

Improving Smallholder Livelihood, Watershed and Soil Management through Conservation Agriculture in Laos

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Abstract

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, 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 altitude plains, in the upper part of the Nam Ngum river basin (Xieng Khouang province), large areas of savannah grasslands are under-utilized by smallholders with main farming systems based on lowland paddy fields, livestock production with extensive grazing on savannah grasslands and off-farm activities. Regarding these situations, the Lao National Agro-Ecology Programme (PRONAE) implemented an iterative research-development approach oriented on Conservation Agriculture in order to find innovative systems to revert, in southern Xayabury, the present ‘resource-mining’ practices and to develop alternatives systems on higher plains in Xieng Khouang province. Direct Seeding Mulch-Based Cropping (DMC) systems with residues management were evaluated and validated by farmers groups in five villages in southern Xayabury during four seasons. Positive results (increase of net income and labour productivity) are evident for direct seeding systems in southern Xayabury, where growing interest and potential for widespread adoption have been observed. Results show that the level of dissemination of DMC systems differs greatly among the villages surveyed depending on their environmental and socio-economic conditions. On altitude plain, in Xieng Khouang province, the economical and technical viabilities of ‘workshop’ fattening were analyzed. Fattening on

improved pastureland (*Brachiaria ruziziensis*) during the rainy season appears to be a very efficient activity with high growth rates recorded. In 2005, weight gain and seed production obtained during this experiment represents a gross income of \$879 (1.5ha) and covers all expenses for fencing, fertiliser, seeds, and bull management over the first year. Income generated in 2006 by bulls fattening can be converted in paddy rice and represents, per ha, 1.8 tons of rice (362 \$US/ha) which is unexpected in this ecology of altitude plains. 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. The approach follows by PRONAE highlights the collaboration process progressively develop with all of the stakeholders (smallholders, agronomists, DAFEO staff, development project, policy-makers and private sector). One of the main challenge of this approach is to transfer, on a medium-term process, research-development programme, systems and technologies to extension agency and private sector.

Keywords

Watershed management, Conservation Agriculture, Smallholder livelihood, No-till systems and residues 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 altitude plains, in the upper part of the Nam Ngum river basin (Xieng Khouang province), large areas of savannah grasslands are under-utilized by smallholders with main farming systems 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.

Regarding these situations, the Lao National Agro-Ecology Programme (PRONAE) is implementing an iterative research-development approach oriented on Conservation Agriculture to find innovative systems to revert, in southern Xayabury, the present resource-mining practices and to develop alternatives systems on higher plains in Xieng Khouang province. Since 2002 in Xayabury and early 2003 in Xieng Khouang, the programme has developed and adapted diversified systems integrating, as much as possible, annual cropping and livestock production. These innovative alternatives are based on no-till systems, with use of multipurpose species (*Brachiaria* sp., finger millet, pigeon pea, *Crotalaria* sp., *S. guianensis*), through a participatory approach involving village communities and groups of farmers. Two mains systems, which are presently extended in both provinces, are presented in this paper.

The first system refers to the extension, in southern Xayabury, of no-till systems with maize residues management. Farmers groups were constituted in different villages to take into account the biophysical diversity of the region and covering farmer's strategies. In 2006, a survey was carried out in four villages in order to estimate the level of dissemination of DMC systems at the village community scale. Agro and socio economic results of this work are presented and discussed in this paper.

The second system described in this paper is on the way of extension; it concerns generation of efficient and economically viable livestock production on altitude plains. Xieng Khouang is the third biggest cattle producing province (Committee for Planning and Investment, 2005) but the lack of feeding resources (Hacker *et al.* 1998) and economic incentives, combine with health problems (Gibson *et al.* 1999), limit the development of the livestock sector. Previous attempts to improve pastureland have been hampered by unavailability of fodder seed, limited fodder growth related to poor soil 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 (1:5 H₂O) of about 5.0, along with deficiencies in nitrogen, phosphorus, potassium, calcium and magnesium. Moreover, these authors also reported that high levels of aluminium saturation are likely 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 the Lao National Agro-Ecology Programme to regenerate savannah grasslands and to diversify farming production. Cattle fattening was performed on improved pastureland (*Brachiaria ruziziensis*) with use of input (thermophosphate and mineral fertiliser). Agronomic and economic data were recorded to analyze the viability of this system.

