. Location of Guizhou province in China and the study area Dafang county

Three study sites, Xiaotun town, lower-middle mountainous agricultural area (<1400 m), is located at the southeast part of Dafang county, about 15 km from the location of county government; Zhuyuan, middle mountainous agricultural area (1400 – 1600 m) in northwest part of the county, about 30 km from the location of county government; and Liulong town, middle-high mountainous agricultural area (>1600 m) at the central county, about 40 km from the location of county government (Figure 3.3). The major natural differences among three sites are shown in Table 3.1. Compared to the other two towns, the terrain of Xiaotun has more small flatlands, basins and thus, more paddy field that shared 21.9% of total arable land, Zhuyuan

10.8% and Liulong only 1.1%. However, based on the collected soil data, yellow, limestone and purple soils are widespread at these three sites, whereas paddy soils are mainly distributed at Xiaotun and Zhuyuan towns, and yellow soil at Liulong. Soil distributes gradually from yellow to yellow brown with the increase in altitude. Organic matter content of yellow soil at Liulong town is slightly higher than those at Xiaotun and Zhuyuan. Other factors are not significantly different based on the investigation.

The major common crops at three sites are corn, wheat and soybean, while rice is mainly grown at Xiaotun and potato is at Liulong. The major cropping patterns and rainfalls in a year at each site are given in Figure 3.4. Figure 3.5 and Figure 3.6 respectively.

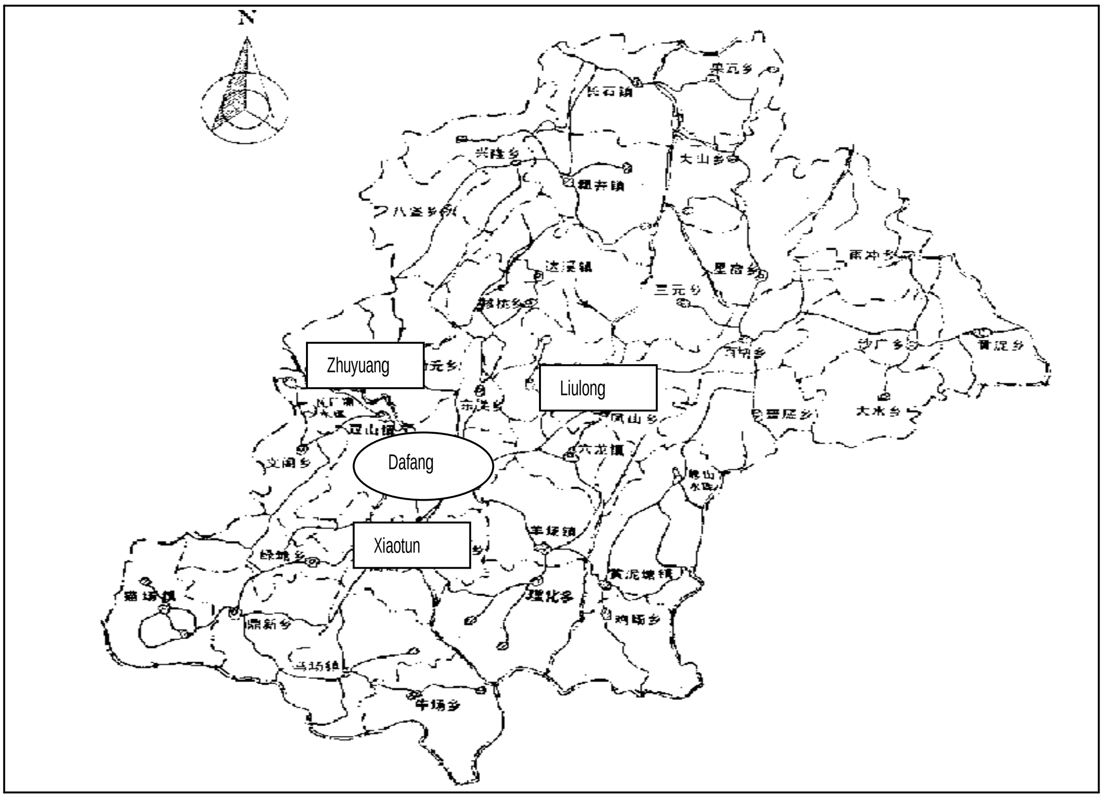

Figure 3.3 Map of Dafang county to show three study sites

Table 3.1. Basic natural condition data about three study sites

Parameters	Xiaotun	Zhuyuan	Liulong
Altitude above the sea level (m)	<1400	1400 –1600	>1700
Total Area (km²)	51.36	51.59	78.77
Total Arable land (ha)	2355.4	2505.8	3209.4
Yearly Average Temperature (°C)	11.7-14.8	11.2-14.6	10.7-14.2
Yearly Average Rainfall (mm)	1,000 –1,085	940-1,180	900-1,185
Yearly Average Relative Humidity (%)	70-85	75-88	80-90
Average Yield of Corn (kg/ha)	4,295	3,876	3,270
Average Yield of Rice (kg/ha)	4,830	4,695	
Average Yield of Soybean (kg/ha)	433	421	
Average Yield of Wheat (kg/ha)	1,935	1,665	
Average Yield of Rapeseed (kg/ha)	713		
Average Yield of Potato (kg/ha)			2,445
Total Number of Big Animals	3,754	3,051	2,956
Total Number of Pigs and Average Pig/Capita	7,341 (1.19)	8,500 (1.71)	9,356 (1.21)

Source: Dafang County Statistics Bureau, 2000.

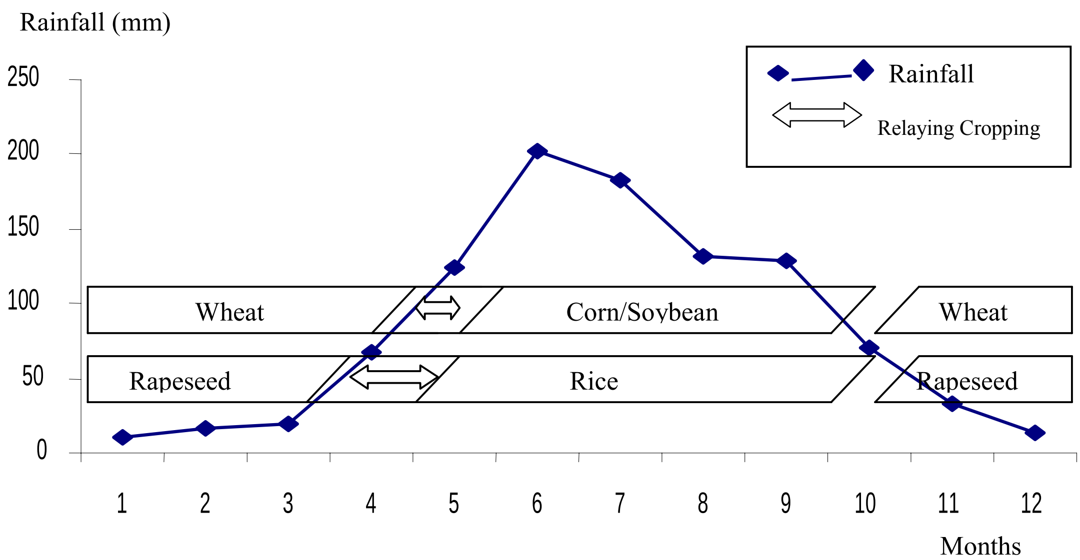

Figure 3.4 Rainfall and cropping patterns at Xiaotun

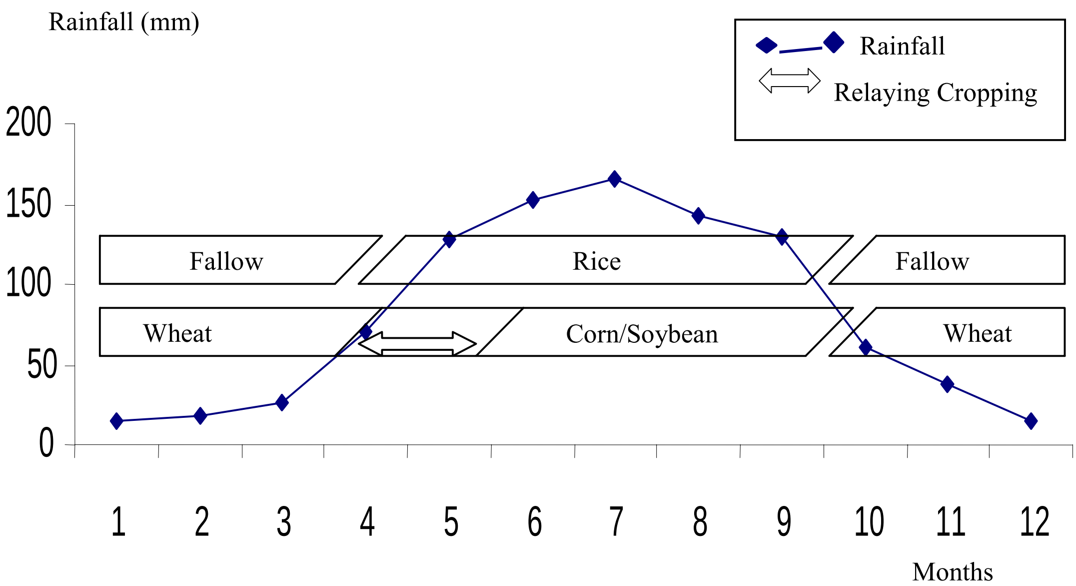

Figure 3.5 Rainfall and cropping patterns at Zhuyuan

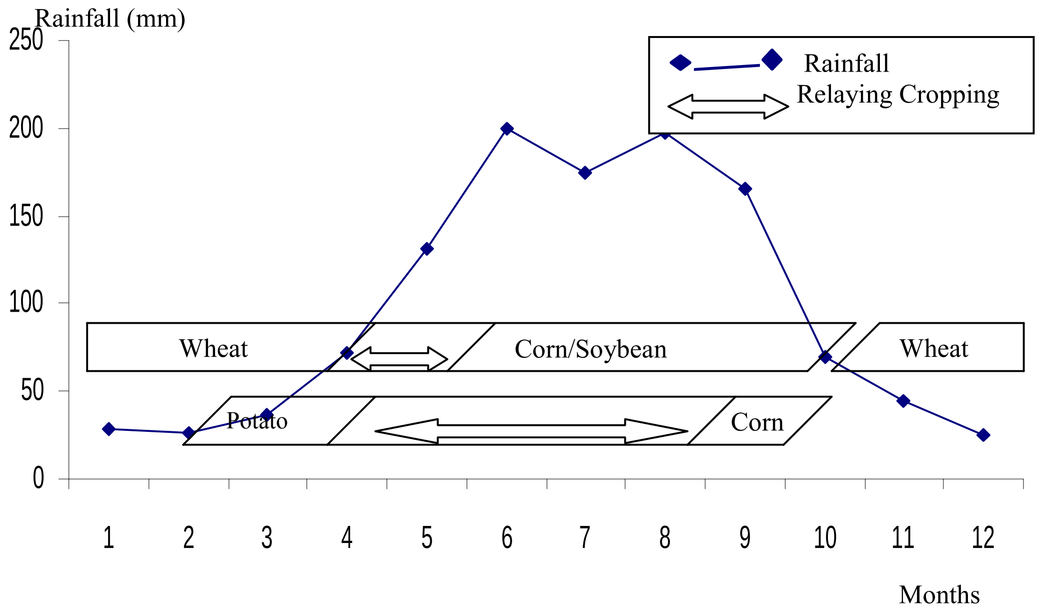

Figure 3.6. Rainfall and cropping patterns at Liulong

As the most important crop, corn varieties are also different among these three sites. Single-crossed varieties such as Fangyu 1, are popularly planted at Xiaotun, double-crossed or tri-crossed varieties such as Guibi 3 and 4 are mainly planted at Zhuyuan, whereas at Liulong, local varieties are widely grown in corn production.

The major cropping patterns at Xiaotun are corn/soybean-wheat and rice-rapeseed. Corn is sown at the end of March or early in April. Normally, corn is raised in the seedbeds covered by plastic film in early stage, then transplanted to the field where wheat is going to be harvested. When finishing transplanting corn, traditionally, farmers interplant soybean with corn. Corn is harvested in September or early October, the field is ploughed as soon as possible for growing wheat. In paddy fields, rice is sown at the same time as corn. There are several ways to raise rice seedlings before transplanting them into the field. When rice is harvested in Autumn, rapeseed is ready to be transplanted to the field after the field is ploughed.

Similarly, farmers at Zhuyuan do the same thing to the upland crops. But in paddy field, cropping patterns are rice-fallow. One reason is that relatively lower temperature with the height increases at Zhuyuan, if rapeseed is grown, it might not be mature next year when rice is going to be transplanted in to the field, this results in yield loss of rice due to short growing period. Another reason is unavailable water. Farmers keep their fields for storing water from rain without dry it up for growing winter crops after rice being harvested.

There are two major cropping patterns at Liulong. Corn, soybean and wheat are the same combination as previous two sites, but the corn varieties are different as described earlier. Another one is corn-potato. Because of high altitude, corn and potato have long relaying period. Corn is sown at early or mid April with the same way of raising seedlings and transplanting. Potato is sown at early February and harvested in August. Potato is a traditionally favorite crop grown in this town both as food and vegetable.

Table 3.2 shows that family size in Zhuyuan is higher than those of Xiaotun and Liulong respectively. Because Zhuyuan is a minority nationality town which 39.75% of its population are Yi and Miao whereas minority people in Xiaotun and Liulong are only 18.94% and19.91% respectively.

Net income per farmer in Liulong was about 350 yuan higher than Xiaotun and Zhuyuan because the local people have more opportunities to have off-farm income from working at companies and factories. Total educated people in Zhuyuan is a little bit higher than those other two townships, partly because the Central Nonggong Democratic Party in Beijing has been giving support to this minority nationality town for more than 10 years focusing on primary education. On the other hand, Liulong has relatively higher ratios of university and high school graduates people.

