Crop-livestock interactions in northern *Viet Nam*: Issues, diversity of farmers' responses, and alternatives for sustainable integration of animals in upland agricultural systems

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Abstract

Animal husbandry is a component of almost all of the highly diverse production systems of the mountainous province of *Bac Kan* in northern *Viet Nam*. Some households only keep buffaloes for animal traction in lowland ricefields, whereas other households rely heavily upon income from cow and buffalo raising. Since decollectivization at the end of the 1980s, population in *Bac Kan* has grown substantially and the institutional and environmental contexts of agricultural production have changed dramatically, but animal husbandry systems have remained unchanged. Longstanding free-grazing practices are harmful to the natural resource base and engender conflicts among and within villages. This chapter describes an exhaustive study of 183 households in two villages in *Ngoc Phai* Commune that characterized household livestock strategies. The data from surveys on livestock practices were joined with a database on cropping systems and farm resource base. A typology was then developed, dividing farm households into ten types according to their crop-livestock strategies. The results are instructive in identifying household types as potential targets for organizational and technical innovations for improving crop-livestock management. Innovations are proposed for systems in which animal husbandry activities complement crop production, rather than competing with it.

Keywords: crop-livestock interactions, upland agriculture, large ruminants feeding, systems approach, northern *Viet Nam*.

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1. Introduction

Cho Don District of *Bac Kan* Province, in the mountains of northern *Viet Nam*, is one of the poorest regions in the country. Predominantly agricultural, the district is inhabited by people of the *Dao* and *Tày* ethnicities. As in much of Southeast Asia, family farms of two hectares or less make up the backbone of agriculture in the region (Devendra and Sevilla, 2002). Most farms produce both crops and livestock. In particular, buffaloes play critical roles as draft animals, sources of fertilizer, and also a form of capital; 80% of *Cho Don* households have at least one buffalo (Eguienta, 2000).

In the last fifty years, changes in land-use policy have contributed to an unsustainable expansion of upland use that has dramatically altered the landscape. However, these changes have not been accompanied by an evolution in livestock management practices. Farmers continue to rely on natural meadows and forests to provide fodder for their free-roaming buffalo and cattle (Eguienta, 2000). In the course of our study, we came across substantial social tensions reflecting current imbalances among the components of the crop-livestock-forestry system. For example, crop damage by animals is not uncommon and offending buffaloes are frequently harmed in return (Tran Quoc Hoa, 1999). In an environment of increasing population, both human and animal, livestock are an important cause of the deterioration of forests and pasturelands (Husson et al., 2001).

The slash-and-burn cropping systems used on the region's hillsides also have had a deleterious impact on the resource base. Since the agricultural decollectivization 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., 2002). In their current environmental and institutional context, these marginalized households have resorted to reducing fallow periods on the hillsides, degrading the fertility of cultivated soils and exacerbating erosion (Husson et al., 2001).

Effective natural resource management in mountainous regions needs to take a holistic approach, taking into consideration livestock systems, cropping systems, and the environmental and socio-economic context. Animal nutrition and chronic shortages of forage resources are currently major constraints upon livestock production across Southeast Asia (Devendra and Sevilla, 2002). However, in *Bac Kan*, the price of cow and buffalo meat has doubled between 1995 and 2000, indicating the potential emergence of profitable livestock systems in the future (Helvetas, 2000).

This diagnostic study was conducted in the year 2000 in two mountainous villages (*Phieng Lieng* and *Ban Cuon*) in northern *Viet Nam*, in the framework of the Mountain Agrarian Systems (SAM) Program. We characterized household animal husbandry systems and their relationships with crops and forests, allowing us to evaluate the systems' performances and identify their constraints (Eguienta, 2000). The goal of this paper is to characterize the diversity of livestock-raising households in terms of their goals, resources, constraints, and needs, in order to better identify intervention points specific to each kind of household. This will help pave the way for the diffusion and application of appropriate, sustainable innovations.

2. Analyzing animal husbandry through a systems approach

The methodology implemented in our study of animal husbandry systems was based on a systems approach. We defined an animal husbandry system as "the combination of resources, animal species, techniques, and activities mobilized by a community or a farmer to convert natural resources into livestock production" (Lhoste et al., 1993). The analysis, the framework of which is presented in Figure 1, consisted of investigating statistical relationships among variables pertaining to household characteristics, cropping systems, and animal husbandry systems (herd management practices, surveillance techniques, use of hillsides) and performance indicators (herd growth, mortality, traction needs met, household rice self-sufficiency levels). From this analysis, we developed a typology of farmers and examined their common characteristics and potential trajectories toward new organizational structures or innovative feed production techniques.

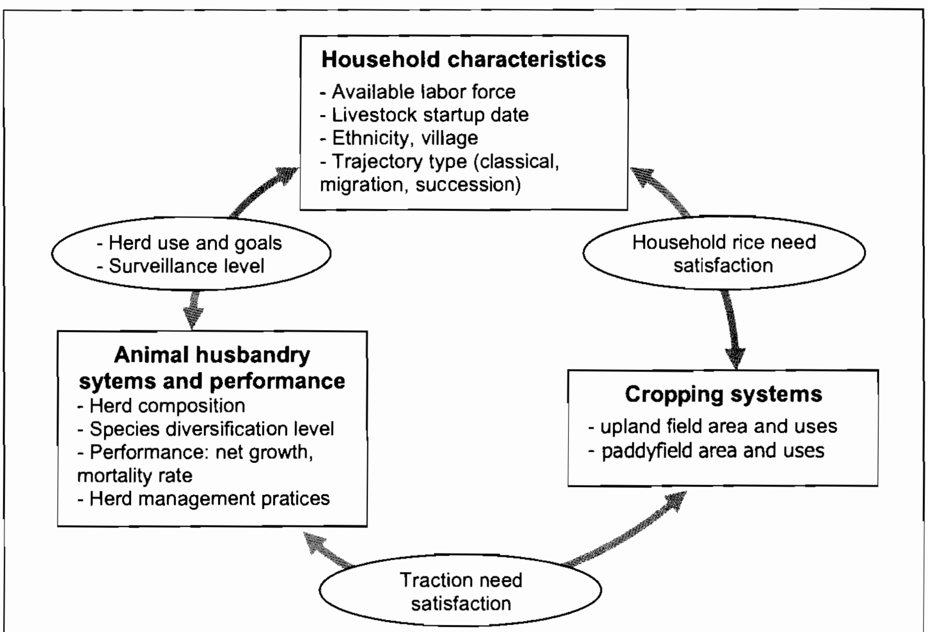

Figure 1: *Analysis framework for farm household typology*

The data collection methodology included field observations, exhaustive household surveys, and interviews with key community members: elders, officials, local cadres, etc. (Table 1). The research reported in this paper is part of a wider spectrum of regional characterization and diagnostic study begun in 1999 (Castella et al., 1999). This study completes an exhaustive database characterizing each household's cropping systems and farm resource base.

3. Animal husbandry in *Cho Don*: extensive natural-resource-based systems, recently developed and exhibiting poor performance

The study was undertaken in two villages with particularly contrasting situations (Table 2). *Phieng Lieng* is a village populated primarily by the *Tày* ethnic group with production systems based on paddy rice cultivation. *Ban Cuon* is a *Dao* village with a tradition of shifting cultivation, primarily on terraces and hillsides. The differences between the two villages arise primarily out of the fact that *Phieng Lieng* farmers enjoy a much higher per capita paddy area than *Ban Cuon* farmers, leading the latter to cultivate a higher proportion of upland crops. This discrepancy arose because of traditional differences between the ethnic groups: *Tày* traditionally settled in lowlands, whereas *Dao* traditionally settled in upland areas. However, in recent decades the situation has become more complex: the most recent round of land allocations left some *Tày* families without paddyland, while some *Dao* farmers have been able to purchase paddy fields in *Ban Cuon* (Castella et al., 2002). Regardless of their ethnicity, households who cannot meet their subsistence needs in the lowlands have had to search for other kinds of income: hillside cultivation, forest exploitation, animal husbandry, and non-agricultural activities.