2 Material and methods

2.1 On-farm validation of no-till systems based on residues management

2.1.1 On-farm validation of no-till systems based on residues management

Experiments were carried out on farmers' fields, on plots of at least 4,000m². The performances of conventional and DMC systems for different crops (choice of crop depends totally on farmer) were assessed under conditions matching those found on farms in the region. These experiments involved 35 smallholders located in five villages, with a total area of 14 ha. Results presented in this paper concern maize, the main crop produced in this region. Fields were chosen for the study according to morphopedological units, 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 under which the experiments were carried out allows 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 impacts of these soil conservation technologies at the farming system level; (ii) estimate the level of dissemination of DMC systems at the village community scale; and (iii) have a better understanding of the processes through which innovations are disseminated within the village communities. Only the second topic is presented in this paper (Tables 2 and 3).

2.2 Cattle fattening opportunities on 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 under this environment. However, *Brachiaria 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 from the local breed were used. Their initial weight ranged from 92 to 115 kg and their total initial value was US\$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 by the 29th of July. Fattening was stopped at the beginning of the dry season (end of November and end of December) and four of the bulls were followed from January to March to estimate their growth fluctuation during the dry season. During this period they were feed in clear forest in the vicinity of the village. In 2006, this trial started with eight bulls and stocking rate was adjusted to five bulls at the end of June related 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 will be followed on improved pastureland during the dry season. Salt stones were used as a diet supplement, while vaccines (against haemorrhagic fever) and deworming treatment were applied at the beginning of the trial. Ticks were controlled with insecticide spray.

2.2.2 Experimental Design and Management

1.5ha was manually sowed on 21st of April 2005 with *B. ruziziensis* at a density of 12 kg.ha⁻¹; this field was used in 2004 for upland rice screening. After the forage sowing, natural weeds were controlled by use of glyphosate (4 l.ha⁻¹). Of five 0.3 ha blocks, four were designated for cattle fattening with one block for seed production. The bulls were kept on one block for a week at a time. Half of a 200 l barrel was as a water trough on each block.

Before sowing fertiliser was applied consisting of 30 kg N as ammonium sulphate, 80 kg P₂O₅ as thermophosphate and 60 kg K as K₂O 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⁻¹. Seeds were harvested from the fifth block at the end of October 2005. In 2006, at the beginning of the rainy season fertilizer was applied consisting of 30 kg N, 80 kg P₂O₅ as thermophosphate and 60 kg K as K₂O per hectare. An additional 60 kg of N was applied at three intervals during the rainy season.

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 the use of morphometric equation using breast and shoulder-tail length (Estimated weight = breast length²*(breast-tail length)*88.4).

Economic Analysis

Economic data recorded during this trial is presented in Table 4. Labour inputs for land preparation, fencing, sowing and fertiliser spreading, 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-till systems and residues management in southern Xayabury

3.1.1 Yield

Maize grain yield variations, according to site characteristics (landscape, soil units) and cultivars, are important for each treatment (Table 1). Such results reflect differences in soil erosion and fertility. For example while Paktom and Bouamlao have the same geological substratum (basaltic stones), large differences in yield are observed. In southern Pak Lai (Kengsao and Bouamlao) and northern Kenthao (Houay Lod), which are recent areas for maize production, yields recorded, in 2005, under DMC systems exceed $5.2\text{t}\cdot\text{ha}^{-1}$. With DMC systems, yield levels were generally close to or even higher than those obtained in conventional systems. In degraded areas (Paktom and Nongphakbong), mean yield recorded with no-tillage oscillates between 3.1 and $3.7\text{ t}\cdot\text{ha}^{-1}$ with maize hybrid, while mean yield with conventional tillage is $3.3\text{t}\cdot\text{ha}^{-1}$. In Nongphakbong, lower soil fertility, poor soil structure due to compaction (high bulk density, data not shown) and crusting seems to be the main yield limiting factor under DMC and conventional systems. Erenstein (2003) reported that short-term yields often depend on the mulch, crop and site characteristics; 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. This first step of DMC systems can not minimize climatic risks with high yield variability observed among seasons.

