Improving Smallholder Livelihoods, and Watershed and Soil Management through Conservation Agriculture in the Lao PDR

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Abstract

Over the past fifteen years, farming systems have changed drastically in the Lao PDR, with swidden systems giving way to more modern agricultural technologies in many areas. In southern Xayabury, agricultural intensification is causing rotational cultivation systems and fallow periods to disappear. These are gradually being replaced by 'resource-mining' agriculture that has serious social and environmental costs, including increased soil erosion (leading to destruction of roads and paddy fields), loss of soil fertility, and chemical pollution of the environment. On elevated plains in the upper part of the Nam Ngum river basin (Xieng Khouang province), large areas of savannah grasslands are under-utilised by smallholders whose main farming systems are based on lowland paddy fields, livestock production with extensive grazing on savannah grasslands, and off-farm activities. Given this situation, the Lao National Agro-Ecology Programme (PRONAE) has implemented an iterative research-development approach based on conservation agriculture. The objectives are to find innovative systems that can revert the present 'resource-mining' practices in southern Xayabury to systems based on conservation agriculture, and to develop alternatives systems for the plains of Xieng Khouang province. Direct seeding mulch-based cropping systems with residue management were evaluated and validated by farmer groups in five villages in southern Xayabury over four seasons. Positive results (increased net income and labour productivity) are evident from these direct seeding systems, and with growing interest observed there is potential for widespread adoption. Results show that the level of dissemination of direct seeding mulch-based cropping systems differs greatly among the villages surveyed depending on their environmental and socio-economic conditions. On the elevated plains of Xieng Khouang province, the economic and technical viability of cattle fattening was analysed. Fattening on improved pastureland (using Brachiaria ruziziensis) during the rainy season appears very efficient, with high growth rates recorded. During trials in 2005 weight gain and seed production of B. ruziziensis earned a gross income of US$879 over 1.5 ha, covering all expenses for fencing, fertiliser, seeds, and bull management for the first year. The income generated by this fattening programme in 2006 was $362/ha, the equivalent of a paddy rice yield of 1.8 t/ha, which is unlikely in this ecology. Development of specific market channels for seeds could indirectly improve pasture management, avoid high stocking rates and generate new income that could be invested in fertilisers and animal care. The approach followed by PRONAE highlights the collaboration process progressively developed with all of the stakeholders (smallholders, agronomists, District Agriculture and Extension Office staff, development projects, policy-makers and the private sector). One of the main challenges involved with this approach is the transfer to extension agencies and the private sector, over the medium term, of a research-development programme with systems and technologies based on the main principles of conservation agriculture (permanent soil cover, no soil disturbance, and diversified crop rotations with use of relay and/or cover crops).

Keywords: Watershed management, conservation agriculture, smallholder livelihoods, no-tillage systems, residue management, cattle fattening, adoption of innovations, dissemination process, holistic approach.

1. Introduction

Over the past fifteen years, farming systems have changed drastically in Laos, with swidden systems giving way to more modern agricultural technologies in many areas. In southern Xayabury traditional systems have collapsed, with a transition from subsistence agriculture to intensive cultivation of cash crops, led by the demands of the Thai market. Notable changes in agricultural practices have included the adoption of heavy mechanisation and use of pesticides. With the support of local traders, maize is now widely sown throughout the region and is spreading to more areas every year. With agricultural intensification, rotational cultivation systems and fallow periods are disappearing, being progressively replaced by a 'resource-mining' agriculture that has serious social and environmental costs, including increased soil erosion (leading to destruction of roads and paddy fields), loss of soil fertility, and chemical pollution of the environment. On elevated plains in the upper part of the Nam Ngum river basin (Xieng Khouang province), large areas of savannah grasslands are under-utilised by smallholders whose main farming systems are based on lowland paddy fields, livestock production with extensive grazing on savannah grasslands, and off-farm activities. As reported by Gibson et al. (1999), this agro-ecological zone is well known for native cattle and buffalo production.

In view of this situation, the Lao National Agro-Ecology Programme (PRONAE) is implementing an iterative research-development approach based on conservation agriculture. The objectives are to find innovative systems that can revert the present resource-mining practices in southern Xayabury through direct seeding mulch-based cropping (DMC) systems based on permanent soil cover, no soil disturbance, crop rotations and use of relay/cover crops, and also to develop alternative systems for the elevated plains in Xieng Khouang province. Since 2002 in Xayabury and early 2003 in Xieng Khouang, the programme has developed and adapted diversified systems that integrate, as far as possible, annual cropping and livestock production. These innovative alternatives are based on no-tillage systems and use multi-purpose species (*Brachiaria* sp., finger millet, pigeon pea, *Crotalaria* sp., *S. guianensis*), through a participatory approach that involves village communities and groups of farmers. Two main systems are in use: i) no-tillage systems (residue management) for maize production in southern Xayabury; and ii) cattle fattening on improved pastureland around the Plain of Jars in Xieng Khouang.

For the extension of no-tillage systems with maize residue management in southern Xayabury, farmer groups were constituted in different villages to take into account the biophysical diversity of the region and to cover a range of farmer strategies. In 2006 a survey was carried out in four villages to estimate the level of dissemination of DMC systems at the community level. The agro- and socio-economic results of this work are presented and discussed in this paper.

