A FEASIBILITY STUDY FOR A BETTER INTEGRATED UPLAND MIXED FARMING SYSTEM: A CASE STUDY OF TABHING COMMUNE, VIETNAM

NGUYEN THI NGOC PHUONG

MASTER OF SCIENCE

PROGRAM IN NATURAL RESOURCES AND

ENVIRONMENTAL MANAGEMENT

MAE FAH LUANG UNIVERSITY

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ABSTRACT

This research study assessed the potential use of sources of unused organic matter such as livestock manure and agro-byproducts in Tabhing Commune, in the central part of Vietnam. The intent of this study is to propose nutrient recycling processes with higher levels of efficiency within the two main mixed farming system components. Data collection used several approaches, including formal questionnaires, group discussions, field observations, and the ten seed technique. Resource flow diagrams were developed to calculate the realistic availability of community resources. Linear programming models were developed to maximize total farm profits under the constraints of mass balance and environmental protection in order to determine optimum nutrient recycling allocation level.

By utilizing nutrient balance flows on an annual basis, enough livestock manure is available for use as potential fertilizer for crops; volume is estimated as equivalent to 2.0 ton of nitrogen (N), 2.3 ton of phosphate (P_2O_5), and 11 ton of potassium (K_2O). Similarly, the gross output of crop by-products is estimated at approximately 450 ton of dry matter (DM), equivalent to 170 ton of total digestive nutrients (TDN) per year in the study area. Applying the model revealed that utilizing manure nutrient could realize a 13% increase in total income from crop production due to increased yields and recycling of crop residues as livestock feeds could allow farmers to increase their total income by 22%. The net profits from two rounds of recycling can increase total income by up to 45% through utilization of additional nutrient manure gained from increased numbers of livestock and supplied tocrops. When factoring in the risk of livestock death, farmers will gain only a 71% increase in total income. If livestock death is not factored in, farmers will gain a91% increase in total income, from utilizing 20% of available TDN from livestock.

This study reveals that a better farming system using optimum nutrient recycling processes is feasible and can achieve powerful positive results. Specifically, using such a system could help studied villages increase their total profits by more than 50%. Important guidelines on manure utilization and treatment methods to increase the use of crop byproducts are also discussed in this thesis. In order to implement this scheme successfully, however, pilot household farms need to be established, monitored and adjusted properly, along with capacity building for local people on how to apply the newly integrated farming system properly in both technical and managerial terms. Growing grass and forage for livestock feed and providing veterinary services for animal health care should also be taken into consideration for further study.

Keywords: integrated crop-livestock farming system / livestock manure / crop by-products / optimum nutrient recycling / farm profit maximization.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

Tables **Page**

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADB : Asian Development Bank

BCI : Biodiversity Conservation Initiatives

FAO : Food and Agriculture Organization

FFTC : Food and Fertilizer Technology Center

GMS : Greater Mekong Subregion

GHG : Green House Gases

MFU : Mae Fah Luang University

NUFLUX AWI: Nutrient Fluxes Area wide Integration

NREM : Natural Resource and Environmental Management center

NTFPs : Non-Timber Forest Products

IUCN : International Union for Conservation of Nature

IIRR : International Institute for Rural Reconstruction

ICLARM : International Center for Living Aquatic Resource Management

NGOS : Non-Government Organizations

IFAD : International Fund for Agricultural Development

PRA : Participatory Rural Appraisal

VAC : Garden, Fish Pond, and Livestock Pen

VND : Vietnam Currency

VISTA : Vietnam Information for Science and Technology Advance

CHAPTER 1

INTRODUCTION

1.1 Background

In Southeast Asia, numerous small household farms can be found in mountainous areas (with an average size of two hectares or less) that mainly produce crops and livestock (Devendra & Sevilla, 2002). With rapid increases in both human and animal populations, even evident land use policies that try to limit expansion of farming into forests and pasturelands have not stopped vast amounts of land from being degraded. These changes impact upland farmers who rely on natural meadows and forests to provide fodder for their free-roaming buffalo and cattle (Castella et al., 2002a). In addition, use of sustainable farming systems in mountainous areas within the countries of the Greater Mekong Subregion (GMS), including Vietnam, has become ever more important in recent years due to the need to achieve a better balance between economic development and environmental protection. Small and marginal farmers in the uplands region have traditionally used sloping upland areas (hills and mountains) for subsistence farming despite these areas typically producing poor yields and low farm productivity. Often, these are the only lands available to them for farming. Such areas are very sensitive to the negative impacts of agricultural expansion. Since these farming systems are not sustainable, these areas suffer from widespread soil erosion and land degradation. Over time, farming here produces poorer and poorer results. Since the agricultural de-collectivization program in Vietnam at the end of the 1980s, successive land reforms have driven the poorest of the mountain people back to their ancestral practices of shifting cultivation (Castella et al., 2002b). In their current environmental and institutional context, these marginalized households have resorted to reducing the amount of time that uplands are allowed to remain fallow, thereby degrading the fertility of cultivated soils and exacerbating erosion (Husson et al.,2001). In some countries in the Asian region, productivity of animals remains very low, although experimental data suggest that their production potential is high. Raising livestock has growing economic potential due to increased market prices for both meat and milk elsewhere in Asia as well as in Vietnam. However, a shortage of feed and forage is the greatest constraint to livestock productivity. Animal nutrition and chronic shortages of forage resources currently constitute major constraints on livestock production across Southeast Asia (Devendra & Sevilla, 2002). Some countries in the region import cereal grains to try to increase livestock production and meet the ever-increasing demand for animal products. Although growth of dairy production can place more pressure on land resources, it can also increase the use of crop by-product, in turn improving nutrient recycling and, if of high quality, can diminish methane production. In order to improve the quality of life of farmers dependent on sloping farmlands, further efforts are needed to identify appropriate production options that are both environmentally stable and economically productive over the longer term. Slash and burn cropping systems have had a significant impact on natural resources in this region. Effective natural resources management in mountainous regions needs to adopt a holistic approach, at the same time taking into consideration livestock systems, cropping systems, and the broader environmental and socio-economic context in which agricultural production is occurring. Higher livestock productivity, however, should be sought instead through better use of locally available feed resources such as crop by-products, forage, and natural grasses. Crop residues, agro by-products, and animal wastes, which are available in appreciable quantities in the region, can play a significant role in providing nutrition to ruminants (FAO, 1995).

The six GMS countries endorsed a Biodiversity Conservation Initiative (BCI) Project at the second GMS summit in July 2005. The BCI seeks to meet human welfare and ecological protection needs in GMS economic corridors through improved conservation and sustainable use of natural systems. The initiative pays special attention to poverty reduction and biodiversity conservation by improving the services that healthy ecosystems provide and by expanding the livelihood options available to local communities (ADB, 2009). As a student assistant in this project, the author took part in four field surveys in Tabhing Commune of Quang Nam Province, in Vietnam's Central Annamite region. These field surveys focused on four villages (Pa Ia, Pa Va, Pa Xua, and Za Ra) with a total of 221 households. These surveys were carried out from 2007 to 2009 to collect basic baseline socio-economic information (including data on livelihood status, poverty incidence, and land and forest resources management) to produce reports in socio-economic and land use assessment.

Going beyond the ADB's general socio-economic assessment project, this study focused on traditional slash and burn agricultural cultivation practices of ethnic minority populations in the same four villages to identify significant problems and seek appropriate solutions to improve existing systems of traditional agriculture in combination with adoption of options available to local communities to alleviate their poverty. The research aims to provide new insights into efficient land use practices and provide innovative approaches to achieve sustainable land use management strategies beyond those that implementing agencies have so far adopted in the BCI. In addition, the intent of this research is to find ways to improve local livelihoods and standards of living with minimal negative impact on biodiversity and landscapes. Lastly, the results will be useful for implementing agencies in their future work within the BCI, ultimately contributing to poverty reduction and collaboration in forest resource protection and management of the BCI program in Vietnam.

1.2 Statement of the Problem

The people of Tabhing Commune have adopted three main activities to meet their subsistence needs for household consumption and income generation: shifting cultivation, NTFPs collection, and home-based agriculture (including raising livestock, fishing, and planting fruit trees and vegetables) (IUCN, 2007). Unfortunately, a significant number of important agricultural problems exist in this area, as summarized below.

1. Crop yields are low. Agricultural practices in this area remain underdeveloped, with few, if any, soil and water conservation measures being used and no soil fertility nutrients being added other than by burning. Most agriculture here is rain-fed, with little in the way of available irrigation systems. Shifting cultivation is used in areas with very steep slopes; people share common access to these planting areas under customary and traditional usage rights. After 2-3 crop cycles practiced here without terracing or any erosion control methods, run-off and topsoil removal plus lack of motivation and limited participation in extension activities by the community despite support from agricultural extension organizations resulted in soil degradation

and declining crop yields. Local people claim that they are not familiar with modern farming techniques, which they believe to be inapplicable in their location. Agricultural products of poor quality and quantity are generated, with their total value being less than the combined total of all forest products being collected (without even attempting to include a value of the ecological services of the forest on which agriculture depends) (IUCN, 2007). Rice productivity is estimated to be about 3 to 3.5 ton/ha/yr for paddy rice but 0.9 ton/ha/yr for upland rice; these low amounts are only enough for subsistence for about 6 months per year (People Committee of Tabhing Commune, 2007).

2. Livestock production is also limited in both quality and quantity. Animal feeding still relies on extensive roaming on meadows and forests. Post-harvest residue resources constitute poor quality feed. There is no veterinary treatment. Lack of capital is a major constraint for local people, particularly the poor who want to increase animal productivity and improve their income but to date have generally been unable to do so.

3. Integration of the area's crop-livestock system is weak. There is little or no understanding of the potential for composting or use of green manure, especially of ways to use existing animal manure. Such activities still exist separately and inefficiently in practice.

Hence, farming system analysis is required to identify existing opportunities to increase crop yields and animal husbandry in terms of waste recycling. Integrating the area's varied components of crop and livestock production in an upland agriculture system is a priority requirement to enhance farming outputs while safeguarding the environment at the same time.

This study aims to answer the following primary question: How can upland farmers increase the potential *productivity of their farming resources through adoption of a more efficient integrated crop-livestock farming system while conserving the area's natural resources?* In addition, the following sub-questions are to be addressed:

How to estimate the nutrient potential from livestock and crop components?

How to efficiently optimize nutrient allocation in crop-livestock integrated farming system, using potential waste recycling, quantification of various interactions, and evaluation of system efficiency?

How to develop a suitable (optimization) model to select the most appropriate (technical, socio-economic, cultural, environmental) options among various possible mixed farming options?

1.3 Study Rationale

The potential benefits of livestock production in terms of income and increasing demand for livestock products presents opportunities for those local small farmers who have the ability to apply it. In terms of environmental impact, a growing number of livestock can have a negative impact on natural resources unless actions are taken to identify farming practices that are ecologically sustainable as well as economically attractive. The dynamic interaction of the various components of a highly improved integrated crop-livestock system can guarantee more sustainable production. This policy therefore constitutes a valid new approach requiring detailed analysis.

Experience in use of this system has shown that: (a) adopting sustainable management practices can improve production while preserving the environment; (b) residues, wastes, and by-products of each component can readily serve as resources for the others; and (c) poor farmers have the traditional experience-based understanding needed to integrate their livestock and crop production. Because of their limited access to knowledge, assets and inputs, relatively few actually adopt such an integrated system. In addition, slash and burn practices are connected closely to traditional cultivation practices of mountain communities.

This study explores the feasibility of using an integrated mixed farming system in Tabhing Commune based on existing socio-economic and land use data sets available from NGOs, government agencies, and the recent BCI project in this area. Some case studies will be observed for improvement of existing farming systems in combination with adoption of new ventures, such as cattle raising, fish production, crop productivity improvement, or efficient nutrient management. These modifications may enhance household food security better than by trying to replace existing methods with completely new “modern” farming systems. Tabhing Commune farmers can increase the productivity of traditional farming systems through adopting an effective integrated system that produces usable biomass while conserving natural resources, and can therefore be sustainable in the long term.

1.4 Study Objectives

The main aim of the study is to identify and then develop an appropriate upland mixed farming system designed to increase the potential productivity and profitability of farmers through more effective nutrient resource utilization under local contexts (technical, socio-economic, cultural, environmental conditions). In line with this aim the study tries to achieve the following specific objectives:

1. To assess potentials of unused organic matter sources such as livestock manures and agro (crops) by-products in surveyed villages through nutrient flows diagram.

2. To propose nutrient recycling processes with higher level of efficiency within the two main components of integrated crop-livestock farming systems.

1.5 Scopes and Limitations of Study

1.5.1 Scope

The study was conducted in an upland region where livestock production and agriculture are integrated in a mixed farming system. The research focuses on assessing the potential of livestock manure and agricultural by-products to find out the feasibility of recycling those wastes within this farming system. Livestock in the study included such ruminants as cattle, buffalo and goats. Findings of the study will be useful to encourage local people to use available organic manure resources to improve their traditional production methods and agricultural productivity as well.

1.5.2 Limitations

In survey design and interview structure, due to the remoteness and the high illiteracy rate in the target community, misunderstandings may emerge in a written interview survey, presenting a poor response rate. As a result, it was necessary to conduct oral interviews. Moreover, the questionnaires contained opened-ended questions to encourage interviewees to provide detailed responses and to elaborate when necessary. Household interviews were mainly carried out in people’s homes where they would feel comfortable and relaxed. The study focused on the current farming system in Tabhing Commune to identify appropriate options, without formal testing. In addition, the study conducted social surveys on livelihood conditions. Due to time, security, and financial constraints, collection of some technical information that should have been done by scientific methods was not possible. The research selected four villages (Pa Ia, Pa Va, Pa Xua and Za Ra) as representatives of the specific characteristics of Tabhing Commune as a whole. In statistical analysis, a thematic coding approach was used to identify respondents' responses to semi-structured interviews to limit errors caused by unexpected situations.

Soil characteristics in the studied area are not available, so some soil characteristics were based on reports by the FAO and case studies from researchers such as Dang (2001). Thus, data inputs for the optimization model are assumed, based on some related articles, to predict and give suitable options for allocating nutrient sources efficiently in a mixed farming system. An example that the assumption of crop yields increased 1.5 times when compared to the current status.

CHAPTER 2

LITERATURE REVIEW

Based on the major study objective, literatures specifically related to livestock production and crop cultivation components in the crop-livestock integrated farming system were reviewed in order to obtain wider theoretical knowledge on the concerned subject matter. Literatures regarding concepts of mixed farming system, interaction between livestock and crop sub - components in such systems, and methodologies of recycling waste and their applications were reviewed in detail to be more specific on the subject matter. Since the study used a linear programming approach to determine the optimum manure nutrient allocation to crops and optimum crop residue allocation to animals, literatures related to the theoretical concepts, assumption, and some past case studies that used linear programming tools were also outlined to provide sufficient knowledge to fulfill the study's objectives.

2.1 Mixed Farming Systems in Upland Regions

2.1.1 Concept of Mixed Farming System

Any farming system consists of a complex arrangement of soils, water sources, crops, livestock, labor, and other resources and characteristics within an environmental setting that the farm family (or corporate farm manager) manages in accordance with their own particular preferences, capacity and available technologies (Shaner et al., 1982). Farming systems are classified into groupings based on their primary components; these groupings include shifting cultivation system, lowland rice-based system, cereal-based system, irrigated smallholder farming system, smallholder farming system with plantation crops and agro-forestry system (Beets, 1990). An upland farming system can be characterized as one that reflects mutual interaction among its different components like crops, livestock, and forestry. As such, it is considered a mixed farming system that is complex, diverse, and predominantly subsistence in nature (Dahal, 1997). Upland farming systems are often characterized by three dimensions: food sufficiency, environmental stewardship and socioeconomic characteristics. Food sufficiency is the ability of agricultural systems to produce food in sufficient quantities to meet the demand of the population over the long term. System sustainability has been increasingly associated with maintenance of environmental quality both on and off the farm. Maintenance of environmental quality essentially means preservation of the productive capacity of the land and associated water resources. Economic and social concerns can be addressed as maintenance of community systems by food efficiency, fair distribution of benefits, institutional support and stewardship values, and generational equity. Upland cultivation will be a destabilizing force in the pace and security if environmental and socioeconomic conditions of dwellers are not improved.

As a closed system of agricultural production, upland farming is probably the most benign system of all from an environmental perspective. The waste products of one system component (crop residues, for example), which would otherwise be loaded back onto the natural resource base, are used by another component (livestock, for example), which returns its own waste products (manure) back to the first one. With more benefits and many opportunities for recycling and organic farming and for a varied, more attractive landscape, mixed farming is the favorite system of many agriculturalists and environmentalists. In particular, farmers have an opportunity to diversify their risks away from single crop production, use labor more efficiently, have a source of cash to purchase farm inputs, and add value to crops or crop by-products (de Hann et al., 1997).

In addition, such a mixed farming system also offers benefits in terms of environmental protection. Environmentally, this system can maintain soil fertilizer and soil biodiversity, make the best use of crop residues, and allow intensified farming as well. For example, rotation of various crops and forage legumes and trees will recycle soil nutrients or allow land to remain fallow and grasses and shrubs to become reestablished. Moreover, this system minimizes soil erosion, helps to conserve water, provides suitable habitats for birds, and makes the best use of crop residues. In tropical semi-arid areas, termite action results in loss of nutrients before the next cropping season, and burning, the other alternative, increases carbon dioxide emissions. Finally, the mixed system allows intensified farming, with less dependence on natural resources. This helps preserve biodiversity in contrast to meeting food demands by crops and livestock activities undertaken in isolation (FAO, 2005).

Mixed crop-livestock systems constitute the backbone of much agriculture in the tropics. With increased population density and less land available, greater integration of crop and livestock production becomes an effective means by which plant nutrients can be rapidly recycled within and between farms. On the other hand, the factors driving intensification often lead to expansion of cropped areas and more intensive cropping practices at the expense of grazing land. In the face of declining grazing land the potential of arable land to provide fodder throughout the year must be enhanced, if the important role of livestock within the farm system for household welfare is to be maintained or developed (Thornton, 2001).

2.1.2 Livestock Subsystems

Livestock, particularly ruminants, traditionally graze in natural pastures, forest areas, roadsides, and fallow lands, or consume crop re-growth or crop residues such as straw, bran, oilseeds, and other by-products. When abundant feed is available, livestock can be considered a form of wealth, power and security, a perception based on their conversion of solar energy captured in biomass into products valuable for human society. In a more intricate way, animals in mixed crop–livestock systems help to sustain crop yields by increasing the rate of nutrient flows. Grazing by livestock usually follows rather than precedes deforestation and/or cropping. In fact, animals -- goats, in particular -- are one of the last means of survival for large numbers of poor people on bare, exhausted, or arid lands.

However, in spite of the importance of animals for the poor classes of farmers, advocates for continued animal production on exhausted soils acknowledge that livestock can tip the final balance in delicate ecosystems (Schiere et al., 2002). Animal husbandry has been considered as an important activity to ensure livelihood security of smallholder farmers in mountainous areas in Southeast Asia due to following many reasons:

1. Livestock can be sold at any time on a market with relatively constant demand and stable prices.
2. Cattle, buffalo and goats can be walked long distances to market.
3. Livestock provide manure to sustain yields of lowland rice and home gardens.
4. Livestock give a relatively high return per unit of labor input.
5. Larger animals eat feed resources that cannot be used for any other purpose.

6. In many cases, livestock are the only means of capital accumulation available to farmers.

7. Livestock are less susceptible to drought and floods and, unlike crops, can be sold in case extreme conditions emerge.

Livestock are raised in extensive, low-input systems that take advantage of naturally occurring feed. Almost all livestock in upland areas are native breeds that are well adapted to the extensive production systems used under local conditions. There is great potential for further livestock development as feed resources are available for cattle and buffalo production in uplands, in addition to many introduced technology options to improve livestock production. Besides, demand for livestock products in Southeast Asian countries has grown substantially over the last decade and is likely to continue to do so in the future. In 2000, demand for ruminant meat was over 4kg per capita and demand for non – ruminant meat was over 25kg per capita, with demand growing ever since. In 2010, ruminant meat demand is anticipated to exceed 6kg per capita, and non – ruminant meat is expected to exceed 35kg per capita (Verco et al., 1997). In Laos, about 75% of cattle and buffalo produced are consumed domestically with the remainder exported. Thailand is a major market for live cattle and buffalo with Laos supplying approximately 20% of the annual demand. However, substantial constraints on livestock cultivation still exist in upland areas; these include disease, adequate forage resources, availability of vaccines, access to credit, market prices, labor availability, etc. (Stur et al., 2002). Improved feeding and animal management, combined with strategic use of veterinary medicines, can provide effective, achievable and sustainable solutions. In many countries, use of available forage has proven to be a useful entry point to engage farmers in solving their immediate problems with livestock feed shortages (Misra et al., 2007; Peters et al., 2001). Livestock management is understood and applied as a means of determining the extent and value of nutrient flows in agricultural landscape by small-scale farmers in Asia (Thorne, 2002).

Livestock production units emit gases that contribute to global warming, eutrophication and bad odors. European emissions inventories show livestock production constitutes 70-80% of total ammonia emissions (Ecetoc, 1994). Atmospheric concentrations of methane (CH_4), a greenhouse gas, have increased 45% since 1850 (Lelieveld et al., 1998). Livestock manure is estimated to contribute 5% to total emissions of CH_4 in the 1990s (Lelieveld et al., 1998;

Steinfeld et al., 2006). Emissions of nitrous oxide (N_2O), a very potent GHG, have increased from 11 Tg per year (1 *Tg*=1 million ton) in 1850 to 18 Tg per year in the mid-1990s, mainly due to increases in agricultural sources (Khalil & Rasmussen, 1992). Manure has contributed significantly to this increase.

In the next 20 years there will be increasing demand globally for food from animal raised in developing countries (Delgado et al., 1999). Clearly this offers a vast opportunity for livestock producers in the tropics to meet this rising demand. There are also profound implications for evolving livestock production systems, affecting the environment and smallholders' welfare as a result. The challenges and opportunities depend very much on the region and the specific systems under consideration. Grazing systems, for example, currently use almost a quarter of the world's land area and produce one-tenth of its meat requirements. Livestock, and particularly ruminants, will continue to play key roles in providing draught power, manure to maintain soil fertility, animal food products, and opportunities for increased income generation. It seems likely that much of the developing world will emphasize milk production in crop–livestock systems involving ruminants, largely because of milk's ability to generate daily income for smallholder households. If productivity is to increase because of increasing demand and increasing land pressure, then there are real research needs to enhance the complementarity between crop and livestock production (Thornton, 2001).

2.1.2.1 Organic resources and livestock

The interactions between organic resources and livestock revolve mostly around the supply of nutrients and energy in feed. Some organic matter may also be used as bedding material for animals. However, this is generally associated with the effective trapping of voided nutrients in feces and urine and is, therefore, more properly associated with the livestock-land interface. Hence, the need is to use capable predicting models of the interface between given plant and animal characteristics (Thorne, 1998).

These nutritional inputs can be managed indirectly, in a grazing or browsing situation; or they can be applied directly by offering feed to stall-feed livestock. In most grazing situations, animals have considerable freedom in choosing what to eat, although the manager can control the length of time in which they have access to the food. Stall-feeding is common in mixed farming systems because it allows farmers to exert more control over the valuable manure outputs of their animals. It also reduces the possibility of free-ranging livestock causing damage to crops (Thorne, 1998). Some systems graze stall-fed livestock periodically as well, often at a particular time of year when seasonal factors make this desirable.

2.1.2.2 Livestock and land

An obvious interaction between livestock and land is through the management of stocking rates, which plays a large part in defining the productivity of grazing systems. Livestock–land interaction also includes production of manure and compost and provision of draught animal power. Livestock play a key role in cycling nutrients to crops, wherever the two are associated (Thornton & Herrero, 2001). To date, few attempts have been made to derive integrated models in which dynamic processes in livestock are linked with dynamic processes in soils in the tropics.

In general, draught animals are used to manage soil through tillage operations, although their role in support of crop processing and marketing activities is important in some situations. Farmers' perceptions of draught animals in mixed farming systems are often ambiguous (Thorne, 1998). Access to them is seen as essential when land preparation must be carried out. However, sometimes it is costly to feed and care for draught animals.

2.1.3 Crops Subsystems

Sloping upland areas dominate most of the countries in Southeast Asia and China. The South China subtropical red and yellow soil regions occupy an area of 218 million hectares, 90% of which is located in mountainous or hilly areas. About 35% of Thailand is hilly and mountainous; most of these areas are concentrated in the northern and western parts of the country. Hilly lands in the Philippines are estimated at 9.4 million hectares, or about 31% of the total land area. Steep lands occupy 4.7 million hectares, or 36% of the total land of peninsular Malaysia. In Vietnam, sloping lands occupy 25 million hectares, or 75% of the country's total area.