3.1.2 Production Cost and Net Income

In 2005, for DMC systems production costs ranged from US\$ 65 to \$95 per ha (Table 1), while costs for conventional system (ploughing) ranged from \$135 to \$226 per ha depending on the slope, field accessibility and rate charged by the tractor owners. Among seasons, production costs under conventional practices increase considerably with use of herbicides for chemical weeding mainly after crop emergence. In southern Pak Lai and northern Kenthao, net income per ha presents mean value of US\$ 415 per ha for no tillage system and US\$ 275 per ha for conventional tillage system. In these areas, high net incomes obtained under DMC systems result by low production costs combined with high yields and higher maize price. It is also interesting to observe that in degraded areas such as Paktom and Nongphakbong, net income per hectare can be improve rapidly after two or three years of practicing no tillage. Globally, net income increase during the last three seasons under DMC with however a large variability among sites.

3.1.3 Labour Requirements and Labour Productivity

Since the first season, labour productivity increases with residue management and was highly significant in Bouamlao, Kengsao and Houaylod (Table 1), ranging from \$7.1 to \$7.8 per day with DMC and from \$3.2 to \$5.8 with conventional in 2005. In 2005, on sandstone unit (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. As observed for net income, labour productivity increase greatly among years with relative increase that ranged from 83% to more than 200%, respectively for Houay Lod and Paktom. However, even if lower labour inputs were required for manual weeding, results show that in most cases of maize mono-cropping with no tillage, weed pressure cannot be controlled efficiently because of the short duration of maize and rapid mineralization of maize straw. Indeed, after harvest and during intercropping (six months), weed proliferation and seeding occur.

Table 1: Data \pm SE from on-farm experiments conducted between 2003 and 2005 in southern Xayabury. Mean value, yield, production cost, net income, labour inputs and labour productivity are presented for five situations. Data is from two to eleven on-farm trials of 1000 m² per treatment.

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

Key: DMC: direct seeding with residue management; CV: conventional – ploughing. Nongphakbong 2005*: all conventional plots were managed with crop residues

3.1.4 Dissemination of DMC Systems: Positive Results and Limiting Factors for Adoption of these Innovations

The degree of dissemination of DMC systems differs 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 percentage of small holds farms practising DMC which ranged from 66% to 76%. In 2006, survey was carried-out under stratified sampling and records presented here included spontaneous dissemination from farmers to farmers. Adoption process has to be highlight in Paktom where, cultivated area under DMC is relatively low with less than 15% but by contrast, percentage of smallholders practising such systems is high. This result is related to large cultivated area per labourer which limits this dissemination. Lack of sufficient equipment for land preparation and sowing is still a constraint. Clearly farmers adopt DMC systems firstly because of socio-economical advantages and not for environmentally positive effects, and secondly when conventional cropping systems are no more productive or economically efficient. For example, in the most fragile area (Nongphakbong), where soil fertility has decreased rapidly because of soil nature (sandstone in Boten district) and erosion induced by former ploughing, crops tend to be diversified (maize, peanuts, rice-bean) in order to limit risk 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. Such areas cannot be farmed through conventional tillage systems because of the high labour requirements for weeding. Recently, new maize production areas in northern Kenthao district (Houaylod), where there is access to the Thai market, have contributed to a drastic increase in total cultivated area per labourer in the last three years. 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 previous areas. Although the economic superiority of the no-tillage system over conventional tillage has been proven every year, both the adoption of DMC systems by smallholders and the area managed with residues remained extremely low (Tables 2 and 3) before this cropping season. In these two villages, where the cultivated area of maize per labourer can easily exceed 2 ha, land preparation through large-scale herbicide application represented considerable drudgery of labour (Tran Quoc *et al.* 2006). Introduction of specific equipments

(sowing and sprayer) and involvement of DAFEO and development project (PASS-PCADR) on extension activities have enhanced the dissemination of such technologies. After one season, 13% of smallholders have started DMC systems in Bouamlaio that represented 8% of total dryland area. Surveys conducted by PASS (Jullien and Rattanatrav 2006) showed that larger areas were mechanically sown in southern Parklay and Kenthao districts with, respectively, a total area of 42 ha and 54 ha. This project gave technical support to 385 families representing 401 ha of crop under DMC systems; spontaneous dissemination was not included in this record.