The second system described in this paper concerns cattle fattening on improved pastureland on elevated plains of 800-1,100 m above sea level. Xieng Khouang is the third biggest cattle producing province in Laos (Committee for Planning and Investment, 2005) but a lack of feeding resources (Hacker et al, 1998) and economic incentives, combined with health problems (Gibson et al, 1999), limit the development of the livestock sector. Previous attempts to improve pastureland have been hampered by the unavailability of forage seed, limited fodder growth related to poor soils and free grazing, and lack of labour. Hacker et al. (1998) and Gibson et al. (1999) reported that chemical soil characteristics are seriously unfavourable with a pH of about 5.0 (1:5 H_2O), along with deficiencies in nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). Moreover, these authors also reported that high levels of aluminium saturation are likely to negatively affect the growth of many pasture species and that severe phosphorus deficiency generates animal health problems. Since 2004 a large range of forage species (*Brachiaria* sp., *Stylosanthes*) tolerant to drought, aluminium saturation and soil acidity have been tested by PRONAE for their ability to regenerate savannah grasslands and diversify farming production. Cattle fattening was performed on improved pastureland (*B. ruziziensis*) with inputs of thermophosphate and mineral fertiliser. Agronomic and economic data were recorded to evaluate the viability of this system.

2. Material and methods

2.1 On-farm validation of no-tillage systems based on residue management

2.1.1 Validation

Experiments were carried out on farmers' plots of at least 4,000 m^2. The performance of conventional and DMC systems for different crops (with the crop decided by the farmers) were assessed under conditions matching those found on farms in the region. These experiments involved 35 smallholders in five villages, with a total area of 14 ha. Results presented in this paper concern maize, the main crop in this region. Fields were chosen according to morphopedological data, access to market and farmers' strategies, with 4, 5, 11, 6 and 2 fields used in Kengsao, Bouamlao, Paktom, Nahin, Houay Lod and Nongphakbong, respectively: these 28 plots were sown with maize.

2.1.2 Data collection, economic analysis and survey of conditions for adoption of DMC systems

Labour requirements and production costs were recorded for all activities (land preparation, sowing, weeding, harvesting), while yield and overall performance were recorded for each treatment (table 1). In addition, the philosophy underlying the experiments allowed for qualitative analysis in order to evaluate the socio-economic viability of these systems and also to have better arguments for extension. A gender-disaggregated survey was carried out in five (2005) and four (2006) villages under stratified sampling in order to: i) assess the socio-economic impact of these soil conservation technologies at the farming system level; ii) estimate the level of dissemination of DMC systems at the village community level; and iii) provide better understanding of the processes through which innovations are disseminated within the villages. Only the second topic is presented in this paper (tables 2 and 3).

2.2 Cattle fattening opportunities in the upper part of the Nam Ngum River Basin – towards the regeneration of savannah grassland

2.2.1 Materials

Many species (*Brachiaria decumbens*, *B. brizantha*, *B. ruziziensis*, *B. humidicola*, and *B. mulato*) exhibit good adaptability and forage production in this environment. However, *B. ruziziensis* was selected for this experiment due to its good balance of seed production, forage palatability and quality, and pasture establishment. In 2005 six young bulls of local breed were selected for the experiment, with initial weights of 92-115 kg and a total initial value of $765. The trial started with two bulls on the 26th of May, and as fodder resources increased this number was progressively raised from two to six bulls by the 29th of July. Fattening was phased out at the beginning of the dry season from the end of November to the end of December. Four of the bulls were continuously observed from January to March to estimate their growth fluctuation during the dry season. During this period they were fed in a forest clearing near the village. In 2006 the trial resumed with eight bulls, although the stocking rate was adjusted to five bulls at the end of June due to erratic rainfall at the beginning of the season. Fattening was stopped at the beginning of the dry season (end of October) but two bulls remained on improved pastureland. Salt licks were used as a diet supplement, while vaccines (against haemorrhagic fever) and de-worming treatments were applied at the beginning of the trial. Ticks were controlled with insecticide spray.

2.2.2 Experimental design and management

On the 21st of April 2005 1.5 ha was manually sown with *B ruziziensis* at a density of 12 kg/ha. This field had previously been used for upland rice screening in 2004. After the forage sowing, natural weeds were controlled by use of glyphosate (4 litres/ha). Of five 0.3 ha blocks, four were designated for cattle fattening and one for seed production. The bulls were kept on one block for a week at a time. Half of a 200-l barrel served as a water trough on each block.

Before sowing, fertiliser was applied. This consisted of 30 kg of N as ammonium sulphate, 80 kg of P_2O_5 as thermophosphate and 60 kg of K as K_2O per hectare. An additional 30 kg of N was applied at two intervals: 15 kg on 19th of May and 15 kg on 11th of July. The cost of this fertiliser was $138/ha. Seeds were harvested from the fifth block at the end of October 2005. In 2006, at the beginning of the rainy season, a fertiliser made up of 30 kg of N, 80 kg of P_2O_5 as thermophosphate and 60 kg of K as K_2O was applied to each hectare. An additional 60 kg of N was applied at three intervals during the rainy season. Seed production was carried out on five blocks after a good flowering and filling stage from 15th of October-15th of November.

2.2.3 Data collection

Growth Rate

Every month, morphometric data was recorded and linear regression performed between the measured weight and the estimated weight by use of a morphometric equation using breast and shoulder-tail length (estimated weight = breast length^2 x (breast-tail length) x 88.4).

Economic Analysis

Economic data recorded during this trial is presented in table 4. Labour inputs for land preparation, fencing, sowing and fertiliser application, and expenses for management of the bulls were also recorded.

2.2.4 Statistical analysis

Graphic representations and calculations of confidence intervals for regressions were carried out with SigmaPlot 9.0 for Windows (Jandel Scientific).