These upland areas are characterized by a diversity of crops and trees. In general, vegetation in the sloping uplands is composed of *Imperata* (cogon) grass, native grasses, and short shrubs, particularly in those areas that are left fallow. In areas that are cleared for agricultural production, as in shifting cultivation, a number of annual crops are grown. As observed in the Philippines, the newly cleared forest area is further cleared of unburned materials at the start of the rainy season. Rice, corn, and other annual crops are dibbled into the soil, using a pointed stick. In the uplands of the northern provinces of Vietnam where shifting cultivation is also commonly practiced, short maturity crops such as rice, maize, cassava, and beans are usually grown (Maglinao, 1998).

In tropical Asia, farms that currently only grow crops have the potential to expand into an integrated farming system incorporating animal husbandry that uses crop products such as green manure or compost for their cropping subsystem or livestock feeding. Crop residues and agro-industrial by-products play a significant role in the nutrition of ruminants in such Southeast Asian countries as Vietnam, Laos, Thailand and Cambodia. Many countries have no data on by-products. In Vietnam, the main parts of the grazing land are hilly, sloping land and over grazing are common; here, agro-byproducts are abundant. These include rice straw, maize stoves, groundnut vines, sweet potato creepers, cassava tops, sugar cane leaves, pineapple tops, and pineapple wastes. Only small amounts of these products are now used as ruminant feed, while the main part is left on the field and then burned (or small amounts are used as fuel by smallholder farmers) (Chinh & Ly, 2001). To understand how to use agro-byproducts efficiently, it is important to know their quantities, seasonal availability, alternative uses, nutritive value and their location versus that of livestock industries. Finally, it is recommended that before setting research priorities, possible beneficiaries should be identified; also, governments, through various means, should promote use of by-products and technology for which there is sufficient knowledge.

Agricultural production activities in upland areas have been known to cause land degradation. In coastal Kenya, farmers are aware of the problem of declining soil fertility caused by continuous cropping without returning nutrients; soil erosion, burning of plant residues, short fallow intervals in food crops production, overgrazing and shallow cultivation are all involved (Mureithi et al., 1996). In addition, loss of soil organic matter and soil farming techniques have been identified as major problems associated with soil degradation in upland regions of Vietnam including the Northern uplands, Northern – Central area, and Central Coast (Dollar et al.,1998). These regions, with limited arable land, less irrigation area, and predominantly sloping hillsides, are susceptible to loss of organic matter. These real-world examples illustrate the importance of modifying and adapting techniques for soil fertility management so that they fit well in local conditions.

Agricultural management in the uplands involves use of erosion control techniques for organic matter retention, as well as addition of organic matter for soil recuperation or restoration. Technologies such as using green hedgerows along contour lines, application of improved tillage techniques, green manure and cover crops (intercropping with legumes species), as well as extension work aimed at stimulating methods for soil improvement, are considered more suitable for farmers' situation in Vietnam (Dang & Klinnert, 2001). Doanh & Tuan (2004) stated that "it is necessary to stop burning and make the best use of crop and natural vegetation residues to improve soil fertility. After soil productivity is restored, it is advisable to adopt no-till or minimum tillage technologies, mulching and planting techniques that reduce soil erosion. Systems approach taking into account the interactions of all inter-related factors (e.g., crop production, animal husbandry, forestry, people, socio-economic and cultural life, customs, agro-ecological and edaphic conditions, etc.) should be used for designing sustainable mountain technologies on sloping lands. In a participatory manner, one should try to understand the inter-relations of different components of farming systems."

Efforts have been made to develop sustainable upland farming practices that can be adapted by a large number of ethnic minority people. Among these, agro-forestry (AF) is considered appropriate. However, to date AF has generally failed to bring about any widespread change in farmers' practices in Southeast Asia (Morrison et al., 1998). Many poor farmers in remote areas, including forest dwellers, cannot access extension services, or they find the recommended technologies too complicated and expensive in required external inputs (Cai et al., 2000). Market services also remain a great challenge for choosing appropriate AF techniques to adapt by researcher, institutions and these farmers. In summary, agroforestry is not a stand-alone approach to conservation. It needs to be seen as one element of a broader conservation strategy that also includes policy and institutional changes and spatial configurations that emphasize maintenance of natural habitats (Swallow et al., 2005).

2.1.3.1 Organic manure and its effects on soil quality and crop yields

Organic manure is bulky organic material, mainly plant and animal excreta, which is returned to the soil either directly or after some degree of processing. It often contains high water content (95% in slurries and 75% in farmyard manure). Such manure has low nutrient concentrations; hence application of 25-40 ton/ha of organic manure is needed to supply some 20-30% of a potato crop's nutrient requirements. Organic manure naturally supplies organic matter to the soil, adding a wide spectrum of plant nutrients to crops (Minh, 2005).

Organic manure includes several sub-categories: traditional farmyard manure, liquid manure, processed organic manure and crop residues returned to the soil (Simpson, 1986). Among the full range of organic manure sources, wastes and by-products of crop cultivation, animal husbandry, forestry, and green manures have been considered the most abundant resource for upland regions particularly. Values of major nutrients (N, P, K) in different types of organic manures from several countries are shown in Table 2.1.

Table 2.1 Values of Major Nutrients in Different Organic Manure Used in Various Countries

Organic manures		**Moisture and nutrient content (%)**			
		Moisture	**N**	**P**	**K**
UK					
Poultry manure	deep litters	32	1.7	0.9	1.1
	broiler litters	32	2.3	0.9	1.1
	poultry - droppings compost	75	1.2	0.4	0.4
	straw-dropping compost	65	1.1	0.9	0.8
	deep litters manure	35	1.9	1.6	1.2
	turkey manure	55	1.2	0.6	0.7
Cattle manure	farmyard manure	76	0.6	0.1	0.5
	feces (fresh)	85	0.4	0.1	0.1
	pig manure	97	0.2	0.1	0.2
Town refuse	municipal	35	0.5	0.2	0.3
	gondard process	20	0.6	0.3	0.2

Table 2.1 (continued)

Organic manures		Moisture and nutrient content (%)			
		Moisture	**N**	**P**	**K**
Town refuse (continued)	wood ash	2	0.1	0.3	1
USA					
Chicken manure	from board, no litter	54	1.6	0.4	0.4
	with litter	61	1.7	0.6	0.6
Cattle manure	dairy cattle	79	0.6	0.1	0.5
	fattening cattle	80	0.7	0.2	0.4
	pig manure	75	0.5	0.1	0.4
	horse manure	60	0.7	0.1	0.6
INDIA					
Poultry		55	1	0.8	0.4
Cow and buffalo manures		92	1.05		
	urine	85	0.43		1.3
	dung	85	1.35	0.2	0.15
Sheep manures	urine	60	0.7	0.05	2
	dung	97	0.4	0.5	0.4
Pig manures	urine	80	0.5	0.15	0.4
	dung		0.3	0.55	0.45
	paddy straw		0.4	0.1	0.7
	cholam straw		0.65	0.25	2.1
VIETNAM					
Pig		82	0.8	0.41	0.26
Buffalo		83.1	0.29	0.17	1
Horse		75.7	0.44	0.35	0.35
Chicken		56	1.63	1.54	0.85

Source: Cooke (1975) and Mariakulandai & Manickam (1975). Modified by Minh (2005)

Organic manure has been used in different forms depending on the purposes and conditions of each region. Each type has different effectiveness. Fresh manure, such as straw, has temporary effects on the soil and reduces nutrients that are immediately available to plants. Composted manures have been used in China, India, and Japan. Organic manure often creates the basis for successful use of mineral fertilizers (FAO, 2000a). The combination of organic manure and mineral fertilizers provides an ideal soil amendment for crops, as the organic manure improves soil properties while the mineral supplies the nutrients needed by plants.

Green manure is used globally for different crops. In China, green manure promotes improvements in soil fertility and productivity. This includes a winter fallow period used to grow green fodder; intercropping sweet clover or hairy vetch with maize to increase the land equivalent ratio; intercropping cereals with legumes that provide fresh vegetables or grain for animal feeds, human foods or industrial use; and growing potassium-rich green manures to overcome soil potassium deficiency (FAO, 1995). In India, the most popular techniques are green manuring and green leaf manuring. Green manuring is practiced by growing and incorporating legume crops into the same crop fields, while green leaf manuring is practiced by applying to the crop fields plant materials brought in from outside.

The fertility and productivity of soil generally correlates with the soil's organic matter. Soil organic matter is derived mainly from organic manure, particularly from plant residues. The role of organic matter has been fully established on the various physical properties (structure formation, water movement, retention and availability of moisture and aeration in the soil), chemical properties or functions and biological activity of the soil. Considering all mentioned aspects, organic manures are rightly called the key to soil fertility (Mariakulandai & Manickam, 1975). Part of organic matter is converted to humus, which remains in the soil. In addition, it improves soil structure, reduces soil erosion, increases soil temperature, helps the soil to restore more moisture, and provides necessary food for the soil microorganism, thus significantly feeding and structuring the soil (FAO, 2000a).

Farmyard manures applied in the winter or spring effects have differential impact on crops' yields. The most profitable yield increases usually occur in crops of potatoes, mangoes, turnips and vegetables. Application of 25 to 30 ton/ha of farmyard manure increased yield of potatoes from 7 to 13 ton/ha (Simpson, 1986). Research in Thailand on applied organic manure in rice, with chicken manure and cattle manure and rice straw, increased the yields of these respective rice varieties (FAO, 1995).

2.1.3.2 Supplementing crop residues and other by-products

There is no doubt that crop residues, particularly cereal straws, are the major source of feed for cattle and buffalo in South Asia. However, the picture is not sufficiently clear particularly in relation to the type and quantity of by-products fed to livestock and the seasonality of feeding. Ad hoc surveys have often pointed out the wide variation that exists in by-product utilization between and within countries. Information is urgently required not only on the total availability of different by-products in each country but also on their availability in relation to the needs in different parts of the country.

Use of urea-molasses-mineral blocks with untreated residues in practical feeding systems should be thoroughly investigated; if proven satisfactory, this could be one of the simplest ways of increasing use of crop residues in the region. Special mention must be made of the necessity for further biological research in the use of fungi and extracellular enzymes. Rapid development of genetic engineering will probably allow manufacture of ligninases in the future. If economically feasible, this could have major application for improving the nutritive value of crop residues.

Although some information is now forthcoming on the influence of supplementing straw-based diets on voluntary feed intake, digestibility and production (milk, meat and draught power) more information is still required, particularly for by-products other than cereal straws. Sugar cane bagasse, cane tops, corn stover and corn cobs are some major by-products that need immediate evaluation.

Supplementation should be made by way of small quantities of green forage, tree fodder legumes (*Glyricidia maculata, Leucaena leucocephala),* industrial by-products (tea wastes, oil seed meals), non-protein nitrogen (poultry litter) and minerals. The effect of different levels of supplements on intake and digestibility of the basal roughage and on production parameters need monitoring. Nutritional studies should be accompanied by economic evaluation, particularly related to small farmers and low levels of productivity.

Studies on the effect of plane of nutrition, using residue-based feeding systems, on reproductive performance and disease resistance need investigation. Improved nutrition will generally improve animals' reproductive performance. This may particularly be true with water buffalo. Incorporating straw and other crop residues in feeding systems suitable for small farmers in the region requires further study. Investigations should be directed towards establishing maximum levels of inclusion of basal roughage for optimizing production.

It is frequently claimed that the buffalo has a greater capacity to consume and digest low quality roughage compared with cattle. They are also credited with being more capable of using non – protein nitrogen than cattle. However, the experimental evidence is not clear and more careful research is needed. Similarities between species will allow extrapolation of nutritional information gained with cattle to buffalo and vice versa. Given the importance of buffalo in this region, if they are shown to be more capable in using fibrous residue than cattle, the evidence will promote development of farming systems comprised of by-product and buffalo components.

Judging from the research priorities for the region, it is evident that rigorous research has to be conducted without delay. However, lack of qualified scientific personnel and facilities for research and extension are two of the major constraints that appear to limit research and development in this region. Poor remuneration and other hardships have driven many qualified personnel away from their homelands looking for greener pastures in the developed world. Improving junior scientists' capabilities through short-term, intensive training courses could be one way to overcome the present shortage of personnel. A more permanent solution to the problem would be to persuade respective governments to provide better facilities and incentives to their scientific personnel involved in research and development.

2.2 Integrated Agricultural System Models

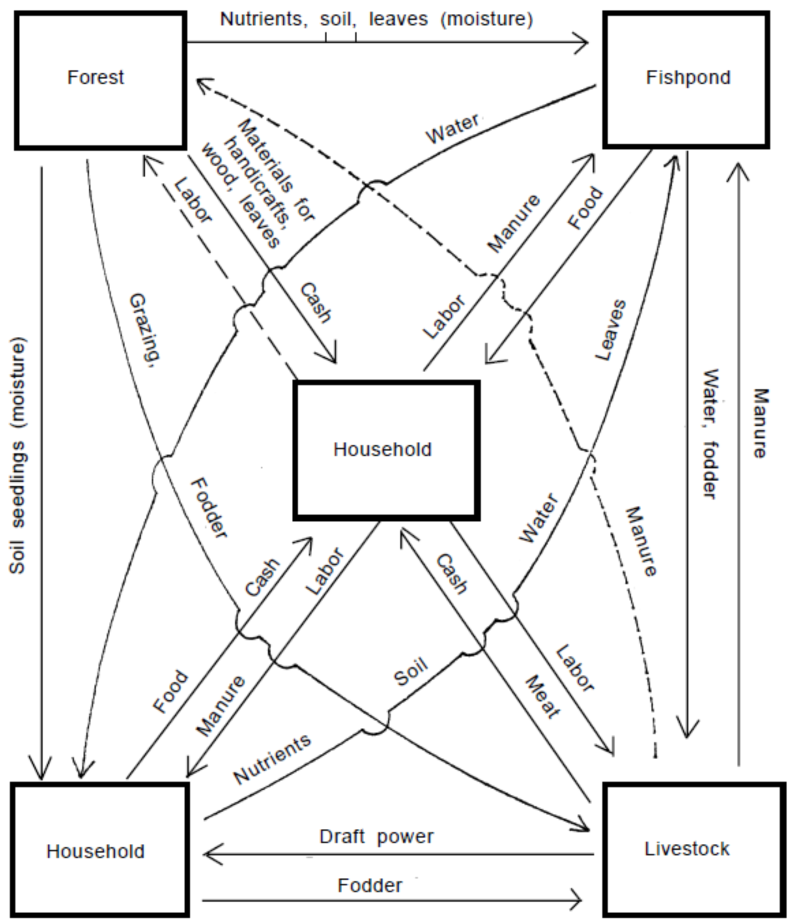
Increasing the linkages between crops and livestock is an effective means by which plant nutrients can be rapidly recycled within and between farms. On the other hand, the factors driving intensification often lead to expansion of cropped areas and more intensive cropping practices at the expense of grazing land. In the face of declining grazing land the potential of arable land to provide fodder throughout the year must be enhanced, if the important role of livestock within the farm system for household welfare is to be maintained or developed (Thornton & Herrero, 2001).

A wide range of integrated agriculture–aquaculture systems are in use in Asia, especially in China, Indonesia, Malaysia, Thailand and Vietnam (IIRR, ICLARM, 1992; and FAO, 2000b). The idea is to bring aquaculture to resource-poor, small-scale farmers who have limited access to the off-farm inputs necessary to exploit modern farming technology. Fish are produced by recycling byproducts of agronomy and animal husbandry into animal protein. Nutrient-rich pond water and mud are potential resources for adjacent crop products. Aquaculture thereby becomes the third partner alongside existing crop and livestock farming subsystems on small-scale farms. The cost of raising fish in such integrated farming systems would be lower than in systems using pond inputs from agro-industry and would be feasible for small-scale farmers.

Two case studies of intensive mixed farming systems are found in the uplands of Java, Indonesia and the mid-hills of Nepal. These examples show how management practices have developed over centuries to enhance the contribution that livestock make to motivating and moderating nutrient flows on very small and continuously cultivated land holdings. The paper concludes by emphasizing the urgent need to understand the biological mechanisms that enable livestock to contribute to the sustainability of intensive smallholder agriculture.

NuFlux AWI, developed by Menzi et al. (2001), is a user-friendly Excel-based calculation model used to assess the nutrient fluxes of intensive livestock production and manure management. It was developed in the framework of a project on area-wide integration of specialized livestock and crop production currently being used in China, Mexico, Thailand and Vietnam under coordination of FAO. The model can be used for regional or farm-specific nutrient and heavy metal balance calculations and as a planning tool for manure management. It provides results on nutrient excretions, amount and composition of different types of manure from pig and poultry production, and nutrient losses to the environment. It is possible to use the model either with integrated region-specific default values on livestock and crop production or with more specific input data.

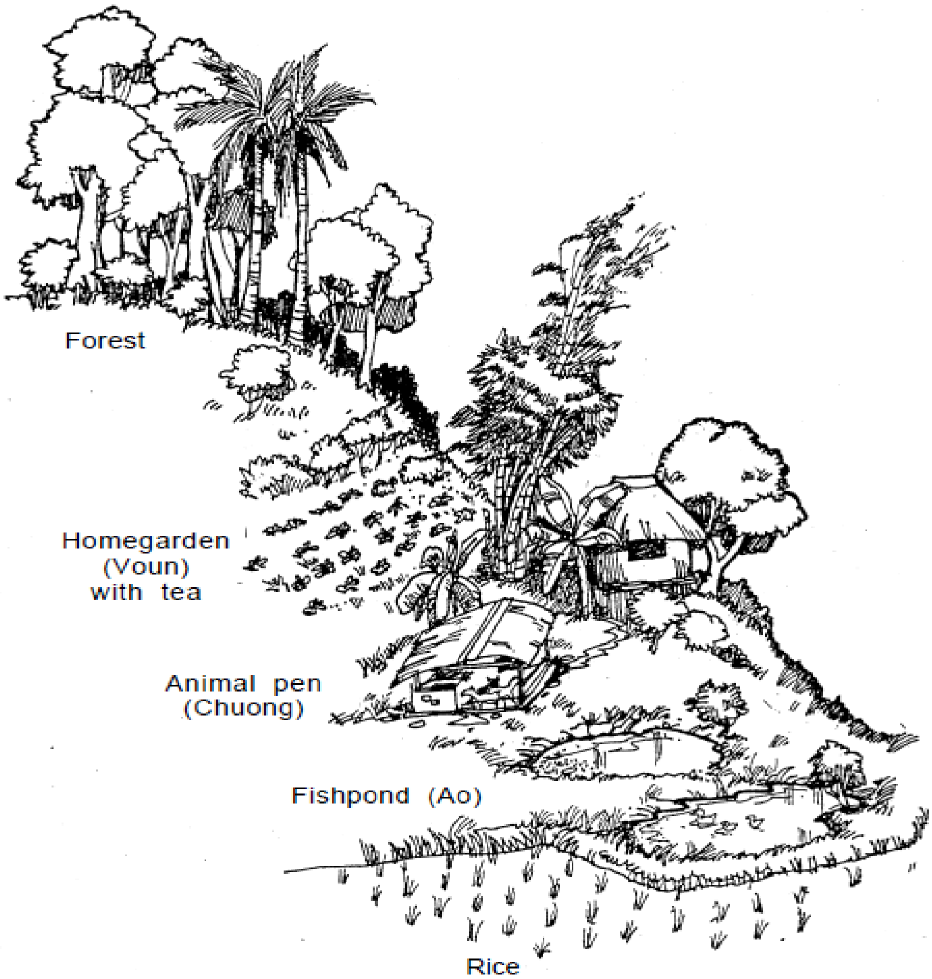
Many indigenous hill communities in Southern Vietnam have developed land use practices that integrate silviculture, animal husbandry and fishery. The components of this crop-livestock integration are a garden ("Vuon"), fishpond ("Ao") and livestock pen ("Chuong"), hence the term VAC. Animal sheds made from bamboo and wood are located close to fish ponds. Some animal manure is released to the pond to support high fish yields. Pond water is used to irrigate crops. Ficus and citrus trees are raised around ponds. Grasses are sometimes grown to provide additional feed for the fish. Mixed tree gardens including fruit trees like jackfruit, apricot and pears mixed with indigenous forest species like Liquidambar formosana, pine, bamboo and chestnut are also common. Empty spaces between trees may be used to plant food crops. These models exemplify an efficient use of space and labor together with an ability to generate high and stable income (Cuc, et al., 1990). VAC is generally described as an integrated and relatively closed nutrient cycling system (see Figure 2.1) (Percy, E.S, 1998).



Source: Cited by Cuc et al., 1990

Figure 2.1 Flows of Energy and Materials in a VAC System

In the midlands of Vietnam, one finds a modified VAC system. Not all farms have fishponds, with the system usually integrated with a rice field whenever natural conditions favor use of rice paddies. Gardens are diverse, containing fruit trees, hardwoods (Melia sp. etc.), bamboo, vegetables, sugarcane, and others. Livestock include cattle, buffalo, pigs and chickens (see Figure 2.2).



Source: Cited by Cuc et al., 1990

Figure 2.2 Diagram of a Model VAC Farm in Upland Area

In central highland Vietnam, DakLak Provincial Agriculture Extension Centre (AEC), together with development researchers, guided key farmers from ethnic minority villages in improving upland farming and organizing field days to disseminate information on effective practices. Ecological impacts such as enhanced soil fertility through crop rotation and use of compost, erosion control and reduction of forest degradation caused by free grazing or logging of timber for pepper planting are as important when assessing the tested practices, as are a balanced subsistence food supply and the potential for additional income generation. In addition, farmers have also successfully tested farming models including hybrid maize, beans as second crop, intercropped cashew, cassava, bamboo shoots and cocoa as well as forage production and silage in animal husbandry. These activities brought back great results. For example, more than 580 women savings and credit groups formed in and outside the project target districts received loans from the bank for farming activities (RDDL, 2009).

In fact, drawing on their lengthy practice of cultivation, many local farmers have a lot of indigenous knowledge in land use for each ecological zone. This basic understanding, combined with technical knowledge transferred from outside, has allowed them to adapt appropriate agro-forestry models to their natural conditions. Some agro-forestry models have proven successful in Vietnam, such as the Fruit Trees – Annual Crop – Livestock Husbandry Model used at Bac Thanh Village, Quyet Thang Commune, Thai Nguyen City; the VAC Model's Garden – Fishpond – Pig Husbandry at Binh Duc Village, Binh Nham Commune, Thuan An District, Binh Duong Province. Several different methodologies were used to assess these models, such as interviews, questionnaires, and economic analysis (CBA) tools. Studies looked at various aspects of the models, such as environment, socio-economic, techniques effectiveness, and challenges (VNAFE, 2008).

Full integration of agricultural systems at the producer or community scale may help slow or even reverse some of the detrimental environmental and economic problems associated with specialized industrial agriculture. Modern agriculture requires intensive inputs. However, use of forage and other diverse crops in crop production can reduce intensive inputs, while in some cases increasing crop yields, enhancing nutrient cycling, reducing plant disease and improving soil quality. Integrated livestock and cropping systems have the potential benefit of enhancing nutrient cycling efficiency, adding value to grain crops, and providing a use for forage and crop residues.

Integrated crop/livestock producers traditionally raised a greater diversity of crops, encouraging crop rotation, and have allowed livestock to convert low-quality crop residues or failed crops into higher value protein. Integration of crop and animal production is well developed in smallholder farming systems. The inputs and outputs of the crop and animal enterprises are integrated inextricably in these systems depending on the available resources. Poor farming households attempt to integrate crop and animal enterprises primarily to maximize the returns from their limited land and capital (Smith et al., 1997). A high integration need to have sufficient access to knowledge, assets and inputs to manage this system in a way that is economically and environmentally sustainable over the long term. Interactions between crop and livestock production can have a significant impact on productivity of both activities because the waste products of one component serve as a resource for the other in an integrated livestock and crops system (for example, manure is used to enhance crop production; crop residues and by-products feed the animals, supplementing often inadequate feed livestock supplies, thus contributing to improved animal nutrition and productivity) (Devendra & Sevilla, 2002).

An integrated farming system consists of a range of resource-saving practices that aim to achieve acceptable profits and high sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment. Based on the principle of enhancing natural biological processes above and below the ground, the integrated system represents a winning combination that (a) reduces erosion; (b) increases crop yields, soil biological activity and nutrient recycling; (c) intensifies land use, improving profits; and (d) can therefore help reduce poverty and malnutrition and strengthen environmental sustainability (IFAD, 2009).

According to Hansen (1998), livestock production and shifting cultivation are integrated through:

1. Use of manure in plant production.
2. Ritual slaughter for crop protection and production.
3. Use of harvested fields and young fallows for grazing.
4. Use of agricultural by-products for animal and poultry feed.
5. The suppression of potentially harmful weeds, especially grasses.
6. Production of animal feed, mainly maize and root crops for animal feed.
7. Use of draft power for transporting crops (occasionally bullocks and mules).
8. Re-investment of incomes generated by selling livestock into inputs for intensifying crop production (e.g. small tractors, tools and seeds).

