On-farm Experiments of Direct Seeding on Crop Residues Southern Xayabury Province

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Abstract

Since the nineties, traditional farming systems in the southern districts of Xayabury province in the Mekong corridor, have changed through extensive agricultural development based on cash crop production. This development, by way of intensification, depends on local market accessibility, technology transfer from Thailand and financial capacity of local enterprises. Thailand is the source of inputs, heavy mechanization and technical skills and cropping is largely opportunistic following Thai market demand. Land preparation based on burning residues and ploughing on steep slopes has allowed for cultivation of large upland areas. As a result of this present development combined with land allocation and increasing population density, fallow periods are disappearing. Furthermore, this 'resource-mining' development generates land erosion, fertility loss, yield decline and chemical pollution as well as destruction of roads and paddy fields. In light of this, the Lao National Agro-ecology Programme has implemented a holistic research approach, in order to propose various systems integrating crops and livestock production to farmers. From a large range of technologies carried out, maize production based on direct seeded grain on former crop residues under no tillage systems has been evaluated. This paper presents results achieved under various conditions with yields obtained close to, and even higher than, those obtained in conventional systems. Labour, costs, soil erosion and increasing income per day are also all observed.

Introduction

Since the nineties, in southern Xayabury, traditional farming systems have changed through extensive agricultural development based on cash crop production. The main dryland crops cultivated are: maize, rice-bean (*Vigna umbellata*), peanut, Job's tears, black bean (*Vigna unguiculata*) and sesame. This development, by way of intensification, depends on local market accessibility, transfer of technologies from Thailand and financial capacity of local enterprises. Inputs, heavy mechanization and technical skills come from Thailand. The cropping system is largely opportunistic related to Thai market demand, no particular crop rotation is followed and usually no fallow period is observed. Land preparation based on burning residues and ploughing on steep slopes has allowed for cultivation of large upland areas every year (Photo 1). As a result of this present development associated with land allocation and increasing population density, fallow periods are disappearing and agricultural systems do not conserve soils and nutrients.

For many years, due to production costs, drudgery of labour for weeding and decreasing soil fertility, farmers have overlooked conventional land preparation and have been shifting from ploughing to herbicides. Spraying before sowing is common and usually goes together with residue burning in order to decrease, for some weeds, the topsoil seed bank. This practice is widely adopted in many degraded areas in southern Xayabury and emphasises the great reactivity, good or bad, of smallholders who relate their practices according to three main ideas:

- Cash income and increasing the area cultivated.
- Labour optimisation.
- Decreasing the drudgery of labour.

However, residue burning, at the end of the dry season, does not protect the soil against erosion and mineral element losses. Soltner (1999) showed that mineral elements contained in cereal straw represent on average two-fifths of the total elements produced above the soil (straw and seeds) for nitrogen and phosphorus, and more than four-fifths for potassium. Results for maize showed that for 4t/ha of seeds, straw contained 32-68 kg/ha of N, 16-20 kg/ha of P_2O_5 and 40-80 kg/ha of K. Moreover, Findeling (2001) showed that soil erosion is reduced significantly even with a small quantity of straw residue.

Crop residue management can be a first step towards reducing losses of soil and mineral elements as well as saving money. The cost of burning is estimated at US$ 50/ha in terms of mineral fertilizer loss for a yield of 4t/ha. Calculated data does not consider returns to the soil from burning (ash production) or from animals free grazing during the dry season.

The use of pesticides is also one of the major problems of this agricultural intensification. Until recently insecticide was not used for cotton production but more recently, its use has been extended to other cash crops such as sesame and rice-bean. The most common insecticide used by smallholders is Folidol, a parathion methyl with high toxicity (lethal dose (LD) of 14 mg/kg). Some herbicides (for example Gramoxone and Atrazine) are also widely used in southern Xayabury.

Gramoxone, is well know globally because of its high toxicity (LD of 157 mg/kg). Gramoxone is used for land preparation after burning or ploughing and it is common to observe spraying of 10 l/ha. The use of Atrazine is more recent and is linked with maize production in southern Parklai. It is frequent to observe spraying of 3 kg/ha, up to fifty days after post-emergence, in order to control *Mimosa invisa*. As described by Naylor (1996), lack of knowledge and often misuse of pesticides, particularly in handling have dramatic consequences for human health and the environment. In addition, to widespread herbicide use, large concentrations of pesticides are applied and could pollute rivers and soil. This is in spite of the fact that many products, which can be used as substitutes for the above chemicals are available on the Thai market. Training sessions, as carried out by Prodessa, the Development Project of the four southern districts of Xayabury Province, are crucial in order to improve choice and handling of pesticides by smallholders.

