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A Participatory Simulation to Facilitate Farmers' Adoption of Livestock Feeding Systems Based on Conservation Agriculture in the Uplands of Northern Vietnam

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In the mountain areas of northern Vietnam, extensive husbandry of large-ruminants is limited by the lack of natural forage. Since 2000, the Mountain Agrarian System Program has been concerned with this issue and has evaluated technical alternatives aimed at sustainable integration of crop-livestock systems. One alternative consists of feeding systems for large-ruminants based on cropping systems with plant cover. Diffusion of information about the new system is supported by a set of interactive communication tools for use between farmers and researchers. A participatory simulation method was developed that combines a compartmental model of the village territory with five technical innovations. Farmers simulate the adoption of the innovations they choose among food-forage cropping systems in rotation or in association, and urea-treated straw. They evaluate the quantity of forage that can be grown for their herd using the chosen set of techniques.

Simulations revealed farmers' constraints and objectives in adopting sustainable cropping systems on the hillsides while maintaining a small animal husbandry system. The results obtained by each farmer provide a useful basis for discussion about the implementation of innovation. This participatory simulation method could be more widely used to facilitate the diffusion of innovations such as integrating livestock feeding systems with conservation cropping practices.

Keywords conservation agriculture, livestock systems, mountain areas, participatory simulation, Vietnam

Introduction

Since 1997, the Mountain Agrarian Systems Program has been investigating land-use changes and prioritising development issues in Bac Kan, one of the poorest provinces in northern Vietnam (Castella *et al.*, 2003a). The diagnostic phase revealed three driving forces for local development that are shared by many other upland areas in northern Vietnam and also by Southeast Asia in general. First, the villagers' access to markets, education, health services and technical information is of critical importance in providing diversified local development opportunities. The geographic diversity of the landscape is reflected in the wide diversity of socio-economic environments (Donovan *et al.*, 1997). Second, the successive land policies that have accompanied the process of agricultural decollectivisation over the last decade have been a major driving force of changes in land use. Land distribution to individual households profoundly modified land-use systems both in the valley bottoms and on the hillsides (Castella & Dang, 2002; Jamieson *et al.*, 1998). Third, crop–livestock–forest interactions were completely transformed by a changing economic context, and by accessibility and land tenure policies. The extensive management of large-ruminants (buffaloes and cattle) has become a major obstacle to agricultural intensification in both the lowlands and the uplands (Castella *et al.*, 2003b; Husson *et al.*, 2001a). The restriction of the access buffaloes and cattle had to their traditional forage resources resulted in their straying into shrub- and forestland, causing problems for forest regeneration and also for the animals, as poor diet leads to poor performance. In recent years major environmental concerns have been raised about mountain agricultural systems, concerns that emerged after the abolition of the agricultural collectives in 1988. Although our research programme could not go beyond the documentation of the impact of accessibility and land policies on land-use changes, we developed a range of technical and organisational innovations to overcome some of the crop–livestock issues that we identified. A diagnostic study carried out beforehand set the stage for the diffusion of the innovations.

A large number of cropping practices based on plant cover and embracing the principles of conservation agriculture were developed as alternatives to slash-and-burn practices and tested in the real conditions that the farmers face (Altieri, 2002; Husson *et al.*, 2001b; Uphoff, 2002). These were designed as basic components of more complex cropping systems that farmers can combine in different ways depending on their specific needs and objectives (e.g. give priority to rice sufficiency, crop–livestock association, put more emphasis on forage for livestock, expansion of perennial crops, etc.). The most promising innovations thus far have been, (1) direct sowing of upland rice or maize in a mulch of *Brachiaria* (grass) or *Mucuna* (legume), (2) crop–legume association (e.g. cassava – *Stylosanthes*, orchard-*Arachis*), (3) vegetative strips (natural vegetation, planted grasses or legumes) along contour lines, (4) a soil slow burning technique that boosts the fertility of degraded soils by releasing phosphorus in a form that the plant can easily uptake, and (5) mini-terraces to control erosion on steep slopes. In addition to restructuring soils, controlling erosion and improving crop management, these innovations can also provide good quality forage for livestock (Eguienta *et al.*, 2002).

Farmers who tested the proposed techniques in their own fields within the framework of the project were very interested in these alternatives to traditional slash and burn practices. They suggested improvements, and proposed some of their own innovations (e.g. treatment of straw with urea) that were tested at a wider scale in the project. However, the diffusion of these new practices was not an easy process. The specific constraints of the mountain environment had to be taken into account in designing strategies for the dissemination of innovation. In most cases it is impossible for subsistence farmers to adopt a complete package; *stepwise adoption* (i.e. the introduction of successive components of a given cropping systems) is preferred. The introduction of any innovation is managed in a *systemic perspective*, as changes in the cropping patterns of small upland farms inevitably affect livestock and forest resource management. For example, the development of cover crops or vegetative strips would limit livestock access to fallow fields during the winter and would thus require farmers (1) to fence their fields to avoid damage to soil conservation crops by straying animals, and (2) to compensate for the restriction imposed on traditional forage resources by growing their own forage or providing access to other grazing areas. The integrated components of farmers' livelihood systems thus cannot be studied or modified independently from each other. Lastly, soil and water conservation techniques enable the highly diverse upland environment to be used to advantage. In the face of the diversity of situations and systems, a *wide range of solutions* is required. Farmers can choose from among the options those that best fit their own particular circumstances and needs.

The above constraints in the diffusion of innovation call for an integrated methodological approach to farmers' livelihood systems and more specifically to crop–livestock management. In such a diverse natural and human environment, only a participatory approach is able to identify farmers' needs in a time effective manner (Castella *et al.*, 2003b; Neef, 2004; Pretty, 1995). However, certain factors that ensure the success of the participatory method (Mosse, 1994) have to be taken into account when designing a method that allows farmers to simulate the adoption of innovation. The participatory simulation approach differs from a 'rapid' appraisal that cannot result in a full understanding of the complex systems involved nor establish a relationship of trust between the local population and outsiders. Furthermore, a participatory approach can accommodate different degrees of participation by participants in a given session, and also different perceptions of the approach by participants (Moser, 1991). The facilitators of the meetings must have good technical knowledge as well as good communication skills to enable all the participants to express themselves. Facilitators also need a good knowledge of the local context to be able to interpret the information generated by the appraisal, particularly the socio-political aspects, in order to avoid misinterpretation (Sayer & Campbell, 2004; Shanks & Bui, 2001). The tools (i.e. tables, maps, figures) used to generate this information may be an obstacle to active participation if they are not easy to understand (Mosse, 1994). In our case, the simulation was not carried out in 'virgin' territory but in a village where project staff (including one native of the village) had been experimenting innovations with local farmers for the past three years. This process had resulted in a good relationship between local stakeholders and researchers and the latter had acquired a good knowledge of the local context.