Many countries in Asia have well developed smallholder farming systems that integrate crop-animal production; these are found in Cambodia, India, Indonesia, Sri Lanka, and Thailand, among others (Devendra et al., 1997, 2000) , with additional details shown more detail in Table A in Appendix B. The main interactions in these mixed farming systems are crops providing a range of residues and by-products for use by both ruminants and non-ruminants. Native pastures, improved pastures and cover-crops growing under perennial tree crops can provide grazing for ruminants. Cropping systems such as alley-cropping can provide tree forage for ruminants. In addition, large ruminants provide power for land preparation and soil conservation. Both ruminants and non-ruminants provide manure for maintenance and improvement of soil fertility. In many farming systems it is the only source of nutrients for cropping. Herbaceous forages can be undersown in annual and perennial crops and shrubs or trees established as hedgerows in agro-forestry-based cropping system (Devendra et al., 1997).

The overall benefits of crop-livestock integration can be summarized as follows:

1. Agronomic, through the retrieval and maintenance of the soil productive capacity;
2. Economic, through product diversification and higher yields and quality at less cost;
3. Ecological, through the reduction of crop pests (less pesticide use and better soil erosion control); and
4. Social, through reduction of rural-urban migration and the creation of new job opportunities in rural areas.

While a number of studies have already shown the potential of agro-pastoral systems that integrate crop and livestock production in sloping lands, limited studies have been conducted on the livestock component of such systems when compared to crop components. The integrated system has proven to be more productive and more efficient than either cropping or pastures alone. In fact, the FFTC has been aggressive in this aspect by conducting workshops and training programs on crop-livestock integration. The livestock component can contribute to the system by serving as a source of power for farm operations and the manure can be used as organic fertilizer to improve the fertility of already degraded soils in uplands. On the other hand, crop residues can be used to supplement the feed requirement of livestock. As agricultural production must be increased substantially, the potential of crop-livestock farming systems should be given due consideration. This system could provide farmers with the means of producing sufficient food from the same land without socially unacceptable environmental costs (Maglinao, 1998).

2.3 Linear Programming as an Optimal Model for Agriculture Systems

In general, optimal models of agricultural systems apply mathematical programming algorithms to identify those specific combinations of inputs that may be most suited to a particular set of circumstances (Thornton, 2001). The preferred farming system in any area has to reflect all relevant local environmental, economic and social constraints. Mathematical programming allows one to select the best performing activities within the constraints of available resources. Linear programming is most often used in the more complicated situations where very limited resources are available.

Many studies use applied linear programming because it is specially designed for resource allocation, and it provides a convenient platform for interdisciplinary discussion. This approach can help allocate resources over time and space with no difficulty other than an expanded matrix size. Linear programming often gives one solution rather than a range, but this issue can be overcome by running the model several times. Several studies explored options and constraints for crop–livestock integration to achieve more sustainable agriculture (Schiere, 2002). Linear programming was also used to determine the optimal number of fry to transfer into a grow-out system, to estimate population growth and production costs, and to determine the optimal harvesting schedule in order to maximize profits from the operation (Forsberg, 1996).

Despite its numerous advantages, linear programming is not free from some limitations. The accuracy of the results obtained from this tool obviously depends on the accuracy of the data collected. Application of mathematical programming is limited mainly by poor data sources rather than by model building. For example, when Nepalese farmers keep poor records, the data gathered for that assessment might limit the precision of the linear programming model. Use of linear programming is limited in case of risk and uncertainties as well. Mistakes in estimating prices, especially relative prices, will lead to poor results in any type of planning (Das, 2005).

In summary, extensive research on interactions between crops and livestock has been conducted on uses of natural resources and how to make better use of residues and crop byproducts in an integrated farming system. Further need exists, however, to study ways to optimize the productivity of livestock and crops in an integrated farming system specific to upland areas to maximize nutrient recycling effectiveness and thereby improve the socioeconomic conditions of remote communities. Some case studies will be observed for improvement of existing farming systems in combination with adoption of new ventures, such as cattle raising, fish production, crop productivity improvement, or efficient nutrient management. These modifications may enhance household food security better than by trying to replace existing methods with completely new "modern" farming systems. The available nutrient resources and integration of different components in a mixed farming system will be calculated, evaluated and quantified through some case studies in Africa (Muendo, 2006) and Asia (Throne, 2002.; Pant, 2004.; Nhan et al., 2007), including in Vietnam (So, 1998). Besides, environmentally friendly recycling of animal manure can mitigate environmental hazards. Recycling will contribute animal nutrients to crop fertilization, thereby reducing the need to apply chemical fertilizers to add nitrogen, phosphorus, potassium and micronutrients to fields.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

This study was conducted to assess the effects of using livestock manure to improve yields of crops grown in slope land in central Vietnam. The study consisted of two main steps: 1) field surveys to gather information on current status of crop and livestock production and available resources; these efforts used questionnaires, ten seed technique, PRA tools, and resource flows diagram to estimate livestock manure nutrients and crop-byproduct quantities; 2) linear programming modeling was used to maximize farm returns when livestock manure is applied to crops.

3.1 Site Selection

Tabhing Commune is located in Vietnam’s central region, about 70 km from Da Nang City; it is at 107^{0}42’41.5” E longitude and 15039’34.2” N latitude (coordinates approximate to the commune’s central point). Tabhing is one of 8 mountainous communes of Nam Giang District, Quang Nam Province; it includes 9 villages with a total population of 2,460. Areas neighboring the commune include Dong Giang District to the north, Phuoc Son District and Dak Pring Commune to the south, Thanh My Town and Ca Dy Commune to the east, and Cha Val and Zuoih Communes to the west. See Figure 3.1.

With a total natural area of 22,800 ha, Ta Bhing is almost completely covered by forests, which account for 75% of its total area. The altitude ranges between 300 to 500 m. A majority of land types here are found on sloped land. Thanh River and Ta Bhing Stream are the area’s main hydrological systems. These in turn play an important role in local villagers’ livelihoods. Ta Bhing Stream, an accumulation of many small branches, supplies water for irrigation as well as drinking.

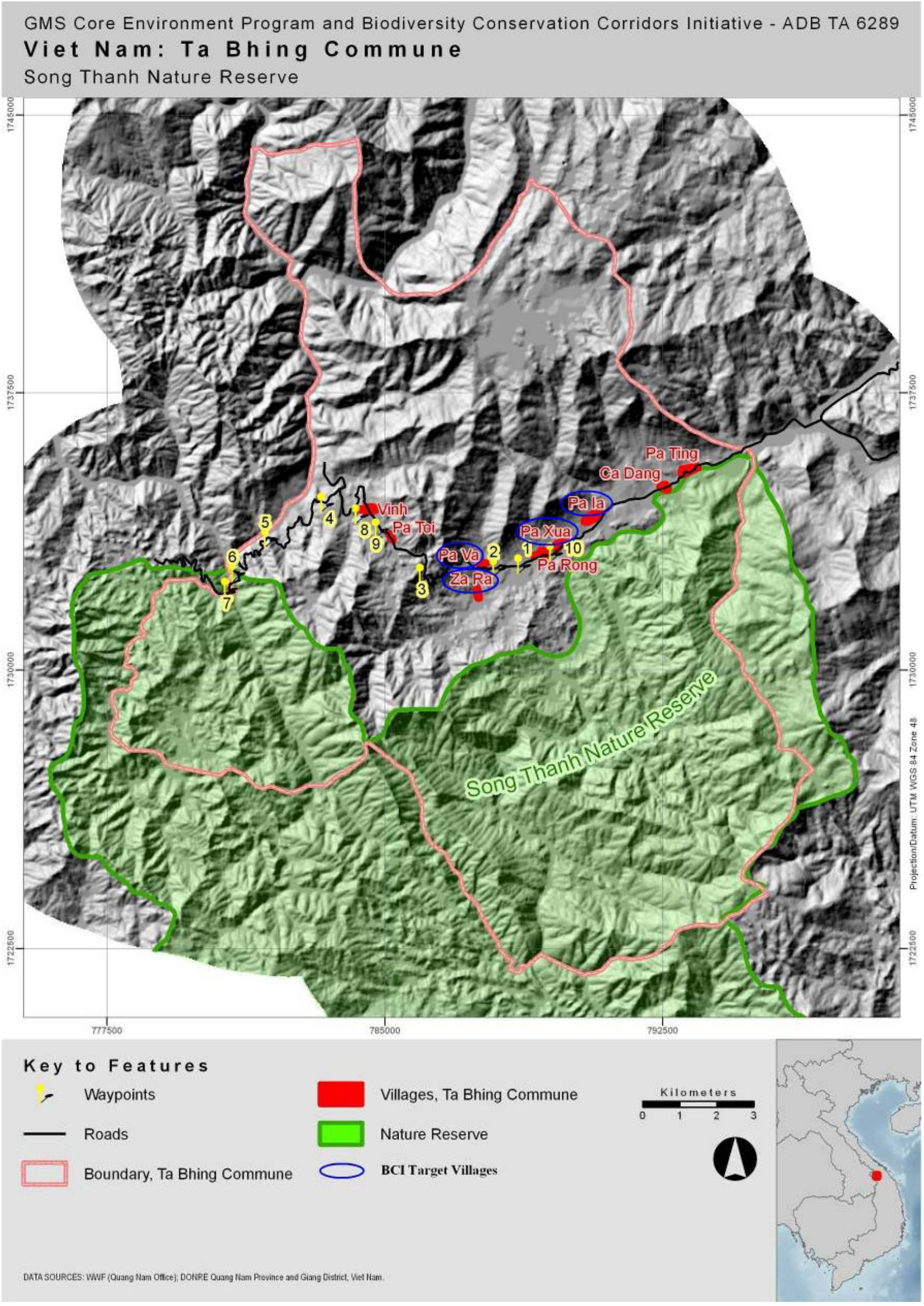


Figure 3.1 Surveyed Villages Location, Quang Nam Province, Vietnam

Tabhing Commune is located in a mountainous central middle climate region with two distinct seasons: a cold dry season that extending from September to February, and a hot rainy season that extends from March to August. Average annual temperature is 24.3^{0}C; monthly maximum temperature occurs in July and minimum in January. Average humidity is 88%. Data are shown in Table 3.1.

Table 3.1 Monthly Average Temperatures at Tra My Hydrometeorology Station

Monthly / year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	20.9	23.6	22.7	26.1	27.6	28.0	26.8	27.0	26.1	24.4	23.7	19.9
2006	21.0	21.9	21.4	26.3	25.9	27.7	27.3	26.7	25.6	24.6	24.1	21.3
2007	20.6	23.4	25.5	25.9	26.3	27.2	27.4	26.8	24.0	24.0	20.8	21.4

Source: Published by Department of Nam Giang District Statistic, Statistic Book in 2008

There are three main wind directions in a year. The first, from the east, occurs from March to August. The second, from the northeast, occurs from October to February with an average speed of 2.9 m/s. The third is from the southwest direction from March to August, accompanied by heat and dry air. Storms usually occur annually from July to November. According to statistical data, this commune was impacted directly by about 1 storm every 2 years and indirectly by some 2 to 3 storms and tropical low pressure events annually.

Annual average rainfall was greater than 400 mm (except in 2006, when annual average rainfall was only 269 mm). In 2007, the highest rainfall occurred in November with amounts above 1,700 mm; in February there was almost no rain. Every year, floods and landslides occur in the rainy season. This has many effects on community life, through livestock loss, damage to crops and agricultural land, and impacts on physical infrastructure and transportation as well. The extension of the dry season accompanied by hot and dry southwest winds and a shortage of water are the main limiting factors affecting the cropping system, particularly in upland fields and home gardens. Rainfall data are shown in Table 3.2.

Table 3.2 Monthly Average Rainfalls (mm) at Tra My Hydrometeorology Station

Monthly / year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	24	29	163	9	172	202	115	143	457	2,299	848	1,010
2006	158	248	45	61	271	63	210	259	376	584	179	771
2007	375	1	61	138	305	198	99	254	292	1,340	1,746	333

Source: Published by Department of Nam Giang District Statistic, Statistic Book in 2008

The forests of Song Thanh Nature Reserve constitute the critical watershed for the Dak Pring, Phuoc My, and Song Thanh Rivers. These large rivers themselves are tributaries of the Cai and Boung Rivers that converge to form the Vu Gia River, which itself joins the Thu Bon River in the lowlands of Quang Nam. Since Quang Nam province is subjected to annual flooding in its lowland areas, causing extensive economic losses, protection of upland forests is crucial to the province's economic development.

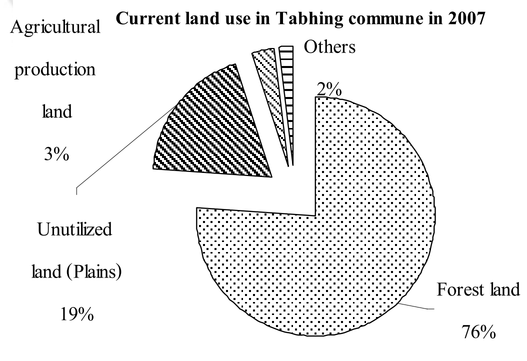
The main river running through Tabhing is the Thanh River, which is 20 km long and ranges from 40 m to 120 m wide. It flows from the South through the center of the Commune to its Eastern boundary. Tabhing Stream is the main stream in this commune connecting with many small streams that feed many of the area's agricultural lands. These streams are important to people's livelihoods in this locality. These streams flow through the flatter lands in the center of the Commune, where most of the people live and cultivate land. The Thanh River is situated some 9 kms away from the main residential areas.

During the rainy season, water in Tabhing's Streams flows strongly, occasionally resulting in partial flooding, but this only affects land adjacent to the two banks of the stream; high water generally does not reach homes. In the dry season, some branches of small streams become exhausted. Fortunately, other small streams still have water year round.

Villagers' daily water supply comes from the waterfalls or streams around the Commune. For instance, of the four survey villages, Pa Ia and Pa Xua receive water from Grang Waterfall, which is located three kms to the North of National Road 14D. The two other villages receive their water from streams nearer to them.

The topography is characterized by many high continuous mountains punctuated by many streams and small valleys. The highlands and mountains dominate the western landscapes of the commune, accounting for 60% of total land area. Almost all of these highland areas have steep slopes (from 20^0 to 60^0). About 30% of the total area is midlands, with lowlands accounting for the remaining 10%. Average altitude ranges from 300m to 500m above mean sea level, with the highest points at 800m to 1,000m. The Thanh River Valley and Pa Ting Village form the area's lowest land areas. The local people have cultivated in the midlands where average slope ranges from 18^0 to 25^0; about 5% of total lowlands is occupied by residential land. Being located on steep slopes, crop production is heavily influenced by soil erosion, with extensive nutrient losses caused by both runoff and leaching.

Tabhing Commune has a total land area of 22,800 ha. Details are in Figure 3.2 and in Figure A of the Appendix. Agricultural land officially accounts for 78.9% of total natural land area; about 2.35% is non-agricultural land; and the remaining 18.76% is unused land. But these statistics are misleading. According to the current government land classification scheme, forest land falls under the agricultural category. It dominates total Commune land area, with 76% in forests and a very low share (3%) actually in agricultural production. A rather large portion of the land that is unused remains so because it contains extensive gravel and stones; other unused land is fallow after cropping.



Source: Quang Nam Department of Natural Resources and Management (2007)

Figure 3.2 Current Land Use Structure in Tabhing Commune in 2007

From 2000 to 2006, Tabhing Commune's land use patterns underwent significant changes. Forest land grew due to reforestation. Upland areas added many more perennial trees in unused waste land. Unutilized land decreased by 5,873 ha. The commune's land use plans for 2015 call for much more unused land to be reforested. This includes planting trees and developing commercial forests. In addition, conversion of unused land to new public infrastructure is expected in the future.

Livelihoods of Tabhing Commune villagers are characterized mainly by upland agricultural practices. Households from all wealth groups within these communities -- from the very poor group to the well-off group -- engage in agriculture. On top of their agricultural activities, villagers generate additional income from NTFP harvesting, livestock husbandry, and gold mining. The well-off group, not surprisingly, has more livelihood options; its members therefore do not depend on farming to the same extent as villagers in the other groups. They can earn money from such other activities as trading and livestock husbandry.

While all four villages reflect the same general livelihood patterns, some differences emerge among them with regard to the percentages of households that are active in each category. In Za Ra Village, for example, some households generate income from traditional handicrafts, whereas none of the other villages carry out this livelihood activity. Za Ra Village also shows a rate of livestock raising higher than in other villages. In the remaining villages, households base their livelihoods mainly on farming and collection of NTFPs. Here the well-off groups' activities are generally related to trading activities, such as at grocery shops.

3.2 Sample Size

The study was carried out in the four villages named Pa Ia, Pa Va, Pa Xua, and Za Ra. 50 households were selected randomly from 221 households in the 4 villages. More details on sample population selection are discussed in Chapter 4.

3.3 Data Collection

The study relies on both qualitative and quantitative information collected through both primary and secondary sources. The research methods used are discussed in detail in the following subsections.

3.3.1 Primary Data Collection

The field survey was conducted in Tabhing Commune from June to July 2009 using structured questionnaires to collect necessary information. A household survey was administered at 50 randomly selected households with each family interviewed individually at their home. The following quantitative and qualitative information was gathered during the survey:

1. Household size, income and expenditures, labor source
2. Socio-economic conditions
3. Landholding, land use system and land allocation
4. Cropping system and cropping calendar
5. Livestock husbandry
6. Agricultural production constraints

In addition, interviews were conducted with key informants, including village leaders, members of the Commune Peoples Committee and traders. Semi-structured interviews were carried out with a number of farmers to gather additional qualitative information on their farming system practices and livelihood status. Data collection instruments were applied as questionnaires. Information on land use and socio-economic conditions also was developed through the use of the ten seed techniques obtained from three ADB field surveys and reports from 2007.

In addition, focus group discussions were used to gather some relevant information (of a particularly of qualitative nature) that could not be collected by using questionnaires. Information collected is discussed in detail in Chapter 4.

3.3.2 Secondary Data

The research effort also included review of various reports and documents from the Department of Local and Provincial Agriculture, Department of Rural Development, Agricultural Research Institutes, and the Commune Peoples Committee Meteorological Station. The secondary data included:

1. physical condition of surveyed villages: topography, temperature, and rainfall
2. demographic profile: population structure and labor force
3. agricultural production: land use status, farming practices, and livestock raising

Several scientific articles were also reviewed. These included case studies of crop-livestock interactions, technologies for calculating nutrient balance flows of components under an integrated mixed farming system, and techniques for evaluating and proposing appropriate options that could be applied at the site.

Information on demographic, population, self-sufficiency, land use status, animal production, farming practices, etc. was also assembled from relevant statistical data. Finally, some useful information related to the site was gathered from available sources, such as policy reports and project progress reports, maps, training manuals, and development strategies (of both government and non-governmental development agencies).

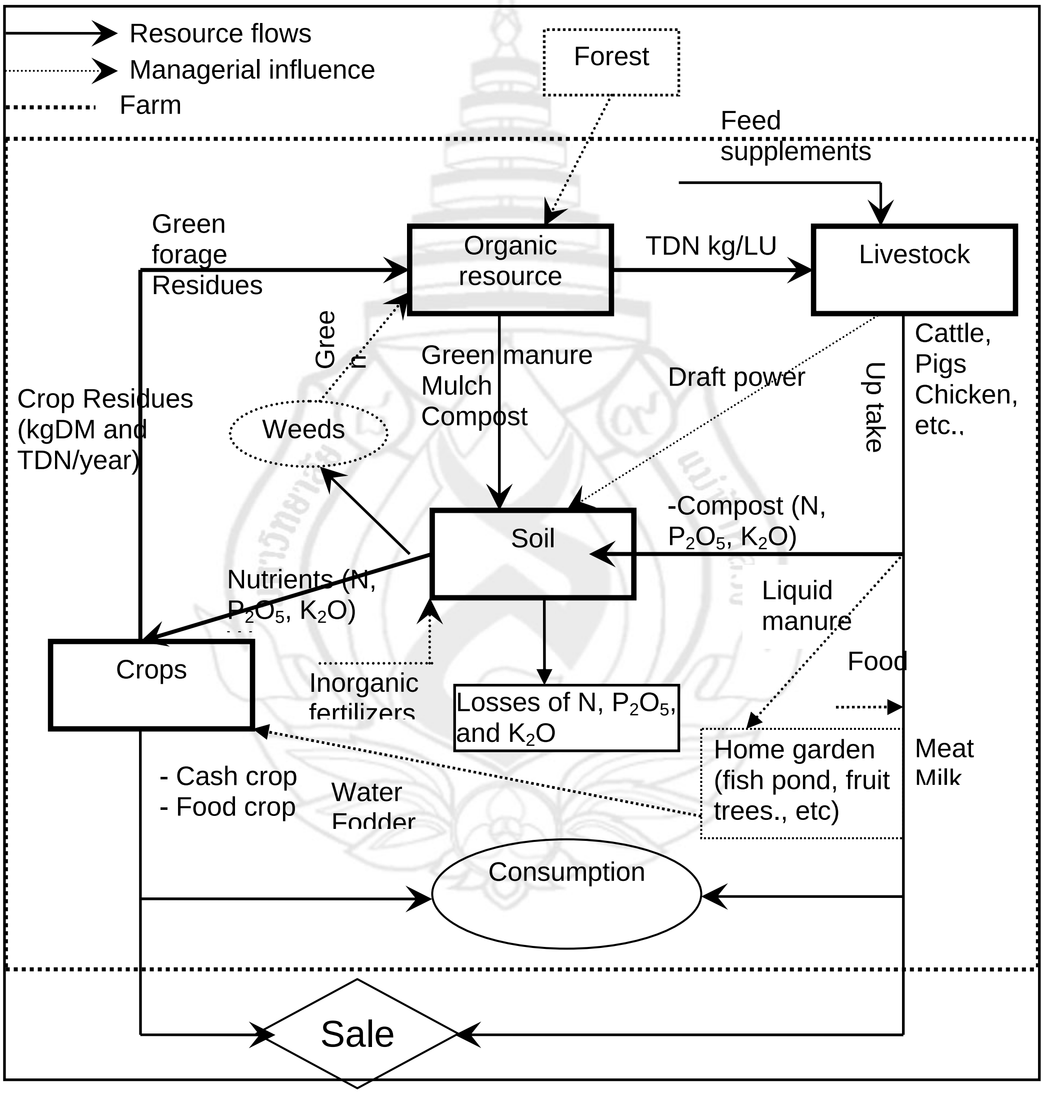
3.4 Data Analysis

3.4.1 Statistical Analysis

The research used quantitative statistical analysis. Organic manure and socio-economic conditions were analyzed by such basic statistical tools as MS Excel and the Statistical Package for Social Science (SPSS).

3.4.2 Organic Nutrients Estimation

The principal nutrient compositions of crop residues (total digestive nutrients, TDN) and livestock manure from cattle, pigs, chickens and goats were calculated based on resource flows diagram (RFDs) shown in Figure 3.3. This is a method used to analyze farm-level material flows within crops and livestock components in a mixed farming system. The RFDs focus on internal flows. For example, on-farm nutrients from wastes and byproducts and auto-consumed products. In previous applications, external inflows (i.e. from areas near-farm as well as further away, such as through the use of inorganic fertilizers) and external outflows (i.e., products for sale as well as discharged wastes that leave the managed farm area to markets or through streams or into groundwater) were not considered within the concept. The content of main crop residues (TDN) and livestock nutrients (N, P, and K) was estimated based on previous studies.



Source: Modified from Throne (1998) and So (1998)

Figure 3.3 Resource & Waste Flows in an Integrated Crop-Livestock Farming System

(1) Livestock session

Conversion of livestock species to livestock units (LU)

LU amount for animal species = Number of such animal * Conversion factors of such animal (1)

Nutrient uptake calculations are required to assess effective nutrient utilization in the next step. This is referred to as the potential supply of livestock nutrient, represented by SN, SP and SK, where S = supply. The potential supply of a nutrient is not simply the amount of that nutrient in the soil, because the plants cannot take up all available nutrients. Some parts of the nutrients are fixed with other elements or matter, and only become available to plants at a slow rate through mineralization and weathering. These processes, and thus the availability of nutrients to the plants, are strongly influenced by soil acidity. As a result, pH (acidity) is often used in calculations of the supply of nutrients. Nutrients in livestock manure are also lost by volatilization (especially nitrogen) due to exposure to sunlight (heat) as well as by leaching.