3.1. Forage resources and livestock production practices

The dramatic landscape of the region, with steep slopes and sharp relief, plays a major role in defining local land use. The pasturing of large ruminants has been regulated since 1996. It is officialy confined to collectively-owned public pastureland located far from village settlements and separated from cultivated land by natural and artificial barriers (fences, trenches, etc.). Local authorities tolerate growing crops on public pastureland, so long as cultivation time does not exceed three years; the subsequent fallow period then can restore fertility to the pastureland if long enough. The forage resources in these upland pastures and forests are heterogeneous, but consistently of low quality. Rotation, fallow, and meadow improvement practices are notably absent from the local system.

Since being officially defined as pasturelands, the public upland areas have evolved in different directions in the two villages. In *Ban Cuon*, with low per-

Table 1: *Data collection approach*

Components	Sub-components	Studied characteristics	Diagnosis results	Approach	Sample
Household location and cropping system	Village territory Forage resources Other agricultural resources	- Forage resource units - Distribution – Surface area - Variations	Participatory mapping	Map analysis Transects, field visits	2 villages
Interface	Feeding and spatial behavior	- Animal movements Resource use	Animals per unit area Description animal movements	Following the herds Gathering observed animal feed	2 villages
Herd	State	- Species, race, genetic type - Working capacity - Composition, structure	Age pyramid	Exhaustive surveys	183 households (all families) 160 reproducing female bovines
	Evolution (changing characteristics)	- Growth and usage rates - Significant events (births, deaths, purchases, sales)	Productivity and evolution of working animals		
	Animal (individuals)	- Female reproductive history - Health - Individual performance	Performance	Surveys Direct observation Informal interviews	
	Production	- Meat, milk, wool, … - Manure, labor, transportation	Herd management calendar Draft needs	Surveys Direct observation Informal interviews	82 households (45% of households covering 70% of animals)
Interface	Conduct and practices: Reproduction, feeding, surveillance…		- Surveillance practices - Feeding system - Reproductive practices	Surveys Direct observation Informal interviews	82 households (45% of households covering 70% of animals)
Livestock farmer	Farm structure, ethnicity, family, projects - Livestock management - Labor organization: family, others		- Socioeconomic logic - Social organization - Global farm structure	Exhaustive surveys	183 households (all families)
Interface	- Land organization - Pasture and other land management - Conflicts and other territorial issues - Strategies (manure, etc.)		- Block diagrams - Descriptions of practices - Pastureland histories - Issue characterization	Open interviews (formal or informal), and surveys of livestock practices	Resource persons (village and commune heads, Party leaders, elders, and other local stakeholders)

Table 2: *Studied villages*

Village name	Number of households	Number of inhabitants	Total surface area (ha)	Average paddyfield surface area per inhabitant (m^2)	Average hillside surface area per inhabitant (m^2)	Average number of buffalo per household
Phieng Lieng	76	382	1,288	518	2,506	2.3
Ban Cuon	116	623	1,579	298	2,249	2.2

capita paddyland area, pasturelands are heavily cropped with upland rice and cassava. The high pressure on the land means that plots are left fallow only for short periods, leaving only the poorest of fields for grazing. In *Phieng Lieng*, with higher per-capita paddyland area, crops are rare on collectively owned lands. Nonetheless, forage quality is low because the meadows are not maintained. The result has been an invasion of inedible or even toxic plants (*Imperata cylindrica*, *Chromolena odorata*, etc.). In both villages, pastureland is being overgrazed and slowly overtaken by *Chrysopogon* and *Paspalum conjugatum* species, both of which have low forage value. In winter, the cold and dry climate inhibits the growth of natural forage species, leading to the chronic shortage of forage. During this critical period, the food requirements of draft and breeding animals are occasionally filled by rice soup, especially for nursing females, and during the past few years by dry rice straw.

Livestock management practices (e.g. health monitoring, nutrition, vaccinations) are minimal, and reproductive management is unheard of. Human intervention usually is limited to a desultory surveillance of roaming animals. In the *Dao* village, most buffaloes are continually watched by children and the elderly, preventing them from damaging upland crops or from being stolen. In principle, in both villages unmonitored animal roaming is only permitted outside of the cropping season (i.e. from November to February), but nonetheless occurs throughout the year, particularly in the *Tày* village where fences protect the most important crops. Four different levels of animal surveillance can be found in the two villages: all-day monitoring with overnight stabling, and free-grazing with three different minimal frequencies of surveillance: daily, weekly or monthly visits. The level of surveillance is an indicator of both the goals of the farmer and the importance to the village of cropping activities on the hillsides.

3.2. Livestock productivity and performance

Animals can be raised either to produce meat or to provide labor (hauling in the forest and plowing in ricefields). In the study area, people essentially do not consume milk. Manure is widely but inefficiently used - fertility transfers are poorly organized and severely limited by the absence of means for transportation of manure in this mountainous area. In particular, most manure from animals grazing in the forest is lost for use in cultivated fields.

In terms of draft power, 1 buffalo can plow an average surface area of 400 to 500 m^2 per working day, corresponding to approximately three hours of work. These numbers are lower than those measured in the Red River Delta region, where 1 buffalo can plow close to 700 m^2 per day in a comparable working period. The Murrah crossbreeds commonly used by farmers throughout Southeast Asia can cover as much as 1000 m^2 per day (Tong Quang Minh and Le Xuan Cuong, 1991).

This paper introduces the indicator of "draft-need satisfaction", calculated for each household based on its irrigated ricefield area, the draft capacity of an average buffalo, and the composition of the household herd. Eguienta (2000) has shown that most of the households with an irrigated rice surface area greater than 1200 m^2 per draft animal cannot meet their draft needs with their own animals, and will need to rely on either mutual help or a hand tractor. If herd size is more than sufficient to meet the household's draft needs, that household may have the potential to move toward marketing their livestock.

Winter is the period in which the major animal-related events take place: female buffaloes give birth, forage becomes scarce, temperatures drop, parasite infestation rates rise, and labor is required both in ricefields and in the forest. Reproductive performance is mediocre in both villages, with fertility rates of 54% and 48%, respectively, in *Ban Cuon* and *Phieng Lieng*. The pre-weaning mortality rate of buffaloes is high in *Phieng Lieng* (close to 31%) and average in *Ban Cuon* (18%) as compared to other places in *Viet Nam* and in Southeast Asia.

3.3. Trends in herd use

Most animals in the studied villages either came from the cooperative herd, which was distributed to households in the 1980's as part of the decollectivization process (Castella et al., 2002), or were born to females who originated in the cooperative herd. The age pyramid shows an elderly herd with a low renewal rate (Figure 2). Figure 3 shows the herd evolution over time. The "usage rate" indicates the number of animals sold in a particular period. Mortality strongly affects net growth and most animal deaths occur before weaning.