Table 3.2. Basic socio-economic data about three study sites

Parameters	Xiaotun	Zhuyuan	Liulong
Total Numbers of Villages	6	11	19
Total Numbers of Groups of farmers	94	89	109
Total Numbers of Household	6,143	4,961	7,421
Total Population	24,244	21,240	26,918
Average Population density	472.0/km²	411.7/km²	341.7/km²
Average Family size	3.95	4.28	3.63
Yearly Average Net Income Per Farmer	997 yuan	1,015 yuan	1,360yuan
Age Structure: % of Total Population (0- 14 Years Old)	34.68%	36.07%	35.74%
Age Structure: % of Total Population (15-64 Years Old)	59.55%	58.81%	58.93%
Age Structure : % of Total Population (>65 Years Old)	5.77%	5.12%	5.33%
Average Birth rate	12.22 $^{0}/_{00}$	13.84 $^{0}/_{00}$	11.06 $^{0}/_{00}$
Natural increase rate	6.89 $^{0}/_{00}$	7.75 $^{0}/_{00}$	5.88 $^{0}/_{00}$
Total Educated People / Total Population	63.43%	70.16%	67.94%
- College Graduates / Total Educated People	0.17%	0.17%	0.22%
- High School Graduates / Total Educated People	3.76%	4.62%	4.8%
- Secondary School Graduates / Total Educated People	15.74%	17.56%	16.42%
-Primary School Graduates / Total Educated People	43.76%	47.81%	46.5%

Source: Dafang County Statistics Bureau, 2000.

3.3. Determination of the Sample Size

The study used the sample survey method to collect data. Determination of the optimum sample size is a complicated process and often requires the help of a statistician. A large number of factors influence sample sizes used in formal surveys relating to Farming Systems and Development. Since total households in these three towns are very large, it is impossible to interview households with a percentage recommended by some scholars in such a short time, limited labor and fund. However, as a practical rule, usually 30 to 50 farmers for each recommendation domain will reasonably well reflect circumstances of farmers in that domain. Others suggest a minimum sample size of 20 from each sampling category (FAO, 1997).

In this study, 78, 65 and 57 households at Xiaotun, Zhuyuan and Liulong were interviewed respectively. Both villages and households were selected randomly (See Table 3.3). During which, 5 representative households were selected from the sampled households in each town and they were asked to take the notes about their daily economic activities on farm for a whole year. Their notes were used for helping better understanding the real farmers' activities and for evaluating the current farming systems.

Table 3.3. Total population, households and sample size

Towns	Total Population	No. of Villages	Total Households	Sample Size	% of Sample Size
Xiaotun	24,244	6	6,143	78	1.2%
Zhuyuan	21,240	11	4,961	65	1.3%
Liulong	26,918	19	7,421	57	0.8%
Total	72,402	36	18,525	200	1.1%

3.4. Data Collection:

Primary Data Collection

Primary data were collected directly from local people, governmental officers and staff in agricultural agencies for those indicators when the secondary data were not available. Household survey was collected through interview, field observations, and group discussion with the key informants in the study area. To collect the primary information from the households, a set of questionnaire was developed based on the requirements of indicator evaluation.

Secondary Data Collection

Since a field survey covering the whole sites is impossible, it is found necessary to use secondary data as well, especially on the changing pattern of population and resources over time. Different secondary data about the whole county and three study sites were obtained from relevant government ministries, departments, research institutes, as well as from books, conference and seminar reports, and thesis and dissertations. These data cover general natural environment and socio-economic conditions.

3.5. Data Analysis

3.5.1. Evaluating Sustainability of Farming Systems at Macro Level

Although quite a good number of indicators are developed and used in different countries, these do not cover all aspects of sustainability. Some emphasize on ecological, some on economic and some on social aspect of sustainability. Moreover, due to biophysical and socio-economic variation, indicators used by others may not be directly used in this study. Given the large population, high population growth rate, scarcity of land, food deficiencies, low industrial base, limited opportunities of non-agricultural activities, low education level and degrading land and water resources in Dafang, based on the concepts of sustainable agriculture and the work that is practical, the following indicators were selected as to determine farming sustainability. Though these selected indicators can not cover all the aspects of sustainability, they can, at least, give a general trend to indicate the situation of farming systems at given areas. Indicators and their measurements are shown in Table 3.4.

3.5.1.1. Ecological sustainability

It is a prerequisite for any farming systems to be sustainable. To evaluate ecological sustainability, 2 indicators covering 4 variables were developed based on the existing farming systems and the data availability (Table 3.4). Individual variable was analyzed as follow:

Table 3.4 Indicators and their measurements

Indicators	Measurements	
	Calculation	Scoring systems
Ecological Sustainability		
1. Landuse patterns		
Percentage of forestry	1). Percentage	1-5
Percentage of leguminous crops	2.) Percentage	1-5
2. Cropping Management		
Use of organic fertilizers	3). Index	1-5
Use of crop residues	4). Percentage	1-5
Economic Viability		
3. Benefits of Crop production		
Input self-sufficiency	5). Ratio	1-5
Benefit-cost ratio	6). Ratio	1-5
4. Tendency of Yield of Crops		
Trend of yield	7). Index	1-5
Cropping diversification	8). Index	1-5
Social Acceptability		
5. Farmers' Satisfactory		
Adequacy of food grain production	9). Index	1-5
Extension service	10). Index	1-5
6. Women's participation in agriculture	11). Index	1-5

(1). Percentage of forestry: Percentage of forestry for the whole area is an important variable for evaluating sustainability of farming systems. Relevant analysis is given in Table 3.5.

(2). Percentage of leguminous crops: The amount of arable land under legume is also important in a farming system. It uses the same score system as in Table 3.5.

Table 3.5. Analysis of ecological variables

Score Index	Variable Values: (% of Forestry, % Legume, Use of organic fertilizers--% of HH, and ICR)	Sustainable Classification
1	0-20	Very low sustainability
2	21-40	Low sustainability
3	41-60	Moderate sustainability
4	61-80	High sustainability
5	81-100	Very high sustainability

(3). Use of organic fertilizers: It uses the percentage of household (HH) that uses of organic fertilizers to evaluate the sustainability. Same system as in Table 3.5.

(4). Use of crop residues: To compare the sustainability of farming systems among 3 sites more precisely, index of removal of crop residues was used as follow:

$$ICR = \frac{\sum S_i f_i}{N}$$

Where:

ICR= Index of removal of crop residues

Si = Scale value of the ith level of removal

f_i = No. of household at ith level of removals

N= total number of households interviewed.

Removal all crop residues from the field, Si = 0, removal half Si = 0.5 and no removal Si =1. When all the residues are removed by farmers from the fields, the ICR

= 0, on the contrary, when all the residues are left in the fields the ICR = 1. The higher index value is, the less the removal of crop residues from the fields, the relatively more sustainable.

By use of scoring systems (use percentage) as shown in Table 3.5, then results could be reached.

3.5.1.2. Economic viability

It is another important goal that sustainable agriculture pursues. Two indicators covering 4 variables were used to evaluate the existing farming systems.

Input self-sufficiency ratio: Input self-sufficiency ratio is the ratio that costs of local inputs to the average costs of total inputs for each household. Local inputs are labor, draught power, local varieties of seed, organic fertilizers, and natural pesticides. So, the scoring systems for each site are given in Table3.6:

Table 3.6. Analysis of Input self-sufficiency ratio

Score Index	Variable Values	Sustainable Classification
1	0.00-0.20	Very low sustainability
2	0.21-0.40	Low sustainability
3	0.41-0.60	Moderate sustainability
4	0.61-0.80	High sustainability
5	0.81-1.00	Very high sustainability

Benefit-cost ratio: Benefit-cost ratio = total return of crop production / total variable cost. Then, the score system maybe as shown in Table 3.7

Table 3.7. Analysis of benefit-cost ratio

Score Index	Variable Values	Sustainable Classification
1	<0.5	Very low sustainability
2	0.51-1.00	Low sustainability
3	1.01-1.50	Moderate sustainability
4	1.51-2.00	High sustainability
5	>2.01	Very high sustainability

Trend of yield: Dumanski (1996) used this indicator in his study. To measure the yield stability, farmers were asked whether crop yields were increasing, decreasing or remaining constantly. On the basis of farmers' responses, the following formula was used to evaluate the trends of yields (Rasul, 1999).

$$ITY = \frac{fi*1 + fd*(-1) + fc*0}{N}$$

Where,

ITY = Index of Trend of Yields

fi = Frequency of responses indicating increasing yield (coefficient = 1)

fd = Frequency of responses indicating decreasing yield (coefficient = -1)

fc = Frequency of responses indicating constant yield (coefficient = 0)

N = Total number of observations fi

Index value is between –1 and 1. –1 not stable, -0.5 half of crops not stable, 0 stable, 0.5 quite stable, 1 highly stable.

Cropping diversification: One of the goals of sustainable agriculture is to minimize the farmers' risk. Cropping diversification can reflect this point due to that one crop fails can be compensated from another crop. To see the differences in crop diversification among the sites, the following formula was used as Thapa (1990):

$$ICD = \frac{Pa + Pb + Pc + ... + Pn}{Nc} \ (\%)$$

Where:

ICD = Index of Crop Diversification

Pa = Proportion of Sown Area Under Crop a (%)

Pb = Proportion of Sown Area Under Crop b (%)

Pc = Proportion of Sown Area Under Crop c (%)

Pn = Proportion of Sown Area Under Crop n (%)

Nc = Number of Crops

Then relevant analysis can be arrived based on the Table 3.8. 100% means that farmers grow only one crop. Less ICD value means less risk to farmers.

Table 3.8. Analysis of cropping diversification

Score Index	ICD values (%)	Sustainable Classification
1	81-100	Very low sustainability
2	61-80	Low sustainability
3	41-60	Moderate sustainability
4	21-40	High sustainability
5	0-20	Very high sustainability

3.5.1.3. Social acceptability

It is also a non-separate component of a sustainable farming system, two indicators were chosen for the study.

Adequacy of food grain production: Producing enough food for consumption is the primary goal of agriculture. To compare the food adequacy more precisely, the index of food security was constructed to measure the variation of food security at the farmers' level among three sites.

$$IFS = \frac{fd1*(-1) + fd2*(-0.66) + fd3*(-0.33) + fo*0 + fs*1}{n}$$

Where

IFS = Index of food security

fd1 = Frequency of responses indicating deficit for 3 months

fd2 = Frequency of responses indicating deficit for 6 months

fd3 = Frequency of responses indicating deficit for 9 months

fo = Frequency of responses indicating no deficit and no surplus

fs = Frequency of responses indicating surplus

n = Sample size

C = Coefficients of different adequate of food grain. – 1 indicating deficit for 3 months, - 0.66 indicating deficit for 6 months, - 0.33 indicating deficit for 9 months, 0 indicating no deficit and no surplus, and 1 indicating surplus for more than 1 year.

The higher index value indicates the food security is relatively higher. Because IFS ranges between –1 (when all the households indicate food adequate only enough for 3 months) and 1 (when all the households have surplus food supply in a year). When it is 0, it means the food supply for all households are exact to meet their need in a year, no more no less. The scoring systems maybe: IFS value < -0.6 very low sustainability, - 0.6– (-0.2) low, -0.2-0.2 moderate, 0.2-0.6 high, and > 0.6 very high.

Extension services: To compare the differences among three sites, the following formula was developed.

Index = S*f.

Where

S = Sustainable scores, and

f = times that farmer indicating extension staff visiting them.

Table 3.9. Calculations of index for extension service

Frequency (f)	Score Index	Sustainable Classifications
Every month	5	Very high sustainability
1/3 moths	4	High sustainability
1/6 months	3	Moderate sustainability
1/12 months	2	Low sustainability
Never	1	Very low sustainability

As compared to the scoring systems, when index value is <20% indicating very low, 20-40% low, 40-60 moderate, 60-80 high, and >80% very high),

Women's participation in agriculture. To compare the different of women involving agricultural activities among the three sites, the index was built as:

$$IDP = \frac{\sum Wi * fi}{N}$$

Where

IDP= Index of Degree of participation

Wi = Weight on ith activities, which are variable according to the importance of the activities, from simple physical activities to mental activities, the values are gradually bigger and bigger ranging from 0.1 to1.0.

fi = Frequency of ith activities

N = Total Number of observation ($\sum fi$).

When interpreting into scoring system, each level maybe like this, <0.2 very low, 0.2-0.4 low, 0.4-0.6 moderate, 0.6 –0.8 high, and >0.8 very high

3.5.1.4. Overall evaluation

In this study, it is assumed that each variable is equally important in contributing to sustainability of a farming system. The score for each variable of the indicators is developed to reflect a reference value.

To be more precisely and make every farming system comparable, the scores for each sustainable dimension (ecological, economic and social) were calculated in average to compare the sustainability of farming systems in each dimension, then the scores from three parts were averaged again. These final results were used to identify the sustainability of farming systems at three sites as a whole by referring the different levels of sustainability shown in Table 3.10.

Table 3.10. Overall average index and sustainability of farming systems

Overall Average index	Sustainability Classification
1	Very low sustainability
2	Low sustainability
3	Moderate sustainability
4	High sustainability
5	Very high sustainability

3.5.2. Record Analysis of 15 Households – Micro Level

To confirm the sustainability analysis at the macro level, 5 households from each site, and totally 15 households from 3 sites were asked to take notes for their daily economic activities. They summarized their incomes and costs once a week according to the items as income (from crop, animals, laboring and others), costs (living, purchasing production materials, education and social activities). Records of 15 households were analyzed follow the steps used at macro level. That is ecological, economic and social aspect. The results were used to compare with the conclusions of macro level, and/or explain the reasons if there were any differences.

3.5.3. A Case Study

Based on the analysis of both macro and micro levels, as the most important crop, corn production in Dafang county was chosen as a case study. Challenges and opportunities of corn production in a sustainable way were analyzed in this part. Finally, recommendations were made to develop sustainable corn production in Dafang.

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1. Sustainable Evaluations – Macro Level

4.1.1. Evaluation of Ecological Sustainability

The study assesses the ecological sustainability through using following 2 indicators.

(1) Landuse Patterns

This indicator includes two variables – percentage of forestry in whole territory and percentage of leguminous crops on all arable land.

Percentage of forestry: According to the data collected, field crops are the dominant types of land use among the sites. About 40-48% of total lands in each site is used for crop production. The second largest part of land use is for forestry, which ranges roughly between 20 and 38%. The rest lands are used for homestead, orchard, pond and grassland (Appendix Table B 1). Percentage of forestry is found the highest in Liulong, followed by Xiaotun and Zhuyuan. In addition, comparing the areas for crop production among three sites, Liulong has the lowest proportion of cropland, followed by Xiaotun and Zhuyuan. Generally, the more intensive cropping systems usually give larger profit but are likely to result in larger soil losses (Troeh et al., 1999). So, higher proportion of forestry with lower intensive cropping systems may suggest that the landuse pattern is more relatively sustainable in Liulong, consequently, followed by Xiaotun and Zhuyuan. The scores given to each site for variable of percentage of forestry are in Table 4.1.