Main manure nutrient excretion and available nutrients for crops:

Annual animal manure = 365 days * Daily manure excreted * Total annual number of such animal (2)

Annual excreted nutrient content = Annual animal manure excreted * Nutrient contents of animal manure (%) (3)

Note: Excretion of nutrient contents (N, P_2O_5, K_2O) calculated based on VISTA standard cited by Dan et al. (2003)

Available nutrient for crop uptake = Total annual excreted nutrient content – Nutrient amount losses (4)

Note: Losses percentage assumption for: N (70%), except in chicken where N losses are 50%; P_2O_5 (20%); K_2O (15%) modified from Eghball (1997) and Howeler (2001).

Estimated annual feed requirement per LU:

Annual TDN required per LU = 365 days * Daily TDN requirement per LU (5)

(2) Crops session

The main crop residues (total digestive nutrients TDN) and livestock nutrients (N, P, and K) content is estimated based on previous studies. The process is mentioned in detail in chapter 4.

Total gross output of crops by products is calculated using the following formula: Annual Dry matter (DM) = Area (ha) * Annual crop by-product amount (ton/ha/yr) * DM fraction (%) (6)

Annual TDN amount = Annual DM amount (ton/yr) * TDN fraction (%) (7)

(3) Other data inputs for an integrated farming system model

Nutrient uptake from soil

According to Dang (2000), organic matter content (OM) in Ferralic Acrisol soil is 1.8% – 2.8%. Among them, organic N composition account for 5% of total OM. In this study, assumption that total OM content is 2.3% then organic N contain in the soil is calculated correspondingly to be 11.5 kg.

Nutrient uptake from the soil (X_0) = Organic N content * Crop based yield without adding fertilizer (8)

According to Bo and Hien et al. (2005), some nutrient variables related to input data of linear programming model are estimated through the application method of specific crop fertilizer amount based on potential yield.

Crop-based nutrient requirement

Nutrient amount to achieve potential yield (X_p) = Nutrient amount to get one ton of crop product (X_t) * Potential yield (Y_p). (9)

Nutrient amount added to achieve current crop yield (X_0) = 11.5 * Current yield (Y_0) (10)

Note: 11.5 = Organic N contained in the soil

Specific crop-based coefficient:

$a = (Y_p - Y_0)/(X_p - X_0)$ (11)

Where

a: Coefficient (crop-based)

X_p: Required nutrient amount to achieve potential crop yield (kg/ha/yr)

X_0: Nutrient uptake from the soil (kg of N/ha/yr)

Y_p: Potential crop yield (ton/ha) [1.4 (rice), 1.35 (maize), 0.8 (beans)]

Y_0: Current crop yield (ton/ha) [0.9 (rice), 0.85 (maize), 0.5 (beans)]

3.4.3 Relation Between Crops Yield and Manure Nutrients

Relation between crop yield and animal manure nutrients is estimated through the following formulas

$$Y_i = a_i * X_i + b_i \qquad (X_i \in [X_0, X_{max}]) \qquad (12)$$

Where

Y_i: Yield of crop i when fertilizer is applied (ton/ha/yr)

X_i: Allocated nutrient amount to crop i (kg/ha/yr)

b_i: Current yield of crop i (ton/ha/yr) (without manure addition)

a_i: Coefficient of crop i (specific crop-based)

3.4.4 Upper Bound Limitation of Required Nutrient of Crops

A recommended maximum nutrient amount is set so that nutrient use does not affect the environment. Nutrients in the model and linear relationships are to be controlled within upper X bounds.

$$X_{max} = (Y_{max} – b)/a \qquad (13)$$

Where

b: Current crop yield (ton/ha/yr) (without manure addition)

a: Coefficient (specific crop-based)

X_{max}: Upper limit of crop-based nutrient amount (kg of N/ha/yr)

Y_{max} : Potential crop yield achieved when applied nutrient (ton/ha/yr)

3.5 Linear Programming Modeling

Many quantitative mathematical analysis tools have been developed to analyze and support decision making in agricultural research and farming systems. These tools allow the analyst to determine how to recycle wastes effectively in an integrated mixed farming system, especially in a crops-livestock system. Optimization of nutrient cycling is carried out using linear programming models.

In order to find the optimum waste allocation for crops and recycling byproducts for livestock under local resource constraints, linear programming models were developed using basic data sources, which are average input and output coefficients and gross margin of agricultural production in 2008. The models can be employed with either maximizing or minimizing functions.

The maximization model used in this study is as follows:

The objective function; $$Z_{max} = \sum_{i=1}^{j} C_i X_i \quad (14)$$

Subjected to constraints; $$\sum_{i=1}^{n} \sum_{j=1}^{m} a_{ij} X_i \leq b_j \quad (15)$$

Non-negative constraints; $X_i \geq 0$

Where

Z_{max} : Maximizing objective function

C_i : Coefficients of increase of inputs to optimize Z

X_i : Decision variables

a_{ij} : Coefficients of usage of resources

b_j : Coefficients of amounts of resources

i : Number of variables

j : Number of constraints

The objective of linear programming model in this study is to maximize the total value of two components (crops and livestock) in a mixed farming system. The gross margin reported by the optimal solution excludes the value of rice assumed to be consumed by the farm family. LP was used to select available possible alternatives evaluated in terms of their efficiency for the whole farming system in providing value to the local farmer, and also to determine the level of implementation that will provide the maximum gross margin. The process is described in detail in Chapter 4.

3.6 Conceptual Framework

This study attempt to determine an appropriate integrated level between crop and livestock components through review of several case studies, surveys of socio-economic condition at the sample sites and current farming system assessments. The study will follow the conceptual framework as set out in Figure 3.4.

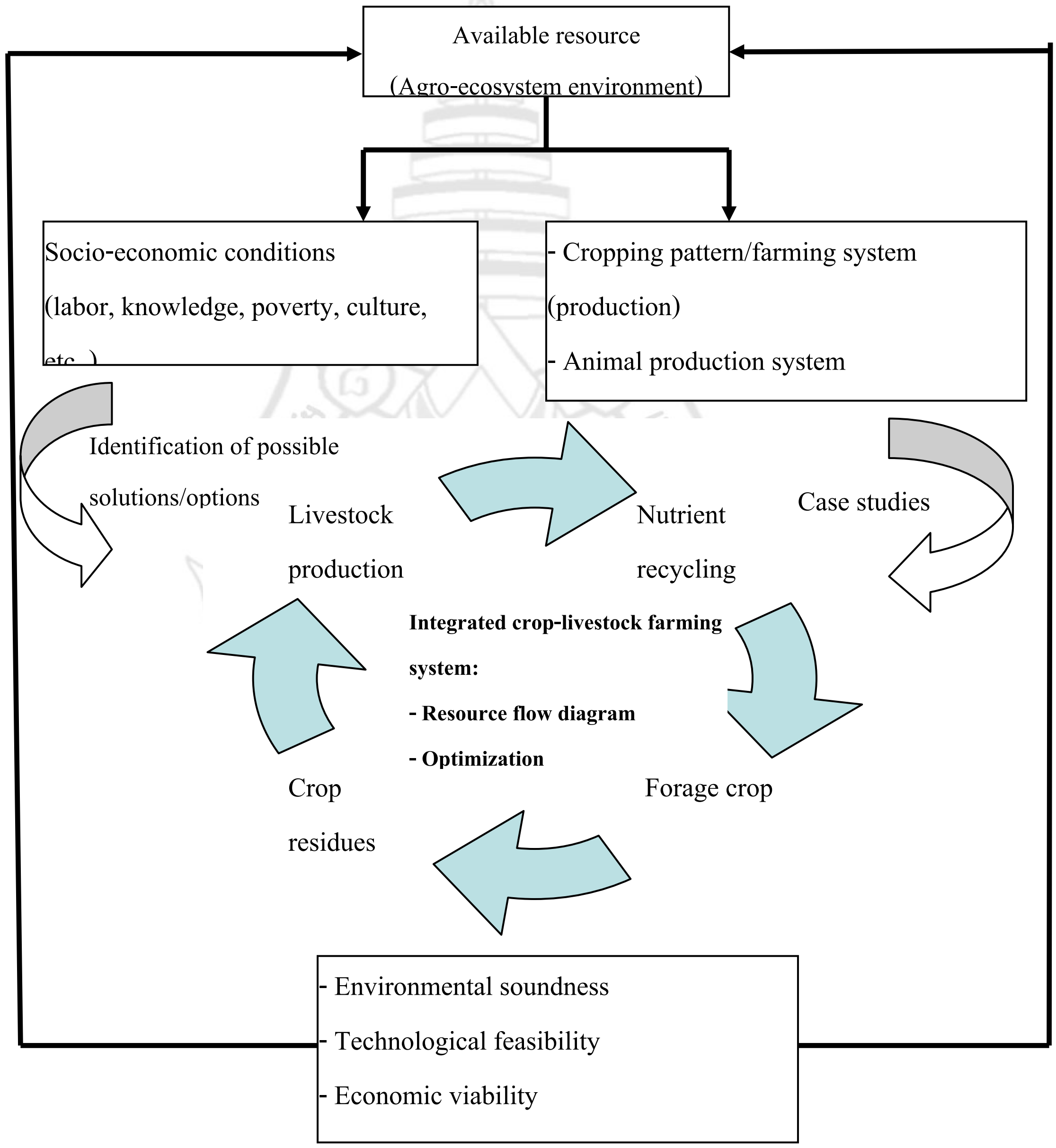


Figure 3.4 Proposed Conceptual Framework for Site Study

CHAPTER 4

RESULTS AND DISCUSSION

This chapter deals with the overall characteristics of the study site, including socio-economic status, crop cultivation activities, and present situation regarding livestock production and management. Additionally, it examines the important role of two key components of household income. It attempts to estimate the amount of manure nutrients (N, P_2O_5, K_2O) excreted from current livestock, and livestock carrying capacity based on TDN (Total Digestive Nutrient) demand. Both elements are calculated from different land resources available in the study site. Based on the resource situation of the study site, an optimization model is used to explore ways to maximize the return to farmers through optimum allocation of nutrient amounts for their crops. Solutions to build local farmers' capacity to use applicable methods of manure livestock management and treatment to increase animals' use of crop residues are proposed to implement an effective integrated farming system.

4.1 Overview of Study Area

4.1.1 Socio-economic Conditions

(1) Household size and population structure

In 2008, Tabhing Commune had a total of 2,640 people in 525 households. The majority are Co Tu ethnic minorities, who make up over 84% of total commune population. Kinh people account for 11% and others (Gie Trieng, Ve, Ta Rieng and Hare ethnic minorities) form the remaining 5%. According to group discussion conducted by the ten seed technique method, poor households account for 45% of total households in the four villages surveyed. Data are presented in Table 4.3. Those less than 15 years old account for nearly one-quarter of the total population those aged 16 to 59 years make up 66%, and those aged over 60 years comprise 9%. Household average 5.4 people each. The family's average main labor force number is 2.4, accounting for 43.7% of total surveyed population Co Tu people still live in the traditional household style, with three generations living together. Women still carry out nearly all (85%) field work and housework. Men undertake hunting, fishing, clearing of land for shifting cultivation, and social communications. Elderly people are involved in many types of supporting roles such as taking care of children, housework, poultry raising, etc.

Table 4.1 Tabhing Commune Demographics (2008) at Four Surveyed Villages

Villages	Population	No. HHs	Female	Labor (%)	Ethnic Minorities	Wealth classification groups (%)			
						Well-off	Medium	Poor	Very poor
Pa Va	222	66	150	62.2	222	22.2	19.5	45.8	12.5
Za Ra	248	54	125	59.7	233	11.3	63	20	5.7
Pa Xua	529	105	277	64.6	485	8.3	45.9	27.5	18.3
Pa Ia	164	40	89	66.7	156	18.8	31.3	34.3	15.6
Total	**1,163**	**243**	**581**	**63.3**	**1,096**	**15.2**	**40**	**31.9**	**13.0**

Note: Poor households in rural areas are classified based on average income equal to or lower than 200,000 VND/person/month (about $10 US/person/month).

Based on group discussions, household characteristics were estimated in terms of the four wealth classification groups: well-off, medium poor, poor, and very poor. Details are shown in Appendix C.

(2) Occupational structure

Based on information collected in the household interviews, agriculture forms the primary occupation of households in the study area. About 83% of all families were involved in agriculture and NTFPs collection. Some respondents were involved in other income generating activities such as government services (5%) and other activities (11%) including small scale business, labor selling, gold sifting, etc. Often this work was conducted in addition to their participation in agricultural activities.

(3) Education levels

The overall literacy rate in surveyed villages -- defined in terms of their skill in reading and writing the Vietnamese language -- was high, about 77.2%. The rate differs quite a bit between villages, however. In Za Ra Village, over half of respondents had completed secondary education, due to accessibility to schools providing higher education and the fact that their livelihoods must be better than in the other villages surveyed.

(4) Livelihoods

From field observations and household interviews, the main livelihood activities of Co Tu people are cultivating rice and other crops on slope lands and in home gardens. They also rely on forest resources by collecting such NTFPs as rattan, honey, and banana flowers and hunting wild animals to protect their upland fields. However, in recent years local people have been subjected to increasing demand from outsiders to work for them to cut trees, mine for gold, and hunt wild animals illegally. Data on the varying livelihoods of the different wealth groups are presented in Figure 4.1.

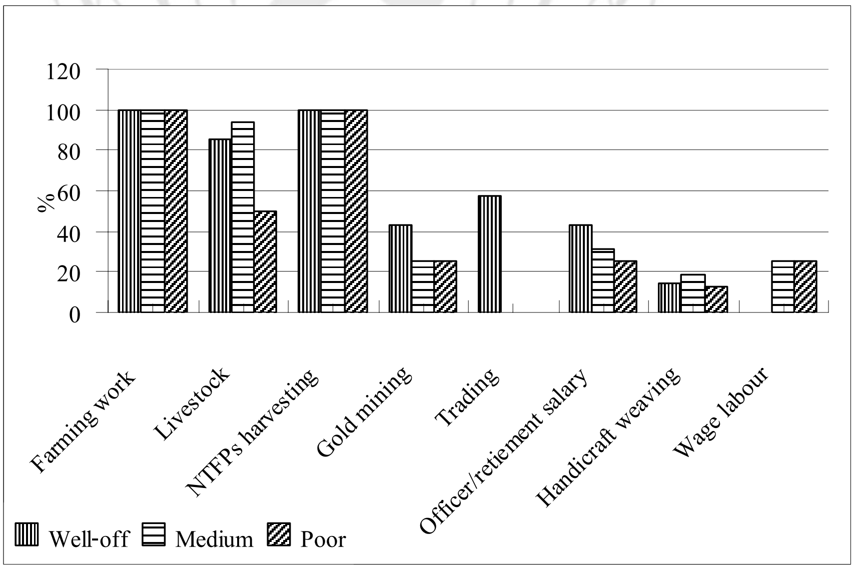


Figure 4.1 Participation of Livelihood Activities of Each Wealth Group

(5) Food sufficiency

According to household interview results, harvests of farm products do not provide sufficient subsistence for many local households year-round. On average, households have only enough rice for about six months per year. After that, they have to buy rice to eat using profits from the sale of cash crops of one kind or another. About only 32.5% of respondents had surplus agricultural products (beans, cassava, corn, etc.) for sale. Many households had no rice to eat for about six weeks each year. During those times, these households have to eat corn, cassava, and/or wild vegetables harvested from the forest. About 67.5% of total interviewed households still had enough supplement food after running out of rice.

When they fall short of food, Co Tu people usually go to the forest to collect NTFPs and hunt wild animals for consumption. About 40% of respondents chose this method. Another 32.5% of households rely on their relatives for supplemental food. Others (17.5%) take out loans from the Commune Peoples Committee Policy Bank or go into debt at one of the local grocery shops (10%). After harvesting agricultural products and NTFPs, they sold these products at these shops to repay these loans.

(6) Income and expenditure sources

Based on survey data from the household interviews, household income in sample villages in 2008 averaged $517 US (8,800,000 VND); total expenditures amounted to $476 US (8,100,000 VND). As shown in Figure 4.2, crop cultivation contributes the highest percentage of total household income (47%), followed very closely by livestock raising (40%). Other non-agricultural activities are truly supplemental income sources: NTFPs collection, trading, wage labor, etc.

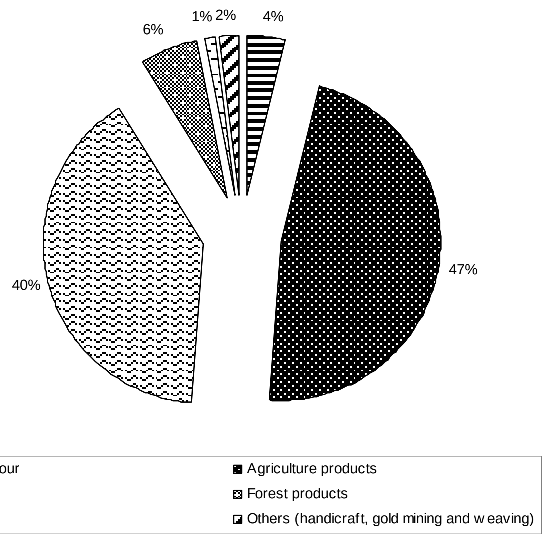


Figure 4.2 Distribution of Household Income Sources in Surveyed Villages

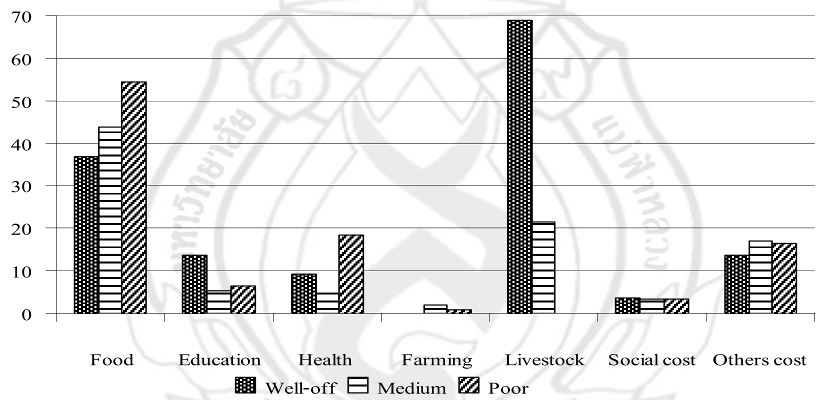


Figure 4.3 Average Household Expenditure by Wealth Group in Surveyed Villages

Principal expenditure categories are quite different among the four wealth groups, as shown in Figure 4.3. The well-off households spend a much higher percentage of their total expenditures for their children's education than do the other households. This reflects the combination of the well – off group's better living conditions and fewer children per household. This group also spends more on raising livestock. In comparison, the poor household groups spend more on health care, and the medium group spend more on farming.

4.1.2 Current Farming System Situation

4.1.2.1 Livestock component

(1) Livestock holdings and management

Livestock is an integral component in these villages' mixed farming systems. Generally three animal species are bred: cattle, pigs and chickens. Almost all Co Tu households raise livestock as a food source and as a main source of cash income. They prefer to raise cattle because its value is so high when compared to other livestock; one mature head of cattle is worth 6 million to 8 million VND. According to our survey, nearly half (44.6%) of total interviewed households kept livestock.

Table 4.2 shows the numbers of livestock in each village. These figures were obtained from village heads' statistics. We can see that Za Ra and Pa Xua Villages each have a large number of high market value livestock. The residents of Za Ra Village appear especially active in livestock husbandry, earning substantial money from this source.

Table 4.3 shows the various uses of livestock in the sample villages. These results were obtained from group discussions with several village households (most of them from the poor group). The figures give an overview of livestock use in the Commune. Because most are poor households, consumption is the dominant use reported. Poor groups generally have few livestock and use it mainly for consumption. It is important to note that an exclusive few well-off households are generally responsible for a large portion of the Commune's total livestock trade.

Table 4.2 Numbers of Livestock in Each Village

Villages	Buffalo	Cow	Goat	Pig	Ruminant
Pa Xua	3	151	3	68	216
Pa Va		77		141	226
Za Ra	7	185	14	46	132
Total	**10**	**473**	**17**	**332**	**726**

Table 4.3 Farmers' Use of Livestock in Each Village

Livestock	Use for Subsistence (%)	Sold or Traded (%)
Cattle	75	25
Pigs	32.5	67.5
Goats	50	50
Chickens	75	25

According to local interviewees, cattle raising does not require much labor. Cattle are simple to take care of. Previously, cows were allowed to graze freely in the forest or along streams. Recently, to prevent disease and simplify their care, some households have shifted to keeping their cattle in simple cages or pens, or tying them outside their house. Cattle raised in these villages are native breeds with relatively small average body weights of around 200 kg to 250 kg per head. Buffalo breeds are not raised so much in these villages because the majority of local land is comprised of upland fields and paddy rice areas, which are not large enough to accommodate these larger draught animals.

While pigs are also being raised in these villages, their numbers have been decreasing nowadays because of disease and lack of capital to reinvest. In the past, each household owned an average of 2 to 5 pigs per year, caring for them for around 6 months before selling them at a profit.

Villagers sell most of their pigs (as high as 70%-80%) to outsiders (through middlemen). Fully 70% of pig producers surveyed allow their pigs to run free in the village; the rest used fencing or concrete floor cages with roofs made of natural leaves. The households who let their pigs roam freely said that they cannot keep these pigs inside cages because they are native breeds that prefer to stay free, and to roam around the village to forage for food by themselves. About 70% of respondents keep native swine because of its advantages in care and the absence of any capital requirements. When necessary they can ask their relatives to feed one or two pigs. Farmers who use pens clean them daily. The liquid wastes generated (to wash away the solid manure and clean the enclosure) are discharged directly into the surrounding environment.

Most households also raise chickens, since initial investments for this livestock are quite low. The respondents said that they feed about 10 to 20 heads of chicken per year. The main purpose of raising chickens is for daily food, and also for holiday food and donations to others. Almost all respondents feed native breeds because of their high economic value and quality. However, the total number of chickens being raised is still small because of the high risks of expanding to a larger scale. Respondents said that the frequency of poultry disease occuring is higher than for other types of livestock.

Since 2001, the Foundation for International Development/Relief (FIDR) has helped the community improve its livestock husbandry activities through two allocation programs, one for pigs and another for cows. With the pig allocation program, they identified interested groups and implemented the support program accordingly. Under the program, one household receives and raises a pig until it produces offspring. The new offspring are given to a second and third household, and so the chain continues. All households in this group benefited from the program and all still currently rear pigs. The cow allocation program follows the same principles. However, after a cow has produced offspring, the mother cow is shifted to another household where it will continue producing new offspring. This altered process is due to the slower reproduction rate of cows. As a result, villagers have been able to increase their livestock numbers. In most cases, however, villagers still do not know how to maintain their assets adequately. Some, especially among the poor group households, killed their allocated livestock for consumption instead of waiting for the animal to produce offspring.

(2) Contributions of livestock to household income

The household interviews revealed that average annual income from this activity is 4,000,000 VND ($229 US) per year. On average, livestock raising contributes about 44% of total household income. Recently, local farmers have expressed greater interest in such activity, especially cattle raising due to its high economic value.

The capital requirements to raise livestock herds in these villages are estimated from household interview results. Details are set out in Table 4.4.

Table 4.4 Average Annual Cost of Different Livestock Species

Item	Feeding mode	Average cost (US$/animal/year)
Pig	- Using locally available feed	$28.57
	- Using both locally available feed and commercial feed	$37.15
	- Using commercial feed	$60.00
Cattle	- Using locally available feed	$85.71
Goat	- Using locally available feed	$ 9.50

(3) Livestock production constraints

Interview results demonstrate that various limiting factors such as lack of capital, poor veterinary services, feed sources' livestock diseases, villagers' low educational levels, and lack of grazing land have affected livestock productivity; details are shown in Appendix E(1). In surveyed villages, many farmers do not have enough money to buy high quality protein sources such as fish meal and soybean meal but are able to produce plants with leaves that can be used as edible nutrient sources for livestock. Examples of these low-protein energy sources are sweet potato leaves, corn grain, rice bran, and cassava root meal, all of which have been used to raise pigs (see details in Appendix E(2)).

Thus to help these farmers feed their livestock based on available local feed sources, it is necessary to introduce unused crop byproducts combined with simple techniques for increasing the nutritive value of feeds with supplements derived from the right types of local plants. Some potential local protein sources such as the foliage from duckweed and stylosanthes, legumes, and elephant grass can become sources to supplement low-protein energy sources derived from local plants.

4.1.2.2 Crops component

(1) Crop cultivation

The ten seed technique allows a rough estimate of different land use distribution. The results are provided in Figure 4.4 as evaluated by villagers.