As buffalo purchases are rare, because seldom affordable for most households, herd growth is closely tied to births and mortality. The number of working buffaloes in *Phieng Lieng* has been decreasing for several years. In recent years, there has been a wave of sales to fund lowland ricefield purchases and terrace constructions (these last particularly in *Ban Cuon*), and to repay loans contracted in 1996. The *Tày* tendency is to use buffaloes exclusively for agricultural production. Recent land reallocations have left many *Tày* landless, so many families have sold their surplus animals. As the possibilities for ricefield

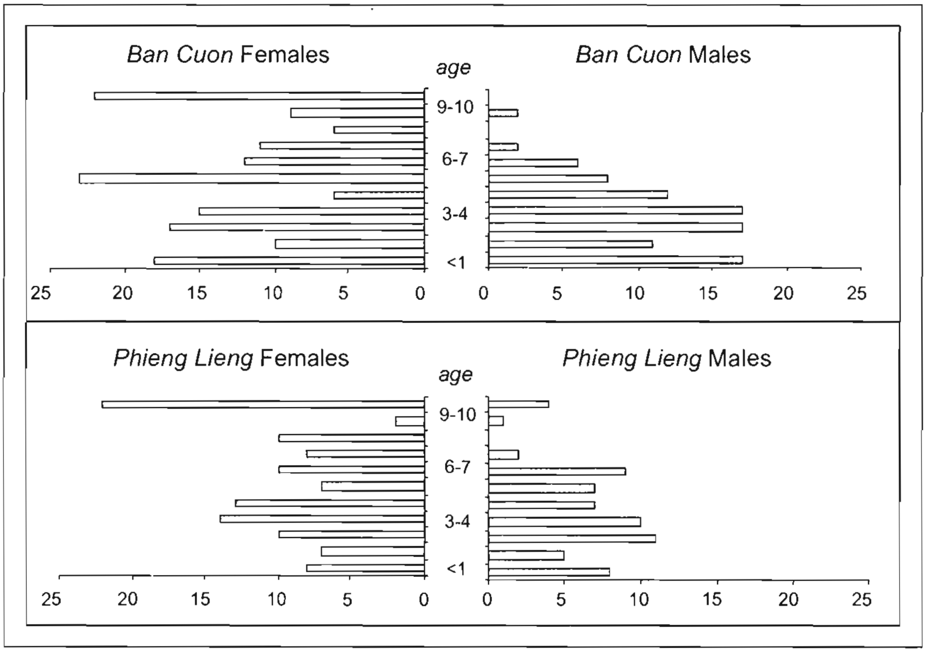

Figure 2: *Animal age pyramid*

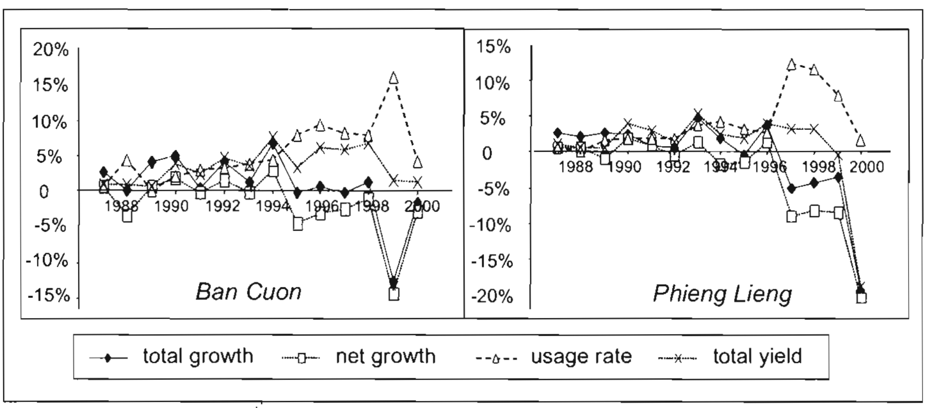

Figure 3: *Herd evolution over time. Usage rate indicates the number of animals sold in a particular period.*

extensification are now limited, buffalo ownership may become an increasingly important means of capitalization. Therefore, we may see herd sizes begin to rise again among the *Dao* and those *Tày* with few ricefields.

At present the livestock market is limited. Animal sales are primarily of culls, particularly females with mediocre reproductive performances and overly aggressive males more than six years old. However, the appearance in the last five years of other ruminants such as cows and goats (at least 30 of each per studied village) predicates the emergence of more market-based animal husbandry systems. The development of livestock markets in nearby areas is a further indication of this rising trend.

3.4. Diversity of recent animal husbandry systems in terms of livestock strategies

The differentiation of animal husbandry systems in the studied region has occurred relatively recently. During the cooperative period (1959-88), the village herd was the property of the cooperative, and only a few families with very large labor forces were able to maintain private herds. When the cooperatives were dismantled (1988), buffaloes were distributed to individual households. Since then, family succession (inheritance, dowries, gifts) has been the primary cause of changes in animal ownership; changes in land ownership and household structure have resulted in diverging trajectories.

Farmers' strategies, including those regarding livestock, are a compromise between a set of desired objectives and the means available to attain those objectives. To analyze farmers according to classical "large-medium-small" landholder categories would be of limited usefulness in this area because land ownership is not the sole factor determining livestock strategies. For example, it is difficult to say whether a large ricefield area represents a revenue source that permits the purchase of a buffalo, or is the basis of the need for such a draft animal. Therefore, instead of analyzing farmers' strategies according to land ownership only, we analyzed it in connection with other factors: i.e. surveillance level, animal traction power needs satisfaction, etc.

At present, crop-livestock interactions have positive effects only in ricefields: buffaloes provide animal traction, can be a source of capital for ricefield purchase, and provide manure that is used as a fertilizer, albeit inefficiently. However, negative crop-livestock interactions abound, and are a major impediment to the development of both animal husbandry and crop production. Apart from much-needed rice straw in winter, crop production does not provide food for cows and buffaloes. Meanwhile, on the hillsides, livestock and crops compete for space. Animals damage crops, indirectly harming inter- and intra-village social relationships. Animal upkeep also demands a certain investment in terms of labor, either in the form of surveillance or construction of adequate fencing for crops.

In the following section, we will examine current agricultural systems and characterize types of farmers, with the intention of arriving at an integrated approach for developing both crop production and animal husbandry. With few exceptions, all farmers in the studied area are involved in both crop production and animal husbandry. The term "farmer" as used in the following sections refers primarily to the livestock component of these agricultural systems, but should not be taken to imply a lesser importance for the crop component of the system.

4. Farm household typology

4.1. Characterization of relevant variables

We analyzed our survey data through a multiple correspondence factorial analysis (MCFA), which enable us to characterize statistical relationships among quantitative and qualitative variables pertaining to the surveyed households. The statistical analysis complemented the more empirical work that was based on land-use analysis and household surveys. We built a typology based on 143 households (covering 78% of *Phieng Lieng* and *Ban Cuon* households). Our household surveys covered every household, but because MCFA cannot accommodate missing data, the statistical analysis was limited to those families for whom we could acquire all of the relevant data. We calculated household food availability by converting all household production to its equivalent in rice, based on market values. We then determined household food self-sufficiency using the reference value of 250 kg rice/person/year (National Committee of Food Security, 1998).

Draft need satisfaction levels were calculated using the method developed by Eguienta (2000). After estimating the average plowing capacity of male and female buffaloes, we calculated the field area that could be covered by each household's herd. We limited the number of working days to twenty-six per year, reflective of the climatic situation and crop seasons in the studied area. The difference between the field area that could be covered by a household herd and the total area of that household's ricefields indicated the extent to which that family could meet its draft needs with its own animals. We expressed this satisfaction level in terms of the number of average buffaloes required to meet the household's animal traction needs. The parameters associated with changes in herd size (birth, mortality, export rates) were calculated for the period 1996 to 2000, to reflect recent trends. Available labor force was calculated based on a distinction between laborers (adults between 15-60 years old) and half-laborers (children younger than fifteen and elderly people older than sixty). We assumed that the entire labor force was available during labor peaks.

We chose to work with only the first two axes of the MCFA (Figure 4). Though they account for only 21% of the total variance, their use is justified by their independence from the other axes. The distribution of modalities for each variable indicates two clear axes of variation: (i) a "cropping systems" axis that separates variables including irrigated rice self-sufficiency level, draft need satisfaction level, and lowland/upland cultivated area ratio; and (ii) a "livestock/time" axis that separates variables including herd size, year of starting livestock farming, and household head's age. The other studied variables do not follow clearly defined axes. We will now characterize household structures and farming systems according to the variables that make up the "cropping systems" and "livestock/time" axes.