Table 4.1 Percentages of forestry and cropland at three sites

Town	Crop Land	Forestry	**Scores**
Xiaotun	45.86%	22.35%	**1**
Zhuyuan	48.57%	20.25%	**1**
Liulong	40.74%	38.51%	**2**

Percentage of leguminous crops: Although there are many kinds of crops, indeed, grown at three sites, among them, corn, rice, soybean, wheat, rapeseed, potato are the major crops. Majority of total arable lands among three sites is used for growing these major crops. With the increase of height, lands for growing each major crop become gradually different. It can be seen among three sites that corn, soybean and wheat are the common crops widely grown in the three sites, their planting proportions have little differences compared to rice, rapeseed and potato among three sites. Rice ranges from about 1 up to 20%, rapeseed is from very little up to 16% and potato is from very little up to 30% respectively (Appendix Table B 2).

Soybean, the major leguminous crop grown at the sites, contributes nitrogen, organic matter and plant nutrients to the soil (Table 4.2). Relatively larger proportion of land used for soybean in Zhuyuan suggests that the land use pattern is relatively sustainable at Zhuyuan among the sites, followed by Liulong and Xiaotun. However, the sustainable score at Zhuyuan and Liulog are the same scores of 2, which is higher than Xiaotun with the score of 1.

Table 4.2. Percentages of sown area for soybean at three sites

Town	Soybean Area (%)	Sustainable Scores
Xiaotun	18.30	**1**
Zhuyuan	24.20	**2**
Liulong	22.50	**2**

(2) Crop Management

This indicator includes 2 variables: use of organic fertilizers, use of crop residues.

Use of organic fertilizers: The declining soil fertility can be addressed through the use of organic fertilizers, balanced use of chemical fertilizers along with cultural manipulation of cropping systems. Farmyard manure, compost and green manure are the most commonly used as organic fertilizers at the study sites. From the investigation, 100% of farmer household use organic fertilizers when asked. The scores for each site are the same 5 and also are in Table 4.3.

Table 4.3. Percentage of household and average amount of organic fertilizer used for major crops at three sites

Towns	Households		Sustainable Scores
	No. of Household	%	
Xiaotun	78	100	**5**
Zhuyuan	65	100	**5**
Liulong	57	100	**5**

Use of crop residues: Crop residues are an important source of organic material in the study areas, which contain significant quantities of nutrients that crop needs. The levels of removal crop residues are divided into 3 grades (removal all, removal half and non-removal) and each grade is given relevant score. Then, according to the relevant scoring systems in Chapter III, results are given in Table 4.4.

Table 4.4. Use of crop residues

Remove Crop Residues	Xiaotun		Zhuyuan		Liulong	
	% of HH	Index value	% of HH	Index value	% of HH	Index value
1. Remove All	31	31*0	42	42*0	81	81*0
2. Remove Half	28	28*0.5	51	51*0.5	11	11*0.5
3. Non-removal	41	41*1	7	7*1	8	8*1
Total	100	55	100	32.5	100	13.5
Scores		**3**		**2**		**1**

4.1.2. Evaluation of Economic Viability

This study assesses the economic viability of existing farming systems among three sites through analyses of 2 indicators. Namely, indicator of benefits of crop production including input self-sufficiency, benefit-cost ratio: indicator of tendency of crop yield covering trends of yield and cropping diversification.

(1) Benefits of Crop Production

Input self-sufficiency: Farmers use both local and external inputs. Local inputs are labor, draught power, local varieties of seed, organic fertilizers, and natural pesticides. These inputs come from farmers' own farms or buy from the fellow farmers. External inputs include chemical fertilizers, pesticides, plastic films, and petroleum. Farmers have no control the supply and price of these resources. Any external disturbances affect the supply and price of these resources.

Average of cropland owned by each household at three sites is obtained from statistics, farmers' inputs are all on these pieces of land (Table 4.5). It is found that input self-sufficiency ratio is the highest at Zhuyuan among three sites, followed by Xiaotun and Liulong. The high dependency on external inputs increases farm vulnerability due to farmers cannot control its supply and price. So, based on the scoring systems in Chapter III, the input self-sufficiency scores for each site are shown in Table 4.5 too.

Table 4.5 Input self-sufficiency in crop production at three sites

Sites	Farm Size (ha.)	Average Costs of Total Inputs for each HH (1)	Costs of Local Inputs (2)	Input self-sufficiency Ratio (2/1)	Scores
Xaotun	0.38	1006	433	0.43	3
Zhuyuan	0.51	610	321	0.53	3
Liulong	0.44	856	306	0.36	2

Benefit-cost ratio: To measure benefit-cost ratio, the average yields of major crops at three sites are given in the Appendix Table B 5. Rice, wheat and soybean at Xiaotun are found higher in yields than the rest two sites. However, corn and potato are found the highest in yields at Zhuyuan among the three sites. There is a general trend that crop yields are higher in Xiaotun, followed by Zhuyuan and Liulong.

Profitability is an important goal that farmers pursue. To compare returns from growing in each site, the total average inputs for growing crop are given in Appendix Table B 6.

According to Appendix Table B 5 and 6, benefit-cost ratio, together with some profitable index calculated are given in Table 4.6. Consequently, the scores are also in the table.

Table 4.6. Return for growing crop at three sites (yuan/ha)

Items	Xiaotun	Zhuyuan	Liulong
Gross Return (1)	3629	1234	2223
By-products Value (2)	500	500	500
Total Return (1)+(2)	4129	1734	2723
Total Variable Cost (3)	2647	1196	1945
Net Profit (1)+(2)- (3)	1482	538	778
Benefit-cost Ratio	1.56	1.45	1.40
Scores	**4**	**3**	**3**

Benefit-cost Ratio = Total Return/Total Variable Cost,

(2) Tendency of Crop Yield

Trend of yield: To measure the trends of major crop productions, the index was developed. Index values are summarized in Table 4.7. The index values range between 1 and –1. When crop yield increase in all the households, it is 1 and when crop yields decrease indicated by all the households, the index value is –1.

Table 4.7. Index values for evaluating yield trends at three sites

Crops	Xiaotun	Zhuyuan	Liulong
Corn	0.064	-0.154	0.123
Rice	0.381	0.128	-
Wheat	-0.191	-0.083	0.140
Soybean	-0.694	-0.138	0.298
Rapeseed	0.100	-	-
Potato	-	0.286	0.281
Total	-0.34	0.04	0.84
Scores	**2**	**3**	**5**

From the Table 4.7, it is found that the total value of index for both Xiaotun and Zhuyuan are close to 0, it indicates that the crop yields in these two sites keep constant in recent years. On the other hand, index in Liulong is very high, it means that crop yields at this site keep increasing. One reason may be the relatively low in crop yields at this site when compares to former two sites. Then, the scores for each site are given in Table 4.7.

Cropping diversification: Cropping diversification was used to explain the risk of farming. To evaluate cropping diversification, the formula reviewed in the Chapter II was used. Then, from the Appendix Table B 3, the ICD (Index of Crop Diversification) of each site for the major crops is calculated as follow:

Xiaotun: ICD = 25.03 Zhuyuan: ICD = 24.03 Liulong: ICD = 25.94

The value of index starts from 100 (when only one crop is grown) and goes to the tendency of zero (when as many as crops are grown). The less the index value is, the higher the cropping diversification will be, and thus, the more relatively sustainable for the farming systems. The index of crop diversification at Zhuyuan is less than the rest two sites, which suggests that the farming system in Zhuyuan is relatively more sustainable than at the rest two sites. Liulong is the least sustainable compared to the former two sites. However, the scores for each site are the same 4, because they are all in the same range 21-40.

Xiaotun	Zhuyuan	Liulong
4	4	4

4.1.3 Evaluation of Social Acceptability

One of the major objectives of agriculture is to provide the basic requirements of food and fibre with the people. Thus, an agriculture that fails to provide an adequate supply of required food and fibre at a reasonable cost is not sustainable. This study assesses social sustainability using following 2 indicators.

(1) Indicator of Farmers' Satisfaction

This indicator includes adequacy of food grain and extension service.

Adequacy of food grain production: Adequacy of food production is very important for the food security. Farmers were asked whether or not their food supply all the year round enough. The results are in Table 4.8. From the table, it is found that households with adequate food supply in a year at Xiaotun is 78.2% of total household, Zhuyuan only 44.6% and Liulong 36.8%. However, households with surplus food supply in a year at Liulong are as high as 35.1%, whereas this percentage at Xiaotun decreases to 14.1% and Zhuyuan 21.6%.

Table 4.8. Adequacy of food grain at three sites

Items	Xiaotun				Zhuyuan				Liulong			
	f	%	C	I	f	%	C	I	f	%	C	I
Adequate for 3 months	0	0	-1	0	0	0	-1	0	0	0	-1	0
Adequate for 6 months	0	0	-0.66	0	0	0	-0.66	0	0	0	-0.66	0
Adequate for 9	6	7.7	-0.33	-1.98	22	33.8	-0.33	-7.26	16	28.1	-0.33	-5.28
Adequate	61	78.2	0	0	29	44.6	0	0	21	36.8	0	0
Surplus	11	14.1	1	11	14	21.6	1	14	20	35.1	1	20
Total	78	100		9.02	65	100		6.74	57	100		14.72
Scores	**3**				**3**				**4**			

C = coefficients of different adequate of food grain. I=index =f*C.

Xiaotun = 9.02/78 = 0.12, Zhuyuan = 6.67/65 = 0.10, and Liulong = 14.72/57 = 0.26

So, the scores for each site are given in Table 4.8.

Extension services: In China, agricultural extension services are provided by the governments starting at town level. However, it was found, from the interview, that farmers do not receive the extension service as they expect because of the reasons (Table 4.9), which will be discussed further in the following chapter. From the table, extension agents do not visit farmers quite often. No visit to each site at all once a month. For every three months, the percentages of visit in Xiaotun, Zhuyuan and Liulong are 4%, 9% and 16% respectively. For every six months and once a year, there are the same trends that extension staffs visit farmers more in Liulong than the rest two sites. The trends are: Liulong > Zhuyuan > Xiaotun. The scores for each site are in Table 4.9.

Index for Xiaotun = (109/78*5) * 100= 27.9%

Index for Zhuyuan = (114/65*5) *100 = 35.1%

Index for Liulong = (113/57*5) * 100 = 39.6%

Table 4.9 Visit of extension staff to farmers

Time	Sustainable Score (S)	Xiaotun		Zhuyuan		Lfiulong	
		f	S*f	f	S*f	f	S*f
Every month	5	0	0	0	0	0	0
1/3 months	4	3	12	6	24	9	36
1/6 months	3	5	15	12	36	12	36
1/12 months	2	12	24	7	14	25	50
Never	1	58	58	40	40	11	11
Total		78	109	65	114	57	133
Score		**2**		**2**		**3**	

(2) Indicator of Women's Participation in Agriculture.

Women's direct involvement in agricultural activities is not only important from women's empowerment perspective but also important for agricultural and over-all socio-economic development of the rural area. It can facilitate labor mobility across the sectors, particularly small landholders and can fill up the labor shortage during the peak seasons.

In the study areas, women's participation in agricultural activities was divided into 10 items for evaluating sustainability of farming systems. These items cover different levels of agricultural production (Table 4.10).

Table 4.10 Women's participation in different levels of activities in agriculture

Activities	Wi values	Xiaotun		Zhuyuan		Liulong	
		f	Wi*fi	f	Wi*fi	f	Wi*fi
1. Land preparation	0.1	52	5.2	59	5.9	26	2.6
2. Seed preservation	0.2	34	6.8	58	11.6	48	9.6
3. Transplanting	0.3	75	22.5	47	14.1	52	15.6
4. Field management (weeding, etc)	0.4	73	29.2	42	16.8	44	17.6
5. Harvesting	0.5	78	39	59	29.5	44	22
6. Threshing	0.6	78	46.8	59	35.4	45	27
7. Post-harvest processing	0.7	75	52.5	29	20.3	39	27.3
8. Vegetable gardening	0.8	78	62.4	53	42.4	48	38.4
9. Raising Livestock	0.9	66	59.4	47	42.3	48	43.2
10. Decision Making	1.0	23	23	38	38	31	31
Total		632	346.8	491	256.3	425	234.3
Scores		**3**		**3**		**3**	

Xiaotun Index=346.8/632=0.548

Zhuyuan Index = 256.3/491=0.522, and

Liulong Index=234.3/425=0.551

The higher index value in the Liulong (though the differences are not much) indicates that the level of participation of women in agricultural activities is slightly higher there, followed by Xiaotun and Zhuyuan. Higher participation of women in agriculture has many positive influences on the sustainable farming systems. With the development of urbanization, more and more young male labors move to the cities to make money, in such situation, women are becoming more and more important in the sustainable agricultural development. The scores for each site are given in Table 4.10.

4.1.4. Summary of All Evaluations and Discussions

Based on the above discussions, the overall summary is given in Table 4.11.

4.1.4.1. Ecological Sustainability

It is found from the calculations that all the sites have the same average scores as 2.5 in ecological aspect. It means, by referring to the scoring systems, that all the farming systems in each site are between the level of moderate sustainability and low sustainability. However, the components of scores are different from each variable. Scores at Xiaotun are slightly sharp distributed, but at Zhuyuan and Liulong they are more evenly distributed. This indicates that farming systems at Xiaotun is relatively less sustainable than the rest two sites.

4.1.4.2. Economic Sustainability

Average scores at all three sites are found higher than the moderate level of sustainability, which means that the farming systems can be considered relatively sustainable. Liulong is higher than both Xiaotun and Zhuyuan. In Xiaotun it is higher in benefit-cost ratio due to relatively higher productivity and profitability, but low in trend of yields. In Liulong it gets higher score in the trend of yield, which may be due to the relatively lower yield in recent years even if it is lower in input-sufficiency ratio. Normally, lower yield of crops may have more potential to increase yield compared to higher yield of crops.