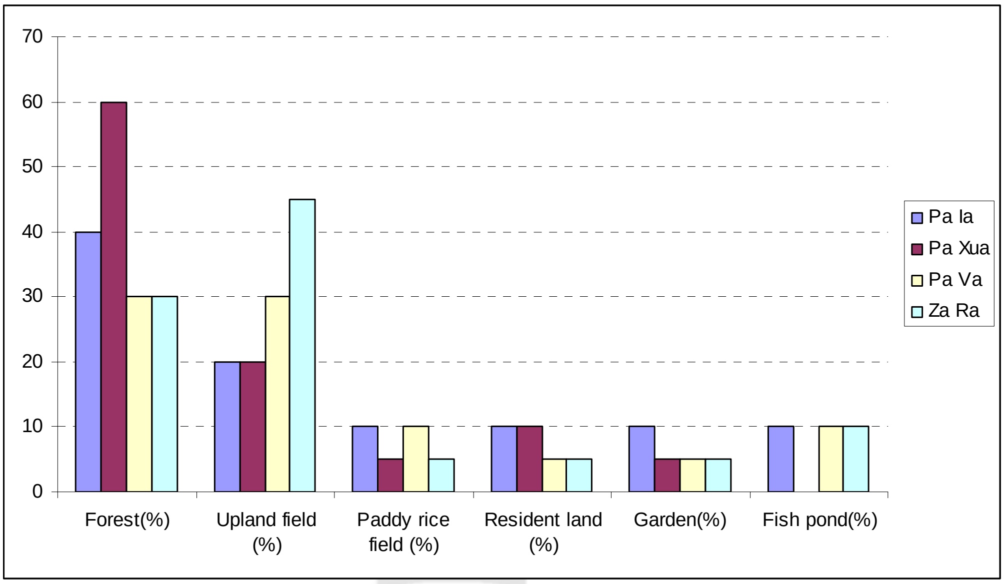


Figure 4.4 Land Use Distribution per Household in Surveyed Villages

We can see here that most of the areas are forest and upland fields. Therefore, local livelihoods here are mainly based on the forests and on cash crops raised in upland fields. Local people can access the nearby forest to collect NTFPs, which provide one of their main income sources. Forests are dominant in Pa Xua while upland fields are dominant in Za Ra. This result is somewhat different from the data for Ta Bhing Commune as a whole partly because, as mentioned above, forests comprise about 76% of total natural land.

Generally, in each village, each household has certain amount of land for its own cultivation. These lands are not located near the household itself but in the uplands. The village committee has authority to allocate these lands to individual households, based on customary arrangements (mouth to mouth communication). Upland fields could be expanded in accordance with government plans. The study area has two main types of cropping patterns: in upland fields and in lowland fields.

From field observation, two types of crops are grown here: rotation crops (upland rice, maize, and beans) and mixed crops (cassava, sugarcane, sweet potatoes, and pineapple). Shifting cultivation, the customary way of farming, applies to all crops grown on slope lands in Tabhing Commune. No fertilizers are applied on upland fields, nor are these lands plowed. The upland fields have no irrigation system, and thus depend heavily on natural rainfall.

Wild animals, weeds, diseases and insects regularly damage crops in these fields. Rain-fed production has limited productivity and thus low economic value. Upland rice grown here is generally completely consumed by the local households, while other crops are mostly sold. Estimates from respondents suggest that fully 90% of the maize, cassava and bean crops harvest is sold. Table A in Appendix D presents details on crop composition of upland field in percentages, as evaluated by villagers.

Differences by village are striking. Pa Xua has by far the most upland rice under cultivation. This village and Pa Va cultivate the most beans and cassava, in equal amounts. These two villages cultivate the most bananas, with Pa Va cultivating slightly more. Pa Xua has the most pineapples.

In addition, these upland areas are also planted with perennial trees such as acacia and cinnamon; such plantations occupy 124 ha. This has contributed to reducing erosion and soil runoff, thus protecting the soil as well as providing further income.

Typically, the size of upland fields being cultivated depends on each household's labor capacity. A household with a large labor force is more likely to be able to expand its land area. The three lower poverty groups base their livelihoods mainly on upland agriculture activities, being significantly more dependent than the well-off group on crops grown here.

Yields of each crop are estimated by villagers in Table 4.5. Accurate data on annual productivity of each crop composition is quite difficult.

From field observations, irrigation-based agriculture found in the commune's lowland regions includes paddy rice activity, fish ponds, and planting of perennial trees. The paddy rice land area is very limited, just about 9.8 ha; it is mainly located near the streams that meander all over the commune's lowlands. Normally, in the absence of an irrigation system, villagers can grow only one crop per season. Here only a very small part of the paddy fields can be provided with enough irrigation water for year-round cultivation, with the rest still cultivated based on available rainwater. However, sometimes two crop cycles can be made per year if rainfall is suitable to fields. In such circumstances the first crop is sown in January and harvested in April; the second crop is sown in May and harvested in November. Generally a month of paddy preparation is needed before sowing a new round of crops. As a consequence, productivity is rather low, averaging only about 2 to 2.8 ton/ha/yr.

Table 4.5 Average Upland Yields of Major crops

Crop items	Ratio of seeds (kg/ha) to cutting stems	Typical yields (ton/ha)
Upland rice	75 – 90	0.9
Maize	75	0.8 - 0.9
Beans	40 – 55	0.3 – 0.55
Cassava	100,000 (cutting stems/ha)	9 - 10

From village heads' statistics, the area of home gardens is also small (about 11 ha). These gardens are planted with fruit trees and perennial trees including cinnamon, chinaberry (Meliaceae), rattan, bamboo shoots, and acacia. While local soil quality is suitable for these species, until now the communities have not made proper investments to enhance productivity. Nowadays, the villagers want to develop the area with commercial trees because of these crops' potentially high market value. From calculations based on the records of village heads, Pa La Village has approximately 1 ha in fruit trees and Pa Xua has 2 ha including banana, mango, jackfruit, longan, and lonkong (no estimates are available for the other two villages). Most individual households have planted only a few fruit trees (if any) because they don't have enough land. Details can seen in Table B in Appendix D.

Based on group discussions, it was possible to devise a calendar of agricultural activities in surveyed villages, shown in Table 4.6. This gives a general view of the timeframe to adopt new alternatives.

Table 4.6 Crops Calendar in Tabhing Commune

Activities	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Paddy rice		First crop						Second crop							
Upland rice															
Bean															
Maize															
Cassava	Hybrid species Native species														
Sub-plant (banana, pineapple, sugar cane)															
Livestock															
Fishery															
NTFPs **Dot** **Long bong** **Uoi** **Rattan**															

Pine apple is in 3 years, banana and sugarcane 7-8 months

Note. ←→ Preparation time

←- - - -→ Planting and harvest

(2) Soil characteristics

According to a 2005 ADB assessment, ferralic acrisols comprise the surveyed villages' main soil type. Details are set out in Table 4.7. Such soils are composed of sand and clay, with very little humus. They have low fertility, with total organic matter content from 1.8% to 2.8 % (Dang, 2001). Almost all areas here have steep slopes, so that the soil is exhausted very quickly if vegetables or forest stands do not cover it. Only in the lowlands in the valleys are there alluvial soils with higher concentrations of humus; but these conditions exist only in very small areas.

In addition, these villagers do not use fertilizers to enrich their soil. As a result, productivity remains quite low. After cultivating rice, cassava, and maize crops for three consecutive years, the soil's organic matter was reduced by 34% to 44% compared with its status at the first slash-and-burn year (Dang, 2001). This phenomenon is consistent with the evidence of decreasing local agricultural productivity year by year at the surveyed villages. Thus it is necessary to add more fertilizer to maintain soil nutrients in order to improve productivity.

Villagers related that the major reason for their non-use of fertilizer is that they do not have enough money to buy them. In our opinion, we should think of using green/organic fertilizers that are available at the site to improve local soil quality, as well as finding suitable methods of cultivation on the slope land, taking into account soil conservation measures at the same time.

Table 4.7 Local Soil Characteristics (Ferralic Acrisols)

Items	Factors	Unit	Estimate
Land quality	Diagnostic		
Water availability (w)	Annual rainfall	mm	> 1,500
Oxygen availability (O)	Soil damage		Very poor
Nutrient Availability Index	NAI		0.1
	N		<0.1
	P		<10
	K		<30
	pH		5
Organic C (%)			1.01
Exchange K		Cmol/kg	0.22
Available P		ppm	3.3
Water retention capacity (R)	Soil texture		CL, Si
Root condition (D)	Soil depth	cm	<15
Salt hazards (S)	Soil salinity potential		Non saline
Topography (T)	Land form and slope		Slope > 5%

Source. Estimated based on1983 FAO land evaluation

(3) Contribution of farming activities to household income

Household surveys revealed average revenues from cropping activities in the surveyed villages. Cash crops were mostly maize, beans, cassava, and rice. Details are shown in Table 4.8. Revenue from rice is higher than from other crops; however, most rice produced is consumed by the households rather than sold. Cassava and beans represent important cash crops for these villagers. These farming activities do not incur any cost except for family labor and arable land. Local people reuse seeds from previously harvested crops or receive government support.

Table 4.8 Total Revenue from Farming in Surveyed Villages

Items	**Area**	**Yield**	**Output**	**Unit value**	**Annual revenue**
	ha	*ton/ha*	*Ton/yr*	*US$/ton*	*US$/year*
Rice	141	0.90	126.90	285.70	36,255.33
Maize	32	0.85	27.20	114.30	3,108.96
Beans	78	0.50	39.00	571.40	22,284.60
Cassava	30.50	9.00	274.50	85.70	23,524.65
Total	**281.50**	**11.25**	**467.60**	**$1,057.10**	**$85,173.54**

Note: 1 USD = 17,500 VND

(4) Crops residues' management

Over half of all respondents to the questionnaires (53%) burned crop residues after harvesting their crops. They take this step in order to prevent weeds from growing on their land and to save on labor. Another 36% said they used harvested by–products for livestock feed. These included green corn stove and sugarcane leaves, sweet potato leaves, and others. People refrain from using crop by-products for their livestock because of the long distances between their houses and their upland fields (estimated about 2 to 3 km on average, taking about 30 minutes on foot). The results overall show that respondents have at best only limited awareness of the possibility of using crop by-products as livestock feed.

(5) Farming cultivation: constraints and opportunities

From field observation, local people at all four surveyed villages face many problems in farming cultivation. The main constraints are lack of skills or knowledge, pests and insects, low prices and few if any markets for agro–byproducts, as well as weather. Details are set out in Appendix E (1). Other major problems as reported by villagers include poor soil quality, lack of high hybrid varieties, shortage of capital, and lack of labor.

From a survey of the sample site, lack of skills and knowledge in farming cultivation among respondents emanates from their generally low education levels, limited communications with the outside world, and poor learning behavior with respect to acquiring and using new techniques. Meanwhile, low prices and lack of markets for agro–products were due to their reliance on selling local products to middlemen directly without separating products at home to add value prior to their sale. The middlemen often reduce the price at which they will buy well below the probable market price in order to enhance their own profits. Markets are so far away from these villages that local people mainly sell their agricultural products to local middleman at prices much lower compared to market prices. Thus almost all products produced locally have low economic value to these villagers, resulting in the villagers having less motivation to produce surplus products. They focus instead on growing for local consumption.

This situation offers a real opportunity to add value to local products. Finally, pests and other diseases are an important factor because the villagers don't use any pesticides nor know any other ways to prevent pest infestations.

Through field survey conducted by group discussions, some opportunities were identified in these villages.

1. Land policies provide usufruct rights on forestlands
2. Large unused land for agro-forestry
3. Farmers have significant traditional agro-forestry knowledge
4. Manure and other farm wastes are available for composting
5. High-quality planting stocks available (acacia hybrid, A. mangium, pomelo)
6. Existing market for pulpwood, betel nut and fruits
7. Government offers low interest rural credits
8. Local enterprises exist to provide technical/extension services

9. One trained veterinarian is deployed in the Commune

10. Strong government support for rural development and poverty alleviation overall

4.1.3 Current Relations Between Crops and Livestock Components

According to household interviews, 47.5% of respondents realized that crop residues are a good feed source for livestock, 39% of respondents said that these are a fertilizer source for soils, while only 13.5% said that they don't know any role for crop residue. The high proportion of respondents who are aware of the potential use of crop residues as livestock feed or soil fertilizer resulted from project training courses organized by NGOs and the district Agriculture Department. When asked about the role of livestock manure, 42.6% of total respondents said that it is a fertilizer source for crops, 10% answered that it improves soil quality, while 16% of respondents had no idea about the role of manure (see Figures 4.5 and 4.6).

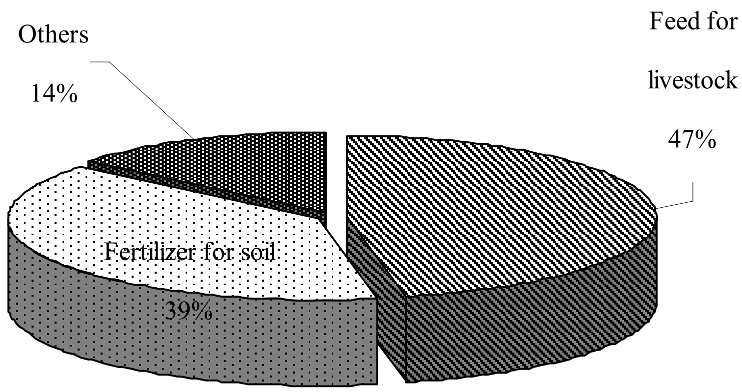


Figure 4.5 Awareness of Crop By-product Role in Surveyed Villages

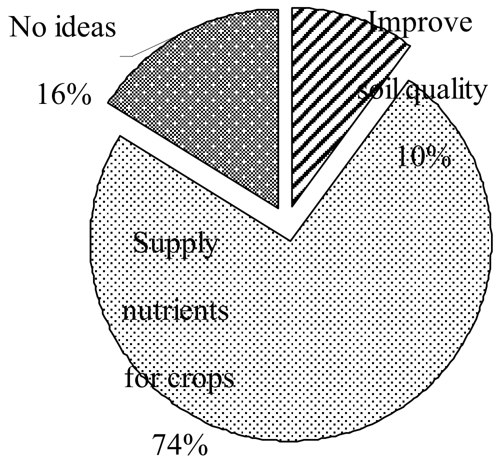


Figure 4.6 Awareness of Livestock Manure Role in Surveyed Villages

94% of total respondents from the surveyed villages said they did not use compost or any organic fertilizers for their crops. A few did report using compost after they were trained by the FIDR project, but almost of them gave up composting not long thereafter. 15.4% cited insufficient time, 32.7% cited lack of knowledge on composting techniques, 9.6% cited lack of available labor, 11.5% cited lack of financial resources, and 30.8% cited other constraints as their reasons for not using compost or organic fertilizers. Many really did not seem to know which crops to fertilize and how to apply manure fertilizer. From these statements, outside groups have not yet transferred to local villagers sufficient knowledge about organic fertilizer use and its potential economic value. Low educational levels are indeed one of the primary factors limiting new technology adoption in rural communities like this one.

When respondents were asked if they would use compost or organic fertilizer if given training and support technology, 50% said they would, and the rest said they would not. Some of them explained their resistance by noting that they haven't seen any explicit results of organic fertilizer application yet. This suggests that the local agriculture extension agency needs to support local people more effectively. Overall, the results show that these respondents have limited awareness of the possibility of using crop by-products and livestock manure.

There is a need to raise awareness of animal manure utilization for soil and crops and use of crop residues for livestock feeding. Because, when only mineral fertilizers are continuously applied to the soil without adding organic manure, productivity of land will decline. But, there are a lot of concerns as recorded, such as insufficient time, lack of knowledge on composting techniques, lack of available labor, lack of financial resources, difficulty of using compost or organic fertilizers, difficulty in identifying crops for fertilizer application, and uncertainty over economic value of such activities. In addition, if only organic manure is added to the soil, the desired increase in crop yield cannot be achieved. On top of that one can anticipate a loss of livestock manure nutrients when it is applied to the soil from volatilization (especially nitrogen) due to exposure to sun (heat) as well as by leaching. Many fertility researches carried out in Vietnam and elsewhere have revealed that optimum results can be achieved only through combined application of both chemical and organic fertilizers.

4.2 Estimation of Animal Manure and Crop Residues Nutrients

4.2.1 Potential to Increase Use of Livestock Manure

Organic matter plays an important role because of its beneficial effects in supplying plant nutrients, enhancing cation exchange capacity, improving soil aggregation, increasing water holding capacity of soils, and stabilizing soil humid content. Organic soil amendments support biological activities and also control root pathogens.

Three main manure types are available in the surveyed villages: slurry, solid manure and liquid manure. Slurry manure is a mixture of urine, feces, and water; solid manure is feces and litter scraped off the floor; and liquid manure is a combination of urine and feces remaining after scraping, and cleaning water. We observed almost all local livestock producers discharging manure freely into the surrounding environment -- into rivers, water channels, and ponds. No one seems concerned about waste storage or pathogen transmission. This situation certainly offers an opportunity to encourage improved livestock manure disposal and use in the community.

To date, there are no precise data on N and P composition in the liquid and solid manure fractions as affected by treatment from Vietnamese animal production. In this context, the nutrient content of the manure was based on the calculated nutrient content in fresh manure. The research roughly estimated nutrient availability in livestock manure using assumptions based on excreted manure composition of VISTA. In addition, most livestock were assumed to be mature animals. Based on these assumptions, the approximate main nutrient composition in livestock manure related to current livestock holding size in surveyed villages is shown in Table 4.9. These are average values of livestock in the best conditions. Main nutrient compositions are calculated before applying manure to the field.

Table 4.9 Estimated Annual Manure Nutrient Excretion and Available Nutrients for Crops

Items	**Heads**[1]	**Daily manure/ head (kg)**	**Total annual manure (ton)**	**N content (ton/yr)**		**P_2O_5 content (ton/yr)**		**K_2O content (ton/yr)**	
				Excreted	**Crop uptake**	**Excreted**	**Crop uptake**	**Excreted**	**Crop uptake**
Cows, buffalo	483	10	1762.95	5.11	1.53	3.00	2.40	17.63	14.99
Pig	332	1.5	181.77	1.09	0.33	0.75	0.60	0.47	0.40
Chicken	726	0.1	26.50	0.43	0.13	0.14	0.22	0.23	0.19
Goat	17	1	6.21	0.03	0.01	0.02	0.02	0.02	0.018
Total	**1,558**		**1,977.42**	**6.66**	**2.00**	**3.91**	**3.1**	**18.35**	**15.6**

Notes: (1) Based on surveyed data in the four villages in 2009.

Chicken manure has the highest nutrient composition compared to the others, but the actual total excreta amounts are much lower than cattle and pig manure because of the much smaller herd size. The next highest nutrient composition comes from pig manure, whose contents in terms of main nutrient composition are higher than cow and buffalo manure but pigs excrete less manure per day than do the larger animals.

However, the actual nutrient value of livestock manure depends on the method of collection and storage facilities, as well as the species of animal. In addition, nutrient composition in livestock manure will be lost or converted to other forms during treatment or storage and handling, affecting its availability for use in growing plants. The type of animal housing system or waste handling method is known to affect the final nutrient composition of the waste (Dan et al., 2003).

In such research, average proportional losses of N, P and K, selected to best suit local conditions, are 70%, 20% and 15% of the total manure nutrients, respectively. Available total nutrient amounts for crop uptake, as calculated, are shown in Table 14.9 for nitrogen (2.1 ton/year), phosphate (3.1 ton/ year), and potassium (15.6 ton/year). Based on these figures, if the livestock here were indeed managed effectively then this total amount of nutrients would be a potentially important nutrient source for crop production in the survey villages. Annually, with such amounts of nutrients available, nutrient manure added to the soil would help to maintain soil texture and organic levels as well.

4.2.2 Potential Crop Residues and By-Products

Crop residues and byproducts play a significant role in the nutrition of ruminants. If we are interested in making better use of these items as animal feed, it is important to know their quantities, seasonal availability, alternative uses, nutritional value, and their location with respect to that of local livestock.

Processes for improving use of these by-products must be practical, economical, and, if possible, should use existing farm machinery and not require new and expensive equipment. Countries in the GMS region must make use of prevailing high ambient temperatures for drying by-products and for enhancing chemical treatment of crop residues.

No inventory of crop byproducts is available for the four surveyed villages. To fill in this important data gap, this research effort prepared a calculation based on studying potential nutritional amounts for livestock in the community. Results are presented in detail in Table 4.10. The gross output of agro-byproducts is calculated in terms of the yield of total digested nutrients (TDN) of varying crop types. The annual amount of TDN content from crop residues and byproducts from areas currently under cultivation is calculated based on different TDN fractions for each crop type. The total estimated supply of TDN yield of crops residues, byproducts, and natural grasses from this whole area is indeed significant for beans vines, rice straw, and old maize stove. Natural grass is considered to have potential value as well, though no precise information exists about the locations and quality of grass.

Table 4.10 Estimated Total Gross Output of Crop By-products

Crop by-products	Cultivated area (ha)	Total waste amount (ton/ha)	Productivity (ton dry matter DM/yr)	Total digestive nutrient TDN (%DM)	Gross output of byproducts (ton TDN /yr)
Bean vines	78	6 – 8	96.72	63.6	57.55
Cassava leaves	30.5	4 – 5	24.40	67.5	15.52
Sugarcane leaves	0.07	7 – 8	0.13	43.3	0.06
Rice straw	141	3 – 4	86.72	45.9	39.80
Old maize stove	32	8 – 8.5	65.28	54.7	35.71
Natural grass[1]	100	6 - 8	143.50	17.0	24.40
Totals	**281.57**	**28 – 33.5**			**173.04**

Source: Calculated based on Chinh and Ly (2001)

However, these byproducts' high content of crude fiber presents the main constraint to their intake and digestion by livestock. If these byproducts were combined and mixed with each other or with cassava or sweet potato tubers, one could get important feed resources and greatly improve the efficiency for smallholder farmers.

4.2.3 Using Crop Residues to Animal Uptake

Crop by-products contain potential nutrition and energy (TDN content). Some sources with high fiber and low protein contents would be good for ruminant diets. Such by-products in Vietnam are abundant, with over 29 million ton DM per year. Their greater use would contribute to improved cattle production in general. Vietnamese farmers are accustomed to using agro-byproducts as buffalo and cattle feed, but only do so with a small part with the rest left out on the

[1] Assumption from land use status in Tabhing Commune in 2007.

fields and then burned or used as fertilizer. Stronger encouragement for farmers to make better use of available agro-byproducts is needed to contribute to their increased income.

Meanwhile, in surveyed villages, crop by-products are estimated in this study with a total TDN content gross output of 173 tons of unused livestock feed per year. Therefore, to encourage farmers to make greater use of these available feed sources for cattle it is better to calculate nutrient requirements per LU than to estimate suitable amounts of additional livestock that should be raised.

The nutrient requirements of the different livestock depend on their age as well as their production performance. Therefore, livestock numbers need to be converted to livestock units in order to calculate their nutrient requirements. Details are shown in Table 4.11.

Table 4.11 Conversion of Livestock Species to Livestock Units in Surveyed Villages

Species	Body weight (kg)	LU conversion factors*	Number of livestock	Livestock units
Cow	200 -250	0.65	473	307.45
Buffalo	250 - 300	0.7	10	7.0
Goat	20	0.1	17	1.7
Pig	80	0.25	332	83.0
Poultry	2	0.01	726	7.26
Total LU				**406.41**

Source: Calculation based on the Tabhing Commune People Committee's statistical data in 2000.

Note: * Based on FAO standard (2005)

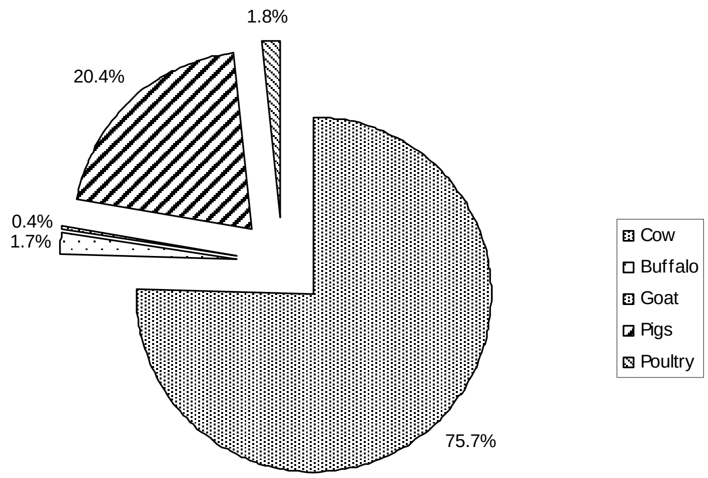


Figure 4.7 Contribution of Different Species to Total Livestock Units

Based on the work of Banerjee (1986), annual TDN requirement amounts were estimated for the four surveyed villages as shown in Table 4.12.