In this paper we highlight the process of innovation diffusion that engaged both scientists and local stakeholders in designing a platform for social learning for the management of natural resources (Röling & Jiggins, 1998). The scientists facilitated the diffusion of innovation by providing all the information needed to enable local people to make their own evaluation of crop–livestock issues, to collectively discover different possible solutions and to adapt them to the specific issues they had defined together. To start the interactive communication process we designed a graphic language to be used by scientists and local stakeholders. The graphic language incorporated two major assumptions derived from previous studies in the same area: (1) the village entity is the relevant spatial and social unit for community-based management of natural resources (Castella & Dang, 2002), and (2) the spatio-temporal dimension of crop–livestock interactions is a key factor to take into account when designing or introducing technical innovations (Castella *et al.*, 2002a). The aim of this paper is to report on our experience using and evaluating the new communication tool as a support for the diffusion of sustainable technical innovations. The method itself is discussed in detail in two other papers (Castella *et al.*, 2002a, 2002b).

The Successive Stages in the Participatory Simulation of Innovation Adoption

We presented our graphic models to representatives of the local community to check that we had in fact designed a 'common spatial language' between researchers and farmers. The common spatial language is intended to provide a concrete support for (1) the participatory validation of local information related to spatial management of natural resources, and (2) the introduction of technical innovations to improve feeding systems for large ruminants. Sixteen farmers attended the first session held on 18 and 19 October, 2001 at the Phieng Lieng People's Committee. The participants were (1) representative (men and women) of the three main household types classified in a household typology made in Phieng Lieng in 2000 (Eguienta *et al.*, 2002); (2) knowledgeable and influential people within the community; and (3) farmers who were familiar with the project activities and innovations through previous involvement in project experiments.

At the beginning of the meeting, the decrease in natural forage resources and the importance of natural resource management were highlighted. At the first session, a 3D model of the village (Castella *et al.*, 2002b) was used as a visual support to show the farmers the main landscape features and the different land-use classes. We established a link between the main landmarks on the 3D model and their representation on a paper-based spatial graphic model. Once the participants were comfortable with the spatial graphic model that represented land use in their village in 2001, we used the same kind of graphic representations to show the changes in land use that their village had undergone over the last 40 years. We were thus able to show how current land use and related issues were a product of the past (Castella *et al.*, 2002b).

At the end of the first session, a blank calendar (Figure 1) was displayed so the participants could represent the distribution of their activities over a period of one year by distinguishing the relative contribution of men and women and the location of the different activities in the village territory. Eight activities were included: irrigated rice, upland crops, orchard and garden, animal husbandry, gathering of timber and non-timber forest products, and off-farm activities. For each activity and gender, the corresponding working period was marked on the calendar. Information about annual distribution of labour between activities and between men and women is very important because lack of labour can be a major constraint in the adoption of innovations.

Interesting information also came to light about interactions between crop and livestock related activities, showing that the animals relied exclusively on natural resources or crop residues for forage:

- After each rice harvest, the ruminants graze in the rice fields (November–December and briefly in May–June).

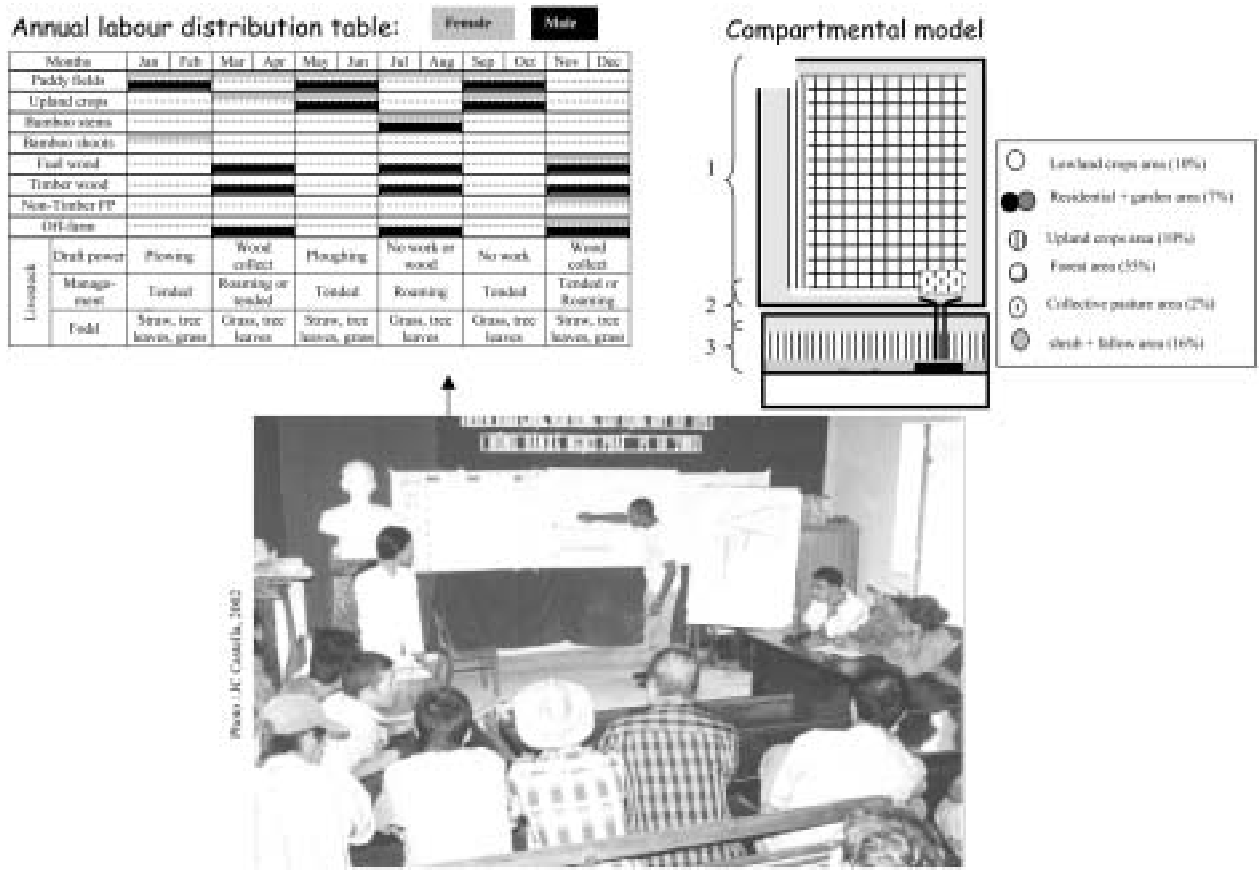

Figure 1 Spatio-temporal dimensions of the simulation

- The only forage resource available in the cropping area during the cropping period is vegetation bordering the fields and this is not sufficient.
- Farmers have to carefully manage their stock of rice straw, which is distributed to the working buffaloes during the second rice cropping season.