3. Results

3.1 No-tillage systems and residues management in southern Xayabury

3.1.1 Yield

Maize grain yield varied, depending on site characteristics (landscape, soil units) and the cultivars in each treatment (table 1). The results reflect differences in soil erosion and fertility. For example, while Paktom and Bouamlao have the same geological substratum (basalt rock), large differences in yield are observed. In southern Pak Lai (Kengsao and Bouamlao) and northern Kenthao (Houay Lod), where maize production began recently, yields recorded in 2005 under DMC systems exceeded 5.2 t/ha. With DMC systems yield levels were generally close to or even higher than those obtained in conventional systems. In the degraded areas of Paktom and Nongpakbong, mean yields recorded with no-tillage oscillated between 3.1-3.7 t/ha with maize hybrids, while the mean yield with conventional tillage was 3.3 t/ha. In Nongphakbong lower soil fertility, poor soil structure due to compaction (high bulk density, data not shown) and crusting seem to be the main factors limiting yield for both DMC and conventional systems. Erenstein (2003) reported that short-term yields often depend on the mulch, crop and site characteristics and therefore a number of seasons are necessary to stabilise the system. As described by Séguy et al. (1998), soil characteristics must be improved in order to generate a conservative system for water and nutrients, with good organic composition to restructure the soil. However, this first step of DMC practices cannot minimise climatic risks and great variability in yield was observed by season.

3.1.2 Production costs and net income

In 2005, production costs for DMC systems ranged from $65-95/ha (table 1), while costs for conventional systems (ploughing) ranged from $135-226/ha depending on the slope, field accessibility and rate charged by the tractor owners. Between seasons, production costs under conventional practices increased considerably with the use of herbicides for chemical weeding applied mainly after crop emergence. In southern Pak Lai and northern Kenthao, mean net income per hectare was $415 for no tillage systems and $275 for conventional tillage systems. In these areas, high net incomes obtained under DMC systems resulted in lower production costs combined with high yields. It was also interesting to observe that in degraded areas such as Paktom and Nongphakbong, net income per hectare improved rapidly after two or three years of practising no tillage. Globally, net income increased during the last three seasons under DMC systems, although with large variability among sites due to low soil improvement and increasing weed pressure under maize monoculture. Obtaining all the biophysical and economic advantages of DMC systems requires a long process. Systems have to be improved gradually with rotational sequences to diversify production (grain production, rational use of forages by grazing and/or cut-and-carry) and so reduce agronomic, economic and climatic risks while optimising the major functions of DMC systems through adequate use of main and relay crops.

3.1.3 Labour requirements and labour productivity

Following improved residue management from the first season in 2005, labour productivity increased significantly in Bouamlao, Kengsao and Houaylod, reaching $7.1-7.8 per day with DMC against $3.2-5.8 with conventional practices (table 1). In 2005 on sandstone plots in Nongpakbong, mean labour productivity among survey respondents reached $5.7 under DMC systems thanks to very low production costs and good management of crop residues. Net income and labour productivity increased greatly over the years with relative increases ranging from 83% to more than 200% for Houay Lod and Paktom respectively. However, even if lower labour inputs were required for manual weeding, results showed that in most cases of no tillage maize mono-cropping, weed pressure could not be controlled efficiently because of the short duration of maize and rapid mineralisation of maize straw. Indeed, after harvest and during intercropping (six months), weed proliferation and seeding occurred.

Table 1: Results from on-farm experiments conducted 2003-2005 in southern Xayabury

		Villages												
Component	**Treatment**	**Kengsao**			**Bouamlao**			**Houay Lod**		**Paktom**			**Nongphakbong**	
	Year (Replications)	2003 (3)	2004 (6)	2005 (5)	2003 (5)	2004 (4)	2005 (4)	2004 (6)	2005 (6)	2003 (8)	2004 (11)	2005 (11)	2004 (4)	2005* (2)
Yield (kg/ha)	DMC	5481 ± 167	4583 ± 325	6355 ± 735	5044 ± 379	3727 ± 379	5220 ± 1045	4976 ± 435	5965 ± 440	2563 ± 329	3383 ± 714	3150 ± 945	2270 ± 434	3725
	CV	4332 ± 691	5215 ± 588	5190 ± 660	5073 ± 281	4629 ± 394	5330 ± 1105	4726 ± 518	5950	2787 ± 316	3477 ± 42	3310 ± 850	3305 ± 811	-
Production cost ($/ha)	DMC	116 ± 13	100 ± 12	90 ± 13	93 ± 3	90 ± 3	77 ± 12	94 ± 0.5	95 ± 4	52 ± 5	89 ± 9	95 ± 10	59 ± 14	64
	CV	169 ± 39	201 ± 40	201 ± 52	142 ± 23	185 ± 46	159 ± 59	194 ± 61	226	88 ± 8	111 ± 16	135 ± 32	86 ± 28	-
Net income ($/ha)	DMC	227 ± 19	243 ± 53	423 ± 71	222 ± 23	236 ± 67	392 ± 78	280 ± 73	429 ± 28	82 ± 17	123 ± 8	161 ± 64	33 ± 41	215
	CV	102 ± 53	190 ± 84	234 ± 93	175 ± 39	190 ± 86	306 ± 138	100 ± 41	288	57 ± 19	107 ± 16	146 ± 75	52 ± 66	-
Labour inputs (days/ha)	DMC	62 ± 5	51 ± 8	60 ± 8	55 ± 9	49 ± 13	51 ± 6	65 ± 10	56 ± 3	61 ± 4	40 ± 12	40 ± 9	31 ± 1	38
	CV	75 ± 7	93 ± 32	94 ± 42	70 ± 6	64 ± 18	50 ± 11	78 ± 24	51	74 ± 7	41 ± 7	35 ± 6	64 ± 4	-
Labour productivity ($/day)	DMC	3.7 ± 0.1	4.8 ± 0.9	7.1 ± 1.5	4.0 ± 0.8	4.9 ± 1.0	7.8 ± 2.1	4.2 ± 0.9	7.7 ± 0.6	1.3 ± 0.2	3.2 ± 1.4	4.0 ± 1.4	1.0 ± 0.8	5.7
	CV	1.4 ± 0.7	2.2 ± 1.3	3.2 ± 2.6	2.5 ± 0.7	3.0 ± 1.5	5.8 ± 1.6	1.3 ± 0.1	5.7	0.8 ± 0.3	2.6 ± 0.5	3.9 ± 2.0	0.8 ± 0.6	-

Key: DMC: direct seeding with residue management; CV: conventional – ploughing. Nongphakbong 2005*: all conventional plots were managed with crop residues. Data represents mean values ± SE of yield, production costs, net income, labour inputs and labour productivity presented for five situations. Data is from two to eleven on-farm trials of 1,000 m^2 per treatment.