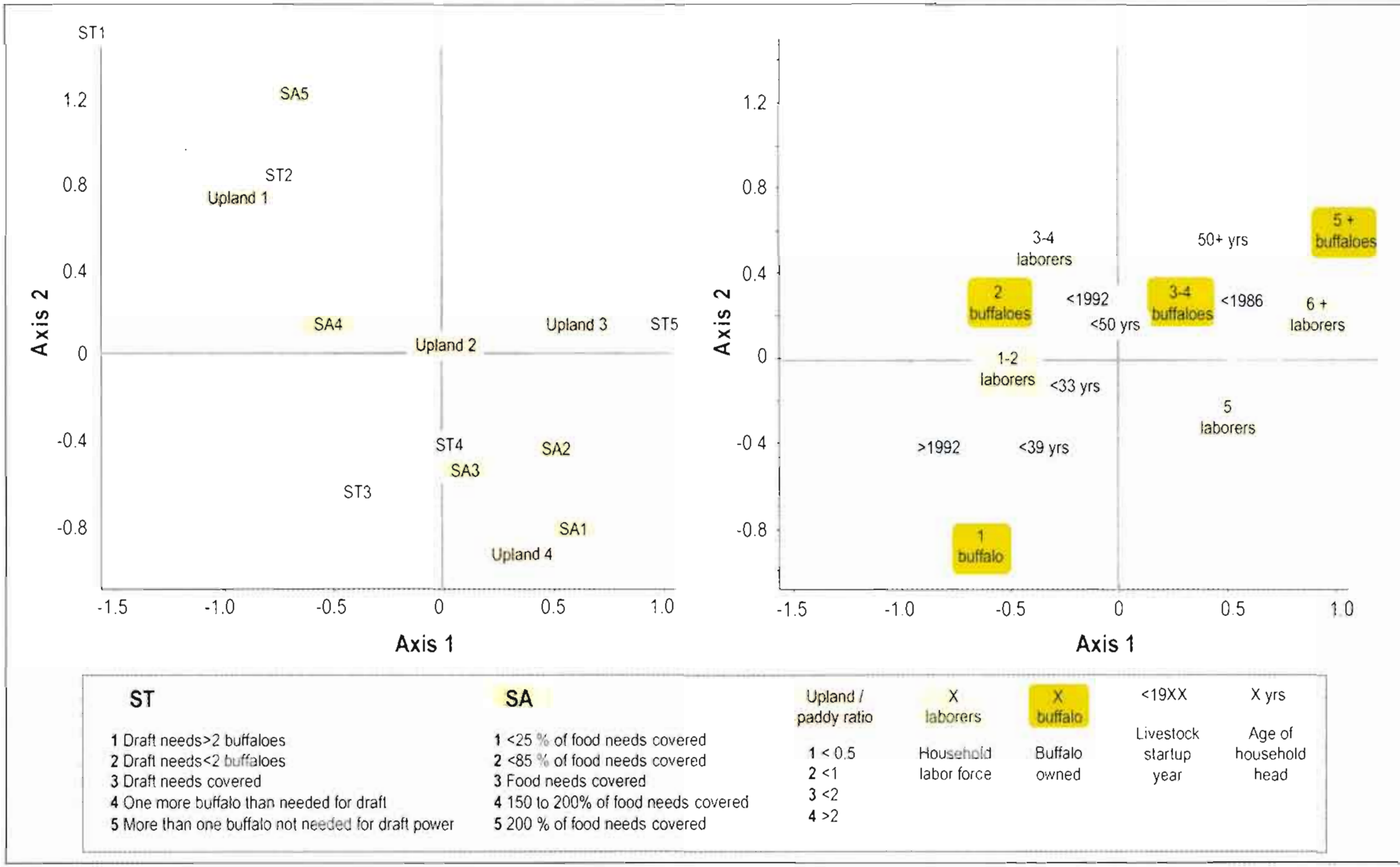

Figure 4: *Distribution of variables on axes 1 and 2 of the MCFA*

4.2. Identification of four major household types

Figure 5 shows the distribution of livestock-raising households on axes 1 and 2 of the MCFA (households without livestock were excluded from this analysis). The "cropping systems" and "livestock/time" axes reveal the ability of each household to meet its food-sufficiency and draft needs, as well as its structural characteristics (number of animals, importance of various crops, age of household head, etc.).

Four main types of households could be distinguished (Table 3, Figure 5):

- Along the "livestock/time" axis, types A and B are the young farmers (head of household younger than 38 years), who began to raise livestock some time after 1992 and currently own one or two buffaloes. Types C and D consist of more established households who have been raising livestock since 1992 or earlier, with household heads older than 38 years, and who own three or more buffaloes.
- Along the "cropping systems" axis, types A and D represent households with large ricefield areas. They are rice self-sufficient and gain income from selling surplus rice. They make minimal use of the hillsides, limiting themselves to some maize crops for pig-feeding and small fruit tree or industrial-crop plantations (timber, bamboo, cinnamon, etc.). They have high draft needs because of their large ricefield areas. Types B and C are households with small ricefield areas. They cannot meet their food-sufficiency needs with lowland rice, and compensate for this by heavily cropping the hillsides (Castella and Erout, 2002). Given their small ricefield areas, their draft needs are easily satisfied by their buffalo herds, giving them the potential to evolve toward a market-based buffalo raising system.

Household labor force does not follow a clearly defined axis in the analysis. However, it is correlated with the age of the household head: in general, the further a farm advances in the household life cycle, the greater the number of members (and thus laborers) in the household. For the younger household types (A and B), the only laborers are the household head and his spouse; the other household members are too young. Type D households tend to have three to four laborers, whereas type C households often have as many as five to ten laborers.

An examination of socioeconomic characteristics (Figure 6) shows a clear correspondence between ethnic or village origin and the types identified in the statistical analysis. Type D is made up almost exclusively of *Tày* families (from *Phieng Lieng*), whereas type C is made up of *Dao* households (from *Ban Cuon*). The explanation lies in the cultural norms of these two ethnic groups. *Tày* children tend to leave their homes fairly early, and only the youngest child lives at home until the farm succession. *Tày* households' large ricefield areas lend themselves well to division among autonomous descendants. In contrast, several *Dao* generations can often be found in the same household, including both individuals with close and with distant family ties (Mellac, 2000). Beyond its cultural roots, this tendency for families to stay together can be related to the small lowland area owned by each *Dao* family – further division of land among descendants would not be feasible. The large number of laborers also facilitates the organization of extensive labor on the hillsides.

Phieng Lieng households (in green in Figure 6) have production systems based on paddy rice, whereas *Ban Cuon* households (in violet in Figure 6) focus equally on the hillsides and the paddylands. However, some *Ban Cuon* households have structural qualities that are similar to the *Tày* in *Phieng Lieng*. These include *Kinh* or *Nùng* immigrants, *Tày* founding families who have returned to the land of their ancestors, and the few *Dao* families who have gained paddy field access since decollectivization.