Table 4.12 Estimated Feed Requirement per Livestock Unit

Items	Body Weight (kg)	TDN requirement Daily (kg/LU)	TDN requirement Annual (kg/LU)
Buffalo	300	2.3	839.5
Cow	250	2.02	737.3
Goat	30	0.4	146
Total		**4.72**	**1,722.8**

The results show that annual feed requirements for buffalo, cows and goats are estimated as approximately 0.01 to 0.8 ton (TDN) per such livestock unit (LU). Assuming that half of the total available TDN amount can be used as feed for livestock (i.e. 86.5 ton/year), it is possible to raise an additional 103 more new LU of cattle or 592 new LU of goats per year in the four surveyed villages. Given that in recent years a total of 400 LU has been raised per year in total in the four surveyed villages, an increase of some 14.8% – 19% in total livestock units reared is feasible. This clearly illustrates the potential of crop residue recycling to enhance the community's efficiency and income generation.

4.3 Optimum Waste Allocation Level in an Integrated Farming System

The study objective is to maximize total profits from the mixed farming system's two core components: crops and livestock. We used linear programming to evaluate available possible alternatives in terms of their efficiency for both the whole farming system and individual local farmers, and also to determine levels of implementation that will maximize revenue.

4.3.1 Model Description

Various factors have to be considered in determining the economics of the integrated crop-livestock production systems. Some of these factors are discussed below.

(1) Physical factors

To obtain an efficient integrated production system, one need to pay attention to physical factors, including environmental conditions of the farm area. Yields can vary in different crops types, and types of livestock stocking (cattle, buffalo, and goats). In linear programming these characters are assumed and clearly defined in determining the economics of an integrated production system.

The study site has grown rice, corn and beans on its farmland. This requires kg of nutrients (N, P, and K) for rice, maize, and beans. The yields (ton /hectare) of the various crops depend on fertilizer and the weather as well. With assumption of good weather conditions plus adding fertilizer to crops the farmer can increase his crops' productivity with equal probability (50%). If current crop yield is 'Y_o', then the potential yield of various crops is given by: $1.5Y_0$.

The yield of various crops is as follows:

	Rice	Maize	Beans
Current crops area	141	32	78
Current yield	0.9	0.85	0.5
Potential yield	1.4	1.3	0.8

(2) Farm size, stocking types and other data inputs

Information on current livestock types and farm size were collected from a survey for integrated production systems. Information on the volume of manure per animal and relationships between crop yields (ton/ha/yr) and animal manure (kg/yr) is calculated based on many supporting data, with results shown in Table 4.10. Other data since then are also estimated for integrated farming system, with details shown in Table 4.13. Together with required information on crop and livestock components, recommendations on stocking rates could be made.

Table 4.13 Data Inputs for Integrated Farming System Modeling

Items	Unit	Crops		
		Rice	Maize	Beans
Crop nutrient achieved ton per ha (X_t)	KgN/ha	24.0	25.7	72.0
Uptaked soil nutrient (X_0)	KgN/ha	10.4	9.8	5.8
Potential yield achieved crop nutrient (X_p)	KgN/ha	32.4	32.8	54.0
Limit crop nutrient (X_m)	KgN/ha	35.7	34.6	60.0
Potential yield (Y_p)	ton/ha/yr	1.4	1.35	0.8
Current yield (Y_0,b)	ton/ha/yr	0.9	0.85	0.5
Coefficient (a)*		0.014	0.013	0.005
Dry matter fraction (FDM_i)	%	90.8	35.5	22.5
Total digestive nutrients fraction ($FTDN_i$)	% of DM	45.9	54.7	63.6
Required TDN amount for LU ($RTDN_j$)	Kg/yr	839.5	737.3	146.0

Note: * Calculated as in Item 3.6

(3) Economic analysis

Costs of crop components are considered as working capital. For the livestock component, costs of breeding and collecting nutrient manure are also included in the model under different scenarios. Market prices (sales price) of crops and livestock were also included in the model with the objective of increasing farm income. Details are shown in Table 4.14. Using the data on costs and returns, net profit can be calculated from the difference between total revenue and total operating cost.

From this information one can determine the economics of the different link level of integrated crop-livestock production systems. The selected type should be the one that gives the highest net profit. While the analysis summarized above provides adequate information for certain farm types, optimum production can be estimated using linear programming model to find the level of "maximum" profit. Production from these farms can be used both for home consumption and/or sold to the market where market access exists.

Table 4.14 Market Price and Costs of an Integrated Farming System

	Items	**Selling price**	**Breeding cost ($/LU)**	**Manure collecting cost ($/LU)**
Crops	Rice	285.7	0	0
	Maize	114.3	0	0
	Beans	571.4	0	0
Livestock	Cows	3.42	122.4	0.02
	Buffalo	2.86	131.9	0.02
	Goats	0.95	85.7	0.02

4.3.2 Model Formulation

To formulate the optimum crop yield and additional livestock number in a crop-livestock integrated farming system, the study used linear programming as the main analytical tool. This allowed selection of the best solution among a range of available possible alternatives evaluated in terms of their efficiency considering sociological and environmental factors, the entire farming system to be implemented by local farmers, and the level of implementation that will maximize revenue. The study objective was to maximize the total profit from a combination of two components of a crop-livestock integrated farming system: crops and livestock. The structure of linear programming model is described as below.

A. Objective function:

MAX= CROPS PROFIT + LIVESTOCK PROFIT

(1) Profit calculation of livestock (PL)

$$PL = \sum_{j=1}^{m} (W_j * P_j * A_j - C_j * A_j) \qquad (16)$$

Where

PL : Profit of livestock species ($/yr)

W_j : weight of LU j (kg/LU)

P_j : market (selling) price of livestock j ($/kg)

A_j : number of additional LU j (LU/yr) when crop residues recycled

C_j : costs of LU j ($/LU)

m : number of livestock species (m=3)

j : index of livestock types (1,2,3 for buffalo, cow and goat respectively)

(2) Profit of crops (after manure application):

$$PC = \sum_{i=1}^{n} CA_i * CP_i * (Y_i - Y_{0i}) \qquad (17)$$

Where

PC : Profit from all crops ($/yr)

CA_i : Area of crop i (ha on a yearly basis)

CP_i : Market price of crop i ($/kg)

Y_i : Yield of crop i (ton/ha/yr) if X_i of manure applied

Y_{0i} : Current yield of crop i (ton/ha/yr)

n : Number of crops (n=3)

i : Index for crop i (i= 1, 2, 3 for rice, maize, beans respectively)

B. Decision variables

X_i: allocated nutrient N to crop i (kg/ha/yr) to get Y_i level (with X < saturation point)

A_j: number of additional LU j (LU/yr) when crop residues recycled

C. Data set:

(1) For livestock component

X_a : Total available nutrient amount (kg/yr)

W_j : Weight of LU j (kg/LU)

P_j : Market (selling) price of livestock j ($/kg)

C_j : Costs of LU j ($/LU) (including feeding cost and labour cost)

$RTDN_j$: TDN amount requirement per LU j (kg/LU)

TN : Total additional nutrient amount (kg of N/yr)

EN_j : excreted nutrient amount from livestock j (kg/LU/yr)

(ii) For crop component

CA_i : Area of crop i (ha on an yearly basis)

CP_i : Market price of crop i ($/kg)

Y_{0i} : Current yield of crop i (ton/ha/yr)

Y_i : Yield of crop i (ton/ha/yr) if X_i of manure applied

TDM : Total available dry matter amount (kg/yr) from crop residues

TDN : Total available digestive nutrients (TDN) amount (kg/yr) from crop residues

FDM_i : DM fraction of crop i

$FTDN_i$: TDN fraction of crop i

X_{max} : Upper limit of nutrient of crop c (kg/ha/yr)

D. Model constraints:

(1) For livestock component

Total of additional animal quantity do not exceed total available TDN amount:

$$\sum_{j=1}^{m} A_j * \text{required TDN per livestock j} \leq 0.5 * \text{Total available TDN} \quad (18)$$

Assuming in this formula, there is only a half of available TDN amount used for livestock feed.

(2) For crop component

Total allocated nutrient amount of such crops do not exceed total available nutrients amount:

$$\sum_{i=1}^{n}\left(CA_i * X_i\right) \leq X_a \tag{19}$$

Due to concerned over negative environmental impacts, allocated nutrient for each crop have an upper nutrient limit level:

$$X_i \leq X_{max} \tag{20}$$

E. Dependent variables calculation:

Additional livestock nutrient per livestock j is calculated in (7) as followings:

$$AN_j = 0.3 * A_j * EN_j \tag{21}$$

In formula (21) approximately 30% of total additional nutrient amount is used as available nutrient that crops can uptake.

Excess quantity of crop i: $EQ_i = CA_i * (Y_i - Y_{0i})$ (22)

Total dry matter amount (TDM) and digestive nutrient amount (TDN) are calculated in (23) and (24) as follows:

$$TDM = \sum_{n=1}^{i}(EQ_i * FDM_i) \tag{23}$$

$$TDN = \sum_{n=1}^{i}(TDM_i * FTDN_i) \tag{24}$$

4.3.3 Model Results

This study carried out five scenarios to assess integration level between livestock and crops components. The details, including process, of each scenario are described in Table 4.15.

Table 4.15 Scenarios List of Optimum Nutrient Allocation under LP Model

No.	Description
Scenario 1	Use of available nutrient manure for uptake crops in an integrated crop-livestock farming system.
Scenario 2	Introducing waste recycling in an integrated crop-livestock farming system
Scenario 3	Using additional livestock manure under waste recycling processes
Scenario 4	Using both existing crop byproducts and additional livestock manure under waste recycling processes
Scenario 5	Using both existing crop byproduct and additional livestock manure including a risk factor into the farming system

Scenario 1: Use of available nutrient manure for uptake crops in an integrated crop-livestock farming system.

In this scenario, the optimum amount of nutrients, obtained from livestock manure, and allocated to achieve the highest yield is 2,000 kg per year for 3 main crop types (rice, maize, beans) in all cultivated areas in surveyed villages. Total farm profit maximization is carried out using the following linear programming model:

Objective function in scenario 1 is to maximize crop profit using all available nutrient manure for crops.

MAX = CROP PROFIT = (16)

The results are shown in Table 4.16. The model revealed that farm profit increase by 13% of total farm income or almost $8,000 per year among the 243 households in the 4 villages (equivalent to $32.90 per household per year at a market price of $285.70 per ton of rice). This gain was derived from 14.8 kgs of allocated nutrients to crops, allowing 1.1 ton of rice to be produced. Profits from increased rice crop yields through manure utilization are calculated using the formula above. However, labor costs for manure collection were not included. Higher yields for maize or beans were not achieved in this scenario due to insufficient manure available from livestock (2 ton produced per year). The LP model allocated all available nutrients from manure to rice crops as this crop type has been determined to be able to most efficiently utilize nutrients when compared to maize or bean crops, resulting in the least waste. The nutrient allocation amount also considered the size of the rice–growing area (141 hectares) and current crop yields (0.9 ton/ha/yr).

Table 4.16 Total Optimum Farm Profit through Using All Nutrient Manure

Items	Unit	Crops		
		Rice	Maize	Beans
Nutrient allocated (X_i)	kgN/ha/yr	14.18	0	0
Crop yield (Y_i)	ton/ha/yr	1.1	0.85	0.5
Crop area (A_i)	ha	141.0	32	78
Excess quantity (EQ_i)	ton/yr	28.0	0	0
Crop profit (PC_i)	US$/yr	44,254.93	3,108.96	22,284.60
Initial value	US$/yr	36,255.33	3,108.96	22,284.60
Total profit	**US$/yr**			**7,999.6 (13%)**

Scenario 2: Introducing waste recycling in an integrated crop-livestock farming system

In this scenario, optimum nutrients are allocated to each crop, and then crop residues are recycled to produce additional animal feed, resulting in a positive feedback loop in which the feed allows for more livestock to be grown that, in turn, produces more manure, allowing more nutrients from manure to be available for crops, and more crop residue by-products to be recycled as animal feed. The objective of this scenario is to maximize (additional) total farming profit from both crops and livestock. Input data are summarized in Table 4.13 and Table 4.14; results are shown in Table 4.17.

The objective function for this scenario is formulated as follows:

MAX = Z = PC + PL = (16) + (17)

In this scenario, operating cost (C_j) is breeding cost of livestock unit ($/yr).

The result shows that when crop by–products are used, profits increase by 22% among all households in the surveyed villages. Profits are derived from 7.9 additional LU equivalent to 12 cattle as well as 28 additional ton of rice gained per year. Additional manure excreted from new livestock units raised and fed from crop by–products is 128.6 kg of N. This potential manure gain can be used for cultivation in the following year. Waste recycling in integrated farming systems between crop and livestock components is highly effective.

Table 4.17 Total Farm Profit with Recycling of Animal Manure and Crop Residues

Items	**Unit**	**Crops**		
		Rice	**Maize**	**Beans**
Total annual available LU manure	kg of N/yr			2000
Nutrient allocated (X_i)	kg of N/ha/yr	14.18	0	0
Crop yield (Y_i)	ton/ha/yr	1.1	0.85	0.5
Excess quantity (EQ_i)	ton/yr	28.0	0	0
Crop products:				
1. Total sales output (PC_i)	$/yr			7,999.60
2. Total crop residues (TDN_i)	ton/yr			11.7
Items	**Unit**	**Animals**		
		Buffalo	**Cows**	**Goats**
Additional animal (A_j)	LU/yr	0	7.9	0
New animal manure (AN_j)	Kg of N/yr	0	128.6	0
Breeding Cost (C_j)	$/yr	0	968.67	0
Livestock profit (PL_j)	$/yr	0	7,151.09	0
Z (total profit)	**$/yr**			**13,797.4(22%)**

Scenario 3: Using additional livestock manure under waste recycling processes

The objective function of this scenario is similar to scenario 2. However, available nutrient amount is altered by utilizing manure gained from new livestock units raised from crop by–products (128.6 kg of N) as presented in formula (26) in the following year. Hence, the model constraint in this scenario is also changed as seen in formula (25).

MAX = PC + PL = (16) + (17);

Total allocated nutrient amount of such crops do not exceed total new available nutrients amounts

$$\sum_{i=1}^{n}\left(CA_i * X_i\right) \leq X_n \qquad (25)$$

Additional new animal nutrient quantity is calculated based on two rounds of nutrient manure recycling from current LU numbers plus new additional livestock units. Hence, total new additional nutrient amount (X_n) gained from new livestock is calculated as in (26):

Total new available nutrient amount: $X_n = 2 * X_a + \sum_{j=1}^{m} AN_j$ (26)

The results of this scenario are found in Table 4.18.

Table 4.18 Total Optimum Farm Profit under Recycling Extra Nutrients

Items	Unit	Crops		
		Rice	Maize	Beans
Total available LU manure	kg N			4082.63
Nutrient allocated (X_i)	kg N/ha/yr	28.95	0.00	0.00
Crop yield (Y_i)	ton/ha/yr	1.31	0.85	0.50
Excess quantity (EQ_i)	ton/yr	57.16	0.00	0.00
Crop products:				
1. Total sale output (PC_i)	$/yr			16,329.72
2. Total crop residues (TDN_i)	ton/yr			23.82

Table 4.18 (continued)

Items	Unit	Animals		
		Buffalo	Cows	Goats
Additional animal (A_j)	LU/yr	0	16.15	0
New animal manure (AN_j)	Kg of N/yr	0	78.75	0
Breeding Cost (C_j)	\$/yr	0	1,977.31	0
Livestock profit (PL_j)	\$/yr	0	11,834.76	0
Z (total profit)	**\$/yr**		**28,164.48 (45%)**	

Scenario 4: Using both existing crop byproducts and additional livestock manure under waste recycling

In this scenario, the objective function also maximizes profits of crop and livestock components, similar to scenario 3. There is no change for the crop component and the formula remains the same as formula (16). For the livestock component, however, there is change in the form of additional LU quantity through utilization of available feed sources. As calculated in Table 4.10, available TDN (total digestive nutrients) amount in surveyed villages is about 173.3 kg per year. It is possible to use 20% of the total TDN amount to feed more livestock. Applying livestock manure that is collected from current livestock on crops will increase productivity and allow reuse of crop byproducts from these new additional crops to feed more livestock. Operating costs in this scenario were LU breeding cost and manure collection cost (labor cost). Livestock profit can be presented using formula (27) below:

$$PL = \sum_{j=1}^{m}(W_j * P_j * A_j - C_j * A_j - X_n * LC_j) \qquad (27)$$

Where

C_j : Breeding cost (\$/LU/yr)

LC_j : Labour cost for compost making (0.02\$/kg)

Hence, the objective function formula for this scenario is formulated as follows:

MAX = Z = (16) + (27)

Total allocated nutrient amount of such crops do not exceed total new available livestock nutrients amount as shown in formula (25).

The addition of total new livestock units are not allowed to exceed 20% of total existing TDN quantity as formula (29) below shows.

New total available TDN amount (NTDN) = Potential available TDN amount + Additional TDN amount. (28)

$$\sum_{j=1}^{m}(AN_j * RTDN_j) <= 0.2 * NTDN \quad (29)$$

Where

- Required nutrient of livestock j (RTDN)
- Potential available TDN amount (173,000 kg/yr)

Additional TDN amount each crop is allocated depends on DM amount and TDN fraction of such crop as shown in formula (24).

Details are set out in Table 4.19. Model results indicate total profits under this scenario will be increased by 91%, or $56,153.44. It is possible to have more than 53.68 LU of cattle fed if using absolutely 20% of total potential TDN amount from current crop residues and natural grass in surveyed villages according to the integrated crop-livestock farming system model. Rice productivity increased by 59.69 ton, allowing the production of 197.88 ton of TDN, which contributed to total available TDN used to feed more livestock. This option increased profits by 46% when compared with the results of Scenario 3, indicated the profitability of increasing cattle raising.

Table 4.19 Total Optimum Farm Profits with Two Rounds of Waste Recycling

Items	**Unit**	**Crops**		
		Rice	**Maize**	**Beans**
Total available LU manure	kg of N			4263.55
Nutrient allocated (X_i)	kg of N/ha/yr	30.24	0	0
Crop yield (Y_i)	ton/ha/yr	1.32	0.85	0.5
Excess quantity (EQ_i)	ton/yr	59.69	0	0
Crop products:				
1. Total sale output (PC_i)	$/yr			17,053.35
2. Total crop residues (TDN_i)	ton/yr			197.88
Items	**Unit**	**Animals**		
		Buffalo	**Cows**	**Goats**
Additional animal (A_j)	LU/yr	0	53.68	0
New animal manure (AN_j)	Kg of N/yr	0	261.67	0
Breeding Cost (C_j)	$/yr	0	6,481.75	0
Labour cost (LC_j)	$/yr	0	223.03	0
Livestock profit (PL_j)	$/yr		39,100.09	
Z (total profit)	$/yr		56,153.44 (91%)	

Scenario 5: Using both existing crop byproduct and additional livestock manure, and including a risk factor into the farming system

The objective function of this scenario is similar with scenario 4. However, a risk factor was included in the model to predict how much farm profit can be gained if livestock deaths occurred. On average, about 20% of livestock die during the time of the second waste recycling process. Hence, livestock profit in this scenario is dependent on 80% of total livestock sold subtract all costs of LU breeding and manure collection labor. This change can be seen in formula

(27) below. There is no change for crop components and the formula used, formula (16), remains the same.

$$PL = \sum_{j=1}^{m}(W_j * P_j * 0.8 * A_j - C_j * A_j - (1.8 * X_a + 0.8 * AN_j) * LC_j)) \qquad (30)$$

Hence, the objective function formula for this scenario is formulated as follows:

MAX = Z = (16) + (30)

Total farm profits under this approach are shown in Table 4.20. The result of this scenario show that total farm profit after two recycling rounds increased about 72% of total income. This gain was derived directly from selling crop-grain and animal meat products. The crop benefit is from effective allocation of 3,808.22 kg of N of animal manure to crops after two rounds of waste recycling, allowing a crop yield of 1.32 ton/ha/yr to be achieved. With the increased crop yield amount, additional TDN produced will be 195.22 ton per year. Such TDN amount may feed more than 53.68 LU, and will return livestock profit into total farm income. So it is possible to gain farm profit by applying all available nutrient manure to crops, allowing these crops to provide livestock with feed from crop residues. Hence farmers are assured of receiving benefits when two rounds of waste recycling processes are applied under the integrated crop-livestock farming system.

Table 4.20 Total Optimum Farm Profits with Two Rounds of Waste Recycling under Risk

Items	**Unit**	**Crops**		
		Rice	**Maize**	**Beans**
Total available LU manure	kg of N			3,808.22
Nutrient allocated (X_i)	kg of N/ha/yr	27.01	0	0
Crop yield (Y_i)	ton/ha/yr	1.32	0.85	0.5
Excess quantity (EQ_i)	ton/yr	53.32	0.00	0.00
Crop products:				
1. Total revenue (PC_i)	$/yr			15,232.11
2. Total crop residues (TDN_i)	ton/yr			195.22
Items	**Unit**	**Animals**		
		Buffalo	**Cows**	**Goats**
Additional animal (A_j)	LU/yr	0	53.68	0
New animal manure (AN_j)	Kg of N/yr	0	261.67	0
Breeding Cost (C_j)	$/yr	0	6,481.75	0
Labour cost (LC_j)	$/yr	0	198.79	0
Livestock profit (PL_j)	$/yr		29,540.98	
Z (total profit)	**$/yr**		**44,773.09 (72%)**	

In all five scenarios, arm profits gained were different. As indicated in this study's results, scenario 4 gave the highest income gain under the integrated farming system due to the usage of all available local resources. Scenario 5 gave the second highest income gain, with total income increasing 72% because risk was factored into the model. The third highest income gain scenario was scenario 3 with total income increasing by 45% because available crop by-products in surveyed villages was not included in the model. For scenario 2, there was a total income gain of 22%, less than scenario 3 because added livestock manure was not recycled in the second round.

The lowest income gain was in scenario 1, with total income increasing by 13% of total income because the livestock component was not integrated into the model. An integrated crop-livestock production system can be designed to match a specific farm scale. Attention has to be given to effective extension since farm yields are sensitive to physical factors, farm size, farm type, and stocking rate. Based on economic analysis by linear programming, an integrated farming system in surveyed villages is proposed as shown in Figure 4.8. Proposed alternatives are also presented in Table A in Appendix F.

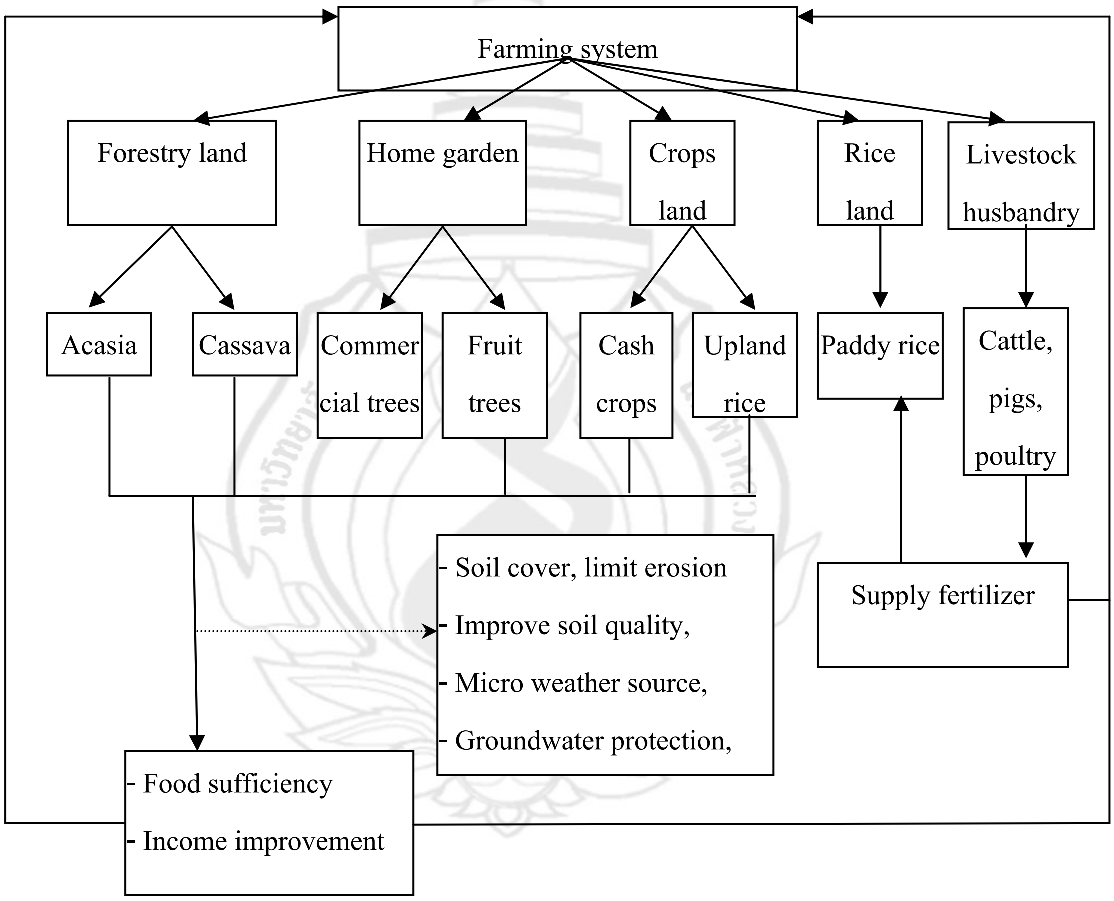


Figure 4.8 Proposed an Integrated Farming System Model in Surveyed Villages

Specific crop experiments could be designed to evaluate the efficiency of using livestock manure for three different crop types. Each experiment would be located in a specific place within the project area. The crops used in the experiments would be typical of those found in actual farming in the area. The experiments would be conducted on farms volunteered from various farmers, who would be responsible for routine activities like watering and weed and pest controls. Farm owners in these crop experiments should be skillful and experienced farmers who are respected by other villagers (most would be heads of villages or successful farmers). All of the farms would have none (or only a little manure) in-situ, so that manure to be used in the experiments would be brought in from other areas. Manure would be applied at the beginning of a crop cycle for rice, maize and beans, before sowing. All experiments should be implemented with some repetition to test the results adequately.