Comparative indicators (MAF 1999) report that the socio-economic paths of the uplands and of the Mekong corridor diverged during 1994-1998 relating to agricultural sector modification and rural economic growth. During 1994-1998, the mean value of household assets represented US$ 471 and US$ 247 for the Mekong corridor and the uplands, respectively, while this value was in the same order of magnitude (US$ 240) in both locations for the period 1986-1993. Some places, like southern Xayabury, experienced important rural growth related to Thai market demand. However, despite very good soils and high potential for agricultural development, natural resources have been rapidly degraded with negative social and economic impacts. Initial assessment of this resource-mining agricultural development showed dramatic land erosion, destruction of roads and paddy fields (Photo 2, 3) and transfer of capital from Kenethao to Parklai district, which is a new zone for cash crop (particularly maize) production. It is obvious that southern Parklai will quickly experience the same situation as Kenethao.

In many countries, due to the issue of soil degradation, smallholders and different stakeholders (extension, research, private sector) develop alternative systems based on green manure, mulching and the use of cover crops to preserve soil potential, stability of the plant-soil system and farmer livelihoods (Flores 1989; da Silva 1999; Richter *et al.* 2002; Erenstein 2003). Direct seeding mulch based cropping systems (DMC) present a large range of technologies. To be efficient these systems should adhere, as closely as possible, to the natural ecosystem which preserves nutrients, water and soil (Altieri 2002; Derpsch *et al.* 2003; Séguy *et al.* 2003). The main principles of direct seeding are presented in a previous paper (Tivet *et al.* 2004). It is clearly difficult to complete all of these principles in a short-term process with smallholders. In order to convert resource-mining production to a stabilising plant-soil system an iterative approach has been implemented to analyse, for each step, the technical and socioeconomic viability of the technologies. The aim of the present work is to compare maize production under direct seeding on crop residues with conventional ploughing systems in southern Xayabury.

Materials and methods

Until 2002, activities were conducted at an experimental site with little technological adaptation by smallholders. This changed in 2002 with the implementation of a holistic research approach as presented in a previous paper (Tivet *et al.* 2004). This programme emphasises generation and adaptation of technologies, focusing on soil conservation, with village communities and groups of smallholders.

General description of the area

The study was carried out in southern Xayabury. As presented earlier, the main characteristics of this region are related to its integration with the Thai market and the dominance of maize production. Maize is a key crop in southern Xayabury; 13,000t of grain were produced here in 2000 and the region holds the third place for production after Vientiane Municipality and Oudomxay Province (State Planning Committee 2000). Due to its low labour requirements and high labour productivity this crop is widely sown and production spreads to new areas every year.

As presented in a previous paper (Tivet *et al.* 2004) quantitative and qualitative household surveys were carried out with targeted farmer groups in order to acquire information on household conditions and farming systems. These surveys were carried out in two villages in Kenethao, one village in Parklai and one village in Botene during the 2003 season. A total of thirty-one households were surveyed.

In 2003, rainfall in southern Kenethao was 1,254mm, however, distribution was very erratic with little rainfall during the two first weeks in May. A short dry season then occurred from the end of June to the beginning of August.

Table 1: Geological and soil characteristics for some sites of southern Xayabury

District or zone	Geology	Soil Characteristics					On-farm trials
		PH	OM	CEC	K [Co(NH^3)6 Cl^3]	P [Olsen-Dabin]	
			%	meq/100g		ppm	
South of Kenethao	Granite	5.6	3.9	12	0.2	7.0	
West of Kenethao & southwest of Parklai	Clayey schist and green stones	6.4	4.0-4.8	21 - 45	0.3 - 0.9	5.0 - 13.0	Nahin, Paktom and Bouamlao
Botene	Sandstone	6.6	1.4	5.5	0.2	5.0	

Soil analysis was conducted by Brouwers (1998) and Bourguignon (2001) for 0-10 cm.

Sandstone, green stones and clayey schist are the dominant geological formations in the region (Raunet 1996).

On-farm experiments

These experiments were carried out on fields, with and by farmers, on plots of at least of 1,000m^2. Cropping systems were assessed on large experimental plots, under conditions that matched those found on farms in the region. Moreover, conventional land preparation was replicated on both sides of the direct seeding plots and arranged on landscape slopes in order to take fertility gradients into account (Photo 4). The number of fields differed between the zones with 3, 5, 8, 5 and 3 sites respectively in Kengsao, Bouamlao, Paktom, Nahin and Houay Ihoum. Some geological characteristics of these sites are presented in Table 1.

Cropping system components

Two main land management practices were evaluated:

- Conventional (burning and/or ploughing)
- Direct seeding with residue management.

Conventional (burning and/or ploughing)

As presented previously, ploughing or pre-sow herbicide used after burning is widespread in southern Xayabury. Conventional practices in Houay Lhoum and Nahin village are based on the use of Gramoxone sprayed with a pump. In these situations, a comparison was carried out between DMC systems on residues and herbicide use after burning.