Table 2: Dissemination of DMC systems according to surface (%) between 2003 and 2006 in 5 villages.

Villages		Houaylod				Paktom (North)				Nongphakbong				Kengsao			Bouamlao			
Total Smallholders		169				131				101				134			383			
(Replications)		(90-103)				(90-124)				(74-80)				(90)			(155-137)			
Land Preparation	Year	2003	2004	2005	2006	2003	2004	2005	2006	2003	2004	2005	2006	2003	2004	2005	2003	2004	2005	2006
	Slash & 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	16.4	5.6	1.5	7.6	2.5	0.1
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	79.3	67.4	37.0	81.6	68.8	31.6	90.1
Ploughing & Herbicide		2.3	1.7	11.7		1.7	0.8	0.9		1.1	0.8	0.8		4.3	26.5	58.0	10.8	28.7	68.3	
DMC		5.8	22.1	43.9	42.6	3.3	4.4	9.2	14.9	6.6	9.8	18.8	42.0	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: Data from a survey carried out by PASS Project (Point d'Application du Sud de la province de Sayabouri) in 2005. Replications differed between surveys conducted in 2005 and 2006. Data were not recorded in 2006 in Kengsao.

Table 3: Dissemination of DMC systems according to percentage of smallholders between 2003 and 2006 in 5 villages.

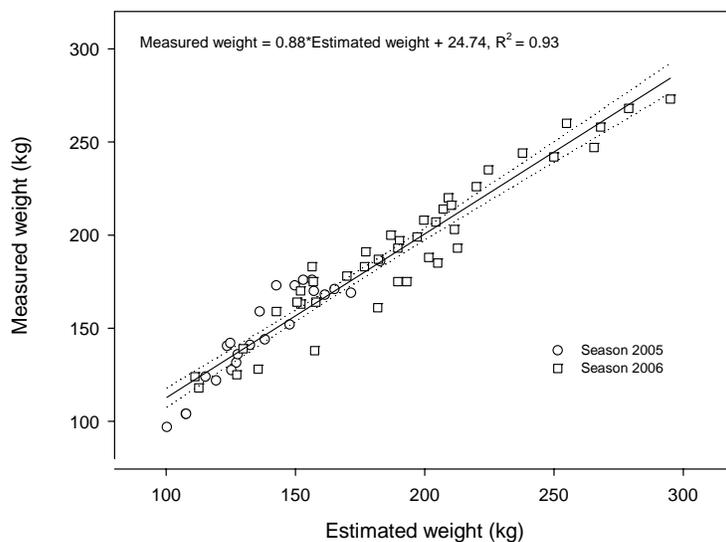
Villages	Houaylod			Paktom (North)			Nongphakbong			Kengsao		Bouamlao		
Total Smallholders	169			131			101			134		383		
(Replications)	(90-103)			(90-124)			(74-80)			(90)		(155-137)		
Year	2003	2005	2006	2003	2005	2006	2003	2005	2006	2003	2005	2003	2005	2006
% of smallholders	4	50	66	8	50	68	5	22	76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

3.2 Regeneration of Savannah grassland - Cattle fattening opportunities on the upper part of the Nam Ngum River Basin

3.2.1 Estimated vs. Measured Weight

The linear regression between morphometric data and measured weight is presented in Fig. 1. Significant regression was obtained between measured and estimated weight; the coefficient of determination, R^2 , showed that this model describe the data well.

Fig. 1: Regression model and confidence interval (95%) between estimated weight vs. measured weight is given for 2005 and 2006.