4.4 Guidelines for Implementing Integrated Farming System

4.4.1 Household Level Assessment

4.4.1.1 Household constraints

According to site observations, some difficulties would arise in implementing an integrated crop-livestock farming system in the study area. These are summarized as follows:

(1) Technical constraints

Most local farmers don't know how to make compost and correctly - composted manure is also not available at surveyed sites. The distances between livestock farms and crop fields are far and the steep slopes of many crop fields' locations make fertilizer transport difficult. Due to these constraints, farmers believed that manure storage is difficult and may pollute the surrounding environment.

(2) Economic & social constraints

The local farmers stated that manure application is laborious while profit from applying this farming system is still unknown. Household's income are unstable, thus farmer investment for livestock raising is also unstable. There is no direct communication between manure suppliers and manure users. Risk of livestock diseases is high because veterinary service does not work in surveyed villages.

(3) Policy constraints

Local environmental regulations for animal farms are not effective. Additionally, land certification is incomplete so that villagers remain confused about their ownership rights and find it difficult to identify their properties. They just understand that the land belongs to them from what the previous generation tells them.

4.4.1.2 Household capitals

Despite these significant constraints, potent opportunities exist to introduce integrated crop-livestock farming system in Tabhing Commune. These may be summarized as follows:

(1) Financial capital

Villagers can obtain needed credit from their local bank, which provides community loans for development of livelihoods. In critical cases, they may also take out a loan from their neighbors or from a village grocery shop owner. Additionally, an ongoing community development fund (under the ADB's BCI project) can support capital for the community. Some individuals who fought in past wars receive monthly pensions from the government and can utilize them for financial capital.

(2) Human capital

Ta Bhing has sizable productive labor resources, with 66% of its total population aged 16 to 59 years. Almost all children are enrolled in government-supported primary school education. So the literacy rate is high among the younger age group, estimated to be over 90%. However, households still regard general knowledge and practical skills as low priority in their communities.

With a high motivation to improve their living standards, villagers have shown a high capacity to grasp and understand new work introduced by the government and other agencies.

(3) Social capital

In Ta Bhing Commune, relationships of trust and mutual support are very important and clearly play a large role in community life. If a household finds itself in a critical situation in which it is unable to feed itself, it can ask for help within the community. Additionally, community members also share experience in cultivation and skills in weaving. Whenever there are issues or orders from the government, the head of each village gathers villagers together in the public house to notify them of the order and discuss its implementation.

Outreach officers in leadership positions are often highly regarded in the community. They have good knowledge of villagers' lifestyles, living status, and expectations; and facilitate community mobilization through the provision of favorable conditions for villagers to understand and carry out proposed activities.

The overall community is familiar with development projects and villagers are relatively easy to contact. They have participated in several training courses over the years aimed at improving their livelihoods. They are eager to implement new alternatives and often provide useful community ideas and perspectives in those livelihood improvement activities. It is moreover clear that their knowledge about socio-economic issues is higher than in the past.

(4) Political capital

In Tabhing Commune, Song Thanh Natural Reserve cooperates with the villagers to protect the local forest. Along with the forest plantation strategy, the "Huong Uoc" regulation was established to encourage villagers to protect the forest through community-based forestry management. Through community-based forest regulations villagers can log timber for their own housing construction and collect NTFPs. Some additional initiatives have provided support through seed provision, tree nursery establishment, and training courses to improve agricultural productivity.

(5) Physical (Environmental) capital

The main road connects Tabhing with surrounding areas, providing opportunities for trade, communication and distribution of other services. Motorbikes are a convenient means of travel for local transportation. It is estimated that on average every local household in the well-off and marginal poor groups owns one motorbike.

The large percentage of unutilized land in this area can be considered an opportunity for future effective land use planning. Along with that, home gardens have the potential to enhance household self-sufficiency. Land certification is ongoing, which can make land transactions among villagers, and with outsiders, easier.

Lastly, livestock raising has already experienced substantial development in both quality and quantity, including those for cattle, pigs, chickens, and goats.

4.4.2 Livestock Manure Management for Crops

Traditional methods for manure management such as storing (whether in covered or not), composting, use in farming, and biogas production are commonly observed today in Vietnamese small- and medium-scale farms. Lack of understanding about the quality of manure and how to manage manure efficiently results in environmental problems. Furthermore, it is a common perception among farmers that animal manure is poor in plant nutrients; most farmers do not understand that poor nutrient content and loss may be due to improper management. Storing manure without cover increases oxygen access to solid manure, which enhances coupled nitrification, denitrification and ammonia volatilization processes. These processes cause nutrient loss and produce gases that are harmful for human and animal health as well.

Some manure management practices commonly used by farmers are likely to result in significant nitrogen losses and hence in poor manure quality, with very low content of plant-available nutrients. This is not sustainable manure management. The following advice for proper storage and composting is appropriate:

1. Liquid manure storage tanks should always be carefully covered to avoid losses
2. Composting will always result in some nutrient losses, but these can be minimized by composting with superphosphate, which lowers pH in the initial phase, and produces a high content of plant available NH4-N.

To reduce or prevent pollution of surface and ground water, recycling manure in agricultural fields requires proper techniques of pathogen reduction and correct use of manure for different crops. Solid manure should be collected daily before flushing so that less water will be needed for cleaning, and there will be fewer nutrients in liquid wastes. Farms without land need to collaborate with crop farmers or middlemen. They must have a location with tanks, or containers for liquid waste storage. Primary treatment such as septic system, biogas, using effective microbes, etc. may be required. For farms with land biogas treatment, an aerobic or biological lagoon may be applied before use of such liquid manure for fertilization. A proposed model for manure management is shown in Figure 4.9.

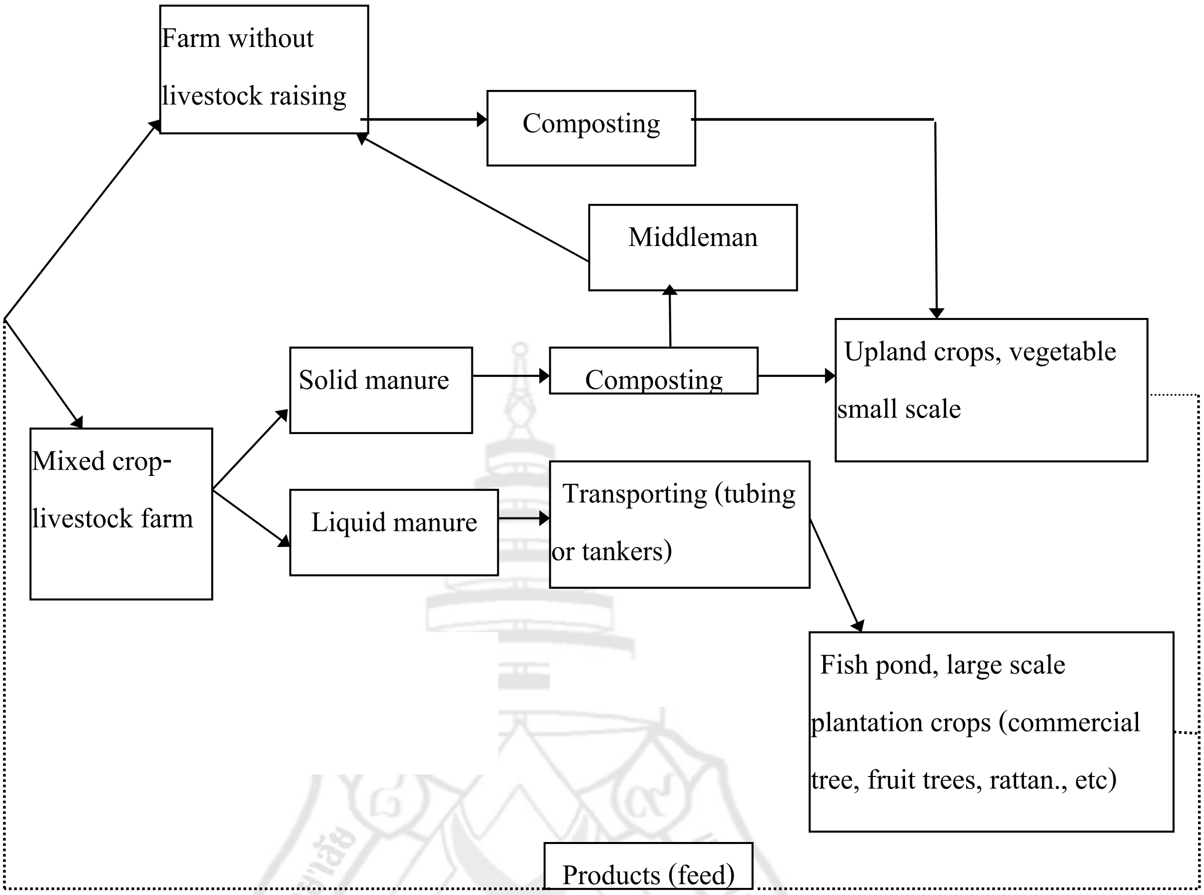


Figure 4. 9 Proposed Livestock Manure Management Model

(1) Manure treatment

Some problems emerge in storing liquid manure before its transport or use. Manure production is continuous, but crops demand fertilizer only at certain times. Farms without their own land need to collaborate with crop farmers or middlemen. Liquid waste is not collected daily, but once every few days. So it is recommended that animal farms and crop farms have storage systems for liquid manure, such as concrete tanks, a hole in the ground, or a lagoon (the latter two being better protected against leaching). Research should be carried out on leaching losses from lagoons or storage holes, insects, etc.

For crops grown on slope land, composting is recommended. However, the following issues are of concern:

(a) The costs of transportation

(b) Responsibilities of animal farmers and crop farmers

(c) Who and how to carry manure to the crops areas?

(d) Ways to control the operation under the Office of Agriculture, especially the Agricultural Extension Office under the Department of Agriculture and Rural Development. District agro - extension technicians should collaborat with commune agro-foresters to help local farmers develop composting technique, and to monitor, record, and evaluate progress.

(2) Composting methods

Location for composting: Recommended placement, with drainage and roof cover,near animal house to limit loss of manure through transport.

Materials: 1 ton of manure comprised of livestock manure, and fillers (such as straw, green manure, sawdust waste, etc.) + 20 kg powdered lime + 10 kg superphosphate.

Methods: The sink and heap methods

Heap method: A layer of lime powder and superphosphate is added to a mixed heap of manure with a 30-40 cm thickness, with another mixed heap added on top of it. If the mixture is dry, it is possible to pour some water on the heap pile. Add one heap pile layer every two days. When the height of the heap reaches 1.5m, cover it with a mixed straw layer. This process is anaerobic decomposition. 1 month to 6 weeks later (depending on temperature), the compost should be mixed again. If the heap is dry, water irrigation is required to wet the compost and cover it hermetically until it has decomposed completely.

Sink compost method : A hole 0.7 – 1 m deep, and 1 – 1.3m wide should be dug, depending on the amount of compost needed. About 20 cm - 25 cm of straw or lime should be placed at the bottom of the hole. Materials can be placed into the hole in the same manner as with the heap method. When the hole is full, straw is added and then soil is used to cover its top surface.

(3) Compost application method for crops

After composting for 2 - 3 months (depending on ambient temperature), apply the compost to the soil. The various time required to apply compost for different crops are shown in the Appendix.

The compost should be removed from its container from the top down, breaking up the material into small pieces. Deep placement in the soil is a more efficient and environmentally responsible method of fertilization. Compost should be placed into small ditches near the maize plant roots, and then covered with soil. This method will increase nitrogen use efficiency because most of the nitrogen stays in the soil, close to the plant roots where it is absorbed more effectively. The net result is that crop yields are increased while pollution is lessened

4.4.3 Crop Residues Management for Animals

Treatment of crop residues to improve their nutritional value needs to be considered in surveyed villages. The animals are fed with crop residues after the residue have been treated by physical, physio-chemical, chemical or biological means to render the structural carbohydrates of the cell walls more digestible by the actions of rumen microbes and/or digestive enzymes. Some treatment methods require high investments in equipment and careful health hazard precautions. Two methods are considered the most potentially practical at the small farm level: physical treatment (such as chopping and soaking) and chemical treatment (using cheap chemicals, such as urea, as ammonia sources).

- Chopping of straw prior to feeding to improve voluntary intake. The animals are given long straw by grazing stubble, hand feeding, or by being allowed access to stacks. This method involves a significant time input in terms of labor, although it requires no other inputs and essentially no capital investment.

- Ammonia treatment using urea solution is a simple method. Urea is easily available and cheap in most instances. The effectiveness and practicality of straw treatment with urea looks very promising. Applying a urea solution to straw at levels from 3% - 5% to bring the final moisture content to 50% and ensiling for 2 – 3 weeks increases the straw's dry matter digestibility by 10 - 12 percentage points. It appears that urea treatment of rice straw gives promising results in terms of improved feed intake and digestibility, and offers potential applicability. Livestock responses in terms of improved digestibility and dry matter intake of urea-treated straw should be studied further The only problem that needs to be solved with this method is devising practical and cheap equipment, enabling the usage of an enclosed environment for straw with newly - applied urea to ensure minimal escape of ammonia throughout the treatment period.

4.4.4 Proposed Policies for an Integrated Farming System

(1) Technical issues

Liquid manure should be used in lowland locales such as home gardens, where it is easy to store and transport. Tankers can be used to transport liquid manure from animal farms to areas where it will be used for agriculture. When livestock farms are located near crop areas, pipe and pump system or channels should be considered for transport, loading, and irrigation of liquid manure onto crops. It is also necessary to have practical testing for optimal use, disinfection, etc. Liquid manure may be spread directly by tanker, by irrigation systems, ditch systems, or sprayed by hand. Research and testing for correct dosage and techniques during rainy seasons should be carried out.

Arable land is narrow and usually located some distance away from most manure sources. In such situations, several "nutrition-accumulated pools" can be formed around concentrated animal farms. Using this nutrient source for crop production is a promising way to reduce environmental concerns and establish a sustainable nutrition balance. However, use of animal production wastes in the project area is just at a starting point. An integrated procedure for consumption of animal wastes will need to overcome not only technical but also several socio-economic obstacles.

Composting should be directly introduced to local farmers through study tours or on-farm experiments to transfer vision effectively. Compost technique should be absolutely simplified and have minimal cost to be easy for ethnic people, who are limited in knowledge and communication skills, to implement.

(2) Education in manure utilization

Farmers should be encouraged to use manure on their crops. Outreach and educational efforts include:

1. Extension work, education, awareness - building about compost techniques, pollution, health risks and environmental protection. Study tours should be given to introduce local farmers to successful integrated farming systems.
2. Detailed recommendations (dose and time for each crop, techniques etc.)
3. Planning assistants about technique and other obstacles
4. Demonstration ("model" farms, TV etc.)

5. Which crops or plants can be fertilized with solid or liquid manure, and which are not appropriate for this action
6. Support provision of additional animals to volunteer households participating in this activity
7. Partially subsidize costs for a waste treatment facility (for example, in some provinces some years ago local governments subsidized 1/3 of the installation cost for biogas treatment systems).
8. Conduct extension programs for on-farm composting or other technological options
9. Introduce cost sharing between farmers for establishment of waste treatment facilities.
10. Establish standards for livestock density limits
11. Provide public sector funding for research on appropriate techniques and private sector funding to cover the costs of application; in addition, impose a strict fine for not adopting techniques that prevent environmental pollution
12. Provide public sector funding for a monitoring program
13. Provide training and licensing for manure middlemen
14. Set up subsidies for manure transport (favorable credit policy for enterprises that produce or assemble vehicles to transport manure)
15. Introduce and enforce quality standards for manure
16. Label 'green' livestock farms as certification

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Livestock manure is readily available in the four surveyed villages. It is a rich nutrient source that farmers are not currently using as organic fertilizer for their crops. In addition, residues from upland crop production constitute potentially valuable livestock feed. This study evaluated the potential of recycling both livestock manure and crop residues within an integrated crop-livestock farming system to increase productivity and contribute to increased farmer incomes. The influence of livestock manure on crop yields was significant, as proven by linear programming modeling. Findings revealed that, with current feed resource capacity, farmers in the study area could maximize their profits from the crop-livestock farming system through optimal manure nutrient allocation and selection of profitable livestock species to receive additional feed. This study proved that an improved integrated crop and livestock farming system can increase total household income (using only family labor) by over 50% in fewer than two rounds of waste recycling.

According to current livestock stocking rates in the surveyed villages, the study estimated that roughly 1,977 ton of manure is produced per year, based on assumptions in of excreted manure composition of VISTA. In addition, the average proportional losses of N, P_2O_5 and K_2O were set at 70%, 20% and 15% of total manure nutrients, respectively, in order to best suit local conditions. The average available main nutrient content for plant uptake is equivalent to 2 ton of nitrogen, 3.1 ton of phosphate and 15.6 ton of potassium from annual livestock manure. These main nutrients are considered potentially important organic fertilizer sources for crop application in this area.

At the same time, available crop by-products comprise potential nutrition source for livestock in the area. While crop by – products such as rice straw, sugar cane leaves, and old maize stems have low fiber content (around 34%) and low protein (5-8%), other crop by-products such as groundnut vines, sweet potato creepers, and cassava tops have suitable fiber content (around 45%) and high protein (11-17% on a dry matter basis), and are therefore suitable for buffalo and ruminant diets. The gross output of crop by-products is calculated in terms of the yield of total digested nutrients (TDN) of varying crop types. Studied villages can produce an abundant amount of over 410 ton of dry matter (DM) per year. The annual amount of total digestive nutrient (TDN) content from crop residues and by-products from crops currently under cultivation is calculated based on different TDN fractions for each crop type. The total quantity of crop by-products that can be used as ruminant feed is over 173 ton of TDN per year. Using these potential sources of livestock feed will promote increased ruminant production without requiring substantial investment.

The results of five scenarios gave positive returns from different integration levels of the crop-livestock farming system. In scenario 1, applying livestock manure increased crop yields, thereby allowing farmers to increase their total annual income by 13% based on set scenarios. In scenario 2, a 22% increase in total income per year resulted from recycling crop residue as livestock feed using residue produced from extra yields. In Scenario 3, the return from using added LU nutrient manure for animal feed is about 45% via two rounds of waste recycling processes (26% from more crop production, plus 19% from added livestock husbandry activity). The scenario 3 model took into consideration investments for animal breeding cost.

Under scenario 4, there are over 53 new LU of cattle that can be raised in the four villages using about 20% of TDN amounts for livestock feed. The addition of new cattle LU contributes to a 13.4% increase in total LUs, which in turn will generate more manure for crops. Hence, such nutrient recycling contributes to total farm return for farmers through increasing crop yields and expanding cattle population, as well as accounting for 91% of total farm profits. The results from scenario 4 showed that the farm profit can be maximized when all available crop residues and forage resources are used as animal feed, doubling total profits when compared with scenario 3. In scenario 5, total farm profits in the form of income increased by 71%, based on the addition of a risk factor that assumes the death of 20% of total livestock. Livestock deaths were included in the total costs of animal production. Even with the addition of a risk factor, farmers will still be able to increase their total income by more than half when compared to a scenario in which an integrated crop – livestock system is not used.

From a financial perspective, a typical household with current crop cultivation and livestock rates can gain from $32.90 to $231.10 per household with a two-time cycling process under an integrated crop-livestock farming system. Considering existing socio-economic conditions, as well as household capacity at the study site, local farmers can use profits obtained under the proposed integrated crop – livestock system to make important gains in poverty reduction.

5.2 Recommendations for Implementing an Integrated Farming System

Considering the results from linear programming, livestock plays an important role in household income in surveyed villages. Livestock management plans should be implemented in accordance with each household's resource capacity. Each individual household constitutes a basic unit in an integrated mixed farming system; it should raise the number of livestock appropriate to the feed resources at their disposal, without relying heavily on the common resource pool.

Maintenance of an integrated crop-livestock system depends on the availability of adequate nutrients to sustain animals and plants and to maintain soil fertility. Intensification of agriculture through appropriate incorporation of small livestock has the potential to decrease the land needed for agricultural production and relieve pressure on forests.

Therefore, it is recommended that the farmers continue intensive use of non-cultivated land such as upland, fallow land, and land along riverbanks by growing grass and forage, and using these outputs to supplement their existing crop residues. This is the most practical and cost–effective method to improve the nutritional value of the area's crop residues. Grass and forage types that make good crop residue supplements include *Vetiver* grass, Napiergrass, elephant grass, and fodder legumes. This combination of feed is also effective in reducing weight loss in animals, particularly during dry periods. Cultivation methods that can be introduced are planting of green hedgerows along contour lines, intercropping, natural fallow, and managed fallow combined with legume species cultivation. These fodder-planting methods have added benefits to soil conservation on slope land in this area.

Given their traditional knowledge and experience, local farmers here are perfectly able to apply an integrated system of the type recommended. In practice, however, relatively few have adopted this system, mainly because they have limited access to credit, technology and training. Associations of grain and livestock producers could fill these gaps and promote adoption of a functioning crop-livestock system. The process of credit distribution and provision of collateral to acquire credit from the government and non-governmental agencies will also aid in promoting the system. Recently, while financial support has become available for poor people to raise livestock, the program seems to have reached only rich households. Findings of this study have shown cattle and goat raising offer the most-profitable alternatives. Therefore, credit should be made available to farmers who raise these types of animals in order to enhance their livelihoods.

Veterinary services are generally unable to reach poor, small-scale farmers in remote areas. For livestock production to be improved here, more effort is required to make veterinary care accessible, particularly in terms of animal disease prevention. It is recommended that providing local people with basic veterinary training and knowledge - as well as with printed materials on relevant topics - will enhance their capacity to implement the integrated mixed farming system effectively. Because local farmers have heavy workloads, it is not easy for them to recall all their training or knowledge. Therefore continuous capacity–building should be conducted to promote effective application of learned skills over time. Households that conduct livestock husbandry under the integrated mixed farm system should also receive veterinary service support, including drugs, for the first several years from local government agencies, particularly the Economic Office of Nam Giang District. Demand for veterinary services can also create potential employment opportunities in local areas in the future.

Improved livestock husbandry and management are required to get rid of diseases. Livestock breeds should be local ones that can adapt easily. Based on the Commune’s financial support, people can borrow money at low interest rates and apply for technical support. In addition, they need to care for their livestock nearby their houses, not let them wander on the grassland. The agricultural officer at district level will coordinate the activity. When the agricultural technician officer does not follow the project all the time while the villagers work independently, cooperation is ineffective. In general, it takes one year to improve the livestock and earn money from this activity. All households can be supported by this activity but the poor are the clear priority. The system needs to plan and allocate grazing areas (for cows and buffaloes). Livestock water demand includes water for drinking and for feed production; the new integrated system can also have an impact on water quality, contaminating it with manure and urine. All of these aspects need to be given due consideration. Select methods to improve crop-byproduct quality among urea-treated rice straws, ensilaged cassava leaves and tops, maize stovers and groundnut vines. Finally, manure transport is an important factor affecting manure use on crops, especially those in upland locales.

In order to get the best overall application, the new mixed farming system needs to have research, experimentation, and testing to generate appropriate implementation recommendations.

Importantly, effective legislation to control management and use of animal wastes is required. From now, several provinces have provisional regulations for environmental protection in animal production. However, those legislation documents are just in general and they are not being effectively enforced.

Cattle are the major income source and significant household assets. Farmers are at high risk of loss should their cattle die. To safeguard the farmers against such potential losses, a livestock insurance scheme should be initiated.

5.3 Recommendations for Further Study

The challenge for development practitioners is to ensure that poor small farmers can increase the productivity of traditional farming systems, adopting an effective integrated system that produces usable biomass while conserving natural resources and can therefore be sustainable in the long term.