Direct seeding with residue management.

At the beginning of the rainy season, residues of the former crop were preserved and systemic herbicides (3 l/ha of Glyphosate + 1.5 l/ha of 2.4-D) are applied to control weeds. This broad-spectrum association allows for control of a large number of weeds. Many authors (Nalewaja and Matysiak, 1993a; Thelen *et al.* 1995) have analysed the efficiency of Glyphosate and reported a strong negative interaction with calcium ions which limits cuticular penetration. Nalewaja and Matysiak (1993a) showed that calcium-sulfate complex can prevent the precipitation of Glyphosate-calcium. As suggested by Nalewaja and Matysiak (1993b), ammonium sulfate showed the greatest efficiency in complexing calcium ions. Because of the lack of ammonium sulfate, sulfuric acid (battery acid), which is very common and cheap but extremely hazardous, has been used at 15 ml per 18l ml with a sprayer; pH of the solution then drops to 3.

Ten days after spraying, crops are sown using a hand-jab planter. With crop residue management, the sowing date may be delayed two weeks. The use of a nonselective herbicide such as Glyphosate requires specific weather conditions and weed physiology. At the beginning of the rainy season the seedling rate is quite low while various weeds in fields have survived through the dry season. Leaves of many weeds have high quantities of cuticular wax in order to decrease water loss by transpiration. This wax is the main obstacle for Glyphosate penetration on leaves (Deschomets 2001). In addition, environmental conditions, specifically temperature and humidity, are not well adapted for spraying.

Three main cultivars are used in this region:

- A maize hybrid from CP[1] widely used in southern Parklai.
- Suwan 2.
- A heterogeneous population resulting from breeding between the above cultivars, sown in Kenethao and Botene districts.

Cultivars were sown between April 20 and May 15, 2003 according to the opportunities and constraints of each zone. For the hybrid, the planting density suggested by CP was followed with about 53,333 plants/ha (0.75*0.50m, two seeds per hole, 15 kg/ha). On the other hand planting density for Suwan 2 and the heterogeneous population ranged from 40 to 80 thousand plants/ha according to smallholder's strategies (weed control). After seedling emergence, fluctuations were observed in plant density due to seed quality and rodent damage.

In order to assess the evolution of the systems over time, two levels of mineral fertiliser were applied:

- Conventional system and one direct seeding plot without the use of mineral fertiliser
- Second plot of direct seeding with medium level of mineral fertiliser to compensate for nutrient exportation by grains.

Fertiliser was applied during sowing with the hand-jab seeder as follows:

- 60kg N as ammonium sulphate.
- 60kg P_2O_5 as triple superphosphate.
- 60kg K as KCl per hectare.

[1] Chareon Pakpong: Seed producing company based in Thailand.

Due to the chemical characteristics of the soil it is not necessary to apply potassium for the zone on green stones. However, in order to simplify the experiments the formulation of 15-15-15 was applied across all the sites. This cost of production is estimated at US$ 100. Mineral fertilisation is supposed to balance losses of mineral elements due to seed exportation.

Data collection and economic analysis

Labour requirements were recorded for all activities (land preparation, sowing, weeding, harvesting). Yield and overall performance was recorded for each treatment. However, the philosophy under which the experiments were carried out allowed for qualitative analysis in order to evaluate the socio-economic viability of these systems. Production costs included ploughing, seeds, sprayer, hand-jab-seeder and hoe. Specifically, one third of the cost of a sprayer (US$ 30) and hand-jab seeder (US$ 15) has been used.

Before sowing, dry matter on the soil was recorded from $4m^2$ samples with 12 replicates per plot. One sub-sample was removed in order to determine the dry weight.

Destructive measurements were carried out at the harvesting stage on plots of $4m^2$ with eighteen replicates per treatment. For each sample, the number of hills, plants and ears, fresh weight of biomass (leaves and stems) and ears were recorded. In order to determine the dry weight of biomass and ears one sub-sample for each treatment (2kg for biomass and 50 ears) was removed. The dry weight of each component was determined after drying for 96 hours at 60°C. The weight of 500 dry seeds was recorded.

Results and discussion

Surveys on cash crop production

Some results relating to the mean cultivated area, labour requirements per crop, labour productivity per crop and net income, are presented according to location of the experiment.

1. Parklai District: Since recently, cropping in southern Parklai (data recorded in Bouamlao) has only shown a low level of diversification. Smallholder maize production is widespread across large areas covering more than 70% of the total cultivated land area (lowland and rainfed). At the same time, maize production represents a net income of at least US$ 200/ha. Labour inputs (lowland and cash crop) represent 83 days per worker and net cash crop income is estimated at US$ 450 per household. During 2003, due to price instability, few areas were sown with Job's tears.