3.1.4 Dissemination of DMC systems: positive results and limiting factors for adoption of these innovations

The degree of dissemination of DMC systems differed greatly among the five villages according to their biophysical and socio-economic environments. Surveys carried out in 2005 and 2006 showed a rapid adoption of these technologies in Houaylod, Nongphakbong and Paktom (tables 2 and 3) with the percentages of smallholder farms practising DMC ranging from 66-76%. In 2006 a survey was carried out with stratified sampling and records to record spontaneous dissemination from farmer to farmer. The adoption process in Paktom stands out, where the cultivated area under DMC was relatively low (table 2), but the percentage of smallholders practising these systems was high (table 3). Over the last three years new maize production areas in northern Kenthao district (e.g. Houaylod), which has access to the Thai market, have contributed to a major increase in total cultivated area per labourer. Common land preparation is based on slash-and-burn practice and DMC systems are spreading rapidly as farmers attempt to increase the area cultivated. Adoption processes in southern Pak Lai (Kengsao and Bouamlao) differed greatly from the areas described above. While the economic superiority of the no-tillage system over conventional tillage was demonstrated every year, both the adoption of DMC systems by smallholders and the area managed with residues were extremely low before this cropping season (tables 2 and 3). In these two villages, where the cultivated area of maize per labourer can easily exceed 2 ha, land preparation through large-scale herbicide application involved considerable drudgery of labour (Tran Quoc et al, 2006). Introduction of specific equipment (e.g. seeder and sprayer) and involvement of the District Agriculture and Forestry Extension Office (DAFEO) and a development project (*Point d'Application du Sud de la Province de Sayaboury*, PASS, *Programme de Capitalisation en Appui à la Politique de Développement Rural*, PCADR) in extension activities have enhanced the dissemination of such technologies. After one season, 13% of smallholders started DMC systems in Bouamlao on 8% of the total dry land area. Surveys conducted by PASS (Julien and Rattanatray, 2006) showed that larger areas were mechanically sown in southern Pak Lai and Kenthao, at 42 ha and 54 ha respectively. The project gave technical support to 385 families representing 401 ha of crops under DMC systems (spontaneous dissemination was not included in this record).

Table 2: Dissemination of DMC systems according to percentage of surface 2003-2006 in five villages

Villages	Houay Lod				Paktom				Nongphakbong			
Total smallholders	169				131				101			
Replications	90-103				90-124				74-80			
Land preparation	**2003**	**2004**	**2005**	**2006**	**2003**	**2004**	**2005**	**2006**	**2003**	**2004**	**2005**	**2006**
Slash-and-burn	72.2	54.5	17.6	**18.5**	16.6	13.7	6.8	**13.4**	35.1	33.3	38.1	**40.9**
Ploughing	19.7	21.7	26.8	**38.8**	78.4	81.1	83.1	**71.7**	57.2	56.1	42.3	**17.1**
Ploughing and herbicide	2.3	1.7	11.7		1.7	0.8	0.9		1.1	0.8	0.8	
DMC	5.8	22.1	43.9	**42.6**	3.3	4.4	9.2	**14.9**	6.6	9.8	18.8	**42**

Villages	Kengsao			Bouamlao			
Total smallholders	134			383			
Replications	-90			155-137			
Land preparation	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2006**
Slash-and-burn	16.4	5.6	**1.5**	7.6	2.5	0.1	**1.7**
Ploughing	79.3	67.4	**37**	81.6	68.8	31.6	**90.1**
Ploughing and herbicide	4.3	26.5	**58**	10.8	28.7	68.3	
DMC	0	0.5	**3.5**	0	0	0	**8.2**

Key: DMC = direct seeding with residues management; Ploughing & Herbicide: Herbicides (Paraquat or Atrazine) are applied after sowing and maize emergence. Source: PASS project survey, 2005. Replications differed between surveys conducted in 2005 and 2006. Data not recorded in 2006 in Kengsao.

Table 3: Dissemination of DMC systems by percentage of smallholders in five villages, 2003-2006

Villages	Houay Lod			Paktom			Nongphakbong			Kengsao		Bouamlao		
Total smallholders	169			131			101			134		383		
Replications	90-103			90-124			74-80			-90		155-137		
Year	2003	2005	2006	2003	2005	2006	2003	2005	2006	2003	2005	2003	2005	2006
% of smallholders	4	50	66	8	50	68	5	22	76	0	2	0	2.5	13

3.2 Regeneration of savannah grassland - cattle fattening opportunities in the upper part of the Nam Ngum River Basin

3.2.1 Estimated vs. measured weight

Linear regression between morphometric data and measured weight of cattle is presented in figure 1. Significant regression was obtained between measured and estimated weight; the coefficient of determination, R^2, showed that this model described the data well.