Type A (large paddyfield areas) is exclusively *Tày*, whereas type B (few ricefields, substantial use of hillsides) is ethnically mixed. Type B is composed of both *Tày*

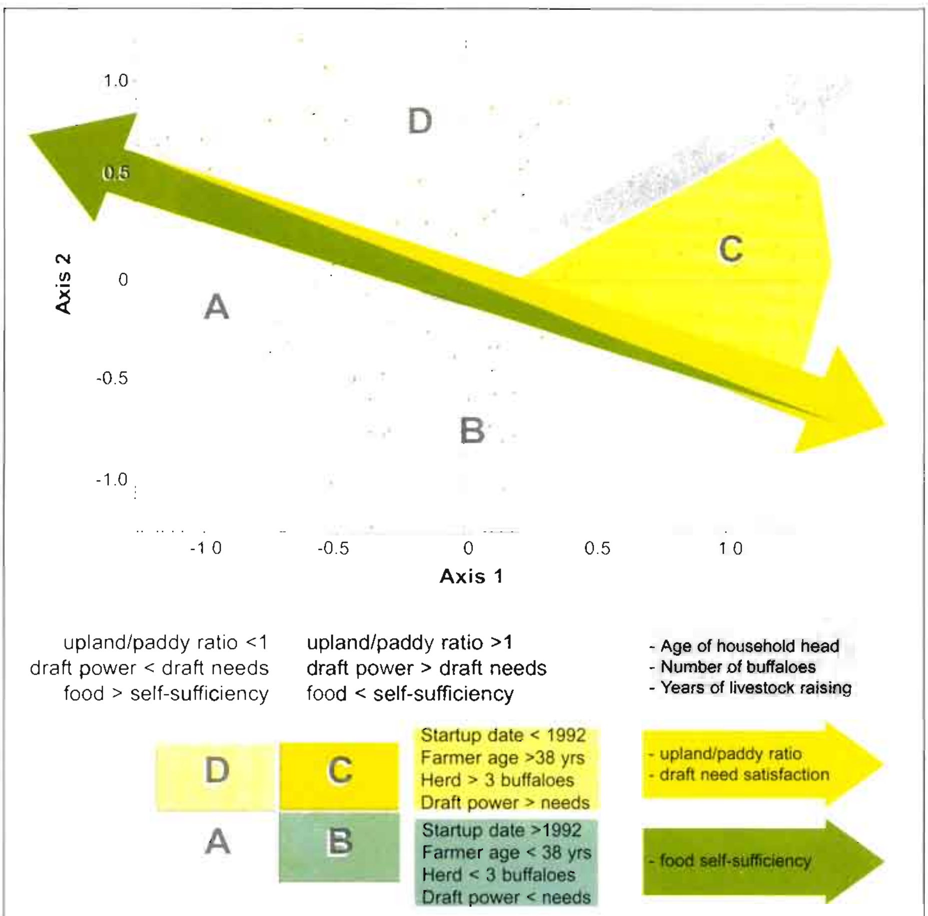

Figure 5: *Distribution of households types on axes 1 and 2 of the MCFA*

Table 3: *Characterization of livestock raising households*

Types	**A**	**B**		**C**			**D**			
Sub-types	**young *Tày* farmers**	**B1 young *Dao* and *Tày***	**B2 stricken**	**C1 merchants**	**C2 savers**	**C3 soon retiring**	**D1 rice-growers w/draft animals**	**D2 rice-growers w/animals for capital**	**D3 stricken *Tày* abandoning husbandry**	**D4 abandoning husbandry**
Food needs	covered	not covered					covered			
Importance of upland crops	low	high					low			
Animal draft needs	not covered	covered					almost covered			
Number of buffaloes	1 to 2 buffaloes			3 to 4 buffaloes	> 5 buffaloes	3 to 5 buffaloes	3 to 4 buffaloes	>5 buffaloes	2 to 3 buffaloes	2 buffaloes
Labor force	1 to 2 laborers		less than 5	6 to 10 laborers			3 to 4 laborers			
Age of household head	less than 38 years		all ages	more than 38 years						
Livestock startup date	after 1992		variable	before 1992						
Hand tractors	no							yes	no	
Other ruminants	no	yes					no			
Ethnicity	*Tày*	*Dao/Tày*		*Dao/Tày*	*Dao*	*Dao/Tày*	*Tày*	*Tày/Dao*	*Tày*	*Tày/Dao*
Animal sales	none			some	occasional	none	some	regular	many	very many
Mortality	none		high	medium	low to medium				medium	none
Surveillance	free-grazing	mixed	night stabling	night stabling	night stabling	night stabling	night stabling	night stabling	mixed	night stabling
Main goal of husbandry	traction (starting up)	capital (starting up)	marketing	marketing	accumulation	capital for succession	traction	capital	abandon livestock	abandon livestock
Proportion of all farmers surveyed	11%	16%	12%	12%	13%	7%	7%	8%	5%	9%

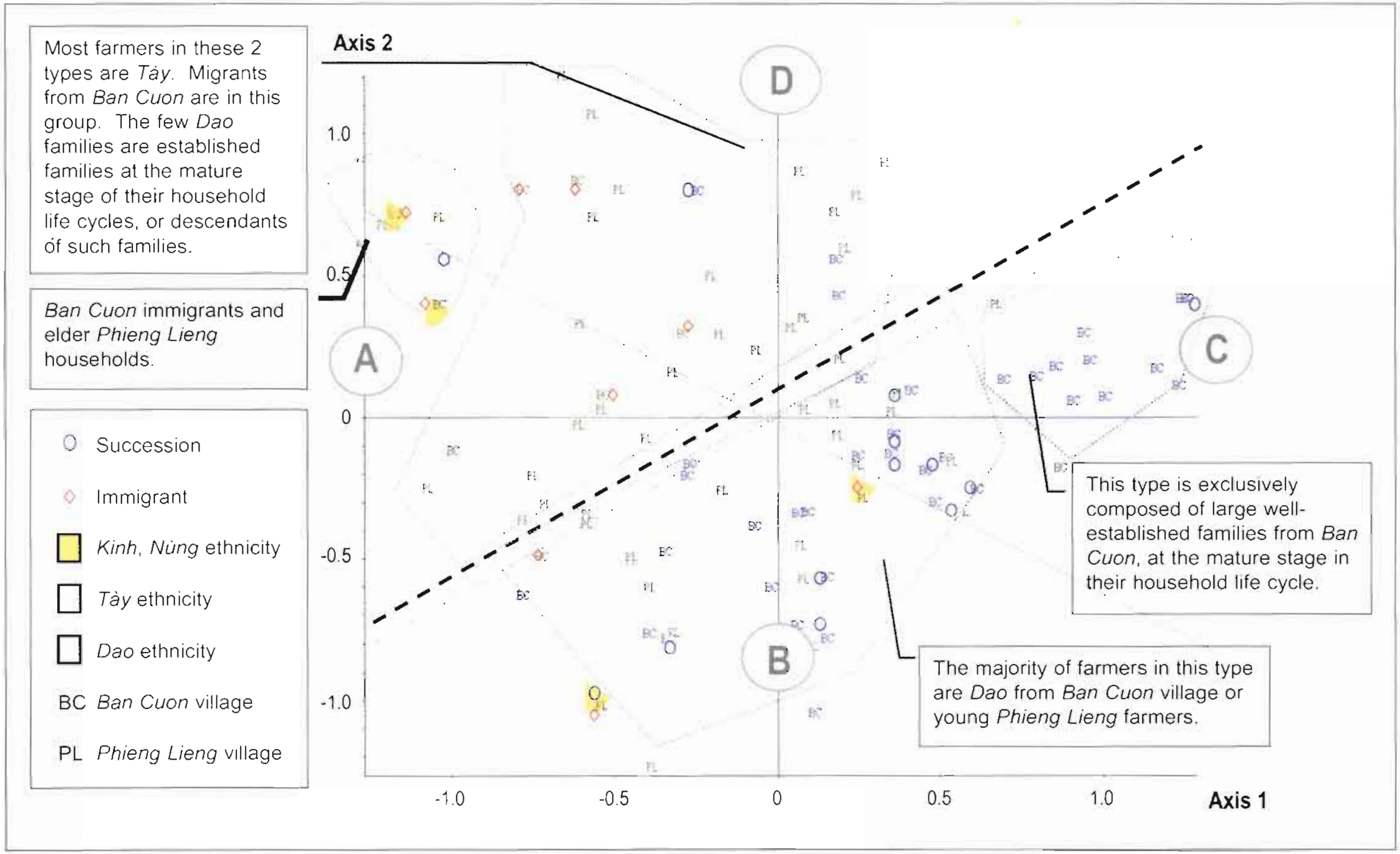

Figure 6: *Characterization of household types according to socio-economic characteristics*

and *Dao* who set up their farm after the end of the land reforms, and have had limited access to paddy fields. The high population pressure and scarcity of paddylands have diminished the ethnic differentiation among households that depend on animal husbandry and hillside crops to make up for a lack of lowland ricefields.