2. Botene District: In contrast with southern Parklai, a combination of multicropping and animal husbandry is observed in Botene, allowing for a balanced distribution of farming activities over space and time. The main dryland crops are maize, peanut, blackbean, rice-bean and sesame. These production strategies aim to reduce climatic and economic risks in a fragile ecosystem. Labour requirements (lowland and cash crop) represent 103 days per worker and net cash crop income is estimated at US$ 175 per household. In this pattern, maize production represents 39% (US$77) of cash crop income. Limiting factors for production of Job's tears and rice-bean are observed, relating to sandy soil with low water capacity retention at the end of the rainy season.

3. Degraded zones in Kenethao District: present a large array of crops; maize, peanut, rice-bean which can be sown in the same field with maize, Job's tears and sesame in order to minimize, as in Botene district, climatic and economic risks. Because of these diversified schemes, labour input is higher and represents 137 days per worker. Net cash crop income per household is higher with US$ 491 per household. However, this situation relates to the good price for Job's tears and rice-bean in 2003 following low production due to erratic rainfall. These surveys show that maize production is minor accounting for less than 11% (US$ 90 per householder) of cash crop income. Regarding soil degradation it is interesting to see that maize productivity (per ha) in Paktom, which has the same geological substratum as Bouamlao, drops greatly with US$ 86/ha and US$ 212/ha respectively. Moreover, labour productivity of maize is lower than upland rice with US$ 1.1 per day. In a few years, land preparation based on ploughing generates heavy soil degradation and depletion of natural resources. Rural stability is based on this natural capital but seasonal migration from Kenethao and Botene is frequently observed due to the rural economy collapsing.

Table 2: Main household characteristics related to cash crop production in southern Xayabury. Surveys conducted in 2003 by students of the Faculty of Agriculture of Nabong

Crops	Vilage	Mean area per household	Labour inputs days/ha	Net Income			Labour Productivity USD/day
				household	labour	ha	
Lowland rice	Paktom	0.36	136	133	35	371	2.7
	Nongpakbong	0.61	124	324	114	510	4.1
	Bouamlao	0.89	114	428	151	456	4.0
Upland rice	Paktom	0.55	154	104	29	189	1.2
	Nongpakbong	0.11	139	18	7	169	1.2
	Bouamlao	0.03	156	6	2	220	1.4
Maize	Paktom	1.05	81	90	26	86	1.1
	Nongpakbong	0.60	66	77	30	124	1.9
	Bouamlao	2.27	60	450	159	212	3.5
Peanut	Paktom	0.22	219	62	16	312	1.4
	Nongpakbong	0.43	181	64	23	151	0.8
Job's tears	Paktom	0.43	81	178	46	373	4.6
Rice-bean	Paktom	0.23	143	131	36	513	3.6
	Nongpakbong	0.29	86	28	12	124	1.4
Maize + rice-bean	Paktom	0.21	82	27	8	118	1.4
Sesame	Paktom	0.03	82	4	2	110	1.3
	Nongpakbong	0.03	81	6	2	240	3.0

Table 3: Mulch remaining at the end of the dry season; on-farm experiments in southern Xayabury. Mean (kg.ha^{-1}) ± SE for 4 to 12 replications is given.

	Sites	
Species	**Southern Parklai**	**Kenethao**
Maize	2,137 ± 299	1,919 ± 81
Job's tears	3,586 ± 306	3,501 ± 377
Rice-bean		2,359 ± 231

Mulching before sowing

A layer of mulch, even a thin one, limits soil erosion by decreasing the kinetic energy of raindrops and run-off intensity (Abrahams *et al.* 1994; Dilshad *et al.* 1996). Interception of rainfall by residues is proportional to their biomass (Arreola Tostado 1996). Moreover, run-off intensity is decreased because of the sinuous pattern that is generated by residues. This wavy pattern increases the path and decreases the effective slope met by the run-off. Findeling (2001) reported that 4.5 t/ha of biomass can represent a 30% slope reduction and reduce run-off intensity by 20%. Gilley *et al.* (1986) showed that the micro-channels generated by residues concentrate a large part of run-off and sediments. Furthermore, this protective layer enhances soil surface aggregate stability and permeability (Findeling 2001; Erenstein 2002). In the on-farm experiments described in this paper, dry matter at the beginning of the rainy season ranged from 2.0 to 3.5 t/ha (Table 3), referring mainly to maize, Job's tears and rice-bean residues. However, this data refers only to the large particles of residues and hides the small aggregates of soil and straw, which greatly reduce run-off intensity (Photo 5 and 6).