At the second session, the spatial model corresponding to current land use was first presented to the participants and the spatial compartment model was then introduced. After the different compartments had been described, a paper copy of the graphic model of the village was distributed to each participant who was invited to locate his or her own land resources in the different compartments. Next, five innovations were proposed together with their feeding capacity for large ruminants. Paper copies of the compartmental model were used as supports for a participatory simulation of innovation adoption. The farmers were then invited to choose among the proposed innovations the one they would like to adopt, to locate it on the compartmental model, and with the assistance of the researchers, to calculate the feeding capacity of their herd. The participants were already familiar with these new cropping systems as they had been tested by some of them in their own village. They were free to propose their own innovations with the corresponding technical parameters.

Modelling Spatial Management of Natural Resources at the Village Level and Related Livestock Management Issues

The compartmental model

The different land-use types in Phieng Lieng village territory were taken from a village scale GIS to create a compartmental model (Castella et al., 2002a), where each kind of land-use was represented proportionally. This communication tool was presented to the farmers attending the simulation progressively in different versions. First, the spatial model corresponding to the current land use (first level of abstraction) that had been shown to the farmers at the previous session was displayed on a paper board. Then the different elements of the spatial model (Castella *et al.*, 2002b) were identified and progressively drawn on a new schematic model in order to lead the farmers to a second level of abstraction: the compartmental model.

Once the schematic model was drawn, a coloured version was presented with proportions of land use areas that showed the real village situation (Figure 1):

- the lowland crop area mainly corresponded to 1–2 cycles of irrigated rice, sometimes maize (hot rainy season) and vegetables (cold dry season);
- the garden area was dedicated to vegetables and fruit trees;
- the upland crop area corresponded to rainfed rice, maize, cassava and plantations;
- the term ‘forest’ included poor and secondary forests as well as woody regrowth.

Finally, each participant received a sheet of paper showing the village model on which they could position their own crop and animal resources along with the innovations they had chosen.

Spatio-temporal constraints linked to animal husbandry

Animal husbandry issues exist in the two dimensions of space and time. At the beginning of the 1990s, the cooperative herd was distributed to individuals (one head/person) who each looked after their own animal. The forage resources that formed the basis of this development were collective pastures and the forest. However, these areas were not controlled and natural resources gradually became insufficient in terms of feeding capacity, causing two serious problems that were inter-related:

- lack of forage during the winter (cold dry season): forepart from a limited quantity of dried rice straw, natural vegetation was the only feeding resource available and its growth was near zero. The result was weakening animals leading to a reduction in fertility, abortion, decreased resistance to disease and low work performance at the beginning of the rainy season (first cycle rice ploughing/harrowing in March);
- intra- and inter-village conflicts: during the winter, starving animals broke fences and damaged crops within the village and during the rest of the year they grazed in the neighbouring village’s meadow.

To clearly illustrate the problems caused by roaming animals, the movement of the village herd in the different compartments was illustrated on the model by arrows (Figure 2). The advantages and constraints of different solutions for individual and/or collective management of the livestock herd were then introduced and discussed:

- closing off access to other village territories would be very difficult as it would require fencing large areas in the upper part of the village watershed;
- extending grazing in the collective area: the land currently used could only feed 12 buffaloes whereas there were in fact more than 100 in Phieng Lieng. Increasing the amount of meadowland would require collective management or individual use of plots in the collective area, neither of which was considered feasible by the farmers at the time;
- implementing feeding systems for large-ruminants by combining innovative cropping systems in space and time on individually owned land: this was the solution chosen by the farmers who agreed to simulate the results of such systems.

Results of the Participatory Simulation

Inputs–outputs

There were two simulation inputs:

- adopted innovation: each innovation has an associated yield and period (winter or summer);
- surface area: 2000 m^2 was chosen as the unit surface area, as it is the size of the average plot.

The output is expressed as the number of equivalent buffalo (equ.bu) per unit area.

Four parameters were included:

- production period, expressed in days (PProd);
- consumption rate for a given forage, ranging from 1 to 10 (CR);

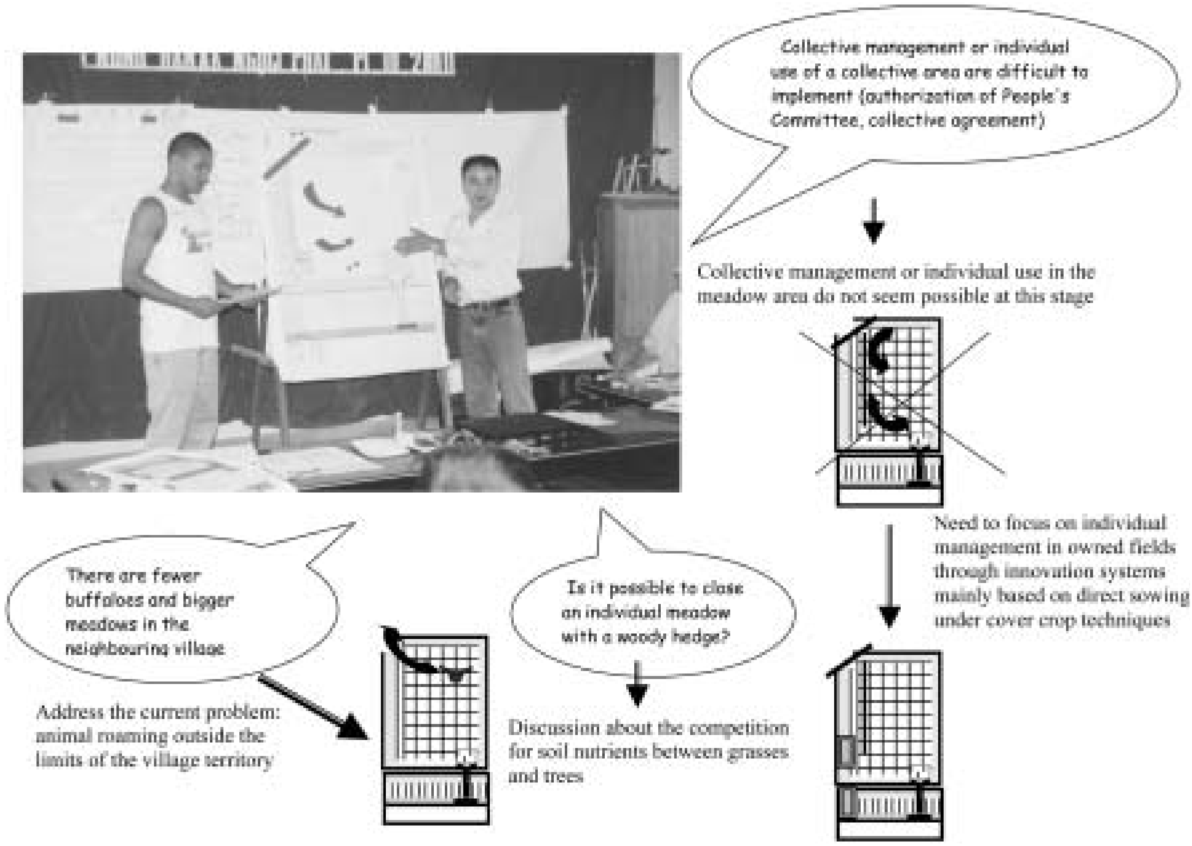

Figure 2 Discussion about a collective livestock management plan

- daily theoretical maintenance needs (MN) for 1 equ.bu, expressed in kg DM/equ.bu/day. The average weight of a buffalo is 300 kg and its daily food requirement is 2.5 kg dry matter (DM)/100 kg. In order to take other animals into account, a cow is estimated as 2/3 equ.bu and a goat 1/10 equ.bu;
- potential yield, expressed in kg/ha (PY). For a 2000 m^2 plot, PY*CR/(PProd*MN) = n equ.bu.