Input self-sufficiency is found the highest at Zhuyuan even it has the same score as Xiaotun. It indicates that better control over resources at Zhuyuan as farmers of this site are relatively less dependent on external inputs.

Table 4.11 Summary of all indicators and their scores

Indicators	Scores		
	Xiaotun	Zhuyuan	Liulong
Ecological Sustainability (Average)	2.5	2.5	2.5
1. Indicator of Landuse Patterns			
Percentage of forestry	1	1	2
Percentage of soybean	1	2	2
2. Cropping management			
Use of Organic Fertilizers	5	5	5
Use of Crop Residues	3	2	1
Economic Viability (Average)	3.25	3.25	3.5
3. Benefits of Crop Production.			
Input Self-sufficiency	3	3	2
Benefits-cost ratio	4	3	3
4. Tendency of Crop Yields			
Trend of Yield	2	3	5
Cropping Diversification	4	4	4
Social Acceptability (Average)	2.67	2.67	3.33
5. Farmers' Satisfactory			
Adequacy of Food Grain	3	3	4
Extension service	2	2	3
6. Women's Participation in Agriculture	3	3	3
Overall average scores	**2.81**	**2.81**	**3.11**

4.1.4.3. Social Sustainability

In social sustainability as a whole, it is found that only average score at Liulong is slightly higher than the moderate level of sustainability. The highest scores for Liulong in social aspect may be due to its larger total area, more total cropland, and less average family size, which helped Liulong to get 4 score in adequate food supply.

4.1.4.4. Overall Sustainability

From above discussions, each site has its own higher scores from different variables. Although Xiaotun gets the higher scores at benefit-cost ratio level, its ecological sustainability was considered the lowest one among the sites. Liulong gets highest scores from both economic and social dimensions, which makes its overall scores the highest among the three sites, both Xiaotun and Zhuyan have the same scores. Therefore, farming systems in Liulong is the highest sustainable, followed by Zhuyuan and Xiaotun.

As compared with the scoring systems presented in Chapter III, average scores of all three sites are not quite different. They are all around at level of moderate sustainability. Only Liulong is slightly higher than this standard. Therefore, farming systems are moderately sustainable at all three sites. However, though all sites are at the moderate sustainability, relatively higher average score at Liulong indicates that farming systems are relatively sustainable than both Xiaotun and Zhuyuan, which received the same scores lower than Liulong.

4.2. Sustainable Evaluation - Micro Level

Fifteen farmers from three sites were asked to take notes for their activities, their records were summarized in Table 4.12. (for detail, in Appendix B Table B 7, Table B8 and Table B 9).

Table 4.12. Summary information from 15 household of each site

Items (average/ household)	Xiaotun	Zhuyuan	Liulong
Social Aspects			
1. Family size (ha.)	4.8	4.6	5
2. Average labor	3.4	2.8	3.2
3. Age between (15-55)	3.8	3.8	4.2
4. Educational levels			
-primary school	2.6	1.8	2.4
-secondary school	1.8	2.0	1.4
Ecological Aspect			
5. Index of cropping diversification (%)	16.67	16.67	16.67
6. Animal numbers			
-cattle	0.2	0.8	0.8
-buffalo	0.4	0.2	0.2
-pigs	2.2	2.8	5.2
-poultry	14.2	8.2	44.2
Economic Aspects			
7. Total income (yuan)	4856	3959	7474
-crops	2185	2077	2120
-animals	795	978	3399
-laboring	1438	420	0
-others	438	484	1955
8. Total expenditures (yuan)	4446	3313	6464
-living	2971	1491	3345
-purchasing production materials	634	602	1283
-education	500	940	1200
-social activities	340	280	620
9. Saving (7 – 8)	410	646	1010

4.2.1. Ecological Aspects

Crop production is the most important component of the farming systems in Dafang as described earlier. Because of the high altitude, complex topography, majority of up-land and odd pieces, mixture of multi-minority nationalities in this county, there are different types of cropping systems. Temperature and availability of water are the main factors affecting the distribution of cropping patterns. It is usually two crops a year with the relay and inter-cropping management due to not enough growing season.

Generally, the total arable land owned by each household at three sites is about the same (Xiaotun 0.68 ha, Zhuyuan 0.68 ha and Liulong 0.64 ha). Compared to the other two towns, the farmers at Xiaotun have more paddy field, which shares in average 30.07% of total arable land, while Zhuyuan 12.18% and Liulong 5.87%. This finding is similar to the second hand data collected at the town level. The major common crop at three sites is corn. Its share is 24.27% at Xiaotun, 45.18% at Zhuyuan and 47.17% at Liulong respectively. This result is also similar to macro-level except for Xiaotun, this may be these 5 households of farmers have more paddy field. Rapeseed is grown mainly at Xiaotun and potato mainly at Liulong with different cropping patterns. At Xiaotun, the cropping patterns are corn/soybean-wheat, rice-rapeseed; at Zhunyuan are corn/soybean relaying with wheat and rice followed by fallow; at Liulong corn-potato.

As the variable, the ratio of soybean planting area at all the sites is lower when compared to the statistical data collected. Even though, the ratio at Zhuyuan, like the trend of macro-level, is still the highest among the sites. This supports the previous discussion. The low ratios for soybean grown in these 15 households were due to the reasons as: (1) low yield; (2) flowering only without bearing seed or very few; (3) competing with corn for labor, fertilizer and land.

Crop types, or cropping diversification at all the sites are the same, which is similar as macro-level. Vegetables are grown for family consumption with few areas (about 3-5% of total crop area) among three sites. If any extra, farmers sell them at local markets.

According to farmers' records, chemical fertilizers still account for the major part of total production inputs. It is found that the external costs at Xiaotun are 32 yuan higher than that at Zhuyuan. On the other hand, costs at Liulong is much higher than Xiaotun and Zhuyuan, this is due to relatively more numbers of animals raised at this site. Farmers have to spend more on animal, which increases the total cost for the households. However, it still indicates that the total external costs in Zhuyuan are lower than the rest two sites. Less depends on external resources indicates relatively more sustainable in farming systems. This finding corresponds with the previous discussions at macro-level.

Most farms integrate both crop and livestock operation at three sites. Farmers raise some types of animals for different purposes in their farming systems. Big animals like cattle and buffaloes are raised mainly as agricultural power to plough fields (buffaloes for paddy-field and cattle for upland field, it is often seen farmers use these animals to plough both paddy field and upland field according to what animals they have). The average number of big animal per household owned at Xiaotun is only 0.6, both Zhuyan and Liulong are 1. But average per household owns 0.4 buffalos at Xiaotun, this number decreases to 0.2 both at Zhuyuan and Liulong, this is because Xiaotun has more paddy-field. Mid-sized animals like pigs, are raised mainly for manure in small-scale farms. Indeed, animal production in Dafang is mainly small-scale pig farm and at low level. In addition to inconvenient transportation, no special organization responsible for buying and selling, traditional feeding method increases cost of raising pigs and makes it low profit, which constrains pig production development. One or two pigs are often raised per household. Farmers directly either collect pig's excrete as manure, or use crop residues to bed pigsty, and then use these as manure. Then, by the end of year in winter during Chinese Spring Festival, they slaughter the pigs for their own consumption. After Festival, they buy piglets to raise again. Per household has 2.2 pigs at Xiaotun, 2.8 at Zhuyuan, but very high at Liulong (5.2), because there is a “specialized household” raising 12 pigs, cattle and 163 poultry there. Poultry like chicken and ducks are raised mainly for pocket money to buy some living necessaries, or consume on special occasions such as guest’s come or birthday parties of family members’.

4.2.2. Economic Aspects

Among crop grown at three sites, Zhuyuan gets highest in corn yield (4860kg/ha), followed by Xiaotun (3930 kg/ha) and Liulong (3555 kg/ha). Yield of corn is 930 kg and 765 kg lower than the macro- level at Xiaotun and Liulong respectively, this maybe contribute to the relatively larger paddy fields in Xiaotun and potato area in Liulong, which compete with rice and potato for limited inputs and land. Farmers in these two sites have to make choice among the crops and normally rice and potato are their first priorities due to higher yields than the corn in these two sites.

Income from crops is still the highest in Xiaotun (2185 yuan) among the sites. This matches the previous study. But Liulong is 43.4 yuan higher than Zhuyan, this may be due to relatively more vegetables planting areas than Zhuyuan.

Among these three sites, Liulong is the largest one in terms of its population and total area, which is also one of the oldest towns with better basic construction in Dafang county, Xiaotun and Zhuyuan, on the other hand, are very small and were newly set up in early 1990s. Moreover, Liulong is rich in natural resources such as coal, iron and ferrosilicon mines, consequently, more organizations and companies are there. Some of these companies belong to the nation, so its agricultural population is slightly decreased to 93.65% compared to Xiaotun 94.67% and Zhuyan 95.68%

(Dafang Statistics, 2000). In other words, its purchasing power is stronger than other two sites.

The biggest expenditure is for living, which are 66.83%, 44.99% and 51.74% of total expenditures at Xiaotun, Zhuyuan and Liulong respectively. Second largest expenditure, as average, either is production input, or education investment if household has child studying at university. For example, one family has one college student, about 80% of total its income at Zhuyan and 66% at Liulong are paid for the child respectively. It is common to see many relatives and friends supporting one student till he graduates in the countryside

4.2.3 Social Aspects

Total income per household from different sources in Liulong is 7474 yuan, Xiaotun 4856 yuan and Zhuyuan 3959 yuan. The high income at Liulong is because the local people have more opportunities to have off-farm income from different sources. As mentioned earlier, more consumers in Liulong provide more chances for the farmers to produce agricultural products like meat, vegetables. Farmers at Liulong raise more animals than Xiaotun and Zhuyuan. This does not match the previous discussion. The reasons are one farm has enough labor forces (all family members are forces, 1.8 higher than the average), more corn planting areas with high corn yield, this make it possible for farmers to provide animal feed. Another household raises mushroom for selling to the local market. He also owns one small grocery and makes money to support their son studying in the university. However, farmers in Liulong have more earns from different sources, even if they earn nothing for being labors as Xiaotun (1448 yuan) and Zhuyuan (420 yuan), their food security is better than those two sites too. Meanwhile, farmers have more opportunities to learn practical techniques from different sources as mentioned earlier, diversification of income, ability to access information, thus, are better than Xiaotun and Zhuyuan too. So, from the social point of view, farming systems are more relatively sustainable at Liulong than the rest two sites. This result is the same as previous discussion at town level.

4.2.4. Conclusions

Based on the above discussions, it is found that the farm sizes are almost the same among 3 sites in terms of amount of arable land and family numbers. Even the cropping patterns are different, their diversity is the same with the same index values (16.67). Crop is still their major income source except for Liulong as an average due to there is one farm specialized in animal production there. All the farms at 3 sites can be regarded as sustainable because their total incomes are higher than their total cost on production and living.

4.3. A Case Study: Sustainable Corn Management in Dafang

4.3.1. Introduction

Corn, or maize (Zea mays L.), is of the most important grain crop grown in Dafang both in terms of quantity produced and acreage area with approximately 5 times that of wheat, the next leading grain crop. Corn is important as a food grain in Dafang even if today comparatively not too much field corn is used directly for human food as it was once before. Though Dafang is one of the major corn production counties in the province, it still requires domestically imported cereal grains to feed its increasing population. In this county, corn is widely grown on from about 800 m to 2,200 m above sea level in different agroecological regions and has been given much priority among food crops. It is produced on 35,000 ha annually and plays an important role in the economy. Great changes have taken place in corn production since 1979 when family system of contracted responsibility was started.

In 2000, the total sowing area for food crops was 153,878 ha. Corn, as a leading crop, accounted for 59.44% of total arable land for food crops, and 50.47% of total food produced in the county. Though the total growing area for corn decreased gradually from 43,597 ha to 35,713 ha, the average yield per ha increased sharply from 1639 kg 4,386kg, giving a total production of 156,638 MT from 71,467 MT over the past decades. Corn production was worth around US $ 15.09 million in 2000. Trends of total sowing areas and yields, per ha yield of corn in Dafang between 1979 and 2000 are given in Figure 4.1 and Figure 4.2 respectively. From these two figures, it is found that both total yield and per ha yield reached historically highest records in 1984 because of the favorable climatic conditions and relevant material and technology inputs, both farmers and government had been misled by this bumper harvest since then. Farmers even had difficulty selling their products, and thus, government loosened up on the production. After that, crop production decreased and fluctuated till 1993 when the government re-realized the importance of corn production in the region.

The major type of corn is flint, with few half-dent grown in Dafang. Traditionally, corn is intercropped with soybean in the cropping patterns like corn/soybean-wheat. Corn grown is Dafang is under rainfed conditions. The major growing season usually begins in April depending on the temperature. Usually, corn is sown in early Spring when the average daily temperature of soil in 5-10 cm deep rises to 12 C^{o}. If the method of raising seedlings covered by plastic sheeting and then transplanting is applied, the planting date can be moved up about 1 week. This can help to increase corn yield by about 30%.