Job's tears and rice-bean are interesting crops because of their:

- Low residue degradation due to a high lignin content, which enhances soil protection by reducing both evaporation and weed pressure (particularly for rice-bean).
- Low rate of C/N for rice-bean residues which avoids mineral nitrogen competition between the crop and micro-flora at the beginning of the rainy season.
- Low level of animal exportation relating to the low palatability of both species.

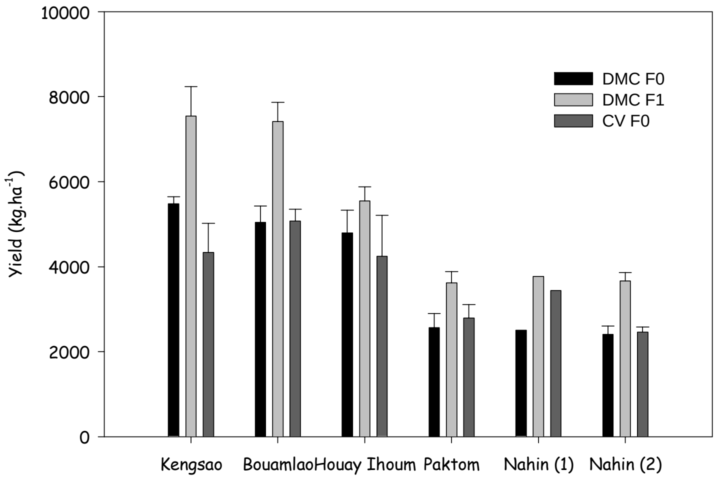
Below ground dry matter was not measured but biological improvement of soil structure by rooting systems is crucial. A crop of Job's tears with long duration and strong rooting system is a good companion crop to ensure this function.

Yield and dry matter

For each treatment grain yield variations for maize, according to site characteristics (landscape, soil units) and cultivars, are important. Such results reflect differences in soil erosion and fertility. For example it is acceptable to consider that Paktom, Nahin and Bouamlao have the same geological substratum, however, large differences in yield are observed.

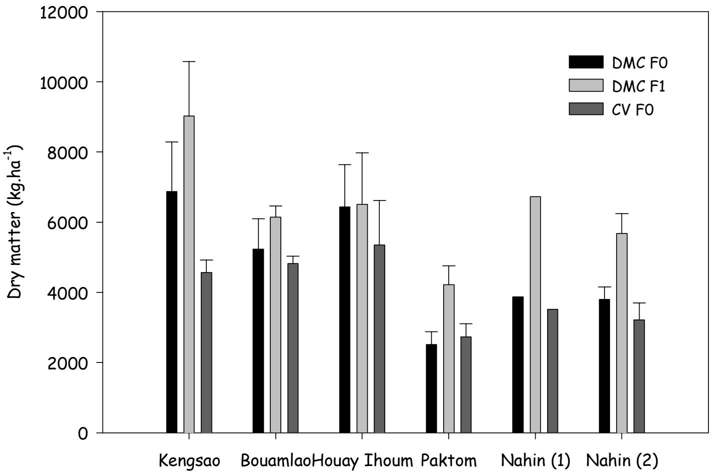
Southern Parklai (Kengsao and Bouamlao) and along the Heuang river (Houay Ihoum), are recent areas for maize production and hybrid cultivars are widely used. Yields usually reach 5 t/ha (Figure 1). Maize production is generally higher when crop residues are preserved but the difference in yield is not statistically significant. For southern Parklai,

Figure 1



Key: DMC: direct seeding with residue management; CV: conventional–ploughing; F0: without mineral fertilizer; F1: 400 kg/ha of 15-15-15. Nahin (1) ploughing and Nahin (2) pre-sow herbicide use after burning for conventional land preparation.

Figure 2



Figures 1 and 2: Mean yield and dry matter SE (kg/ha) from residue management and conventional - ploughing land preparation. Data is from two to eight on-farm trials of 1,000 m².

Figure 1 presents a yield increase of 56% with use of fertiliser, which can counterbalance the cost of production. In contrast, the use of fertiliser does not appear to be suitable for fields located along the Nam Heuang River. Low radiation interception, related to surrounding fallows, and alluvium soils could explain this. However, long-term experiments are necessary to confirm this result.

In the most degraded areas in Kenethao (Paktom and Nahin) average yields reach 2.4 t/ha with conventional maize populations. With DMC systems, although yield levels were close to, or even lower than, those obtained in conventional systems (Figure 1) no significant difference was observed. For two on-farm experiments in Paktom a maize hybrid was used but yield, with conventional land preparation, ranged from 1.5 to 3.2t/ha. Farmers do not usually sow this cultivar, which is not economically viable under conditions of low soil fertility and high weed pressure. In Nahin, yields were similar between pre-sow herbicide use after burning and residue management (Nahin 2).