The following actions are needed to further promote an integrated farming system:

1. Conduct research on composting by assessing the quality of compost manures in terms of their nutrient contents at different periods of composting and their effects on soil fertilizer and crop yields as well.
2. Test soil characteristics to identify and improve effective optimum nutrient allocation.
3. Implement experiments with various crops that will determine the long-term effects of using animal manure on soil quality and crop productivity. The data will also help assess interactions among livestock manure, crop nutrient uptake and biological nutrient transformation in soil.
4. Improve linkages between livestock, crops and other components within the farming system to maximize improved nutrient use efficiency at farm level.
5. Pay attention to farmers' contexts and needs in order to supply appropriate advice to households seeking to diversify, ensuring that the important factors of wealth status, agro-ecology and market opportunities are all identified as drivers for successful application of integrated farming systems.

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APPENDIXS

APPENDIX A

Land Use Map in 2007 Tabhing Commune

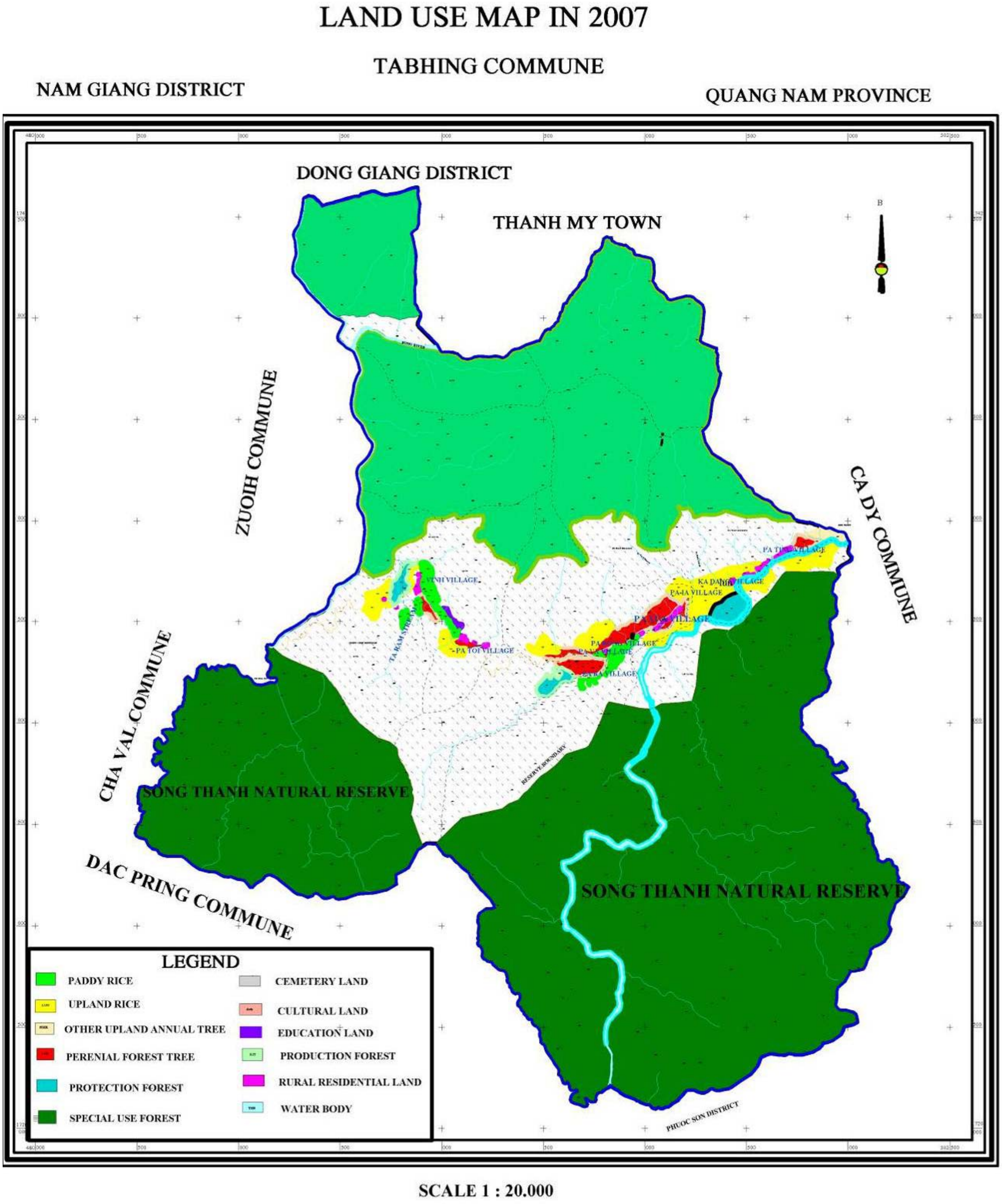

Figure A Current land use map in Tabhing Commune

APPENDIX B

Some Examples of Crop-Animal Interactions in Asia

Table A Some Examples of Crop-Animal Interactions in Asia

1. Southeast Asia

Country	Interactions
Cambodia	Use of buffalo for draught power in rice in Siem Reap Province.
	Use of rice straw by buffalo in Siem Reap Province.
	Use of manure for rice production in Siem Reap Province.
Indonesia	Use of manure in rice/maize/grain legume systems in upland Java.
	Introduction of forages in crops for use by cattle on Bali.
	Use of cattle for draught power in rice in southern Sumatera.
Lao-PDR	Use of buffalo/cattle for draught power in Luang Prabang Province. Use of manure in rice seedbeds in Luang Prabang Province.
Malaysia	Use of large and small ruminants for weed control and manure application under rubber and oil palm.
	Introduction of forages under rubber and oil palm for ruminants.
Thailand	Utilisation of rice straw by cattle and buffalo in the northeast Province.
	Use of manure from stall-fed large ruminants for rice production in the northeas Province.
	Use of buffalo for draught power in rice in the northeast Province.
Myanmar	Use of cattle for land preparation in rice production in Bago Division. Utilisation of rice straw by cattle in Bago Division.
Philippines	Use of small ruminants for weed control under coconut in southern Luzon.
	Use of manure from cattle feedlots for pineapple production in Northern Mindanao.
	Use of ducks in rice paddies to control golden snails (rice pests) in southern Luzon.
Vietnam	Use of buffalo for draught power in rice in Song Be Province.
	Utilisation by buffalo of crop residues in Song Be Province.
	Use of weeds by ducks in ponds fertilised by pig manure in central and northeastern areas

2. South Asia

Country	Interactions
Bangladesh	Use of rice straw by cattle and buffalo throughout the country.
	Use of manure from large ruminants for rice throughout the country.
	Use of buffalo for draught power in rice throughout the country.
Bhutan	Use of rice straw by cattle in the western lowlands.
	Use of manure from cattle for cropping throughout the country.
	Use of cattle for draught power in the lowlands.
India	Use of manure from small ruminants folded on arable land in Gujarat and Rajasthan states.
	Use of sorghum residues by cattle in Andhra Pradesh state.
	Use of cattle for draught power in rice-wheat systems on the Gangetic plains.
Pakistan	Introduction of forages in irrigated cropping systems in Sindh and Punjab provinces.
	Use of crop residues by buffalo and cattle in the Barani areas of Sindh and Punjab provinces.
	Use of manure from large ruminants for cropping in Sindh and Punjab Provinces.
Nepal	Use of manure from cattle and buffalo for composting in the Mid-Hills region.
	Use of crop residues by cattle in the Tarai region.
	Use of cattle and buffalo for draught power in the Tarai and Mid-Hills regions.
Sri Lanka	Use of buffalo for land preparation in rice production in the wet and intermediate zones.
	Utilisation of rice straw by cattle in the irrigated dry zone.
	Use of cattle for weed control and manure application under coconut in the intermediate zone.

Sources: Devendra et al., (1997, 2000).

APPENDIX C

Characteristics of Categorized Wealth Groups

Table A. Characteristics of Categorized Wealth Groups

Wealth group	Well-off (20%)	Medium poor (30%)	Poor (40%)	Very poor (10%)
HH Size	4	5.2	3	1
Properties	Wood frame house with roof and ceramic tile floor Have TV set and satellite dish Own motorcycle, Have access to electricity	Wood frame house with roof and dirt floor Have TV set and satellite dish Own motorcycle, Have access to electricity	Bamboo frame house with cottage roof (supported from 134 program) Have no TV Have no motorcycle Have access to electricity	No owned residential land, located on neighbor's or relatives' land Have no properties
Livestock herd	>= 7-8 cows >= 5-6 pigs 10 chickens, 5 ducks	4 cows, 2 pigs, 5 poultry	<=1 cow, 1-2 pigs (only 5% of total poor HHs), 5 poultry	No livestock
Land owned	8-10 ha of production forest land 0.3 ha of wet land rice, <1 ha home garden, <1.5 ha upland rice	0.2 ha wet rice land, <0.5 ha home garden, and <1 ha upland	Less land no wet rice land, <0.5 ha home garden, and <0.5 ha upland field	No arable land
Occupations	Trading, Teachers, Raising livestock, Fabric weaving, Gold making, Government officer	Some are government officers, trading, upland cultivation and livestock raising	Upland cultivation, NTFPs collecting	Pension monthly
Income	>=200,000 VND/people/month	100,000 VND/people/month	30,000 VND/people/month (total of about 20% HHs) and 5,000-10,000 VND/people/month	Leading a difficult life Get support from government monthly
Sufficiency	Annual sufficiency, no loans, contact with outsiders	Monthly sufficiency but some loans	Daily sufficiency, typically in debt	Insufficiency

APPENDIX D

Crops Components, and Nutrient Content for Calculating

Table A Crops Grown in Plantation Area in Upland Fields in Surveyed Villages

No.	Village	Upland rice	Maize	Beans	Banana	Cassava	Pine apple	Sugarcane
		ha	ha	ha	brush units	ha	ha	ha
1	Pa Ia	18	2	9	594	3	0.009	0.002
2	Pa Xua	60	11	27	1,171	13	0.017	0.005
3	Pa Va	28	11	27	1,380	4.5	na	na
4	Za Ra	35	8	15	567	10	na	na
Total		141	32	78	3,712	30.5	0.0250	

Table B. Perennial Crop Area in Irrigation Land in Surveyed Villages

Village	Bamboo shoot (Bat Do)	Rattan	Acacia	China berry	Longan
	brush units	brush units	tree units	tree units	tree units
Pa La			40,540	2,480	65
Pa Xua	459	241	23,305	6,595	
Pa Va			36,860	6,994	
Za Ra			48,800	2,325	833

Table C. The Nutrient Content for Calculating (%)

Livestock	Water	N	P_2O_5	K_2O	CaO	MgO
Cattle, buffalo	83.1	0.29	0.17	1.00	0.35	0.13
Pig	82.0	0.60	0.41	0.26	0.09	0.10
Poultry	56.0	1.63	0.54	0.85	2.40	0.74

Source: VISTA standard cited by Dan (2003).

APPENDIX E

Livestock Production Constraints and Awareness on manure role

1. Livestock production constraints

Of all the respondents, 25.8% said that capital is the most important factor that affects livestock productivity. The second is the poor availability of suitable veterinary services, which accounted for 20.2% of respondents. Because local people lack capital, they have no ability to buy improved livestock breed or commercial feed but use whatever feed is available feed in their home garden or upland field, and so often have nutritionally suboptimal or stressed animals that are more prone to disease. The third principal limiting factor, accounting for 15.9% of respondents, was livestock diseases. A low education level contributed to the limited capacity to access good animal husbandry and rearing techniques to reduce the risk of some or to prevent other livestock diseases. The land for livestock raising is becoming a problem for farmers because they still keep livestock freely on grazing land but the majority of the land is arable crop land so that the concern of damage to other farmers crops from livestock grazing, with the required compensation, is another concern which accounted for 11.1% of respondents.

As interviewed, some of the limiting factors, such as feed source, labor, etc., are viewed as having less affect on livestock productivity and accounted for 17.2% of respondents. The absence of a local market is considered as indirect limiting factor of productivity, accounting for 9.8% of respondents. In the respondents' opinions, they paid less attention for taking care of their livestock in terms of investment so that these factors play a lower role in agricultural productivity.

2. Awareness of crop residues and livestock manure

In total, 47.5% of respondents realized that crop residues is a good feed source for livestock, 39% of respondents said that these are the fertilizer source for soils, while 13.5% said that they did not know of any role for them. The high proportion of respondents seemingly in knowledge on livestock feed and soil fertilizer is the result of a training course from some projects established by NGOs and the district agriculture department. When asked about the role of livestock manure, 42.6% of total respondents said that it is the fertilizer source of crops, 10% answered that it improved soil quality, while 16% of respondents had no idea about that.

However, 94.7% of the respondents said they did not use compost or any organic fertilizers for their crops. The rest said that they used to use compost when they were trained by the FIDR project but then almost all of them gave up composting afterwards. Of these, 15.4% cited insufficient time, 32.7% cited a lack of knowledge on composting techniques, 9.6% cited a lack of available labor, 11.5% cited a lack of financial resources, and 30.8% cited other constraints, as the reason why they did not use compost or organic fertilizers. In addition, they do not use organic fertilizers because they really do not know which crops to fertilize and how to apply it. From those statements, local villagers haven't been transferred enough knowledge in the use of organic fertilizers or the potential economic value from utilizing organic fertilizers. A low education level is considered as one of the limiting factors of acquiring and maintaining (let alone improving) new technology.

When respondents were asked if they would utilize compost or organic fertilizer if given training, and technology, 50% said they would, and 50% said they would not. This again suggested that villagers still doubt the benefits of utilizing organic matter or are reluctant to change their old "tried and tested" traditional ways for something new that seems to entail more effort and may or may not work. Some of them said that they don't agree due to the fact that they haven't seen any results of organic fertilizer application yet. This highlights the importance of model (demonstration) farms where the advantages can eventually be seen, as well as the problem (who will be the first) and the requirement of the local agriculture extension agency to support local people more effectively.

The result of the questionnaire also revealed that 53% of the total respondents burned crop residues after harvesting crops in order to prevent weeds or to save labor, while 36% said they used harvest by-products for livestock feed, such as green corn stove and sugarcane leaf, sweet potato leaf and others.

APPENDIX F

Proposed Alternatives for Integrated Crop Livestock Farming System

Table A. Proposed Alternatives For Integrated Crop Livestock Farming System

1. Encourage more villagers to adopt nutrient-fixing plants along contour lines to improve upland field crops and maintain soil quality

No	Execution				
Justification	**Technical details**	**Organization**	**Timeline**	**Possible Constraints**	**Performance indicators**
80% households participated in this model already proposed, but only a few maintain it To increase awareness of the community about this intervention because they are not patient enough to follow this long-term intervention This is a sustainable solution and take time to see the effects No need to use chemical fertilizers It helps improve not only soil quality but also productivity	Based on the contour lines to apply this model To plant the chosen species which can fix the nutrients in the soil around the contour The crop plants will be planted between these contour lines After few months (3-4 months) the nutrient-fixing plants will be cut and used as fertilizers for crop plants The villagers will be trained and provided that kind of plant to grow on their land	The villagers are the ones who are willing to carry out the intervention. This intervention is applied on the upland fields The agricultural officer of Ta Bhing commune is the coordinator of this intervention The officer as well as head of each village will be trained to monitor this project It does not cost much; except of investments to have right plants, in addition to some necessary tools, and training courses to be provided.	The preparation steps are to find the suitable plants, explain to the villagers to follow, offer training courses, and then implement this. Expected to need 2 months before implementation The result can be seen after 2-3 years The monitoring will be done after one crop/season to see if the steps are followed t in right way.	The villagers just follow at the first time because it take long time to see the result Need to persuade and train the villagers to take long-time perspective	At the time the nutrient-fixing plants can be harvested and used as fertilizers, we can monitor whether they do it right or not This is a long-term intervention so that after 2-3 years, we can see the effects based on the productivity

Table A. (continued)

2. Utilize bare lands as grazing pastures (Planting grass for raising livestock (cow))

No	**Execution**				
Justification	**Technical details**	**Organization**	**Timeline**	**Possible Constraints**	**Performance indicators**
The villagers currently leave their cattle in the common pasture of the commune, but rarely look after them. To plant grasses to increase more grasses as feeds for cattle and keep them in their house.	Find the suitable grass species with soil quality Plant and harvest grasses to feed the cattle	The villagers are used to carry out this activity The government officers in Ta Bhing commune will coordinate the implementation	This is a short term intervention because grasses just take few months for growth	To find the suitable grass species with soil quality and with taste of cattle	Areas of grazing pastures Number of livestock (both quantity and quality). Additional incomes generated for villagers

Table A. (continued)

3. Improve livestock husbandry

No **Justification**	**Execution**				
	Technical details	**Organization**	**Timeline**	**Possible Constraints**	**Performance indicators**
Improve the livestock to increase more income of villagers Lack of experience, knowledge and capital to invest People are eager to raise livestock and get more money than farm work	The main chosen are cows and pigs with local breeds. Based on the commune's financial support, people can lend money with low interest, and apply for technical support Need to zone the livestock nearby their house, not let them wander on the grassland Take care of their veterinary condition	Animal husbandry household is priority The agricultural officer at district level will coordinate the activity	In general, it takes one year to improve the livestock and earn money from this activity.	The coordinator does not follow the project all the time while the villagers work independently, cooperation is ineffective. Should plan and allocate grazing areas (in case of cows and buffaloes)	The number of livestock The income from raising livestock

APPENDIX G

Household Questionnaire

Household questionnaire in Tabhing Commune, Quang Nam province, Vietnam

Code: ....

Date of survey: ....

Location (village): ....

Name of interviewer: ....

Group (ethnic): ....

Name of interviewee: ……………………………….. ....

1. General household information

1.1 Who is the head of household?

Male/Female: .... (Age): ....

1.2 How many people are there in your family?

Male: ....people./ Female: ....people.

<15 years old?_______

(Male): ....people.   (Female): ....people.

From 15 to 59 years old?__________

(Male): \.......................people.(Female): ....people.

>60 years old?_____________

(Male): \.......................people.(Female): ....people.

1.3 How many main labors are there in your family?

...............................people

1.4 How many sub labors are there in your family?

...............................people

1.5 Education level of the respondent

☐ Illiterate

☐ Primary

☐ Lower Secondary

☐ Secondary

☐ Higher

1.6 What is your main occupation?

☐ Farmer

☐ NTFPs collector

☐ Merchant

☐ GO officer

☐ Other (specified) …………

2. Land using and livestock husbandry

2.1. What type of land do you have? (specified type of soil)

Total land area....................................ha

- Resettlement land ………….ha
- Rice land …………………ha (………………………..)
- Crop land …………………ha (………………………..)
- Commercial tree land ....ha (.................................)
- Fish pond land................................ha (................................)
- Newly cleared land …………ha (………………………..)
- Abandoned land ……………ha (………………………..)

2.2. How much have you spent on each item

(Landuse type)	(Area: ha)	Seed using (kg)	Cost of seed (.000d)	Labor using (hr/ha)	Fertilizer using/yr	(yields: kg/yr)	Price (.000d)	% own use	% sell
Paddy rice fields									
Dry season									
Rainy season									
Upland crops									
Upland rice									
Cassava									
Maize swidden									
Bean									
Others									
Homestead garden									
Fruit									
Vegetable									
Tree									
Other plant									
Total									

2.3. Do your family have livestock husbandry? for what purpose:

☐ Cow/buffalo ……….....................

☐ Pigs ………………….................

☐ Chicken …….............................

☐ Goat ……..................................

☐ Rabbits ……..................................

☐ Others ....

Item	Cattle	Pigs	Ruminants	Goat	Others
1. Labor using	Who takes care them?				
Main labor Wife Husband					 ....
Sub labor Old people Children					 ....
2. Animal keeping	How to keep them?				
Free grazing House construction	....	....			
3. Reproductively ability	How much can you get from them?				
Litter per year % survival for selling (head) Price of selling (VND/head)	....	....	....	....	....
4. Cost	How much have you spent?				
Litter buying					
Feeding					
Health care					
Others					

2.4. Which kind of animal genetic resource do you prefer to feed?

For pigs

☐ Mong cai..............................

☐ Co (local name).....................

☐ Others.................................

For cows:

☐ milk production

☐ meat production

☐ others

2.5. Why do you prefer it?

☐ High productivity

☐ High price

☐ Less disease

☐ Easy feeding (technique)

☐ Others

2.6. What kind of feed sources have your household used for livestock husbandry?

☐ Other crop by products (other than crop residue)..

☐ Grazing..

☐ Collected grasses/forage...

☐ Green fodder..

☐ Compound feed...

2.7. Where can you get the livestock feed sources? (continued to 2.9)

☐ Natural feeds..

☐ Crop residues..

☐ Feed crops...

☐ Purchased (how much/where to buy)..

☐ Others..

2.8. Do you family plant forage for livestock?

☐Yes ☐No

No.	**Types**	**Amount**	**Yield (kg/ha)**	**Harvest period**

2.9. How long do you spend to collect grass for livestock?

Types	**T11-T2**		**T3-T6**		**T7-T10**	
	times/day	**Kg/time**	**times/day**	**Kg/time**	**times/day**	**Kg/time**
From forest, upland field						
From road side,						
Other						

2.10. For average, how much your family earn from livestock production last year?

Type	Consumption (%)	Sale (%)	Value
Cows			
Pigs			
Chicken			
Goats			
Others			

2.11. Whom do you sell your livestock?

☐ Merchants

☐ Midleman

☐ Local people

☐ Other

2.12. How do you think about the price of livestock products?

☐ High price

☐ Low price

☐ Acceptable price

☐ Others opinions

2.13. What are the constraints from crop cultivation?

☐ Time/labor...

☐ Price/market...

☐ Knowledge/skills..................................

☐ Soil quality......................................

☐ Irrigation issues.............................

☐ Feed resources...............................

☐ Others.......................................

3. Crop residue/livestock manure management

3.1 Please give more information about crop residues

Type	Yield (kg/yr)	Harvest period
Rice straw		
Maize stover		
Maize		
Cassava leaf		
Other		

3.2 What have you ever used crop by-products for?

☐ Feed uses (if No to continue 3.3)...

☐ Burning...

☐ Grazing...

☐ Non feed uses (construction material, fuel)..

☐ Others...

3.3 What kind of crop residues have you collected for livestock feeding?

☐ Rice..

☐ Maize..

☐ Cassava..

☐ Others..

3.4 What have you known about the important of crop by-products as?

☐ Fertilizer for soil..

☐ Livestock feeding..

☐ Others……………………………………

3.5 Have you ever kept crop by-products for manure/compost?

☐ Yes (why)...

☐ No (why not?)...

3.6 If yes, give more information about them?

- amount (kg/yr):..

- process (describe) ....

3.7 If no, what are the reasons?

☐ Lack of labor

☐ Lack of time

☐ Less green material availability

☐ No skills/technique

☐ No capital

☐ Other

3.8 Have you known about the important of livestock manure?

☐ source of organic matter..

☐ nutrients for crop growth..

☐ improve soil physical condition

☐ Others.......................................

4 **Household Food Security**

4.1 For how many months each year does your household have sufficient rice to eat? (plus buying rice)________ (months)

4.2 For how many days each year does your household suffer from hunger (i.e. you do not have enough rice, other foodstuffs mixed with rice, or replacement food such as cassava or corn to eat)?_____ (months)

4.3 How many months supply of rice do you currently have in storage?

_____ (months)

4.4 How many days each year does your family have other crop for substitute rice?

- Which type is it?
- Where does each come from?

4.5 On average how much cash income does your household earn each month from all sources?

(Sale of crops-describe):……………………………………………………………………

(Amount): ………………………………………………………………

(Sale of livestock-describe): ……………………………………………………………

(Amount):…………………………………………………………………..

(Forest Timber): ………………………………………………………………………..

(Forest firewood): ………………………………………………………………

(Sale of NTFPs):

- other wild vegetable…………………………………………………………….

(Wage labor) ……………………………………………………………………………..

(Income from shop or service) …………………………………………………………

(Free food or other goods supplies by government/NGOs): (describe)

(Kind and amount of goods) ………………………………………………………

(other): ………………………………

(Amount): ……………………………...

(Service supplies by government/NGOs): (describe)

(Kind of service)………………………………………………………………

5 What are your household's main cash expenditures?

(Food)

(Rice)____

(other food)______________________

(Agricultural investment)

(crops)_________________

Describe: ____

(fertilizer)_______________

(Pesticide)____________

(Hired labor)__________

(No. of days:……. for land preparation, transplanting, weeding, harvesting, etc)

(Irrigation)_______________

(Social activities and other property.)

(cloths) _______

(Weddings, funerals, and other rituals)_______________

(Property) _________

Education, health care

(School fees) _____________

(Medical care)_________________

(Others)______________

CURRICULUM VITAE

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