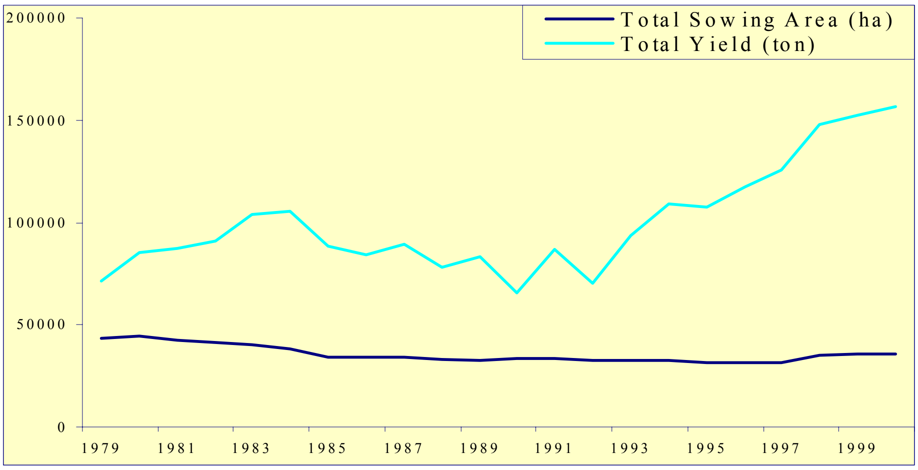

Figure 4.1. Trends of sowing area and total yield of corn in Dafang
(Source: Guizhou agricultural statistics yearbook, 2001)

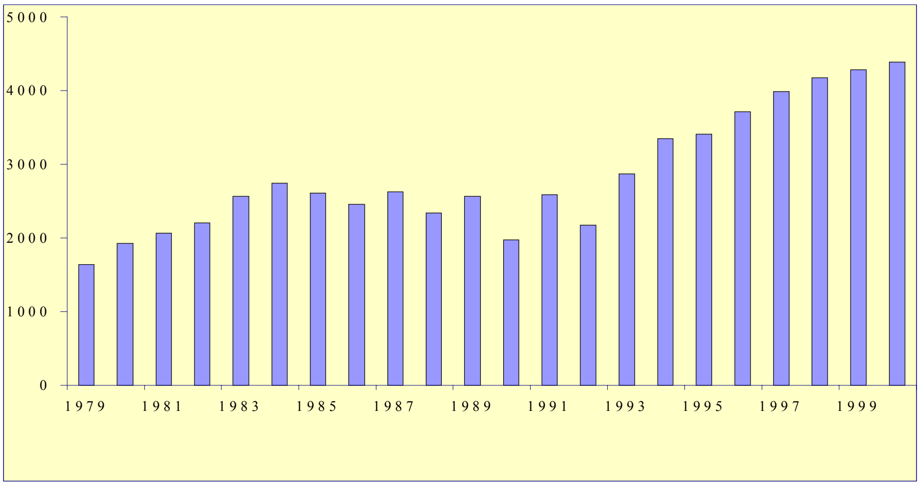

Figure 4.2. Trend of per hectare yield of corn in Dafang.
(Source: Guizhou agricultural statistics yearbook, 2001)

4.3.2. Challenges of Sustainable Corn Production

The most typical characteristics of farming in Dafang is that its scattered and small pieces of arable land, serious soil erosion, and steep slope. Corn is grown under rainfed conditions (unreliable supply of irrigation water) in the very low soil fertility.

Some farmlands in the Northwest even locate in the steep slopes with greater than 50 degrees. Meanwhile, natural calamities like hail, lower temperatures in spring, an unbroken spell of wet weather, frequent droughts both in spring and summer have a serious impact on corn production.

Climate, soil and crops vary according with the height increases. Rice is merely grown in a small ratio and mainly in the southwestern part at low altitude, while upland crops are widely grown throughout the county from lower to the higher altitude. In the lower area, two crops a year with the relatively long growing period of the varieties usually grow well. In the middle region, which is the major part of the county, two crops a year, usually with the relaying cropping systems is popular. In the mountainous region, traditionally only one crop a year is grown. In some parts of the mountainous areas, where traditional practices are used to grow corn, it does not grow well or sometimes cannot even reach maturity because of low temperatures in the season. Only potato and buckwheat can survive in these places. However, if plastic sheeting is used to cover corn, the corn can grow well in these areas

Another important characteristic of farming in Dafang is its small scale farm structure, with an average farm size of less than 0.5 ha. This small-scale farm structure, together with high illiteracy in the rural population, makes the extension and application of new technology very difficult. In addition, insufficient institutional credits and inadequate extension services are also constraints for the corn production. In some remote and poor villages, there are relatively more minority nationality people living there, farmers still use old-fashioned methods to cultivate crops. Because of the poor economy, farmers' inputs, such as high yielding varieties, chemical, fertilizers and agricultural plastic sheeting, are not sufficient to obtain the required yields.

4.3.3. Possibility to Increase Potential Yield of Corn

Demonstrations of high yields

Although corn production has achieved great successes, it still stays at the lower level as an average. Statistics showed that in 1999 the average yields of corn were 4284 kg/ha in Dafang, 336 kg lower than in the province, and 660 kg lower than the national average, much lower than some other advanced corn production provinces. For example, Jilin was 7950 kg/ha, Ninxia 6975 kg/ha, Liaonin 6375 kg/ha, Xinjiang 6305 kg/ ha and Jiangshu 6045 kg/ha in 1998 (Agricultural Statistics Yearbook in P. R. China, 1999). It indicates that the average yields both in Dafang and Guihzou are much lower. In other words, there is a huge potential to increase the yield of corn.

Within the Guizhou province, there are many examples of high yields, too. For example, the "*66.7 Thousand Hectare Corn Project*" carried out by Guizhou General Agricultural Extension (GGAE) across different ecological regions in 1997 achieved an average yield of 5271.6 kg/ha, 1086.6 kg higher than the average level of the province in the same year. "*10000 Hectare Corn Project*" carried out by former Guizhou Agricultural University in western Guizhou in 1998 obtained an average yield of 5362.8 kg/ha, 1118 kg higher than the province's average level and increasing yields by 20.84%. In smaller experimental plots, even higher yields were achieved. For example, in Fuquan city, 7131 kg/ha. was obtained on 0.5 ha of land, and in Anshun city, 7534.5 kg/ha was obtained on 9.4 ha in 1997;

In Bijie prefecture, which consists of 8 counties including Dafang, on an area of 6.98 ha with the help of experts and professors from different institutions organized by the Department of Sciences and Technologies in Guizhou, an average yield of 10867.5 kg/ha was achieved in 2001. A program named "High Yield Engineering Project of Corn" carried out in an area of 145,800 ha with an average yield of 6542 kg/ha between 1999 and 2000. In Weilin county of this prefecture, for example, an average yield of 9560 kg/ha was achieved on an area of 178 ha. Some examples of high yields from counties within the prefecture are given in Table 4.13.

Table 4. 13. Some high yields of corn checked and accepted by the Guizhou Science and Technology Department at levels of counties and prefecture

Names of counties	Area (ha)	Average Yield (kg/ha)
Bijie	8.91	8730
Nayong	10.15	8361
Qianxi	4.68	9049
Jinsha	7.48	9244
Hezhang	6.39	7608
Zhijin	2.5	8908

Source: Anonymous, 2000.

In Dafang itself, there are also some high yield examples. Among 36 towns in the county, the level of corn production is different. Such as Dafang, Shuangshan, Xiangshui, Wenge, their average yield is 133 kg higher than the county's average. From the same project mentioned above, average yield of 9344 kg/ha on 7.61 ha was achieved in 1999. Even at the town level, high yield examples are widely spread. Such as at Xiangshui town, an average yield of 7050 kg/ha was obtained on 3.69 ha; in the even smaller areas, for example in Wenge town the yield was as high as 11116.5 kg/ha in 1999, and up to 13876 kg/ha in 2000. This result has been checked and accepted by the experts organized by the Guizhou Science and Technology

Department. It has set up a typical example of super high yield of corn to the prefecture, or even to the whole province.

Theoretical estimated yield of corn

Many studies have shown that there is a huge gap between actual production and theoretical estimation for corn yield. With the best utilization of light, temperature, water supply and soil fertility in Guizhou, the theoretical estimated yield of corn is as high as 9,255 kg/ha. (Wang, 1998), which is quite similar to the experimental results shown above. Zhang et al. (2001) indicated that the potential yield of corn even could be 17281 kg/ha in prefecture if the water, fertilizer, technologies, CO_2 supply, and plant shape were well organized based on the local production conditions. According to their study, the utilization ratio of climate resource is only 55.2% in current corn production. One of the most important reasons for the current lower yields of corn is that light energy is not efficiently utilized. Investigation showed that there were only 30,000 – 37,500 plants per ha on farmlands, by contrast with high yield fields, where plant density was 52,500-60,000 plants per ha. In some places, it even climbed up to 61,500 – 85,500 plants per ha with an average yield of 12,510 kg (Zhao and Zhang, 2001).

4.3.4. Sustainable Management of Corn Production

With the increase of population, decrease in arable land and development of animal production, growing corn is even more important than before. Retaining sowing land for corn and choosing the right hybrid varieties (varieties that are best adapted to local conditions), with a relevant package of integrated technologies to increase yields, will be an important component in sustainable agricultural development in Dafang.

Cultivar choice

Cultivars have an important role in increasing corn production. Correspondingly, their correct choice is also important. Given the complex geography and vertical agro-ecological conditions, one or two cultivars cannot dominate all the county's corn production. At the moment, single-cross, double-cross, three-way cross and top-cross hybrids in combination with open-pollinated, and/or some local varieties are widely grown in the county across different agro-ecological and socio-economic conditions.

To fully utilize the potential of hybrids in increasing yields, it is important to choose the cultivars that are most adapted to local conditions. Generally, in the lower altitude area below 1200 m above sea level with good natural and economic conditions, single-cross hybrids such as Fangyu 2, Bidang 4, with high potential yield are highly recommended. However, if the natural conditions are poor in this area, such as with shallow topsoils, poor soil fertility, and shortage of input, two-crossed and three-way cross cultivars like Guibi 303 should be selected. In the areas between 1200-1600 m, varieties with good adaptability like Hedan 4 and Bidan 7 should be chosen; and in the even higher regions (>1600 m), early maturing varieties with good resistance to adverse factors, or cold tolerance, such as Huidan, Nudan, and some open-pollinated or local varieties are recommended.

Integrated technology packages

The Chinese experience with agriculture has often been cited as an example of sustainability of land resources (John, 1994). Many studies have shown that variety combined with relevant integrated practices is successful in increasing corn yield.

Green manure earth ridges are one of the features of corn production in Dafang, which can supply soil with organic matter continuously. The green manure is ploughed, formed into ridges and covered by soil along its planting rows when it reaches its highest biological yield; then corn is sown on the top of ridges. It can also protect sloping land from soil erosion and increase yields by 5.66-8.81% (He et al., 1999). *Vicia sagetalis Thuill*, and *Ipomoea turbinata* Lag are the main two types of green manure crops growing in Dafang with intercropping mainly with corn, wheat and tobacco.

Seedling raising and transplanting is widely applied in the county. This technology can make seedlings stronger, growing evenly, easily taken care under the well-controlled conditions, and early planting. Early planting and transplanting can help corn to avoid drought in summer and increase 6,000 to 9,000 plants per ha. The practice of seeding raising and transplanting requires single or double plants transplanted in a certain direction, with all the leaves from each young plant stretching in the same direction when they are transplanted in the fields. Experiments proved that this requirement increased 24.54-37.24% of yield than the normal transplanting method. In areas over1600 m above sea level, the corn can grow well if plastic mulching is used to keep the soil warm, humid and fertile. The practice can increase yields by 8.26 – 31.5% (GGAE.1998). If these two practices are combined, the yield could be increased more significantly as the area altitude increases.

Corn is a short-day crop, dividing land into sections and crop rotation is another feature of corn production in Dafang because sequential crops are impossible to grow there due to low temperatures. At the same time, this practice can control erosion (Douglas et al., 1999). To fully utilize natural resources, farmers divide fields into sections, and crops are assigned to specific sites. The sites are changed in subsequent growing seasons; in the following year they grow crops in another belt before the previous crop is harvested. Crop rotation is the primary strategy for controlling pests and is used to create biodiversity in organic farming systems (Acquaah, 2002).

Balanced application of fertilizers

In Dafang, more fertilizer is applied to corn than to any other crop grown. Sustainable corn production could not be achieved without a set of relevant scientific method of application of fertilizers. Optimum fertility not only maximizes yield but also minimizes cost unit of production and preserves the environment. Too much fertilizer, particularly excess nitrogen, constitutes an economic loss to the producers and may pollute surface and groundwater. On the base of application 15 –20 MT /ha of organic manure, 7-8 MT/ha of compound fertilizer is needed. All of P and K fertilizers should be used as base fertilizer, then 20% of N as base fertilizer, 20% as seedling fertilizer, much high as to 50% is applied in boot stage, finally the rest 10% is used after boot stage. If the corn is cultivated by covering plastic sheet, the application of N fertilizer should be 60% as the base fertilizer, and 40% as the boot stage fertilizer, combined with deeper application skill to increase fertilizer efficiency (Anonymous, 2000). Unfortunately, in practice, application of P and K fertilizer is ignored partly or completely in some areas by farmers. This maybe the higher price than the N fertilizer. Meanwhile, producers should always obtain a soil test from local agricultural experiment station to determine needed nutrients and soil pH in order to efficiently use limited inputs.

Application of new technologies

Biotechnology has enormous potential as a tool in improving agricultural productivity. It will play an increasing role in developing sustainable agriculture. Guizhou Agricultural Academy of Sciences has developed several bio-fertilizers and bio-pesticides, such as “150 fungus liquid”, which have been shown to be very effective and should be widely applied in corn production in Guizhou.

Treating seeds with special chemicals, nutrients, or natural substances extracted from plants is another way to prevent corn from being destroyed by insects and diseases both at the early stage and in the later growing season. It can also supply corn with nutrients, such as Membrane Juice P and C in the early stages. However, this technique has only recently been pioneered and it needs to be better developed before it is applied in the field. Some of the chemical –intensive practices in use today will not be acceptable in the future (Papendick and Michalson, 1999).

Compact varieties of corn have compact shape and vertically-growing leaves, and are suitable for high density growing, with higher yields than normal hybrids. Experiments indicated that this could increase yields of corn by 7.9%, 7500 to 22500 plants more per ha than normal hybrids (GGAE, 1998). However, since it needs relatively high inputs and intensive management, it is not widespread in the province. At the same time, since this type of variety comes from northern China, it is impossible for it to be grown throughout the region due to the complex agro-ecological conditions. Much more research work is needed in this area.

4.3.5. Further Suggestions

More research on intercropping soybean with corn

Soybean and its products are very famous in Dafang for its good quality and taste. Traditionally, soybean and corn are intercropped. However, with the increase of cropping density of corn and use of chemical fertilizers, the yield of soybean is likely decreasing. According to the investigation, farmers complain their lower yield of soybean. It is quite often to see that soybean does not flower, or it can flower but can not bear the seeds (with empty pods). More research is needed on this problem in further study.

Increase subsidies to the farmers

As the most important crop grown in Dafang, each year the government subsidizes the input to the farmers such as plastic sheet (300 yuan/ha), hybrid varieties (0.5 yuan/kg), chemical fertilizers (300 yuan/ha), seed of green manure (63.75 yuan /ha), etc. However, these subsidies are not enough. Most importantly, these subsidies are used only in the small-scale high yield demonstration plots. For most of farmers, they are not given any subsidies.