Mechanization and livestock diversification

The households with the fewest ricefields have the most diversified livestock systems (types B and C), as their inability to meet subsistence requirements with lowland rice has pushed them to the hillsides. Their buffalo raising is specialized in breeds with high quality meat, regardless of draft power. Since its introduction in the commune, about three years ago, cow production is preferred, as cows do not destroy fences and have much more of a herd instinct, allowing for a more lax surveillance. Furthermore, cows reproduce more frequently than buffaloes (one calf per year), and the marketing channels for their meat are better developed (Helvetas, 2000).

Families with hand tractors are either *Dao* or *Tày* with substantial ricefield areas (exclusively type C). The purchase of a hand tractor is made possible by the sale of buffaloes, or by off-farm income such as soldiers' pensions or cadres' salaries. Families with hand tractors are usually close to having their draft needs covered by the household herd, as they tend to own more than three buffaloes each. This shows that the ownership of a hand tractor does not preclude buffalo raising - the two activities are complementary. Buffaloes are a form of security in case a hand tractor should break down, and can also be loaned or sold at a profit. However, if the current conflicts due to crop-livestock interactions should persist, we may see hand tractors begin to replace buffaloes in households with this option, increasing social differentiation levels.

High herd export rates can be explained by three elements of the household situation:

- Availability of mechanization (hand tractors, motorcycles, mills);
- The need for capital for purchasing ricefields, repaying loans, or meeting social requirements (marriage, schooling, etc.); and
- Abandoning livestock raising for various reasons (theft, natural resources degradation leading to high winter mortality, farm succession, etc.).

An examination of structural and historical herd characteristics (input-output balances from sales, mortality, etc.) allows us to further subdivide the household types defined above into ten distinct subtypes (Figure 7, Table 3).

Surveillance practices based on ethnicity and circumstance

In *Ban Cuon*, the presence of crops in the collective pasture areas makes close surveillance and nightly stabling veritable necessities. For families that have been

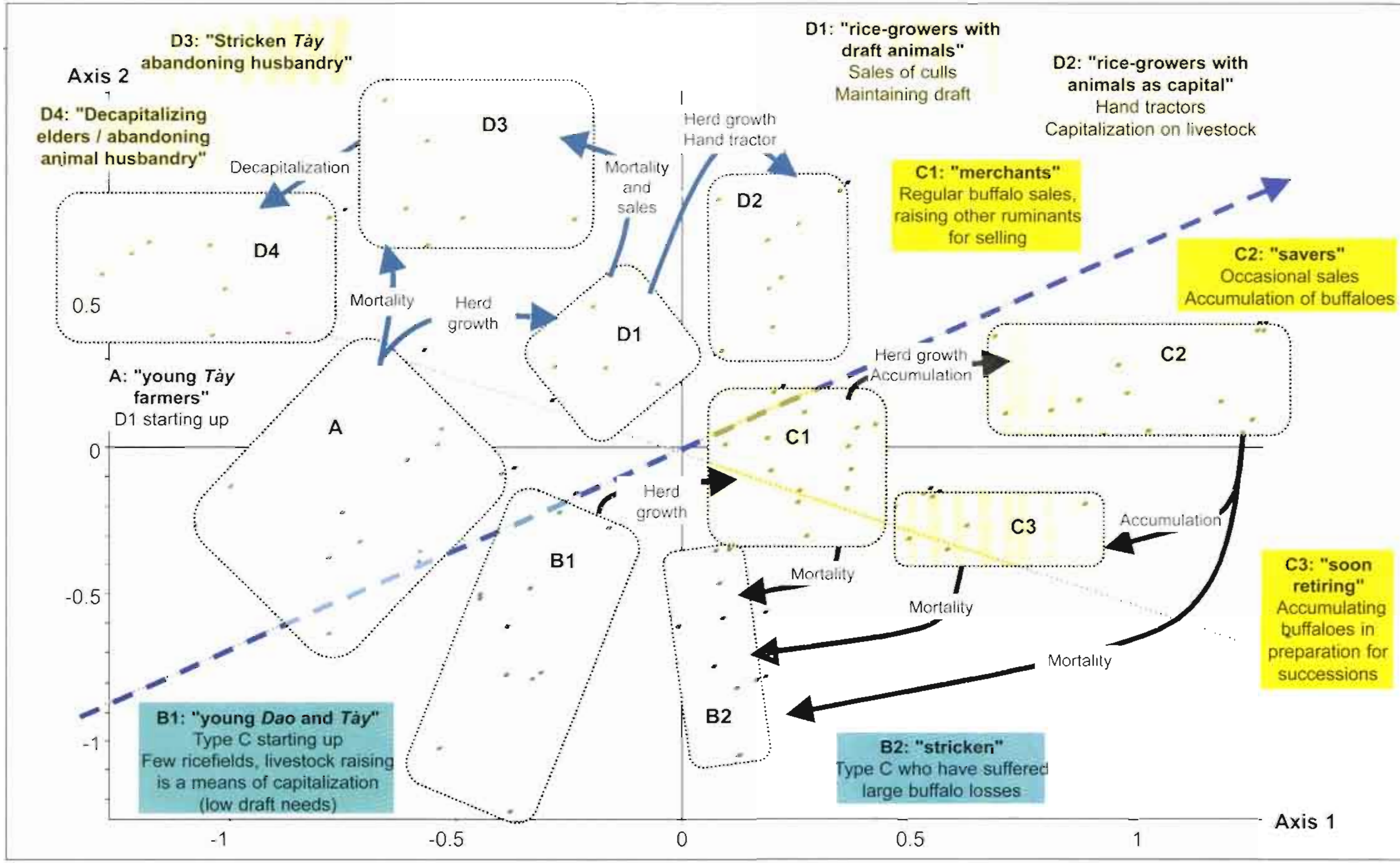

Figure 7: *Characterization and recent evolution trajectories of crop-livestock households*

raising livestock for more than 10 years, surveillance is daily (Figure 8), due to their increased experience and greater importance of livestock as an income generation source.

In *Phieng Lieng*, upland crops are mostly in areas that are not accessible to animals and are rarely located in collective pastures, permitting a lax surveillance of livestock. There are only two categories of *Tày* families that watch over their livestock very closely: (1) those who have been victims of high animal mortality; and (2) elder families, which distribute many of their animals to their children settling new households. Such families are motivated to monitor their livestock closely (mostly to guard against theft) because of the relative importance of the few remaining buffaloes they possess. In both villages, older families (i.e., household head over 40 years old, with eldest children starting to found their own households) tend to watch over their animals more closely than younger families. Here again, this is likely because of a greater availability of labor force, but also in part because of their longer experience with animal husbandry practices.