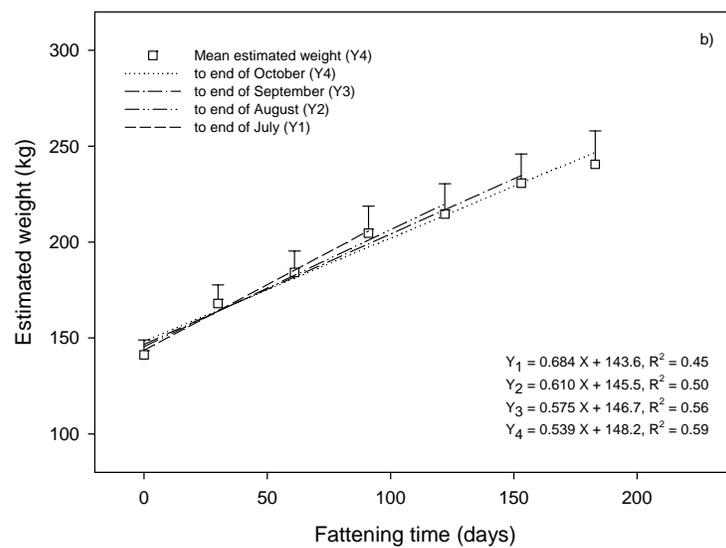
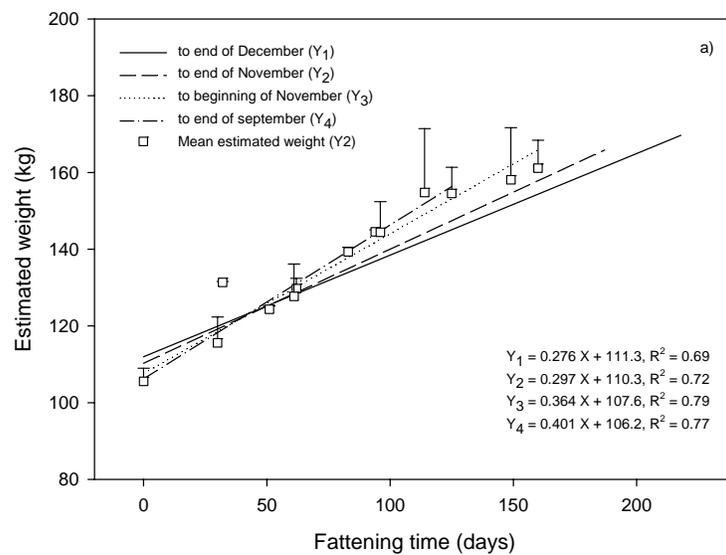


3.2 Optimal Fattening Period

In 2005, four models follow, in Fig. 2 (a,b), of the bulls' growth rate during the different fattening periods. The first model represents daily growth during the rainy season, from end of May (26th) to end of September (28th). High growth was obtained during this period with a mean daily growth of 401 g/day, a high rate considering that the bulls were not fed with protein supplements and were from a local breed. After this period, daily growth drops rapidly and averages at 276 g/day for the period end of May to end of December. Differences in the slope of these relationships were not determined by covariance analysis, but a drop of daily growth rate could be observed after the beginning of November. The bull fattening period was then revised to include only May to the beginning of November (Fig. 3, Y₃ equation), giving a mean growth rate of 364 g/day.