Developing new uses of corn

Corn is clearly a diverse with many specialty uses and types. In addition to the development of corn for larger use of the human consumption, livestock feeder in the county, it is necessary to develop new products, which had been developed for special uses in many countries. Development of new uses of corn is important for sustainable corn production. For example, waxy corn, with its products, can serve essential functions in foods, including the improvement of uniformity, stability, and texture in various food products. Popcorn has been a commercial commodity in the U. S. for more than 100 years. The prepopped-popcorn industry, which includes the flavored candy coated, and normal popped flakes, has taken a different approach to make popcorn available in another form to millions of consumers. Super sweet corn is becoming popular among farmers and consumers. It has been utilized in various forms of canned products that are now being marketed both locally and internationally in Thailand. Various vegetable corns are now grown for human consumption in many countries. These corns consist of sweet corn, waxy corn and baby corn.

There are many uses of corn indeed. Changes in modern living styles, the desire for more human convenience, and progress in various industrial and food technologies will surely lead to greater demand on specialty corns. Corn breeders must allocate resources wisely to breed corn to meet the demand of different purposes. Corn production is not only on high yield and good quality, but also on different process of procedures.

Issue of relevant policies

Corn production is not only determined by physical factors but also influenced by those not related to agronomy. These influences probably have the greater impact on the patterns of crop production. So, the policies of governments should assist farmers in different fields including finding or developing markets for their products.

4.3.6. Conclusions

Corn is a leading grain crop in Dafang, in terms of total yearly output and growing area. Over the past 20 years great advances – the total output from 71,467 to 156,638 MT – have been achieved in corn production. But still, as demand increases so do the difficulties of meeting it. Raising crop productivity to the extent of feeding a rapidly growing population without further damaging an already degraded ecosystem is a major issue, concerning which much debate has taken place in recent years.

Dafang still imports grain food from other areas. Among three major cereal crops, increase total food output by increasing yields of rice is impossible for there is only less than 5% of total sowing area of grain crop is found in the county. Wheat as a winter crop, even it has potential to increase its yield, compare to the corn, to feed the increasing population, clearly, corn has to play a major role in Dafang.

Traditional technologies have been used together with naturally rich resources in improving agricultural productivity. With natural resource deterioration it is necessary that more advanced technologies should be applied. Increasing corn yield without damaging environmental resources is possible if the right packages of integrated technologies are meticulously assembled and appropriately applied. The problem of food self-sufficiency for people in Dafang can be solved. Long-term food supply will depend on agricultural development that is environmentally sound, socially equitable and responsible, as well as economically viable and productive.

CHAPTER V

CONCLUSIONS

China has currently 20% of the world's population (1.3 billion people) and has <7% of the world's arable land, an average of < 0.1 ha per person. In meeting the needs of a large and growing population from a small and diminishing base of natural resources, producing sufficient food to feed a growing population under any form of agricultural management is an incredible challenge, but one that is not new to Chinese agronomists and farmers.

With the development of Chinese economy, some major problems are facing agricultural production. They are: 1) there is a strained relationship of man-land due to growth of population, decreased of cultivated land, and shortage of water resource, 2) the agricultural environmental gets worse, 3) a great amount of surplus labor forces exist in countryside, 4) investment in agriculture decrease, 5) the productive cost in agriculture is higher, and the growth of farmers' income is slow, 6) there are less agricultural technicians in the countryside (Gong and Lin, 2000). In attempting to resolve the conflicts between ever-intensifying agricultural production and the resulting agro-environmental problems, sustainable agriculture has become a popular issue in different levels of governments in China. The government and populace have realized both from the theoretical point of view and the practical point of view, that sustainable agriculture can increase profitable and productive production at the same time if the conservation of soil, water, energy and biological resources, and other productive resources are well done. It can meet subsistence needs of people and improve agricultural resource management systems simultaneously. Moreover, it can minimize variable costs in using of external inputs. In addition to this ecological dimension of sustainability, China is also concerned about the social aspect of sustainability, for it can increase self-reliance among farmers and rural people through the better use of knowledge and skills of farmers. The Chinese population is still largely rural, with 70-80% of the people working as farmers. Improving farmers' income and living standard are important factors for maintaining the stability of Chinese society (Xie et al., 2002).

A farming system, ecologically sound, economically profitable and socially responsible, should reflect three combinations: combination of farmers and the government for social needs, combination of ecological and economic issues for benefits, and combination of use and conservation of resources. That makes an optimum farming system (Liang, 1998). Farming systems are the meeting point of natural, economic and social systems, each of which has its own dynamics. For farming systems to survive, they have to be simultaneously sustainable in each of these dimensions (Marsh, 1997).

Promoting the sustainable management of natural resources is a compelling task that requires new approaches and strategies (Lopez-Ridaura et al., 2002). The main constraints, however, to promote sustainable farming are poverty, high population growth, lack of alternative income sources, lack of alternative management options and weak information dissemination. Farmers are rational in decision making. To make them attractive in this type of farming, viable alternative options need to be made available to them. Given the constraints of land and capital and relatively abundant labor, low technology and high population growth ratio, the strategies of sustainable farming systems should be the best use of available human resources and conservation of land, water and other productive resources so that productivity can be increased on a sustainable basis.

5.1.Overall sustainability of farming systems

In terms of ecological, economic and social dimensions of sustainability, it is found that farming systems at all sites are moderately sustainable. Out of 6 indicators of sustainability, from the ecological point of view, performance of farming systems at Xiaotun is the worst due to its sharp fluctuation of different variables even the scores at all three sites are the same. From the economic point of view as a whole, performance of farming systems at Liulong is found slightly better than the rest two sites due to its very high stable trend of yield, but benefit-cost ratio is found highest at Xiaotun. At the same time, from social perspectives, farming systems at Liulong are also found better than the rest two sites due to adequate food supply and relatively better extension services. In general, the farming systems at Liulong are relatively more sustainable than the Xiaotun and Zhuyuan in respects of all the 3 dimensions of sustainability, even though they are all considered to be moderately sustainable as compared with the scoring systems.

5.2 Recommendations

5.2.1. Diversity of Agriculture

One of the most important characteristics of sustainable agriculture is its diversity. There are four main elements of agrodiversity in agricultural production, namely, agrobiodiversity, management diversity, biophysical diversity and organizational diversity. To develop sustainable farming systems in China, it is important to adopt this approach at different levels. Especially, the organizational diversity should be given more attention. Sustainable agricultural (or farming) systems are not isolated from other parts of society. A systems perspective is essential to understanding sustainability. It is important to point out that reaching the goal of sustainable agriculture is the responsibility of all participants in the systems, including farmers, laborers, policymakers, researchers, retailers, and consumers. Each group has its own part to play, its own unique contribution to make to strengthen the sustainable agriculture community.

It is necessary to diversify the cropping patterns as much as possible. This would help to maintain soil fertility, reduce risk of inset and pest attack, and improve nutrition supply. Some crops provide higher return than that of corn and wheat, but marketing problems and farmers' concern about the food security probably are the two main constraints. To promote these crops it is necessary to increase their storage, processing and marketing facilities. Biodiversity conservation is an essential objective of sustainable development, and especially for the multifunctional role of agriculture, for most of the existing stock of biological and cultural diversity occurs in areas under some level of agricultural management. Biodiversity contributes for agricultural sustainability by providing genetic and managerial alternatives that improve resource use efficiency and production security.

Luckily, it is found, from Guizhou Daily on March 3, 2003, that there is a project named "10000 mu high quality chilli base" carried out in Dafang at the moment. There is 3.6 million yuan investment for the project and it is estimated about 7.5 million yuan output comes. This must be very beneficial for the farmers to earn money from cropping diversification, and reduce the possible failure from only growing some major food crops. Moreover, traditionally, Dafang is also famous for its good quality chilli products. So, this project uses techniques like raising seedlings, transplanting, plastic film mulch, balanced fertilizer use, and advanced processing. Unfortunately, this project only covers 3 towns. Hopefully, there are more and more this kind of projects carried out in not long future in different parts of the county.

5.2.2. Integrated Plant Nutrient Management

The declining soil fertility is one of the major problems in crop production. Crop residues and cattle manure, which was traditionally used in soil to fertilize lands, are now largely utilized as fuel or other usage. High population growth with decreasing per capita land area and the growing needs for energy put great pressure on available biomass resources.

It is well-known that additions of organic matter (OM), e.g. manures, composts, above-ground crop residues, or increases in soil organic matter (SOM), e.g. below-ground crop residues, microbial biomass, can improve soil properties. This was, and continues to be, the basis of much traditional farming (Loveland and Webb, 2003). Maintenance of soil fertility as a part of "soil health" is very important goal in the development of sustainable agricultural systems (Eltun et al., 2002).

Moreover, the present trend of corn dominated cropping pattern, which is gradually eliminating other crops, leads to monocropping. Monocropping along with intensive use of land, relatively less or no use of organic matter and green manure, and imbalanced use of chemical fertilizers lead to degradation of soil quality, declining land productivity, and water pollution. To maintain crop yield, farmers need to use gradually higher amount of chemical fertilizers and pesticides, which makes the systems unsustainable.

However, as Troeh et al. proposed (1999), the dramatic increase in fertilizer use has improved both the quality and quantity of crops produced. This trend is likely to continue to be an essential component of efforts to provide food and other needs for the world's growing population. In the study areas, chemical fertilizers contribute largely for the production, it is impossible to reduce its application within short term. So, integrated nutrient management and balanced use of chemical fertilizers are extremely important. Thus, emphasis should be gradually shifted from present heavy dependency on agro-chemicals to integration of resources, nutrient recycling, and to better management of land and water and better use of available human resources and knowledge. So that the land, water, and other productive resources can be conserved, and productivity can be increased on a sustainable basis. Research, extension, credit and other support services also need to be reoriented accordingly.

5.2.3 Integrated Pest Management

Integrated pest management (IPM). It is a complex process. It requires certain skills and some basic training. To promote IPM, an effective extension program, including a media campaign, should be launched to inform and educate farmers on benefits of IPM and its different methods. Moreover, emphases need to be given to develop appropriate technologies and demonstrate the available technologies to motivate farmers. But, despite the remaining problems, modern pesticides are making possible several agricultural improvements. They have helped increase crop production during recent decades and are needed to continue that trend in the future (Troeh et al., 1999).

Biological control of insect pests is a very important method in sustainable farming systems, which has high efficiency, long-term and less residues in the systems, and has been widely used in vegetables, fruits, tea and tobacco production throughout the country. However, it is found only less than 5 % of cropping land used in Guizhou province, which are mainly in suburbs, or large farms. The major reasons the farmers do not use bio-chemicals are relatively high price of bio-chemicals, farmers are used to the traditional chemicals which are fast effective, low price, and simple management. Another important reason is that most farmers and few sellers do not know what bio-chemical is, what its functions are in sustainable farming systems. On the other hand, there is also problem from extensions, which will discuss more below.

5.2.4 Enhancing the Extension Services

This study revealed that the present agricultural extension service is neither appropriate nor adequate. Sustainable agricultural development requires a more intensive extension services which focus on farmers' needs and constraints, on site-specific conditions and on cropping systems and practices used by farmers. This demands a reorientation of extension services that will not only deliver information to farmers but also convey information back to the research system on farmers' needs and constraints.

Currently, there are hardly any effective linkages between research organization and extension agencies. As a result, technologies do not reach to the farmers for whom it was meant and scientists are not getting necessary feed back from farmers. Moreover, there is no effective coordination among the research institutions working in the different fields of agriculture and rural development, like crop production , livestock, fishery, and forestry. To bridge this gap, scientists, extension agents and farmers should be linked in an interactive process.

Meeting with farmers with group rather than present individual contact farmer will increase the total number of farmer coverage under extension service. Training can be divided into different groups based on the location, or socio-economic background, women farmers. This will not only increase efficiency and cost-effectiveness but will also increase farmers' participation in the planning and management of extension services.

To be of benefit to the rural poor, agricultural research and development should operate on the basis of a "bottom-up" approach, using and building upon the resources already available: local people, their knowledge and their natural resources (Miguel, 1987).

5.2.5 Government Policy Support

Government policy should cover any parts of sustainable development. Without proper policy support, sustainable agriculture will not promote automatically. Research, extension, credit and other support systems need to be reoriented accordingly and through policy support financial incentives need to be directed towards them whose farming are more environmental friendly, use less external inputs (chemical fertilizers, pesticides) and more on-farm resources, and make better use of resources through reuse, recycling and nutrient recycling.

5.2.6. Importance of Animal Production Systems

In the study sites, small farm scenario is characterized by low capital input, limited access to resources, low levels of economic efficiency, diversified agriculture and resources, and conservative farmers who are illiterate, living on the threshold between subsistence and poverty, and suffer from an inability to use new technology. As rural population pressures increase, crop and livestock production become integrated in order to intensify output. Mixed farming systems provide farmers with an opportunity to diversify risk from single crop production, to use labor more efficiency, to have a source of cash for purchasing farm inputs, and to add value to crops or their by-products. Combining crops and livestock also has many environmental benefits, including the maintenance of soil fertility by recycling nutrients and providing entry-points for practices that promote sustainability such as the introduction of improved forage legumes. Mixed farming systems maintain soil biodiversity, minimize soil erosion, conserve water, provide suitable habitats for birds, and make the best use of crop residues that might otherwise be burnt leading to carbon dioxide emissions (Devendra and Thomas, 2002).

Despite an emphasis on crop production, mixed farming systems (where crops and animals are integrated on the same farm) form the backbone of small-scale at the sites. It was found through survey that every household raises animals. The major animals raised at sites are cattle, pigs and poultry. Only two farms are found to raise goats. But study found that these raising are mainly used for crop production sector. The average cattle owned per household is only 0.57 at Xiaotun, 0.50 at Zhuyuan, and 0.88 at Liulong respectively. The major function of cattle is as power for field tillage, and its waste for manure. The average number of pig owned by each household is 2.4 at Xiaotun, 2.5 Zhuyuan, and 2.8 at Liulong. The pigs are raised mainly for organic fertilizer, and then for family consumptions on important occasions, such as Chinese Festival. There is little different among the sites in number of poultry (about 10 –15) owned by each household. If any extra, they sell it for making some money to buy the necessity

Animals are important component of Asian agriculture, though their role is secondary to that of crop production. However, their contribution to and interactions with cropping are extremely important for the promotion of sustainable agriculture and the protection of the environment. Improved productivity from animals will be necessary in the future if the increased demands for animal products are to be met, poverty alleviated and the livelihoods of resource-poor farmers improved (Devendra and Thomas, 2002). Animal should play more important role compared its at the moment

5.2.7 Fully Mobilizing the Enthusiasm of the Women in Agricultural Production

Women account for about ½ of the total population in west part of China. It is an important component of agricultural activities. Their involvement in the degree and scope has heavy impact on the sustainable agricultural development. As compared with men, they are the group with lower educational level and poor living conditions. Sustainable development is not concerned with economic dimension only, but is to promote progress of the whole society. Women development will be an important part of this progress. Due to influence of original system, ideas, social cultural background, women as an important human resources, its development is backward compared to the whole economic development. To construct the ecological environment, rural women's action is both conserving and destroying, their attitude is both passive and initiative, and they know little but long for learning. They are in the contradiction. To break this deadlock, it is essential to have input and support from government and whole society, so to realize the really "men and women equal".