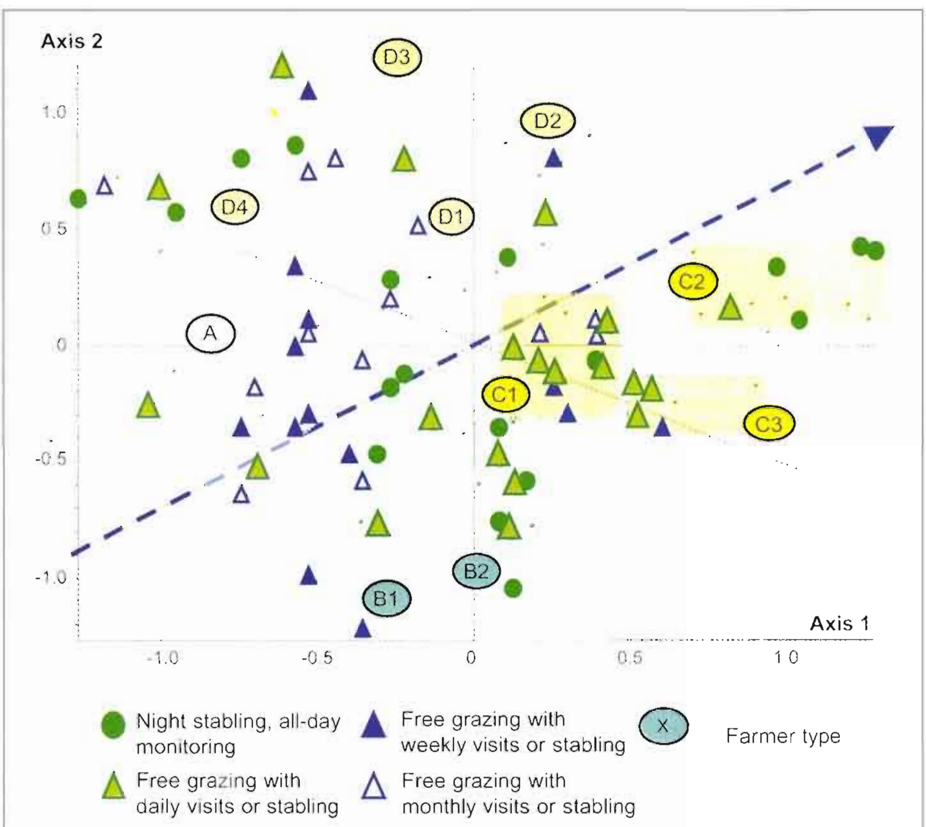

Figure 8: *Livestock surveillance techniques of various household types and sub-types.*

4.3. Recent trajectories of household evolution

About 10 years into the differentiation process initiated by paddyland allocation and livestock distribution, the household types and observed trajectories are similar to the one that have been documented by Castella and Erout (2002) in other case studies in *Bac Kan* Province (i.e., driven by farmers' access to paddyland, and within each household type, according to the stage in the family life cycle).

Trajectories for descendants of families who founded *Phieng Lieng*

Type A is largely homogeneous. These young *Tày* farmers are just starting out in their livestock production, are well endowed in terms of irrigated ricefields, and have inherited one or two buffaloes from their families. Their large capital endowment is the result of the privileged position of their families, who were among the founders of *Phieng Lieng* (Castella et al., 2002). Since starting up their animal husbandry practices, they have neither sold animals nor faced animal deaths. Their buffaloes allow them to integrate themselves into mutual aid networks associated with ricefield work.

Type D evolved naturally from Type A (Figure 7). Four different sub-types of farmers can be found within Type D. They represent various stages in the evolutionary trajectories of *Tày* farmers, most of whom live in *Phieng Lieng* village:

Type D1 farmers are lowland rice growers who raise buffaloes for their draft power. They plan to increase the size of their herds until their draft needs are covered, including contributions from mutual aid. Their strategy is a balance between maintaining a minimal herd and generating additional income from animal husbandry.

Type D2 consists of *Tày* families with higher numbers of buffaloes who have decided to turn to mechanization to provide traction for their ricefields, either by purchasing or by renting hand tractors. Livestock in this system is for capital and savings. Livestock sales are regular and often involve multiple animals. These are the most prosperous households in both villages.

Types D3 and D4 are households whose herds have decreased considerably in size in recent years. Type D3 is made up of middle-aged farmers whose herds have been stricken by high mortality. Their draft needs are high (shortages range from two to seven buffaloes per household), but past losses have discouraged them from trying to increase the size of their herds. They may also have sold a number of animals, and now keep only two or three buffaloes. Some rent hand tractors for ricefield work, but most households in this type meet their needs with the help of labor exchanges based on mutual help. Their remaining buffaloes let them participate in mutual aid networks.

Type D4 families are nearing the mature stage of their household life cycle and are in the process of distributing most of their capital among their children. They have a minimal labor force to occupy and their children have already set up their own farms or are in the process of doing so. Livestock numbers are decreasing either because of gifts to children or sales. The animals that remain are for financial security.

Trajectories for other families

Type C1 consists of middle-aged farmers who have developed their livestock herds to make up for insufficient ricefields. Their draft needs are covered and their goals are market-oriented. Some raise cows and goats in addition to buffaloes. Type C2 is made up of older households with larger herds. They regularly sell culls, and their livestock represent accumulated capital. Type C3 households are also older but they do not have a history of selling their animals; instead, they are accumulating livestock and preparing to pass it on to their children. As these households do not have large ricefields, the buffaloes will be the major part of their children's inheritance.

Types B1 and B2 have very small herds. Type B1 is made up of farmers who are just starting up livestock production. With minimal access to ricefields, their most likely trajectory is toward type C1. Type B2 households were initially type C2 or C3 farmers who then suffered high rates of animal mortality, and therefore have not sold any livestock in the last five years. These were well-established families who lost animals to chance occurrences (disease, losses in the forest, deaths of calves, etc.).

5. Discussion: developing sustainable livestock feeding systems

5.1. Improving crop-livestock interactions

Given the increasing land scarcity and shortage of natural fodder, the priority for animal husbandry systems in the region is to find ways to feed livestock through the entire year by developping integrated food-feed cropping systems. Responding to this need must take precedence over any efforts to improve the performance (meat and labor production and reproduction rates) of livestock raising systems in the area. However, because of the diversity of households' strategies, the best option for meeting this need is different for each of the ten household types.

There is a pressing need to find alternatives to free grazing for large ruminants. New approaches need to allow for the maintenance or growth of household herds without damaging the natural resource base, in a way that complements the extensive hillside agriculture already present in the system. In the future, farmers should be able to create livestock feeding systems from a series of components that make use of local resources in a timely and labor-efficient fashion. The components of such systems could incorporate the following concepts:

Integrating forage production into innovative rotational cropping systems

Within the studied area, techniques are already being researched in the framework of the SAM Program to implement cropping systems that make use of improved fallow management. The idea is to develop a rotational cropping system that incorporates two to four years of forage production. This portion of the rotation would serve both to produce feed for animals and to improve soil fertility via improved, permanently-covered fallow. Trials currently are underway with certain cover and fodder crops that improve soil structure (grasses such as *Braccharia* and *Pennisetum*, forage legumes such as *Stylosanthes*, etc.). However, fences are needed both to protect fields from overgrazing and to ensure sustainable rates of fertility extraction. Given the high labor inputs for annual repair of traditional fences (bamboo and wood), and the high cost of alternative materials such as barbed wire, hedges seem to offer the best fencing option. SAM Program is conducting trials in the two studied villages with multiple-function living fences composed of combinations of complementary species: fodder trees (e.g., *Glyciridia* spp.), fertility-restoring plants (e.g., *Acacia* spp.), and thorny hedges. In addition to feeding animals and protecting cultivated fields, these fences can also provide green manure by pruning, which can be incorporated to help restore soil fertility of the whole field. Here, the challenge is to balance fertility flows at the plot level, by giving back fertility exported through nutrient uptake by plants (and then through plant consumption by animals). Another way to achieve a fertility balance is to return manure from buffaloes to the corresponding fodder-providing field, but suitable modalities (secondary cowshed close to the plot, controlled direct grazing, etc.) still need to be tested in the particular circumstances of *Cho Don* farmers.

Supplementary forage production outside of agricultural fields, in rotating improved pasturelands

This technique involves growing hedges as well as intensifying and maintaining meadows as part of a rotating forage cutting system. However, the implementation of this system would be costly (transportation of feed across long distances, high labor investment, required pasture surveillance, cost of chemical inputs). The system would be most feasible if the costs were shared by the village community as a whole on collective lands, and even more so if it could be supported by commune and district authorities (e.g., through land-use authorization and/or economic subsidy). In addition to its technical requirements, the implementation of improved public pastures would require an effective collective management of the system by the village community. Again, returning manure to the pasturelands would help substantially in maintaining soil fertility levels.