Origin of the innovations and the model parameters

The cropping systems with plant cover simultaneously enable sustainable agriculture on sloping land and improved animal feeding. These techniques were first tested under controlled conditions on experimental plots hired from the farmers. Once validated in local conditions, they were implemented by farmers on their own plots with the assistance of technicians who collected the data and feedback from farmers about the success they had and the difficulties they encountered while implementing the new techniques.

At this point, five types of innovations had been selected in consultation with farmers, each one specific to an agro-ecological unit (or compartment of the village landscape).

- Food-forage crop rotation (e.g. three years of *Brachiara* sp. then maize) allows feeding of one buffalo/unit area from March to November.
- Food-forage crop association:
  - *Brachiara* sp. interlined with maize allows feeding of half buffalo/unit area from August to November;
  - *Stylosanthes guyanensis* – cassava or orchard (perennial system, one year settlement and weeding required) allows feeding of one buffalo/unit surface from March to November;
- orchard soil covered by *Arachis pintoï* (perennial system, one year settlement and weeding required) allows feeding of one buffalo/unit area from March to November;

- urea treated straw allows feeding of:
  - one buffalo/unit area from December to March for maize straw;
  - two buffaloes/unit area, same period for rice straw.
- Winter oats in the irrigated rice fields allows feeding of one buffalo/unit area from December to March.

Values for parameters (Table 1) were estimated from experimental results obtained in the Mountain Agrarian Systems Program from 2001 to 2003 and from the literature (FAO). In order to be realistic and to highlight the constraints of innovative cropping systems, reference yields correspond to minimum values obtained with a low level of inputs on poor soils. During the discussion, information about computed yields was complemented by information about forage values distinguishing between protein and energetic forages (Figure 3) and considering the biophysical effects of the cover crops:

- grasses with a deep and strong root system, such as *Brachiaria* sp., play a key role in soil decompaction and in the improvement of porosity; they also play the role of 'biological pump' by recycling minerals that are not accessible to associated or rotated crops;
- legumes, such as *Stylosanthes* and *Arachis* spp., improve chemical fertility of the soil by fixing atmospheric nitrogen;
- urea treatment of rice and maize straw are alternatives to burning straw that help reduce CO_2 emission while providing good quality feed for livestock;
- winter oats cropping in paddy field is a possible first step toward more complex cropping systems associated with a living plant cover. A substantial increase in the soil organic carbon content in the 10 cm topsoil layer in no-tillage soils compared with soils under natural vegetation and long-term conventional tillage (Séguy *et al.*, 2003) can occur due to high crop-residue input and lack of soil disturbance. Moreover, micro and macro-fauna populations, abundance, diversity and soil biological activity decrease during traditional cultivation systems. Conversely, the soil structure is improved when a vegetal cover with a strong root system is permanently maintained on the soil (Husson *et al.*, 2003; Uphoff, 2002).

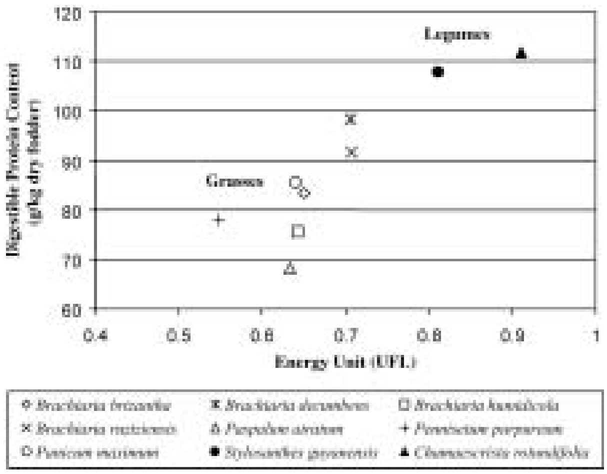

Figure 3 Forage values of some grasses and legumes tested (Husson *et al.*, 2003)

Implementation of the simulation

Positioning farmers' resources on the model

Farmers drew lines on the graphic model to show the land they owned or could use in each compartment, i.e. the limits of their individual land-use system (Figure 4). A table was distributed so each farmer could note down the size of his buffalo herd.

Table 1 Values for parameters of the innovations used for the simulation

Innovation	Potential yield (kg/ha)	Production period (days)	Consumption rate	N equ.bu
Brachiaria rotation	2000	275	5	1
Brachiaria association	500	122	5	0.5
Stylosanthes association	2000	275	5	1
Arachis-orchard	2000	275	5	1
Urea-treated rice straw	3600	121	2.5	2
Urea-treated maize straw	900	121	5	1
Winter oats	900	121	5	1