5.2.8. Study on the Soybean Problems the Farmers Face

From 15 household records, it is found that farmers gradually grow few and few soybean due to reasons. Less growing leguminous crops in farming systems indicates less sustainable. To solve the problems, it needs both government and research organizations including extensions to adjust their research priority from what they think most important to what problems existing in the production practices.

5.2.9. Integrated Fruit Trees into the Systems

From both town level and farmers' records, it is found that fruit trees are very few. Traditionally, there are several kinds of trees grown in Dafang, which are famous in the province, lacquer even famous in China. One reason for low crop yields is the poor fertility of the land due to serious soil erosion. To solve this problem, one effective way is to return land from cropping to trees and grass. At present, government policy support this program, but not so effective.

5.2.10. Individual Suggestions for Each Ecological Zone

Clearly, Xiaotun is representative for the major corn and rice production areas. In these areas with good natural conditions, increase of yields for both corn and rice in the even higher levels is their concerns. So, choice of single-cross varieties, with the integrated technology packages together, would increase its potential yields.

In Liulong, potato is very important in crop production and it is a major potato production area. Selection of relevant varieties for different purposes, use of virus-free seed, diversified use of this product including process will give full play to potato production. Meanwhile, success of some enterprises of pig farms in this town indicates that there is potential to develop animal production for the whole county, even for the areas nearby.

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APPENDIX

Part A: Household Survey Questionnaires

Table A1. Basic Information

Name of the Head of the Household: Name of the Village: Name of the Township:	Respondent's Personal Information Name: Age: Sex: M F

Name of the Interviewer: Date of Interview:

Table A2. Information about Household (HH) Members

Members	Sex	Age	Educational Status	Occupation	Unemployed
1.					
2.					
3.					
4.					
5.					
6.					
7.					

Table A3. Land Ownership and Land Use for Different Purposes (Mu)
(1 mu = 1/15 hectare)

Land Use / Ownership	Owner Land	Rented in	Rented out
Homestead			
Field Crops			
Fish Ponds			
Orchard			
Forest			
Grazing Land			
Uncultivated Land			
Others			
Total			

Table A4. Total Area and Types of Crop Land of Household (Mu)

Total Cultivated Land	Single Cropped Area	Double Cropped Area (Corn-wheat, Rice – rape, etc)
Irrigated (Mu)		
Rainfed (Mu)		

Table A5. Area by Crop and Crop Production

Crops	Planting Area (mu)	Production (kg/mu)	Consumed (kg)	Sold Last Year		
				Amount (kg)	Price (yuan/kg)	Income (yuan)
Corn						
Rice						
Wheat						
Soybean						
Rapeseed						
Potato						
Vegetables						
Others						
Total						

Table A6. Major Crops' Cropping Calendar

Crops	Variety	Cropping Patterns	Seed Needed (kg/mu)	Date of Sowing	Date of Trans-planting	Flowering	Harvesting
Corn							
Rice							
Soybean							
Wheat							
Potato							
Rapeseed							
Others							

Table A7. Crop Production Problems Faced by Farmers

Corn	Problems					
Rice	1.	2.	3.	4.	5.	6.
Soybean	1.	2	3.	4.	5.	6.
Wheat	1.	2.	3.	4.	5.	6.
Potato	1.	2.	3.	4.	5.	6.
Rapeseed	1.	2.	3.	4.	5.	6.
Others	1.	2.	3.	4.	5.	6.

Table A8. Crop Rotation and Crop Combinations (Patterns)

Area Under Monocropping		Area Under Crop Rotation	
Crop Types	Area	Crop Combinations	Areas
1. 2. 3.	1. 2. 3.	1. 2. 3.	1. 2. 3.

Table A9. The Reasons of Whether or not Crop Combinations

The Reasons of Crop Combinations	The Reasons of not Crop Combinations
1. 2. 3.	1. 2. 3.

Table A10. Practice of Mixed Cropping

Area and Reasons for Mixed Cropping Practice	Reasons for not Mixed Cropping Practice
Area: (mu) Reasons: 1. 2. 3.	1. 2. 3. 4.

Table A11. Application of Organic Fertilizers (kg/mu)

Organic Fertilizer	Corn		Rice		Soybean		Wheat		Others	
Compost	Area	Kg/mu	Area	Kg/mu	Area	Kg/mu	Area	Kg/mu	Area	Kg/mu
Green Manure										
Farmyard Manure										
Others (Specify)										
Total										

Table A12. Use of Fertilizers By Types of Land (kg/mu)

Land Types		Compost	Green Manure	Farmyard Manure
Irrigated	Single Cropped			
	Double Cropped			
Rainfed	Single Cropped			
	Double Cropped			

Table A13. Use of Crop Residues

Items	Corn	Rice	Wheat	Soybean	Rapeseed	Others
Remove Crop Residues 1. All 2. Half 3. Non-removal						
Use of Crop Residues 1. Fuel 2. Feeding Livestock 3. Keeping in the Field 4. Sell						

Table A14. Information of Leguminous Crops Cultivation (mu)

Types of Legumes	Irrigated	Non-irrigated
1.		
2.		
3.		
4.		
5.		

Table A 15. The Reasons of not Cultivating Legumes

Reasons	Rank
1. 2. 3. 4. 5.	

Table A16. Areas and Amounts of Fertilizers Use by Crops (kg, mu)

Crops	Chemical Fertilizer 1			Chemical Fertilizer 2			Chemical Fertilizer 3			Chemical Fertilizer 4		
	Area	Kg/mu	%	Area	Kg/mu	%	Area	Kg/mu	%	Area	Kg/mu	%
Corn												
Rice												
Soybean												
Wheat												
Potato												
Rapeseed												
Total												

Table A17. Information about Know ledges of Fertilizer Use

Ways of Knowing how to Use Chemical Fertilizers	Reasons of not Knowing how to Use Chemical Fertilizers
1. Extension Agent 2. Training 3. Co-Farmers 4. NGO Workers 5. Fertilizer Sellers 6. Others (Specify)	1. 2. 3.

Table A18. Frequency of Application of Chemical Fertilizers to Different Crops

Crops	1 time	2 times	3 times
Corn			
Rice			
Soybean			
Wheat			
Potato			
Rapeseed			

Table A19. Major Types of Pests and Diseases for Major Crops and Their Ranks

Crops	Types of Pests					Types of Diseases				
	1	2	3	4	5	1	2	3	4	5
Corn										
Rice										
Soybean										
Wheat										
Potato										
Rapeseed										

Table A20. Mark of Measures Used for Control Pests and Diseases

Biological Control	Use Chemical Pesticides	Both

Table A21. Biological Measures Used to Control Pests and Diseases

Kinds	Choice of Effectiveness
1.	1. Highly effective; More or Less Effective; Not effective
2.	2. Highly effective; More or Less Effective; Not effective
3.	3. Highly effective; More or Less Effective; Not effective
4.	4. Highly effective; More or Less Effective; Not effective

Table A22. Types of Pesticides Used for Different Major Crops

Name of Pesticides	Name of Crops	Amount (kg/mu)	Times (1, 2 or 3)	Price (yuan/kg)	Remarks
1.					
2.					
3.					
4.					
5.					
6.					

Table A 23. Problems Happened By Using Pesticides

Problems	No. of Members Affected	Occurrence			Costs of Treatment (Yuan/one time)
		Frequently	Sometimes	Rare	
Headache					
Skin Disease					
Vomiting					
Stomachache					
Others (Specify)					

Table A24. Evidences of Water Contamination

Evidences	No. of Members Affected	Occurrence		
		Frequently	Sometimes	Rare
Body Irritation in Water				
Infection in Fish				
Dying of Frogs				
Diarrhea				

Table A25. Costs of Production for Each Major Crop in Yuan

Costs	Corn	Rice	Wheat	Soybean	Potato	Rapeseed	Others
Land Preparation							
Human Labor (Man-day * wage)							
Animal Power							
Seeds							
Organic Fertilizers							
Chemical Fertilizers							
Pesticides							
Plastic Sheets							
Irrigation							
Interest on Operation Capital							
Others							
Total Variable Costs							

Table A26. Crop Yield Increase, Decrease, or Constant and the Reasons in Recent Years

Crops	Increase	Decrease	Constant	Reasons
Corn				1. 2. 3. 4.
Rice				1. 2. 3. 4.
Wheat				1. 2. 3. 4.
Soybean				1. 2. 3. 4.
Potato				1. 2. 3. 4.
Rapeseed				1. 2. 3. 4.
Others				1. 2. 3. 4.

Table A27. Factors Constraining Crop Harvest Security

Crops	Drought			Flood			Lower Temperature			Pests and Diseases			Others		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Corn															
Rice															
Soybean															
Wheat															
Potato															
Rapeseed															
Others															

(Percentage of damage corresponding with different crops and calamities: 1 = low, 2 = medium, 3 = high)

Table A28. Problems the Farmers Face or Satisfaction

Problems or Satisfaction	Yes	No	Rank
1.Declining soil fertility			
2. Small land holding size			
3. Fragmented land holdings			
4. Low crop productivity			
5. Inadequate compost, green manure, farmyard manure			
6. Labor shortage			
7. Drought			
9. Floods			
10.Pest and diseases			
11.Poor extension services			
12.Low price			
13.Inadequate credit facilities			
14.Shortage of irrigation facilities			
15.Unavailability of seeds, fertilizers, pesticides in time			
16.Inadequate marketing facilities			
17.Inadequate irrigation facilities			
18.Others (specify)			

Table A29. Livestock Species and Numbers

Types of Livestock	Number Raised	Number Sold Last Year	Income from Selling
Cattle			
Buffalo			
Goat/Sheep			
Pigs			
Fowl (eggs)			
Others			

Table A30. Sources of Feed

Types of Livestock	Total Feed (kg/year)				Total Cost	Crop Source %
	Crop Source	Cost (yuan/kg)	Non-crops	Cost (yuan/kg)		
Cattle						
Buffalo						
Goat/Sheep						
Pigs						
Fowl						
Others						

Table A31. Annual Average of Household Income and Expenditure (yuan)

Income		Expenditure	
Sources	Amount	Consumption Items	Amount
Field Crops:		FOOD ITEMS:	
1. Cereals		1. Cereals	
2. Other Than Cereal Crops		2. Other than Cereal Crops	
Livestock		3. Livestock Products	
Orchard		4. Orchard	
Fishery		5. Fish	
Services		6. Processed Food	
Others		NON-FOOD ITEMS	
		7. Clothing	
		8. Agricultural Inputs	
		9. Education	
		10. Business	
		11. Services	
		12. Health/Social Obligation	
		13. Others	
Total		**Total**	

Table A32. Adequacy of Food Grain Produced to
Fulfill Household Requirements (kg)

3 months	6 months	9 months	1 year	Surplus (how much)

Table A 33. The Times of Extension Agent Visit the Farmers and the Sources
Farmers Access Knowledge

Times of Agent Visit	Sources of Farmer Access Knowledge	Farmers' Training
Never	Extension Agent	1. Attended
Once 1 Month		
Once 3 Months	Training	Compost Preparation
Once 6 Months	NGO Workers	Management
Once 1 Year	Sellers (Seed, Pesticides)	Use of Fertilizers and Pesticides
Satisfactory	Fellow-Farmers	Others (Specify)
Unsatisfactory	Others (Radio, TV. Etc)	2. Not Attended

Table A34. Women's Participation in Agriculture

Activities	Highly Participated	Medium Participated	Rarely Participated
1.Land Preparation			
2.Seed Preservation			
3.Transplanting			
4.Field Management			
5.Harvesting			
6.Threshing			
7.Post-harvesting Processing			
8.Vegetable Gardening			
9.Raising Livestock			
10.Decision Making			
11.Others			

Part B: Relevant Data Summarized from Appendix A and Used for Evaluating Sustainability of Farming Systems at Three Sites

Table B 1. Land use for different agricultural purposes at three sites

Town	Total Land	Crop Land	Home stead	Orchard	Pond	Grass Land	Forestry	Uncultivated Land
Xiaotun	5136	2355.4	146.6	13.4	59.8	4.9	1147.8	1408.8
		45.86%	2.85%	0.26%	1.16%	0.09%	22.35%	27.43%
Zhuyuan	5159	2505.8	17.9	33.6	45.2	66.7	1044.9	1270.1
		48.57%	3.47%	0.65%	0.88%	1.29%	20.25%	24.62%
Liulong	7877	3209.4	258.6	4.7	54.5	6.9	3033.3	1309.9
		40.74%	3.28%	0.06%	0.69%	0.09%	38.51%	16.63%

Uncultivated land refers to rocks, barren hills, etc.