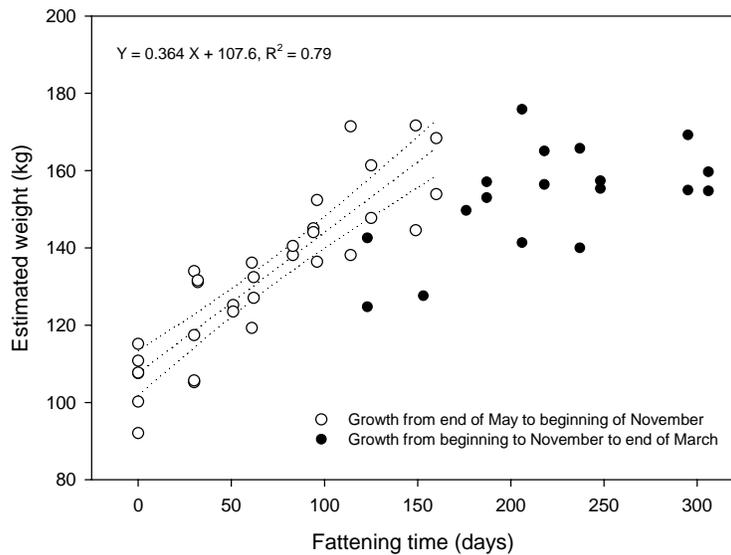
The same period (to end of October) was taken into account for cattle fattening during the wet season 2006 but a drops in mean (Fig. 2b) and individual (Fig. 4b) growth rate was observed after end of July. The mean growth rate from end of May to end of October reached 539 g/day. Rainfall was very erratic in May and June 2006 and stocking rate was adjusted from 8 (end of May) to 5 bulls (end of June).

Fig 2: Linear regressions for different fattening periods are given for 2005 (a) and 2006 (b). Mean \pm SE is given from beginning of fattening period to beginning of November (2005) and to end of October (2006)



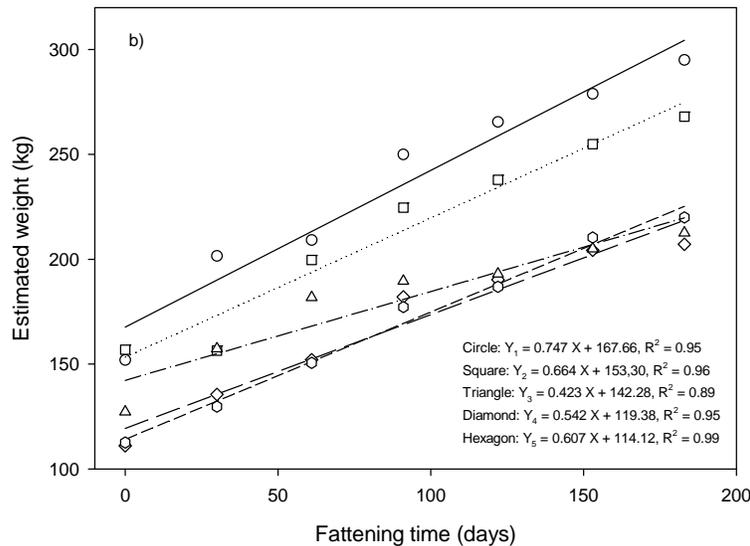
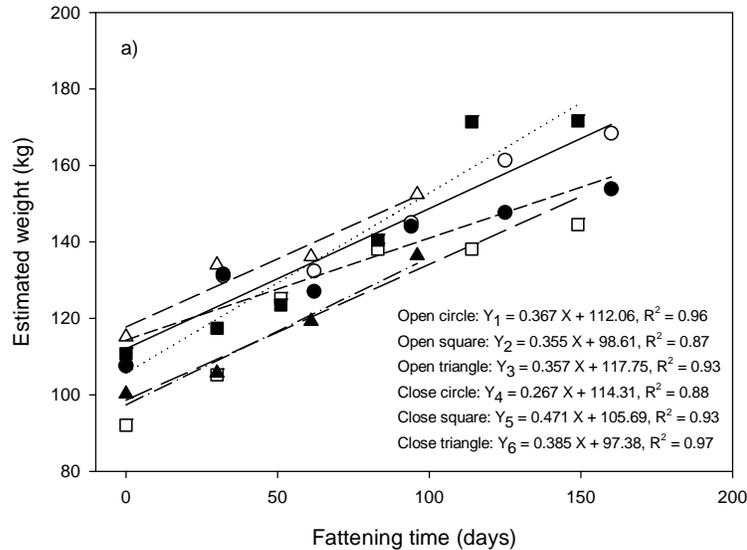
In 2005, a clear break point could be identified at the beginning of the dry and cold season (Figs. 3), indicating that weather conditions, and fodder resources (quality and/or quantity) were not optimal to maintain the same daily growth rate. A steady state was observed from November to the end of March but the overall loss of weight during this period was not very pronounced.