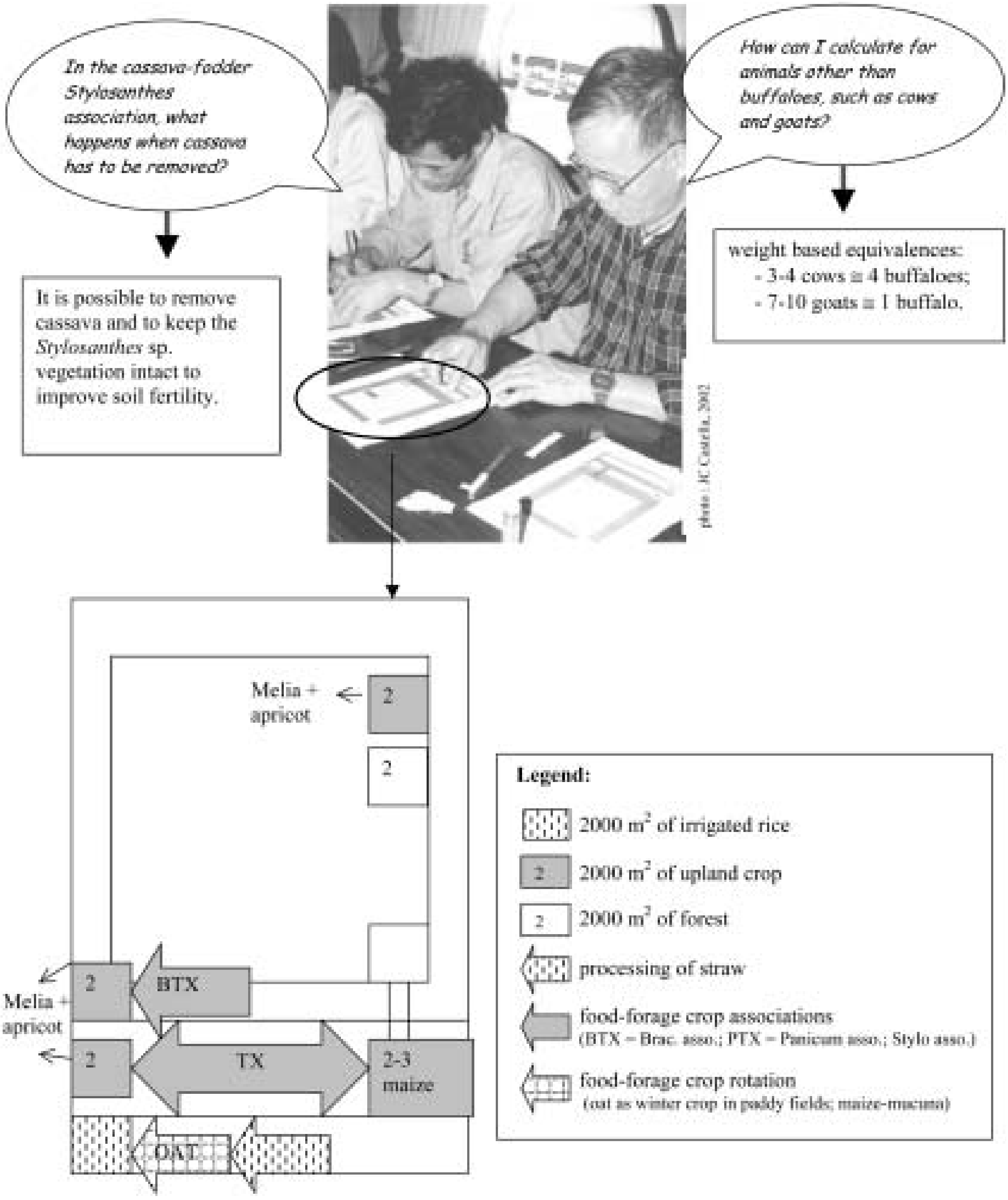

Figure 4 Positioning farmers' resources and innovations on the compartmental model

Presentation of the innovations

The innovations were presented on a table (Figure 5) giving potential outputs (equ.bu/unit area) within the production period along with specific characteristics (settlement time, fertilisation and labour requirements, etc.), and illustrated with photos taken during previous experiments in their village.

Choice of innovations by the farmers and evaluation of the results

Coloured squares corresponding to the different innovations were explained and then distributed to the farmers who chose some of them and placed them in the relevant compartments on their schematic model. A brief demonstration showed them how to calculate the number of buffaloes fed

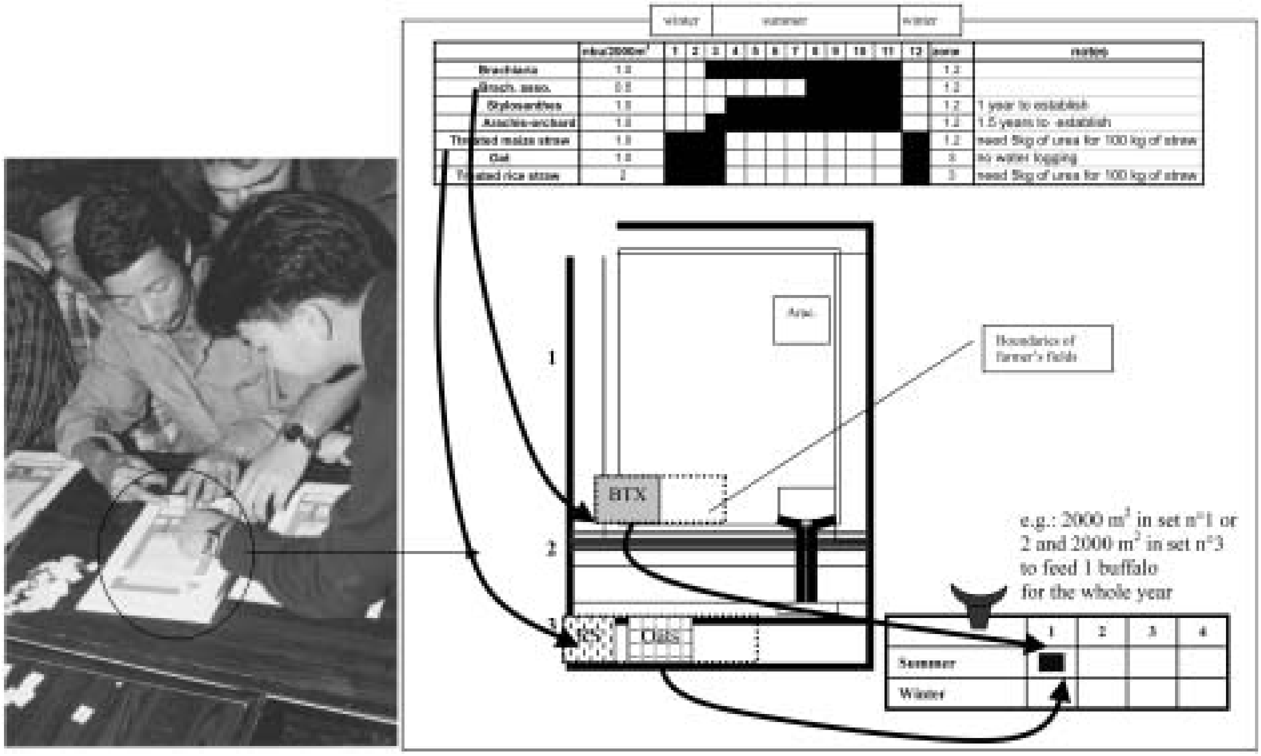

Figure 5 Discussions betqeen farmers and researchers about the simulation in terms of feeding capacity

during the different periods of the year. The result was then transferred to the buffalo table. In addition to the demonstration, it was explained that:

- the feeding capacity linked with the innovation is only estimated and in practice it may be slightly different;
- only the simplest and cheapest techniques had been presented, and these would not be sufficient to feed all the buffaloes even if they were applied to the whole village territory;
- at this stage, the calculation did not take labour requirements into account.

The farmers were then invited to make their own calculations based on their own specific situation, with the assistance of the project staff, and to enter the result on their own table, enabling them to see if their whole herd could or could not be fed from their individual plots. This triggered a lively discussion (Figure 5). At the end of the session they were reminded that this was only the first step in solving their problem, and they were encouraged to contact the team if they wished to implement the proposed innovations.