Erenstein (2003) reported that short-term yield effects often depend on the mulch, crop and site characteristics; therefore a number of seasons are necessary to stabilise the system. Moreover, with low mulch covering of the soil and poor soil structure, yield is frequently lower with direct seeding technologies. As described in a previous paper (Tivet *et al.* 2004) and by Séguy *et al.* (1998), soil characteristics must be improved in order to generate a system that conserves water and nutrients with good organic composition to restructure the soil. Moreover, enhancement of soil biological activity is crucial as below ground insect and microbial populations improve soil structure and plant nutrition. Because conventional agriculture has greatly modified the soil, medium and long term processes are required for these main functions to be completed

In southern Parklai and along the Nam Heuang river maize crops generate high quantities of dry matter which can control weeds and efficiently protect the soil at the beginning of the next season (Crovetto 1996; Scopel *et al* 1999). In the experiments, dry matter ranged from 2.5 to 6.4 t/ha with residue management and from 2.5 to 5.4t/ha with conventional land preparation. Exportation by animals occurred at many sites and obviously this biomass will not be on the soil at the beginning of the next season. No quantitative analyses were recorded to evaluate physical and biological evolution of the soils after two years of crop residue management. Qualitative analysis showed an enhancement of biological activity and aggregate stability in comparison with conventional practices. However, in many areas of Kenethao, production with residue management is quite low (2.5 t/ha) and the biophysical advantages of mulching are largely forfeited.

External inputs such as fertilisers and improved cultivars may present three main advantages:

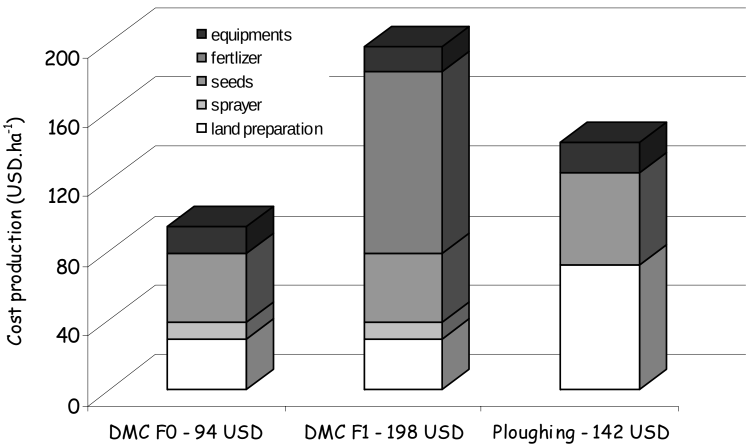
- Decrease constraints to crop growth.
- Increase labour productivity in good soil.
- Boost yield and dry matter production.

Large variations in dry matter yield ratio were observed. In many situations this ratio ranged from 1.0 to 1.25 but in Nahin this value reached 1.7 misrepresenting a low potential of this cultivar to generate grain. Populations (resulting from breeding between CP 888 and Suwan 2) are heterogeneous in terms of duration, weed competitiveness and yield. As observed in previous work (Soulayakham *et al.* 2002), a drop in yield of 1 t/ha is observed with the first generation of CP 888. This is linked to less seeds per ear.

Economic analysis

Production cost and net income

High variations are observed for economic components - such as production costs, net income and labour productivity – mainly related to a few replications and site characteristics (Table 4). One example of analysis of production costs referring to southern Parklai is given in Figure 3. For ploughing, production costs ranged from US$ 40 to 125



Key: DMC: direct seeding with residue management; F0: without mineral fertilizer; F1: 400 kg/ha of 15-15-15.

Figure 3: Cost production analysis in southern Parklai, mean of six replications is given.

per ha depending on the slope, distance from the main road, stones and/or stumps in fields. In comparison, the cost of herbicide spraying is about US$ 30 per ha.

Except for the on-farm trials conducted in Houay Ihoum and Nahin (2) production costs were reduced by between 31 and 48% with residue management representing a gain of US$ 36 to 72 per ha (Table 4). In southern Parklai (Bouamlao and Kengsao), net income per ha was highly significant with values close to US$ 230 and US$ 135 per ha for direct seeding and conventional system respectively. Only in this zone was a higher net income observed with the use of mineral fertiliser because of good soil fertility and lower weed pressure. However, pre-sow herbicide use after burning (Nahin (2) and Houay Ihoum) presented lower costs of production and higher net income related to low investment for equipment (no hand-jab seeder) and no post-sowing herbicide application.

Labour requirements and labour productivity

Crop management is greatly modified with herbicide-based residue mulching. A delay in sowing date and less calendar flexibility have been observed for early crops (peanut and maize), which benefit from rainfall at the beginning of the rainy season. However, no particular adverse effect has been observed in yield and labour inputs.