Fig 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



The growth rate of each bull during the same period was calculated using linear regression (Fig. 4 a, b) for 2005 and 2006. No statistical analysis was performed to compare these models. Daily growth rate seems relatively uniform in 2005 for four of the bulls (1, 2, 3 and 6, Fig. 5a) with a mean of 366 g/day^{-1} ; the fourth presents a growth rate of 267 g/day and the fifth 471 g/day . In 2006, growth rate were higher but differed greatly between cattle (Fig. 5b) and ranged from 747 g/day to 423 g/day . As observed in 2005 and 2006, one bull presented lower growth rate and it seems that this kind of bulls were not cross breed with improved race.

Fig 4: Daily growth rate of six young bulls from beginning of fattening to beginning of November 2005 (a) and end of October 2006 (b) is given.



3.3 Economic analysis

In 2005, weight gain and seed production obtained during this trial represents a gross income of \$879 (Table 4) and covers all expenses for fencing, fertiliser, seeds, and bull management over the first year. Fencing (barbed wire) and fertiliser formed the main expenses. Moreover, the lack of cash income at the end of this first fattening period will not allowed smallholders to buy fertilizer 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. Additional income was provided by the 132 kg of seeds produced on the fifth block. Growing these seeds provides an opportunity to extend the area of improved pasture land or to sell the seed to others smallholders who wish to generate new income. Sowing *Stylosanthes guianensis* on 5 m contours on the forage fields would protect the pasture from wild fires during the dry season and provide protein supplements for the cattle. In 2006, without taking into account seed production, bulls fattening represents a gross income of \$804 covering all expenses and generating a net income per ha of \$362 and a labour productivity of 9.8 \$US. Seed production is not included in this income and an expectation of 130 kg is presented. Moreover, during this second season of cattle fattening all of the blocks showed good flowering and filling stage. Seed production and harvesting will be carried-out on the five blocks.

Table 4: Economic data recorded for bull fattening during two seasons (2005, 2006) on the vicinity of Phonsavanh (altitude plains, upper part of the Nam Ngum River Basin) on 1.5 ha. An expectation of 130 kg seed is presented for 2006.

Improved pastureland 1.5 ha	Unit	2005			2006		
		Unit cost (US \$)	Qty	Total (US \$)	Unit cost (US \$)	Qty	Total (US \$)
COSTS							
Plot fencing							
Wood posts	piece	0.4	440	176			
Barbed wire	piece	5	60	300			
Nails	kg	0.9	20	18			
				494			0
Plot designing							
Shelters for animals	piece	5	4	20			
Drinking trough	Oil barrel	8	2	16			
				36			0
Land preparation							
				35			0
Seeds							
B. ruziensis	kg	2	23	46			
				46			0
Fertilizer							
15-15-15	Ton	340	0.34	116			
Urée (46-0-0)	Ton	300	0.12	36	330	0.34	112
Thermophosphate (0-16-0)	Ton	100	0.51	51	100	0.85	85
KCl (0-0-60)	Ton	280	0.09	24	280	0.17	48
				226			245
Animals care							
Salt stone	piece	3	2	6	3	2	6
Vaccine and vermifuge	piece	3	3	9	3	3	9
				15			15
TOTAL COSTS				852			260
LABOUR							
Fencing	working.day		20				
Land preparation	working.day		3				
Sowing	working.day		55				
Fertilizer broadcasting	working.day		2			2	
Seeds harvesting	working.day		30			30	
Bulls management	working.day		50			50	
TOTAL LABOUR			160			82	
BENEFITS							
Bulls added value (difference initial-final value)	US Dollars		6	615		8	804
Seeds production	kg	2	132	264	2	130	260
GROSS INCOME		US \$		879			1,064
NET INCOME		US \$		27			804
LABOUR PRODUCTIVITY		US \$/day		0.17			9.81