From Simulation to Action

Understanding and discussing the model and proposed innovations

Follow-up visits (two sessions totalling five days, between the end of November and the beginning of December) were made to Phieng Lieng farmers who had attended the simulation. The aim was to maintain the farmers' interest in innovations initiated by the simulation, to check their understanding of the model, and to get their points of view about the feasibility of the innovations. The surveys were conducted as open interviews to:

- listen to the farmer's comments about the meeting and participatory simulation;
- check the farmer's understanding of the model. Before discussing the innovations the farmer was interested in, he was asked to describe the three main compartments of the model, the location of his resources and the innovations he had chosen, in order to check his understanding of the model and to clarify any points that had not previously been made clear;

- discuss the innovations chosen (constraints, plans, etc.).

All those interviewed expressed positive reactions to the meeting. Most of the participants correctly understood the model and the simulation game. This result confirmed their interest and ability to concentrate during the testing of the model. Farmers' comments, plans and constraints about possible innovations and their applicability are presented in Table 2. The general columns describe ideas for which there was a consensus in the community. The specific columns are based on individual comments made by farmers of each farm type classified by Eguienta *et al.* (2002).

- The lack of forage in winter was a major constraint for most of the respondents. It has negative effect on performance, reproduction and resistance to diseases. In 2000 there was an epidemic that led to the death of many buffaloes.
- Apart from individual activities, the project may assist the village in a collective activity proposed by one farmer to grow mucuna on the collective pasture area to regenerate the soil and overcome weeds. Mucuna is easily cleared and other crops can then be grown. The project could thus initiate a dynamic of collective management that could partly compensate for problems caused by individual implementation.
- Many respondents were worried about the fact that forage crop planting time (March) may coincide with the spring season. There is a risk of a labour shortage at this time and some households would thus not be able to implement the innovations.
- Very few of the farmers interviewed were interested in rotating forage and food crops. They appeared to consider it a waste of land and to prefer associating these crops, which highlights the land saturation situation.
- Some farmers fear that urea treated straw, especially maize straw, could be dangerous for their livestock.
- Only a few farmers were interested in growing winter oats because the paddy fields are usually not fenced during the winter. This absence of fencing is also a serious constraint for innovation implementation in the hillsides. Most of the crop associations are planted in the residential/garden area where surveillance is easier.

Table 3 shows the diversity of the participants represented by the wide range of agricultural and animal resources. Farmers' strategies during the simulation were influenced by their available resources, capabilities and objectives, resulting in a wide range of reactions and innovation choices (Figure 6). The objectives of their animal husbandry activities differed as a function of their individual circumstances. These can range from owning a couple of buffaloes for land preparation in the paddies, to developing a living capital, producing meat or diversifying sources of income. All these parameters influenced the farmers' interest in the simulation, their choice of innovations, and their motivation to actually implement the innovations. For instance, some farmers who did not own large ruminants also played the game, either because they planned to buy an animal or because they were interested in the soil fertility improvement function of the techniques, or in the feeding value of the cover plants for fish farming. It can also be seen that some constraints affect the whole community while others are specific to some households: available labour is a problem for some farmers, while for others it is the dispersion of their plots or their remoteness that prevents them from fencing.

The main outcomes of this experiment in participatory simulation were first that farmers were not prepared to collectively manage forage resources at the village scale in order to feed their entire buffalo herd. They preferred to rely primarily on the animal feed they could produce on their individual plots (Castella *et al.*, 2002b). Secondly, cropping systems based on cover crops would be developed on the hillsides only through a stepwise process that would solve the problem of forage deficit during the winter before establishing cover crops on the slopes and therefore avoiding damage by animals to upland fields. New forage resources from the valley bottom would facilitate the introduction of the conservation cropping systems on the hillsides.

Implementation of innovations

The following winter season (2001), two innovations were proposed to the farmers: urea treated rice straw and winter oats. The aim of these two new components in the livestock feeding systems was to lower animal pressure on the new cover crops on the hillsides as well

Table 2 Synthesised information from farmer interviews (survey data). The general columns describe ideas for which there was a consensus in the community. The specific columns are based on individual comments made by farmers in the indicated categories

Type/husbandry	Comments		Plans		Constraints	
	General	Specific	General	Specific	General	Specific
No buffaloes	Presentation useful for: • knowing history; • long-term strategy building; • understanding the limits of natural forage resources; • knowledge of constraints and their resolution	Interested by the double function of cover crops: feeding + soil restoration	• Gradual innovation implementation (stepwise) • Using cover crops also for fish and pig feeding	Animals sold, sometimes replaced by a cultivator; plan to buy 1–2 buffaloes	• Lack of fodder, especially in winter; • weed control; • fences (cost and efficiency); • human labour force; • inputs and knowledge: need for material and technical assistance	• Animal mortality; • animal labour force
Buffaloes for labour		Expecting individual allocations from collective area		Cowshed near the upland fields		• Under-exploited land; • Time for grass cutting
Capitalisation (buff. and/or ox)		Cover crop = complementary fodder		Storage for treated straw		• Livestock roaming; • plot scattering and distance; slope
Diversification (buff., ox, goat)		Unwilling to exploit forest (labour cost and conservation)		• *Mucuna* in the collective area; • collective organisation		• Lack of agricultural resources; • animal watching

Table 3 Basic statistics about some farmers' agricultural and animal resources (Source: Mountain Agrarian Systems Program)

Parameter	No. workers/ household	Paddy area (ha)	Upland area (ha)	Forestland area (ha)	No. buffalo	No. cattle
Mean	2.9	3.186	2.918	8.081	3.8	0.7
Max.	10	6.750	10.000	20.000	15	8
Min.	1.5	590	0	1.500	0	0