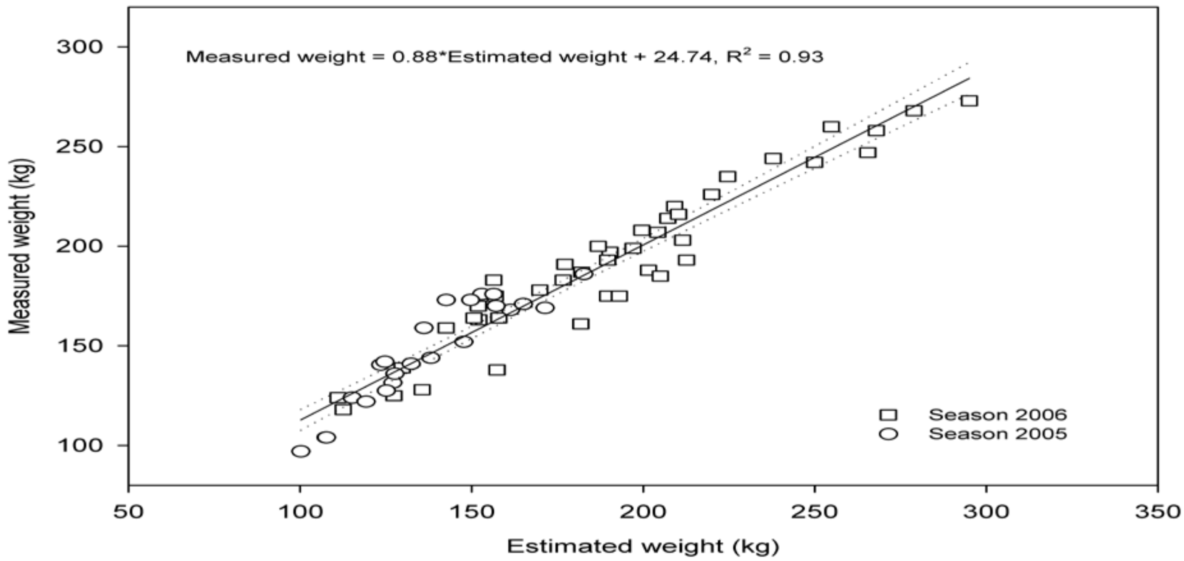

Figure 1: Regression model between estimated weight vs. measured weight 2005-2006 (confidence interval 95%)

3.2 Optimal fattening period

In 2005 four models of the bulls' growth rate, representing different fattening periods during the rainy season, were evaluated (figures 2a and b). The first model represents daily growth from end of May (26th) to the end of September (28th). Growth during this period was 401 g/day; a high rate considering that the bulls were not fed with protein supplements and were of local breed. After this period, daily growth dropped rapidly and an average of 276 g/day was recorded from the end of May to the end of December. Differences in the slope of these relationships were not determined by covariance analysis, but a drop in the daily growth rate was observed after the beginning of November. The bull fattening period was then revised to consider an optimal fattening period from May to the beginning of November (figure 3, Y_3 equation), giving a mean growth rate of 364 g/day.

The same period (to the end of October) was taken into account for cattle fattening during the 2006 wet season but a drop in mean (figure 2b) and individual (figure 4b) growth rate was observed at the end of July. The mean growth rate from the end of May to the end of October reached 539 g/day. This local breed, which seems to originate from a crossbreed between native cattle and Redsindhi, is well adapted for fattening and showed a strong response to improved fodder.