In all on-farm experiments a mean gain of 17 days/ha was observed with residue mulching (Table 4). This gain is linked to less labour inputs for sowing, weeding and eventually spraying herbicide. Large mechanisation adaptations are necessary; seed distribution by the hand-jab seeder has to be improved specifically for the expensive maize hybrid (US$ 2.2/kg). Using conventional pump spraying, smallholders manipulate a large quantity of water (1,000 l/ha), which can contribute to water and soil pollution. Low volume spraying of 100 l/ha was achieved with a nozzle from Berthoud (BV 30).

Labour inputs for weeding depend greatly on the history of the field and on the nature of the former crop. Rice-bean (*Vigna umbellata*) is an ideal crop to start a direct seeding system on residues. With a long cycle duration (seven months), this species

Table 4: Data ± SE from on-farm experiments conducted in 2003 in southern Xayabury. Mean value, Yield, Production cost, Net income, Labour inputs and Labour productivity are presented for five situations. Data is from three to eight on-farm trials of 1000 m^2 per treatment.

Key: DMC: direct seeding with residues management; CV: conventional – ploughing; F0: without mineral fertilizer; F1: 400 kg.ha^{-1} of 15-15-15.

	Treatment	Kengsao	Bouamlao	Paktom	Nahin		Houay Lhoum
Components	Replications	3	5	8	2	3	3
Yield (kg/ha)	DMC F0	5481 ± 167	5044 ± 379	2563 ± 329	2507	2407 ± 196	4789 ± 537
	DMC F1	7542 ± 693	7413 ± 451	3616 ± 268	3769	3666 ± 195	5549 ± 329
	CV F0	4332 ± 691	5073 ± 281	2787 ± 316	3438	2461 ± 120	4242 ± 965
Production cost (US$/ha)	DMC F0	116 ± 13	93 ± 3	52 ± 5	46	50 ± 9	83
	DMC F1	220 ± 13	198 ± 3	145 ± 11	153	155 ± 9	191
	CV F0	169 ± 39	142 ± 23	88 ± 8	84	32 ± 2	67 ± 16
Net income (US$/ha)	DMC F0	227 ± 19	222 ± 23	82 ± 17	84	75 ± 19	291 ± 41
	DMC F1	252 ± 53	265 ± 27	43 ± 11	43	36 ± 8	242 ± 25
	CV F0	102 ± 53	175 ± 39	57 ± 19	95	96 ± 7	264 ± 66
Labour inputs (days/ha)	DMC F0	62 ± 5	55 ± 9	61 ± 4	64	65 ± 1	67 ± 6
	DMC F1	65 ± 2	65 ± 9	67 ± 5	65	64 ± 4	67 ± 6
	CV F0	75 ± 7	70 ± 6	74 ± 7	93	83 ± 6	82 ± 5
Labour productivity (US$/day)	DMC F0	3.7 ± 0.1	4.0 ± 0.8	1.3 ± 0.2	1.3	1.2 ± 0.3	4.3 ± 1.0
	DMC F1	3.9 ± 0.8	4.1 ± 1.4	0.6 ± 0.2	0.7	0.6 ± 0.2	3.6 ± 0.4
	CV F0	1.4 ± 0.7	2.5 ± 0.7	0.8 ± 0.3	1.0	1.2 ± 0.2	3.2 ± 0.6

covers the soil rapidly at the beginning of the rainy season and competes fiercely with weeds.

Little data was recorded in the field but it is common to observe a decreasing number as well as a change of weeds in the second year of direct seeding. In southern Parklai, with residue management, *Ageratum conizoïdes* became the dominant species and *Mimosa invisa*, which is the major weed associated with ploughing and burning, was significantly reduced. Dominance of this species in the conventional system is mainly related to the fact that burning tends to boost seedling emergence (Lao-IRRI 2000).

Except in one situation (Nahin 2), labour productivity increased with residue management and was highly significant in Bouamlao, Kengsao and Houay Ihoum ranging from US$ 3.7 to 4.3 per day (DMC F0). As reported previously, this component is an interesting guide to defining agricultural constraints.