The introduction of a cold-resistant crop in ricefields in the Fall

Such a crop could help to provide for livestock during the most difficult period of the year. Barley, oats, and wheat all have shown promising results in trial plots. For example, oat plots in *Bac Kan* yielded 2 kg/m^2 of vegetative-stage fodder in January (under an average monthly temperature of 14°C). These crops not only could provide an additional source of income for farmers, but also could enrich the soil if part of the biomass was left in the field as a mulch into which the next crop would be directly sown. As with the innovations described above, returning manure to the system is an important way to counter nutrient loss from crop uptake. Winter fodder production could be particularly effective in the case of poorly-irrigated fields that are only suitable for one rice crop per year.

Efficient use of crop residues through improved silage

For several years, *Bac Kan* farmers have been countering fodder shortages by storing rice straw to distribute it to animals during the winter. Researchers can contribute to the further improvement of this practice by offering adaptive techniques, such as treating rice straw with urea. This treatment consists in cutting the straw into 15-20 cm lengths, moistening it with a 3-4% urea solution, and storing it for 1-1.5 months in anaerobic conditions (e.g., in plastic bags or in boxes made of bamboo plait and banana leaves that are buried in the soil). This technique, commonly practiced in other regions of Southeast Asia, has not yet spread widely in the study area because of the lack of local materials and poor farmers' knowledge on this technique. It increases the straw digestibility and nutritional qualities while preserving it against damage from rats, insects, and fungi.

In summary, there are at least four components that farmers could incorporate to create sustainable livestock feeding systems: (1) feed-food crop rotations, (2) improved management of common pastures, (3) cold-resistant winter fodder crops, and (4) improved silage techniques. In deciding how to integrate these components into livestock feeding systems, it is important to consider both specific household types and the needs of the community as a whole. Households who maintain minimum herd sizes to meet their draft needs (e.g., types A, D1 and D4) probably will not participate as actively in community-based livestock management schemes as households whose income relies on the sale of a larger number of livestock (types D2 and C1). Regardless of household type, the implementation of any of the above systems would require substantial labor input, particularly during the first year of fodder species establishment, and may also require chemical inputs. These input requirements conflict with already-existing crop production practices – farmers will need to make cost-effective decisions regarding how to allocate their labor force.

New livestock systems will require a major shift in the perspectives of farmers toward the labor requirements of animal husbandry. Animals currently free-graze and feed upon natural resources; neither the animals nor the resource base requires substantial interventions on the part of farmers. Farmers' priorities are in the ricefields, and as such, it is the ricefields that receive most of their attention, and also the bulk of animal manure. Meanwhile, commercial mineral fertilizers are too expensive for most farmers; only the descendants of *Tày* founding families have sufficient capital in the form of ricefields, plantations, and cattle to invest in expensive commercial fertilizers (Castella et al., 2002). The transportation of animal manure to the hillsides remains a very real problem that was quickly identified in a trial effort to feed cows with a *Braccharia* cover crop. Part of the problem is that most of the laborers engaged in livestock management are children and the very elderly. In contrast, the transportation of manure and *Braccharia* are tasks that an adult must perform.

The challenge remains to develop a feeding system that is not overly labor-intensive. Part of the solution may be to improve the spatial management of forage resources that shift between pasturelands and forests during the course of the year. Feeding could be simplified through the effective use of stables and improved meadows, forage crops integrated with food crops, and on-the-spot feeding (with a moving corral or animals tethered to stakes, in appropriate fields).

To implement any of the above combinations, changes in the spatial organization of livestock management could be beneficial. An on-the-spot feeding system would minimize labor requirements during peak labor periods and make possible fertility transfers that are presently limited by transportation difficulties, benefiting both the crops and the livestock that feed upon them. Keeping animals in stables makes it possible to care for them better during the most critical winter period, and better care during the winter will result in more efficient animal traction in the ricefields. Finally, combining several of the innovations listed above can give grazing lands (i.e. both pastures and forests) a period to regenerate, reducing the pressure of livestock on the natural landscape and thereby benefiting the community as well as the individual farmer.

5.2. The role of research and extension

To implement the above systems, farmers will need to be assisted by research and extension experts. Currently, peak labor periods are already fully occupying farmer labor when livestock is left to roam freely. Thus, the proposed livestock practices will not only require a switching of labor from current practices but also a local validation of research findings, and an education of farmers in the following areas:

- Forage crops that can resist winter conditions;
- Most efficient production levels of forage crops, as well as their values as fodder or as green manure to improve soil fertility;
- Optimal fertilizer amounts for a balance between satisfactory production and minimal input cost;

- Quantification and assessment of the management modalities of available forage resources (cutting, on-the-spot consumption, rotation, quantities, etc.);
- Animal needs (identified through feeding trials that include examination of animal growth and health);
- Methods for fodder quality improvement through cutting, drying, and silage treatment, with minimal chemical input costs.

The issues associated with fertility transfer require further research, given their importance to sustainable interactions between crop production and animal husbandry. Research is needed in improving both the quality of the manure itself, and the management of the manure. Higher quality manure leads to better fertilization and thus to higher-quality forage crops, resulting again in higher quality manure - a positive feedback loop. Some *Bac Kan* farmers already are treating cowpats by composting, first adding vegetable scraps and later urea. However, composting practices remain rudimentary. For example, trenches for composting are covered only with palm leaves, allowing rainwater to percolate. Alternatively, manure can be enriched by covering stable floors with rice straw, which immediately mixes with animal wastes.

In addition to enriching the manure, the constraints to manure management, particularly to economical transport, remain to be addressed. To spread 800 kg of manure across a 1000 m^2 field, laborers must make approximately 20 round trips between the stable and the field, which indicates the need to streamline the fertility transfer process.

Researchers also need to continue to devote themselves to experimentation within the farmers' environment. Farmers'-field experimentation is an effective way to remain aware of the constraints faced by farmers and to develop customized feeding systems in consultation with the farmers who will use them. Finally, experience has shown that the adoption rate of technical innovations is highest when farmers have access to training (Hoang Lan Anh et al., 2002). Technical innovations practiced in isolation risk losing their effectiveness because of low adoption rates. It is thus very important to institutionalize within the Government extension system the effective innovations that will develop from research or development activities.

6. Conclusions

The raising of large ruminants in the mountains of northern *Viet Nam* is an important, even vital activity for most farming families, whatever their ethnic origin. Extensive cow-buffalo raising systems can offer draft power, capital, and meat to farmers, but are currently in crisis and need to evolve if they are to survive. Up to now, neither the livestock systems nor the imminent system crises have been analyzed or documented. Solutions to problems of crop-livestock interactions in this region need to begin with a solid understanding of the multi-faceted livelihood strategies of the farmers involved.

Households with only a few draft animals can use rice-harvest residues and winter crops to feed livestock in winter, providing the energy that will be needed for spring labor. The rest of the year, animals could feed on forests and natural meadows. For households with greater means who are more reliant on livestock raising, it would be worth considering investments in forage-crop production either in the form of crop-forage rotations on cultivated fields or improved pastures. These alternatives need to be effectively organized both spatially to minimize labor requirements, and temporally to avoid conflicts with labor peaks and to ensure that the needs of livestock are met during the most crucial periods of the year. Identifying the most effective arrangement of resources in space and time necessitates the use of the tools of participatory diagnosis, communication, and adaptive decision-making (Castella et al., 2002a). Hopefully, new livestock-feeding practices could be organized in the frame of innovative food-feed cropping systems whose components (see section 5.1) are spatially and temporally combined in accord with the characteristics of the different farm households. This would result in better animal performance, making such feeding practices a worthwhile investment for farmers.

This characterization of livestock systems and farmer situations makes it possible to orient research or development activities based on a thorough understanding of household strategies and crop-livestock interactions. Cultivated fields producing forage crops can constitute an initial stage in a stepwise process of food - feed systems integration. It could be complemented by subsequent innovations such as fertility management and improved labor efficiency. The development and intensification of sustainable animal husbandry practices through food-feed cropping systems integration has the potential both to increase agricultural production and to improve the living standards of mountain people.

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