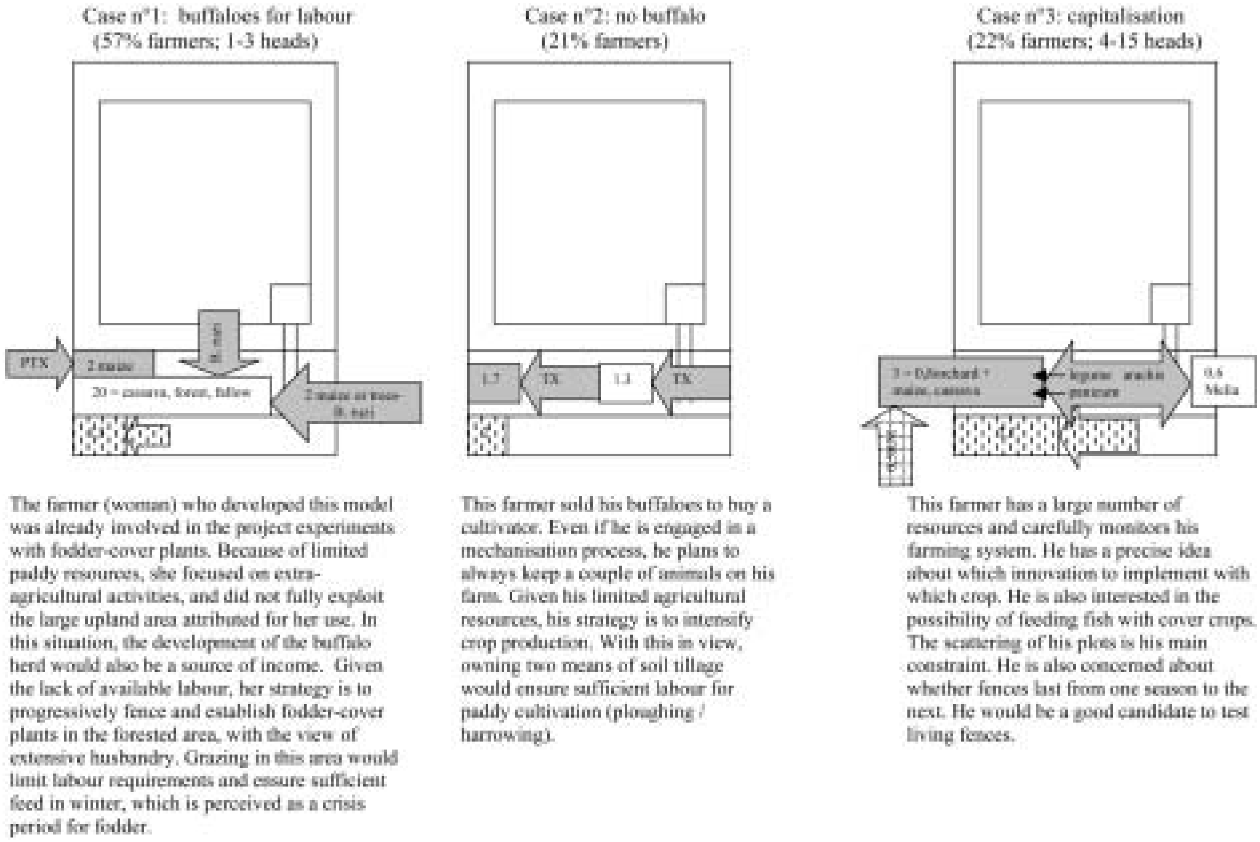

Figure 6 Example of three contrasted individual models (surfaces × 1000 m^2)

as on the natural meadow and forest resources during the winter season.

Urea-treated rice straw

Given farmers' reluctance to treat maize straw (considered unsuitable for ruminant feeding), we proposed urea treatment of rice straw, which has three advantages:

- better conservation: untreated straw stock is sometimes damaged by fungi, rats or insects;
- increased digestibility: the treatment is in fact 'pre-digestion' which enables the animal to eat a larger quantity;
- increased forage value.

Farmers usually burned rice straw from irrigated fields after the autumn harvest and kept a small quantity which was dried and used as occasional fodder during the winter. Although the ash was then used to fertilise rice nurseries, the net result was the export of plant material from the field. Exporting rice straw for animal feed thus providing manure for lowland rice fields is a more sustainable management technique.

Briefly, the technique consists of cutting dry rice straw into segments (between 15–25 cm long), which are moistened with a 4% urea water solution (between 80–100% DM) and then salted (0.5–1% DM) (Nguyen, 2004). Recommendations for the duration of fermentation range from three to four weeks. This technique was introduced in three steps:

- preliminary discussions with the farmers who chose this innovation during the simulation (12 farmers) about their objectives and constraints;
- identification of farmers willing to take part in the experiment and demonstration of the straw processing and the distribution of treated straw to the buffaloes owned by the project (staff of the agricultural extension service were invited to participate);
- distribution of technical leaflet about the technique of straw treatment with urea.

In the end, six of the 12 farmers did not implement this technique due to insufficient straw, lack of labour (to cut straw and dig holes) or because they wanted to check the results of this technique with their neighbours before adopting it themselves. The project assisted the six other farmers with straw treatment. They found the technique simple, cheap and not overly time consuming.

Winter oats in the paddies

Most of the farmers did not use their irrigated rice fields during the winter (though a few grew vegetables on small areas protected by bamboo fences). They usually ploughed and then flooded their field in December–January (depending on available labour) in order to prepare it for the first crop of rice as soon as the rainy season begins. It was suggested to these farmers to grow oats in these fields to cut as green forage during the winter. The idea was to organise the field into daily cutting plots in such a way that the first plots had sufficiently regrown when the last plot had been cut, as a function of the number of animals to be fed, the quantity required per animal and the speed of oat regrowth under the local conditions. If the farmers did not have a big enough rice field, a combination of oats, natural vegetation, and urea treated rice straw was determined with them as feeding system components to improve winter feeding.

During the simulation, only three farmers chose this innovation both because of the fencing constraint (in winter, animals roam in the paddies) and because of the novelty of this crop. Finally, the project supported the volunteer farmers by providing fencing and oats were sowed directly under the mulch of rice straw. The large quantity of biomass produced (around 1 t DM/ha at flowering) considering the season and the lack of forage at that time, was sufficient to convince the farmers. In 2002 this activity expanded and included other winter cereals (wheat and barley) in the paddy field but also on the lower part of the hillsides.

Within one year, 80% of participants had tested in real conditions some kind of innovative cropping system that they had discovered during the simulation. For example, in January 2002, half the farmers treated rice straw with urea as a winter fodder complement. The simulation revealed that this strategic supply of improved fodder met the farmers' needs, and this led us to provide assistance to a larger number of farmers in the whole Cho Don district. Extension agents from the Agricultural Services of the district were trained during treatment of straw on the farms, and the following year, they trained farmers in other villages in the district. During the 2002 rainy season, half of the participants implemented other innovations on their sloping fields (association *Arachis pintoi*-orchard, settlement of *Brachiaria* sp. for forage production, etc.)

Conclusions

The participatory simulation provided many new elements for agricultural diagnosis and helped us improve the proposed crop–livestock model. Farmers were clearly interested in the proposed innovations and asked very relevant questions. During the follow-up visits we were able to confirm that farmers were more aware of local issues related to crop–livestock interactions and were ready to undertake concrete actions toward sustainability that they had encountered during the simulation. These results show that the simulation was effective in enhancing farmers' participation in thinking about and in undertaking action toward more sustainable cropping systems and animal husbandry systems at field, household and village levels. The monitoring of innovation diffusion processes provides a basis to assess the effectiveness of the model itself. It should allow for spontaneous adaptations as well as alternative sources of innovation provided by the farmers themselves. For instance, in other villages, some farmers hire workers to go farther into the forest to cut and carry back natural grasses. Others have their animals tended by farmers who are located where sufficient forage is available.

Despite these encouraging results, not all the farmers adopted the innovations proposed. Some were prevented from doing so by the technical skills required by the new feeding systems or by the inputs, particularly fencing which is expensive for the individual farmer. After this successful test in real conditions the method will now be applied to other villages in Bac Kan province. We need to test it in many different natural and human environments for further validation. In the future, it may be applied on a routine basis by local extension agents.