Table B 2. Sown area of each major crop (ha) and their percentages at three sites

Towns	Total Cropped Area	Land Available for Field Crops						
		Corn	Rice	Soybean	Wheat	Rapeseed	Potato	Others
Xiaotun	2355.4 (ha)	969.9	515.8	431	650	381.6	-	715.8
	(%)	41.18	21.89	18.30	27.60	16.20	-	30.39
Zhuyuan	2505.8 (ha)	1307.5	270.6	606.4	608.7	-	218.0	749.2
		52.18	10.79	24.20	24.29	-	8.69	29.90
Liulong	3209.4 (ha)	1688.1	35.3	722.1	860.8	-	856.9	567.7
		52.60	1.09	22.50	26.82	-	26.70	17.69

Table B 3. Cropping diversification calculation

ICD (index of cropping diversification) $ICD = \frac{Pa + Pb + Pc + \ldots + Pn}{Nc}$

Xiaotun $ICD = \frac{41.18 + 21.89 + 18.3 + .27.6}{5}$=25.03

Zhuyuan $ICD = \frac{52.18 + 10.79 + 24.2 + .24.29 + 8.69}{5}$=24.03

Liulong $ICD = \frac{52.6 + 1.09 + 22.5 + .26.82 + 26.7}{5} = 25.94$

Table B 4. Use of crop residues (ICR calculation)

ICR (Index of removal of crop residues) $ICR = \frac{\sum S_i f_i}{N}$

Xiaotun $ICR = \frac{24*(-1)+22*0+32*1}{78}$ =0.10

Zhuyang $ICR = \frac{27*(-1)+33*0+5*1}{65}$ = -0. 34 and,

Liulong $ICR = \frac{46*(-1)+6*0+5*1}{57}$ = -0.72

Table B 5 Average yields of major crops (kg/ha) in 2000

	Items	Xiaotun	Zhuyuan	Liulong
Crops	Corn	4860	4950	4320
	Rice	7500	5445	5370
	Soybean	930	390	975
	Wheat	2505	1755	1515
	Rapeseed	2670	-	-
	Potato	-	4508*	3214*

* The yield calculated in potato uses ratio 1:4. i.e. 4kg potato = 1 kg cereal

Table B 6 Total costs of crop production at three sites (yuan/ha)

Input	Xiaotun	Zhuyuan	Liulong
Labor (5yuan/day)	1138	634	700
Chemical Fertilizers	1090	280	903
Seed	188	126	123
Plastic Films	150	100	150
Pesticide	81	56	69
Total	**2647**	**1196**	**1945**

Table B 7. General Information about 15 households (HH) from Xiaotun

Items		HH 1	HH 2	HH 3	HH 4	HH 5	Average
1. No. of family members		5	4	5	5	5	4.8
2. Average Age		33.0	38.0	32.2	27.4	20.2	30.2
3. Sex	Male	3	3	2	3	2	2.6
	Female	2	1	3	2	3	2.2
4. Labor Force	Male	3	1	2	3	1	2.0
	Female	2	1	2	1	1	1.4
	Total	5	2	4	4	2	3.4
5. Years ranges	0-15	0	1	0	0	3	0.8
	15-55	5	2	5	5	2	3.8
	>55	0	1	0	0	0	0.2
6. Educational Levels	Illiterate	0	0	0	0	0	0
	Primary School	2	2	2	2	5	2.6
	Middle School	3	1	2	3	0	1.8
	High School	0	1	1	0	0	0.4
	College or University	0	0	0	0	0	0
7.Crop Growing Areas (mu)	Rice	3	3.5	3	3.5	3	3.2
	Corn	1	3	1.5	6	1	2.5
	Rapeseed	3	2	3	2	3	2.6
	Wheat	1	2	0	3	0	1.2
	Soybean	2	0.5	0	0	0	0.5
	Potato	0	0	0	0	0	0
	Vegetables	0	0.5	0.2	0.8	0.1	0.3
	Total	10	11.5	7.7	15.3	7.1	10.3
8. Crop Yields (kg/mu)	Rice	400	550	380	600	375	461
	Corn	250	490	170	200	200	262
	Rapeseed	83	140	76	90	85	94.4
	Wheat	300	180	0	140	0	124
	Soybean	48	65	0	0	0	22.6
	Potato	0	0	0	0	0	0
	Vegetables	0	0	0	200	500	140
9. Animal Numbers.	Pigs	1	1	4	3	2	2.2
	Goats	0	0	0	0	0	0
	Cattle	0	1	0	0	0	0.2
	Buffalos	1	0	0	1	0	0.4
	Poultry	10	0	25	6	30	14.2
10.Income sources (yuan)	Crops	1453	5010	1156	1452	1854	2185
	Animals	561	0	1740	544	1130	795
	Laboring	2360	0	1780	2330	720	1438
	Others	764	413	277	603	133	438
	Total	5138	5423	4953	4929	3837	4856
11. Expenditures Items (yuan)	Living	3472	2886	2541	3234	2723	2971.2
	Production Materials	831	934	415	650	342	634.4
	Education	0	1000	300	400	800	500
	Social Activities	200	450	250	500	300	340
	Total	4503	5270	3506	4784	4165	4445.6

Table B 8. General Information about 15 households (HH) from Zhuyuan

Items		HH 1	HH 2	HH 3	HH 4	HH 5	Average
1. No. of family members		4	5	5	4	5	4.6
2. Average Age		37.75	29.6	22.6	27.75	36	30.74
3. Sex	Male	3	3	4	2	2	2.8
	Female	1	2	1	2	3	1.8
4. Labor Force	Male	2	1	1	1	1	1.2
	Female	1	2	1	1	3	1.6
	Total	3	3	2	2	4	2.8
5. Years ranges	0-15	0	0	2	1	0	0.6
	15-55	4	5	3	3	4	3.8
	>55	0	0	0	0	1	0.2
6 . Educational Levels	Illiterate	0	1	0	0	0	0.2
	Primary School	1	1	4	1	2	1.8
	Middle School	1	2	1	3	3	2
	High School	1	0	0	0	0	0.2
	College or University	1	1	0	0	0	0
7.Crop Growing Areas (mu)	Rice	2	0	2.2	0	2	1.24
	Corn	3	6	3	3	8	4.6
	Rapeseed	0	0	0	0	0	0
	Wheat	2	0	2	1	2	1.4
	Soybean	2	1	0	0	0.5	0.7
	Potato	2	7	0	1	0	2
	Vegetables	0	0.2	0.5	0	0.5	0.24
	Total	11.2	14.5	7.2	5.5	12.5	10.18
8. Crop Yields (kg/mu)	Rice	400	0	470	0	550	284
	Corn	320	300	500	300	200	324
	Rapeseed	0	0	0	0	0	0
	Wheat	180	0	150	55	75	92
	Soybean	0	100	0	0	100	50
	Potato	2500	1800	0	300	0	920
	Vegetables	0	0	150	0	200	70
9.Animal Numers.	Pigs	4	5	2	1	2	2.8
	Goats	0	20	0	0	0	4
	Cattle	1	2	1	0	0	0.8
	Buffalos	0	0	0	0	1	0.2
	Poultry	20	0	0	7	14	8.2
10.Income sources (yuan)	Crops	3150	2667	820	1244	2504	2077
	Animals	1350	1840	900	0	800	978
	Laboring	0	0	0	2000	100	420
	Others	450	700	300	630	340	484
	Total	4950	5207	2020	3874	3744	3959
11. Expenditures Items (yuan)	Living	810	2784	561	750	2550	1491
	Production Materials	350	742	420	650	850	602.4
	Education	4000	0	100	600	0	940
	Social Activities	250	150	200	500	300	280
	Total	5410	3676	1281	2500	3700	3313.4

Table B 9. General Information about 15 households (HH) from Liulong

	Items	HH 1	HH 2	HH 3	HH 4	HH 5	Average
1. No. of family members		5	6	4	5	5	5
2. Average Age		30.6	39.5	28.4	30.2	39	33.54
3. Sex	Male	2	2	2	4	4	2.8
	Female	3	4	2	1	1	2.2
4. Labor Force	Male	1	1	2	4	2	2
	Female	1	3	1	1	0	1.2
	Total	2	4	3	5	2	3.2
5. Years ranges	0-15	0	0	0	0	0	0
	15-55	5	4	4	5	3	4.2
	>55	0	2	0	0	2	0.8
6 . Educational Levels	Illiterate	0	0	0	0	0	0
	Primary School	2	5	1	4	0	2.4
	Middle School	0	1	3	1	2	1.4
	High School	2	0	0	0	2	0.8
	College or University	1	0	0	0	1	0.4
7.Crop Growing Areas (mu)	Rice	1.8	1	0	0	0	0.56
	Corn	2	5	3	8	4.5	4.5
	Rapeseed	0	0	0	0	0	0
	Wheat	0	0	1	6	2	1.8
	Soybean	0	0	0.2	0	1	0.24
	Potato	1	5	0.5	2	1.5	2
	Vegetables	0.1	0.2	0.3	0.8	0.8	0.44
	Total	4.9	11.2	5	16.8	9.8	9.54
8. Crop Yields (kg/mu)	Rice	375	250	0	0	0	125
	Corn	175	200	180	330	300	237
	Rapeseed	0	0	0	0	0	0
	Wheat	0	0	120	125	185	86
	Soybean	0	0	0	0	50	10
	Potato	2500	1500	0	0	1650	1130
	Vegetables	250	200	130	0	500	216
9. Animal Numbers	Pigs	3	5	5	12	1	5.2
	Goats	0	0	0	0	0	0
	Cattle	0	0	1	3	0	0.8
	Buffalos	1	0	0	0	0	0.2
	Poultry	20	15	12	163	11	44.2
10.Income sources (yuan)	Crops	1080	3520	1421	3214	1367	2120.4
	Animals	920	1850	1780	12400	45	3399
	Laboring	0	0	0	0	0	0
	Others	5620	200	2114	540	1300	1954.8
	Total	7620	5570	5315	16154	2712	7474.2
11. Expenditures Items (yuan)	Living	1914	3362	1897	7424	2124	3344.6
	Production Materials	1241	524	655	3241	750	1282.8
	Education	5000	0	600	0	400	1200
	Social Activities	400	400	360	1740	200	620
	Total	8555	4286	3512	12405	3474	6464.4

Table B 10. Cropping intensity

Cropping intensity (CI): $CI = \frac{TCA}{LAC}$

Where CI = Cropping Intensity
TCA = Total cropped Area
LAC = Land Available for Crops
Xiaotun: CI = 1.85, Zhuyuan: CI = 1.82; Liulong: CI = 1.42

Table B11. Proportion of household and land involved in mixed cropping

	Xiaotun	Zhuyuan	Liulong
Proportion of household	% of household	% of household	% of household
involved mixed cropping	35.71	34.46	62.50
Proportion of land used	%	%	%
for mixed cropping	19.82	31.25	18.57

$$IMC = \frac{PLMC - PLNMC}{100}$$

Where IMC = Index of Mixed cropping
PLMC = Proportion of Land under Mixed Cropping
PLNMC = Proportion of Land not under Mixed Cropping.

Xiaotun: IMP = (19.82-80.18)/100= - 60.36
Zhuyuan: IMP = - 37.5;
Liulong: IMP = - 62.9

Table B12. Use of organic fertilizers in three towns

Towns	Households		% of Area fertilized
	No. of household	%	
Xiaotun	78	100	68.39
Zhuyuan	65	100	87.66
Liulong	57	100	74.33

Table B13. Use of crop residues

Items	Xiaotun				
	corn	rice	wheat	soybean	rapeseed
Remove crop residues	%	%	%	%	%
1. All	33	42	13	38	30
2. Half	34	21	31	15	50
3. Non-removal	33	37	66	47	20
Use of crop residues	%	%	%	%	%
1. Fuel	12	-	54	42	45
2. Feeding livestock	76	91	38	58	23
3. Making manure	12	9	8	-	32

Table B14. Cultivation of leguminous crops in three sites

Towns	Households		Cropland	
	No. of Household	%	Area (ha.)	%
Xiaotun	49	63	313.3	13.3
Zhuyuan	45	69	506.2	20.2
Liulong	53	93	561.7	17.5

Table B15. Interpretation of soil properties in three sites

Soil properties	Soil test values			Optimum range
	Xiaotun	Zhuyuan	Liulong	
pH	6.92	6.35	5.78	6.5-7.3
Organic matter %	2.33	2.64	2.87	1.72-4.04
N %	0.19	0.17	0.17	0.92-1.42
P (mg/kg)	9.75	5.13	6.42	16-24
K (mg/kg)	95.75	129	138	180-226

Table B16 Methods of pests and diseases control by farmers

Methods	Xiaotun		Zhuayuan		Liulong	
	f	%	f	%	f	%
1. Chemical pesticides	78	100	57	88	51	89
2. Other than chemical methods						
3. Both 1 and 2			8	12		
4. Nothing					6	11
Total		100		100		100

Table B17. Average yield and monetary value of major crops (mu)

Crops	Price	Xiaotun		Zhuyuan		Liulong	
	(yuan/kg)	AY	VOY	AY	VOY	AY	VOY
Corn	0.96	324	311	330	317	288	276
Rice	1.18	500	590	363	428	358	422
Soybean	2.2	62	136	26	57	65	143
Wheat	0.9	167	15	117	105	101	91
Rapeseed	1.82	178	324				
potato	0.45	603	271	1202	541	856	385

AY= average yield (kg/ha), VOY= value of yield in yuan,

Table B18. Sources of farmers access knowledge

Sources	Xiaotun		Zhuyuan		Liulong	
	f	%	f	%	f	%
Extension agent	6	8	7	11	10	18
Training	11	14	12	18	16	28
Sellers (seed, pesticides, etc).	8	10	29	45	27	47
Fellow-farmers	66	84	53	82	43	75
Others (radio, Television, etc)	43	55	18	28	40	70

Table B 19. Farmers' training

Training	Xiaotun		Zhuyuan		Liulong	
	f	%	f	%	f	%
1. Attended	11	14	18	28	23	40
Compost preparation	2	3	-	-	2	4
Management	3	4	2	3	4	7
Use of Fertilizers and Pesticides	-	-	11	17	11	19
Others	6	8	6	9	6	11
2. Not Attended	67	86	47	72	34	60

BIOGRAPHY

Mr. Gu Ming was born on August 18, 1963 in Kaili city, Guizhou province, People's Republic of China. He received his Bachelor degree in agronomy from Southwest Agricultural University in Chongqing in 1984, and worked as a teacher in former Guizhou Agricultural University for 6 years after graduation. He came back to pursue his further study funded by the China National Commission of Education, and received a Master degree (Agricultural Systems) in 1992 from the Asian Institute of Technology (AIT) in Bangkok. His present position is a teacher at the Department of Agronomy, Agricultural Institute, Guizhou University, Guiyang, Guizhou, People's Republic of China.

In 2000, he was accepted by the Suranaree University of Technology to pursue Ph.D. in the School of Crop Production Technology, Institute of Agricultural Production Technology. Assist. Prof. Dr. Hatsachai Boonjung is his advisor. His research conducted in the topic entitled "Sustainability Analysis of Farming Systems in Dafang County, Guizhou Province, People's Republic of China".