Socio-economic viability

Many elements must be taken into consideration to appreciate the complexity of socio-economic viability. In contrast with semi-arid conditions, the level of residue exportation is quite low in sub-humid areas (Erenstein 1999). However, maintaining crop

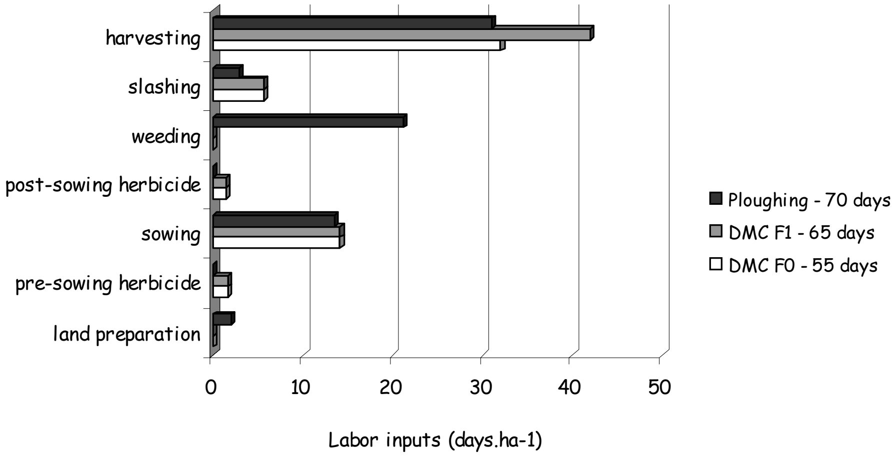


Figure 3: Labour inputs in southern Parklai, mean of six replications is given. Labour inputs for threshing and transport are not presented. Sowing was carried out without the use of a hand-jab seeder.

residues on fields is a difficult process where land management modification during the dry season has to occur. In southern Xayabury, it is common to observe wild-fires during the dry season that are imposed upon farmers by others. This problem relates to mutual land management because it is unrealistic for smallholders, with little available labour, to make firebreaks. Conserving residues has to take place in a setting whereby residue rights are defined and respected by the community. As proposed by the programme and as suggested by Sain and Barreto (1996), one option is to enhance the attractiveness of mulch, linking this component to other technological changes that tend to increase cash income – such as new cultivars or fertiliser use.

Moreover, economic incentives such as provision of credit have to be promoted. As observed in southern Xayabury and reported also by Petersen *et al.* (1999), one of the major limiting factors to adoption may be that the practice promoted was first perceived as being closely associated with a need to use cash income for equipment and inputs. In southern Xayabury, traders gave ploughing and seed credit at the beginning of the season. For many smallholders, even if higher interest rates (50% over 8 months) are used, this function is overall a positive one as it gives them the opportunity to not have to use any cash.

Conclusion

Positive or neutral results of direct seeding systems based on residues were shown in southern Xayabury where growing interest and potential for widespread adoption have been observed with a lot of smallholder requests for technical and financial support. Any increase in fields and number of farmers will be evaluated during the next season.

However, to complete all of the biophysical and economical advantages of DMC systems involves a long process. In order to overcome the constraints of residue management technologies an iterative approach of generating and adapting technologies has to be organised by village communities and groups of smallholders with the support of research and extension agencies. The amount of residues remaining on fields is relatively low due to low production, biomass weathering and animal exportation. This does not ensure good soil protection and/or weed control. In order to efficiently control weeds (smothering and/or allelopathic effect) and thereby generate systems that are less dependent on herbicides, DMC systems have to be progressively improved with rational crop rotations, relay crops and cover crops (Kegode 1999; Florentin *et al.* 1991; Petersen *et al.* 1999). Enhancing attractiveness of residue mulching - cover crops and generating short-term profit (cash or labour) is essential. DMC systems are most likely to be adopted when their uses address specific opportunities (fodder, grain for feeding small animals) and have rapid short-term pay-offs for smallholder (Erenstein 2002).

The impacts of herbicides on environmental and human health have long been addressed by DMC systems. Many authors report that the use of pesticides (herbicides and insecticides) decreases rapidly under DMC systems with appropriate use of mulching and cover crops (Jansen 1999; Scopel 2003). Moreover, DMC systems which exhibit high biological activity (macro fauna and micro flora) actively degrade pesticides (Crovetto 1999). The trapping effect of mulch for Glyphosate was analysed by Jansen (1999) who reported that herbicide concentration in soil (active matter) was estimated at 0.03 mg/kg and 1.29 mg/kg, with DMC systems and conventional spraying on bare soil respectively. However, permanent evaluation of effects on pesticides must be evaluated under different DMC and conventional systems.

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Photos

Photo 1: Conventional land preparation in southern Xayabury: ploughing and residues burning. Village of Kengsao, southern Xayabury, 2004.

Photo 2: Land erosion generated by ploughing and destruction of paddy field. Village of Nam Leng, southern Xayabury, 2004.

Photo 3: Ploughing on steep slope, southern Xayabury, 2004.

Photo 4: Comparison of conventional land preparation based on ploughing and DMC systems based on residues management. Rice-bean crop, village of Nahin, 2004.

Photo 5: Direct seeding of rice-bean on Job's tears residues, southern Xayabury, 2004.

Photo 6: Direct seeding of maize on former crop residues, southern Xayabury, 2004. Left side: conventional land preparation; right side: DMC systems.