4 Discussion and Conclusion

Positive results are evident for direct seeding systems based on residues in southern Xayabury, where growing interest and potential for widespread adoption have been observed. After one season, the development project involved in southern Xayabury (PASS-PCADR) followed this approach in supporting farmers groups and structuring environment and exhibited after one season great impact on promoting no-till systems and transferring these systems to small hold farms and private sector. Despite rapid adoption of DMC systems (based on residue management) in some areas, no-tillage systems have to 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 will tend to increase and labour productivity and profits will tend to decrease. Local species like rice-bean and Job's tears are ideal for starting a direct seeding system. With long-cycle duration (seven months), these species produce high amounts of dry matter ($>20 \text{ tDM} \cdot \text{ha}^{-1}$ 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 system will be promoted during the coming season with a biennale cropping sequence between [maize + *B. ruziziensis*] and direct sowing of soybean or rice-bean the second year on *B. ruziziensis* mulch and maize residues. Use of specific equipments allowed overcoming constraints previously identified in some villages as Bouamlao and Paktom where large areas of maize are sowed every years and where the main constraint was based on drudgery of labour for land preparation and sowing (Tran Quoc *et al.* 2006). Nowadays, the main challenge lies in the capacity in transferring knowledge, systems, and equipments to smallholders and private sector through rental-selling process. Furthermore, many smallholders said that a major limitation to dissemination of DMC systems is the lack of any credit system for inputs. For many smallholders, even if extremely high interest rates are given for ploughing credit (50% over eight months), this still represents a good opportunity to avoid investing any cash at the beginning of the season.

On altitude plain in Xieng Khouang province, the economical and technical viabilities of 'workshop' fattening were analyzed. It used a simple model to evaluate the daily growth rate of young bulls, while focusing on fattening during the rainy season which appears to be a very efficient activity with high growth rates recorded. This cattle breed used seems well adapted

for fattening and showed a strong response to improved fodder. It does seem, however, that the animals originate from a crossbreed between native cattle and Redsindhi. Higher growth rates were recorded in 2006 probably related to the fact that bulls stayed permanently on field, with earlier and longer daytime fattening that improves also pasture land with better fertility restitution. Income generated in 2006 by bulls fattening can be converted in paddy and represents, per ha, 1.8 tons which is unexpected in this ecology. Yields in lowland paddy field ranged to 1.5 t/ha and 3.5 t/ha and rice cropping on the savannah after ploughing reaches in the best situation 250 kg/ha. Improve pastureland is a first step through a medium-term process of improvement of altitude plains for rice cropping and others staple and edible crops. Further work remains in estimating the maximum stocking rate of heifers on improved pasture for the dry season, and in comparing the animal growth rate 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, 2004; 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 forage for cattle feeding. Second, 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 fertiliser is already operational in Xieng Khouang province through Vietnamese traders. Moreover, the soil does not need to be disturbed by mechanical actions and land preparation are 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 could be that the system was first 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 as *B. ruziziensis*, *B. decumbens*, *B. brizantha* and for *Stylosanthes guianensis* (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.

To evaluate the feasibility of cattle fattening under smallholder conditions, this livestock system was proposed during this season to various farmer groups in seven villages (27 families) of Pek district. Field areas ranged from 0.3 to 1 ha per household. Forage species were direct 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 a 50% credit during the 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 fertiliser with farmers able to repay with forage seeds (\$1.5/kg of *B. ruziziensis*). In conclusion, despite positive economical and technical results of cattle fattening, a global approach involving credit access, technical and political support has to be defined to develop productive and efficient systems on this ecology. This poses a great challenge which, if grasped, could yield great benefits on 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, on a medium-term process, research-development programme, systems and technologies to extension agency and private sector. However, self-management of research-development programmes at PAFO and DAFEO 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.

Acknowledgements

The authors wish to thank the Xayabury and Xieng Khouang Provincial authorities. We gratefully acknowledge the support of Mr. Bouasone Daravong, and Mr. Piane Chanthip heads of the Department of Agriculture and Forestry of Xieng Khouang and Xayabury provinces. The authors wish to thank the Ministry of Agriculture and Forestry, the National Agriculture and Forestry Research Institute, and the PCADR for encouraging our activities, and the French Development Agency (AFD), the French Global Environment Facility (FFEM) and the French Ministry of Foreign Affairs for their financial and technical support.

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