A

B

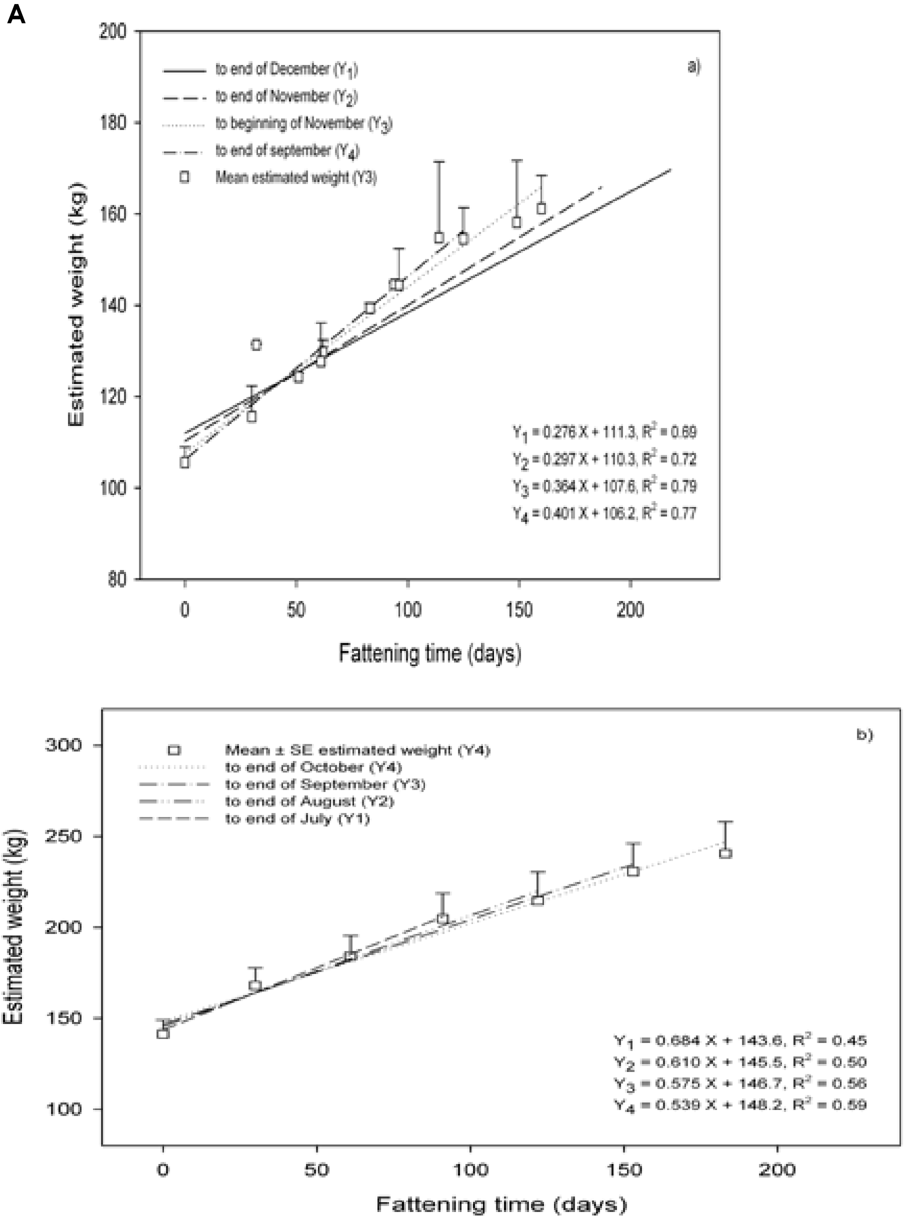

Figure 2: Linear regressions for different fattening periods in 2005 (A) and 2006 (B)

Mean ± SE is given from beginning of fattening period to beginning of November (2005) and to end of October (2006).

In 2005, a clear break point could be identified at the beginning of the dry and cold season (figure 3), indicating that neither weather conditions nor fodder resources (quality and/or quantity) were optimal for maintaining the daily growth rate. A steady state was observed from November to the end of March but the overall weight gain during this period was not very pronounced.

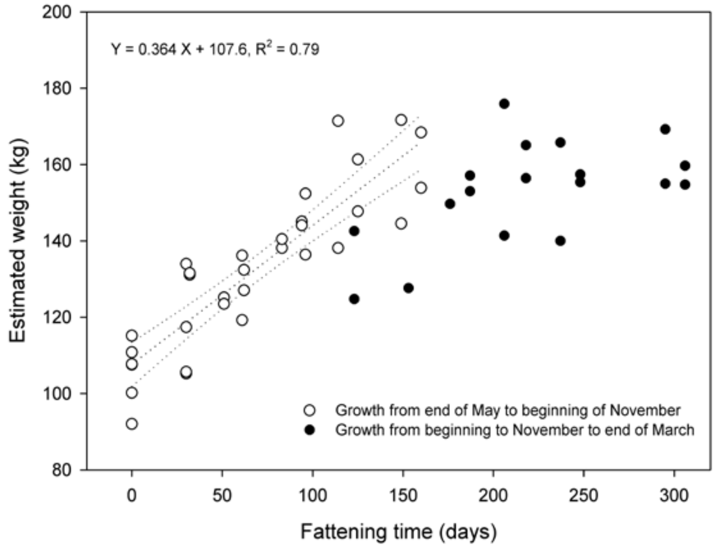

Figure 3: Mean daily growth rate of six young bulls from beginning of fattening (May 2005) to end of March 2006

Linear regression represents optimal fattening period from May to beginning of November 2005; confidence interval (95%) is given.

3.3 Individual growth rate

The growth rate of each bull during the same period was calculated using linear regression (figures 4a and b) for 2005 and 2006. No statistical analysis was performed to compare these models. Daily growth rate seemed relatively uniform in 2005 for four of the bulls (1, 2, 3 and 6, figure 5a) with a mean of 366 g/day; the fourth presented a growth rate of 267 g/day and the fifth of 471 g/day. In 2006 growth rates were higher but differed greatly between animals (figure 5b), ranging from 747 g/day to 423 g/day.

3.4 Economic analysis

In 2005 gross income from weight gain of bulls and seed production during the trial totalled $879 (table 4), a sum that covered all expenses for fencing, fertilisers, seeds, and bull management over the first year. Fencing (barbed wire) and fertilisers formed the main expenses. Moreover, a lack of cash income at the end of this first fattening period meant that smallholders could not buy fertiliser for the next season. In the medium term, the cost of fencing could be reduced by growing living fences (hedges) using species such as *Acacia mangium*, *A. auriculiformis*, *Calliandra calothyrsus*, and *Jatropha* sp.