So far, most of the participants have been reluctant to develop concerted rules for community-based livestock management. Although they are conscious of the potential benefits for the whole village, setting up the negotiation platform has to go through a preliminary stage of individual adoption, taking into account the particular circumstances of each household. Once farmers have been convinced of their individual benefit in adopting the technical innovations it will be easier to engage negotiations about organisational innovations to rationalise forage resource management at the village scale. Our participatory simulation method proved very effective in supporting individual decision-making. Further development of our methodology will aim at community-based management of natural resources.

Regarding the feeding systems themselves, important work still remains to be done, such as adapting them to situation-specific constraints and labour allocation, and enabling farmers to concretely implement the proposed innovations (seeds, environment-friendly herbicides, fencing, etc.). With this in view, socio-economic components such as social networks, policies, and credit have to be closely examined. The feedback received from farmers during the participatory simulations will also help improve the technical innovations while taking into account the socio-economic context of their implementation.

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References

Altieri, M.A. (2002) Agroecology: The science of natural resource management for poor farmers in marginal environments. *Agriculture, Ecosystems and Environment* 93, 1–24.

Castella, J.C. and Dang, D.Q. (eds) (2002) *Doi Moi in the Mountains. Land Use Changes and Farmers' Livelihood Strategies in Bac Kan Province*. Hanoi, Vietnam: The Agricultural Publishing House.

Castella, J.C., Eguienta, Y. and Tran, T.H. (2002a) Spatial compartment model: An interface between scientists and local stakeholders to facilitate the diffusion of innovative livestock feeding systems. *SAM Paper Series 13*. Hanoi: Vietnam Agricultural Science Institute.

Castella J.C., Tran, T.H. and Eguienta, Y. (2002b) Use of spatial graphic models as a common language between researchers and local stakeholders. *SAM Paper Series 12*. Hanoi: Vietnam Agricultural Science Institute.

Castella, J.C., Chabanne, A., Dang, D.Q., Ha, D.T., Husson, O., Le, Q.D. and Tran, D.L. (eds) (2003a) *Towards Sustainable Agricultural Development in Mountain Areas of Northern Vietnam. Experience from the Mountain Agrarian Systems Program in Bac Kan Province, 1998–2002*. Hanoi: Vietnam Agricultural Science Institute. Multimedia CD-Rom and Web site: www.knowledgebank.irri.org/sam/home_en.html.

Castella, J.C., Boissau, S. and Hoang, L.A. (2003b) Enhancing communities' adaptability to a rapidly changing environment in Vietnam uplands: The SAMBA role-play. In R.C. Serrano and R.T. Aggangan (eds) *Sustaining Upland Development in Southeast Asia: Issues, Tools & Institutions for Local Natural Resource Management* (pp. 203–236). Los Banos, Philippines: PCARRD.

Donovan, D., Rambo, A.T., Fox, J., Le, T.C. and Tran, D.V. (1997) *Development Trends in Vietnam's Northern Mountain Region. An Overview and Analysis*. Hanoi: National Political Publishing House.

Eguienta, Y.K., Martin, C., Lecomte, P., Husson, O. and Castella, J.C. (2002) Crop-livestock in northern Vietnam: Issues, diversity of farmers' responses and alternatives for sustainable integration of animals in upland agricultural systems. In J.C. Castella and D.Q. Dang (eds) *Doi Moi in the Mountains* (pp. 221–247). Hanoi: The Agricultural Publishing House.

Husson, O., Castella, J.C., Ha, D.T. and Naudin, K. (2001a) Agronomic diagnosis and identification of factors limiting upland rice yield in mountainous areas of northern Vietnam. *SAM Paper Series 2*. Hanoi: Vietnam Agricultural Science Institute.

Husson O., Ha, D.T., Lienhard, P., Le, Q.D. and Seguy, L. (2001b) Agronomic diagnosis and development of direct sowing techniques. Upland rice-based cropping systems in mountainous areas of northern Vietnam. *Contribution to the First World Congress on Conservation Agriculture*, ECAF/FAO, 1–5 October 2001, Madrid, Spain. At www.knowledgebank.irri.org/sam/sam/pdf/2001_PosterMadrid_E.pdf.

Husson, O., Chabanne, A., Ha, D.T., Lecomte, P., Martin, C., Castella, J.C., Tivet F. and Séguy L. (2003) Integrating crops and livestock through direct seeding on vegetal cover in Vietnam. *Proceedings of the II World Congress on Conservation Agriculture: "Producing in harmony with nature"*, Iguacu Falls, Parana, Brazil, August 11–15, 2003 (pp. 357–367). Ponta Grossa, Brazil: FEBRAPDP.

Jamieson N., Le Trong Cuc, Rambo A.T. (1998) *The Development Crisis in Vietnam's Mountains*. Honolulu: East-West Centre.

Mosse, D. (1994) Authority, gender and knowledge: Theoretical reflections on the practice of participatory rural appraisal. *Development and Change* 25 (3), 497–526.

Moser, P.K. (1991) *Knowledge and Evidence*. Cambridge, New York: Cambridge University Press.

Neef, A. (ed.) (2004) *Participatory Approaches for Sustainable Land Use in Southeast Asia*. Bangkok: White Lotus Publishers.

Nguyen, X.T. (2004) An evaluation of adoptability of alkali treatment of rice straw as feed for growing beef cattle under smallholders' circumstances. *Livestock Research for Rural Development* 16, 52. At http://www.cipav.org.co/lrrd/lrrd16/7/trac16052.htm.

Pretty, J.N. (1995) Participatory learning for sustainable agriculture. *World Development* 23, 1247–1263.

Röling, N.G. and Jiggins, J. (1998) The ecological knowledge system. In N.G. Röling and M.A.E. Wagemakers (eds) *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty* (pp. 281–307). Cambridge, UK: Cambridge University Press.

Sayer, J. and Campbell, B. (2004) *The Science of Sustainable Development: Local Livelihoods and the Global Environment*. Cambridge, UK: Cambridge University Press.

Séguy, L., Bouzinac, S., Scopel, E. and Ribeiro F. (2003) New concepts for sustainable management of cultivated soils through direct seeding mulch based cropping systems: The CIRAD experience, partnership and networks. *Proceedings of the II World Congress on Conservation Agriculture: "Producing in harmony with nature"*, Iguacu Falls, Parana, Brazil, August 11–15, 2003. Ponta Grossa, Brazil: FEBRAPDP.

Shanks, E. and Bui T.D. (2001) *Field Based Learning and Training in Participatory Approaches to Rural Development. A Decade of Experience in PRA from the Vietnam Sweden Cooperation Programme and Challenges for Formal Education, Research and Donor Organisations*. Hanoi, Vietnam: Swedish International Development Agency.

Uphoff, N. (ed.) (2002) *Agroecological Innovations*. London: Earthscan.