A

B

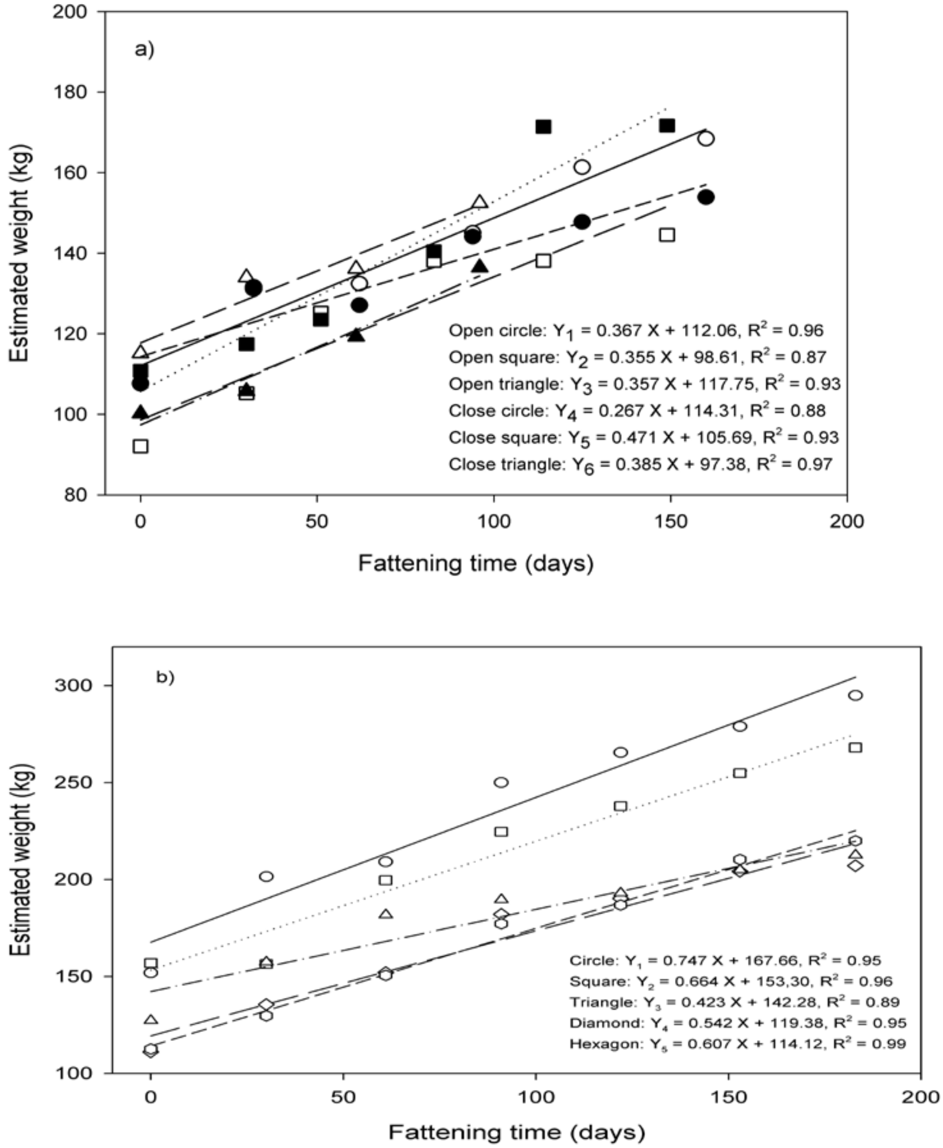

Figure 4: Daily growth rate of six young bulls from beginning of fattening (May) to beginning of November 2005 (A) and end of October 2006 (B)

Additional income was provided by the 132 kg of seed produced on the fifth block. Growing these seeds provided an opportunity to extend the area of improved pasture land or to sell the seed to other smallholders who wished to generate new income. Sowing *Stylosanthes guianensis* on 5-m contours on the forage fields protects the pasture from wild fires during the dry season and provides a protein supplement for the cattle. In 2006, without taking into account seed production, bull fattening earned a gross income of $804, thereby covering all expenses and generating a net income of $362/ha and labour productivity of $10.4. Seed production brought a gross income of $252/ha and labour productivity of $8.4.

Table 4: Economic data for bull fattening, 2005 & 2006 seasons

Improved pastureland 1.5 ha	Unit	2005			2006		
		Unit cost (US$)	Qty	Total (US$)	Unit cost (US$)	Qty	Total (US$)
COSTS							
Plot fencing: Wooden posts	piece	0.4	440	176			
Barbed wire	piece	5	60	300			
Nails	kg	0.9	20	18			
sub total				494			0
Field design: Animal shelters	piece	5	4	20			
Drinking trough	oil barrel	8	2	16			
sub total				36			0
Land preparation				35			0
Seeds: *B. ruziziensis*	kg	2	23	46			
sub total				46			0
Fertiliser: 15-15-15	tonnes	340	0.34	116			
Urea (46-0-0)		300	0.12	36	330	0.34	112
Thermophosphate (0-16-0)		100	0.51	51	100	0.85	85
KCl (0-0-60)		280	0.09	24	280	0.17	48
sub total				226			245
Animal care: Salt lick	piece	3	2	6	3	2	6
Vaccines and deworming		3	3	9	3	3	9
sub total				15			15
TOTAL COSTS				**852**			**260**
LABOUR							
Fencing	working days		20				
Land preparation			3				
Sowing			55				
Fertiliser spreading			2			2	
Seed harvesting			30			30	
Bull management			50			50	
TOTAL LABOUR			**160**			**82**	
BENEFITS							
Value added to bulls (difference between intial-final value)	US$		6	615		8	804
Seed production	kg	2	132	264	1.5	168	252
GROSS INCOME	US$			**879**			**1,056**
NET INCOME				**27**			**796**
LABOUR PRODUCTIVITY	US$/day			**0.17**			**9.71**

To evaluate the feasibility of cattle fattening under smallholder conditions, this livestock system was proposed during the 2006 season to various farmer groups in seven villages (27 families) of Pek district. Field areas ranged from 0.3-1 ha per household. Forage species were directly sowed after chemical control of natural pasture land. Technical support was given for land preparation, sowing and pasture management. Forage seeds were provided by the project with 50% credit during the first season. Households were responsible for fencing, pasture and animal management. Fertiliser cost was shared between the project and the farmers. A one-year credit deal was proposed for fertilisers with farmers able to repay with forage seeds ($1.5 /kg of *B. ruziziensis*).

4. Discussion and conclusions

Positive results were evident for direct seeding systems based on residues in southern Xayabury, where a growing interest and potential for widespread adoption were observed. The PASS-PCADR project followed an approach of supporting farmer groups and structuring the environment and, after one season, this exhibited great impact on promoting no-tillage systems and transferring these systems to smallholder farms and the private sector. No-tillage systems must be progressively improved with rational crop rotations, relay crops and cover crops in order to achieve all the biophysical and economical advantages of DMC systems. The present system of monocropping under no-tillage is an incomplete system in which diseases, weeds and pests tend to increase while labour productivity and profits decrease. Local species like rice bean and Job's tears are ideal for starting a direct seeding system. With long-cycle durations (seven months), these species produce high amounts of dry matter (>20 t DM/ha for Job's tears), have low residue degradation due to high lignin content, present low levels of animal exportation owing to the unpalatability of both species, and also compete fiercely (especially rice bean) with weeds during the rainy season. Other systems will be promoted during the coming season with a biannual cropping sequence between [maize + *B. ruziziensis*] and direct sowing of soybean or rice bean in the second year on *B. ruziziensis* mulch and maize residues. Use of specific equipment overcame constraints previously identified in Bouamlao and Paktom villages, where large areas of maize are sowed every year and where the main constraint was the labour drudgery involved with land preparation and sowing (Tran Quoc et al, 2006). Farmers adopt DMC systems firstly because of socio-economical advantages and not for their environmentally positive effects, and secondly when conventional cropping systems are no longer productive or economically efficient. For example, in the most fragile area (Nongphakbong), where soil fertility had decreased rapidly because of the nature of the soil (sandstone in Boten district) and erosion induced by former ploughing techniques, crops tend to be diversified (maize, peanuts, rice bean) in order to limit risks due to soil and climatic factors. Furthermore, in order to increase cash income, most small and medium households are shifting to DMC systems to cultivate wastelands infested by the *Imperata cylindrica* weed with rice bean cropping systems. Such areas cannot be farmed through conventional tillage systems because of the high labour requirements for weeding.

The next main challenge is to transfer knowledge, systems, and equipment to smallholders and the private sector through rental-selling processes. Many smallholders say that a major limitation to the dissemination of DMC systems is the lack of any credit system for inputs. For many smallholders, even when extremely high interest rates are given for ploughing on credit (50% over eight months), this option still represents a good opportunity to avoid investing any cash at the beginning of the season, when money is needed for other agricultural activities (livestock, farm equipment) or the household requirements (health, school, etc).

This study also analysed the economic and technical viability of cattle fattening on the elevated plains of Xieng Khouang province. The team used a simple model to evaluate the daily growth rate of young bulls, which were fattened during the rainy season. This appears to be a very efficient activity with high growth rates recorded. Higher growth rates were recorded in 2006 (539 g/day, figure 3) probably related to the fact that the bulls stayed permanently on fields, with earlier and longer daytime fattening that also improved the pasture land through better fertility restitution. The income generated by this fattening programme in 2006 was equivalent to what could be earned by a paddy rice yield of 1.8 t/ha, which is unlikely in this ecology. Yields of wet season lowland paddy rice range from 1.5-3.5 t/ha while rainfed rice cropping on the savannah after ploughing reaches 250 kg/ha in the best situations.

Improvement of pastureland is a first step in the medium-term process of improving the elevated plains for rice cropping and other staple and food crops. Further work is required to estimate the maximum stocking rate of heifers on improved pasture for the dry season, and to compare animal growth rates on improved pastureland with the traditional extensive method of free grazing on savannah grasslands, clear forest and paddy fields. This bull fattening activity presented three major constraints: First, animal fattening is clearly related to market access and meat demand. Rural areas of Laos have traditionally struggled to find markets for products because of low population density and poor transport links. However, Xieng Khouang province has begun to show a high commercial rate of cattle export to Vietnam (Onekeo, 2005; Syphanravong et al., 2006) and the recent experiences of the Forage for Smallholders Projects (CIAT-NAFRI) show increasing commercial opportunities in places where smallholders are growing forages for cattle feeding. Secondly, it seems difficult for smallholders to carry out this kind of livestock production without technical support for land preparation, pasture growing and cattle management. The local ecologies on schist and granite present good physical properties but low mineral contents (Hacker et al, 1998) with high deficiencies of N, P, K, Ca, Mg and micronutrients (Zn, Bo, Mn). Thermophosphate addition is thus essential, providing reasonable quantities of Ca, Mg and P and allowing implementation of efficient livestock production and cropping systems. A market channel for such fertilisers is already operational in Xieng Khouang province through Vietnamese traders. Moreover, the soil does not need to be disturbed by mechanical action - land preparation is based on direct sowing of forage species after control of natural pasture land. Direct sowing shows very good results (reducing production costs and land erosion) on the Plain of Jars and could be extended to staple and cash crop production. However, specific equipment adapted to local economic conditions (sowing machine for hand-tractor) must be promoted to decrease labour inputs for land preparation and sowing. The third limiting factor is that the system was initially perceived as requiring an initial cash investment. On these high plains, innovative farming systems based on direct mulch-based cropping and better integration of livestock and cropping activities could be stable and profitable if, at the same time, economic incentives (access to market, inputs, credit, agriculture and livestock product processing) are promoted.

Seed production does not seem to be problematic in this ecology. Promising results have been observed for Brachiaria species like *B. ruziziensis*, *B. decumbens*, *B. brizantha* and for *S. guianensis* (cv. CIAT 184). Development of specific market channels for seeds could indirectly improve pasture management, avoid high stocking rates and generate new income that could be invested in fertiliser and animal care. As reported by Hacker et al. (1998), the best option may be to improve small areas through strategies that are specific to smallholders' particular situations, using adapted forage species and thermophosphate. In conclusion, despite positive economic and technical results with cattle fattening, a global approach involving credit access plus technical and political support has to be defined if productive and efficient systems are to develop in this ecology. This poses a great challenge which, if grasped, could yield great benefits in the upper part of the Nam Ngum river basin.

Finally, the approach followed by PRONAE highlights the collaboration process, progressively developed with all of the stakeholders (smallholders, agronomists, DAFEO staff, development project, policy-makers and private sector). One of the main challenges of this approach is to transfer, in the medium-term, research-development programmes, systems and technologies to extension agencies and the private sector. However, self-management of research-development programmes at PAFOs and DAFEOs seems a long process since authorities and extensionists have to understand the benefits and advantages of these activities in supporting and promoting continuously extension activities.

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