**Abstract**

Increasing population pressure is reducing fallow periods in the traditional slash-and-burn rice based upland systems of the Lao PDR. Short fallow periods have rendered these systems unsustainable as soil erosion, weed pressure and labour inputs have increased; and soil fertility and yields declined. The end result is lower returns on productivity and increased poverty. This situation has created a demand from both farmers and government agencies for sustainable agricultural technologies to improve upland farmer livelihoods.

Over the years considerable research effort has been devoted to the development of sustainable upland technologies, however, adoption by farmers has been limited. One reason for slow adoption is the high diversity encountered in the uplands. There is considerable biophysical diversity (as seen in differences in climate and soils), socio-economic diversity (such as ethnic and cultural diversity and large differences in opportunities and constraints between individual households) and market diversity (particularly market opportunities and market access). With such diversity, technology recommendations will necessarily be site specific. This diversity necessitates the use of participatory and adaptive research approaches through which researchers and farmers can develop technologies suited to local conditions.

The authors’ objective is to develop more productive and sustainable upland rice-based cropping systems. Ensuring rice sufficiency at the local level will allow for greater diversification in other upland fields. A multifaceted, participatory and adaptive research approach has been used to develop sustainable upland systems, which has resulted in the development of a number of technologies. First, superior upland rice varieties were identified. Traditionally, local upland rice varieties grown in Laos have been selected for their performance under favourable conditions with long fallow periods and, as such, are not well suited to short fallow conditions. Through a participatory variety selection (PVS) programme, two upland rice varieties have been identified which yield 0.3 - 0.5t/ha more than local check varieties (an 18-27% increase in yield). Second, improved rotational systems that address problems related to weeds, soil fertility and declining yields are being developed and tested by farmers. Depending on population pressure, potential cropping systems range from extensive (for farmers that still rotate fields) to intensive continuous cropping on the same piece of land. Examples of extensive systems are rattan, paper mulberry and pigeon pea rotated with rice on a three-year cycle. Intensive systems involve continuous cropping rotations with dry season fallows. This paper discusses these technologies in greater detail as well as the process by which these technologies were developed.
Upland rice systems in Laos - systems in peril

Rice is the most important crop in Laos and accounts for about 70% of total calorie intake across the nation (Maclean et al., 2002). Although at the national level Laos is sufficient in rice, northern Laos suffers a rice deficit, a situation that has either not improved since 1975 (figure 1) or is getting worse (ADB, 2001). This deficit is linked with increasing population pressure. Population pressure is increasing due to natural causes, but also due to village migration and land allocation policies, which have increased population pressure on limited land resources, especially along roads. Such pressures are putting stress on the fragile slash-and-burn agricultural systems in much of northern Laos resulting in declining upland rice (staple crop) yields and increasing poverty.

Upland rice is the main crop grown in the highlands of northern Laos where rice is grown in slash-and-burn systems. The normal rotational system for upland rice in slash-and-burn systems is a single year of rice followed by two or more years of natural or weedy fallow. Traditionally, fallows have been for up to 40 years but increasing population pressure is often reducing fallow periods in these systems to only two years. While it is not possible to provide a general figure for a minimum sustainable fallow period, all would agree that two-year fallows are not sustainable under current management practices. Short fallow periods have rendered these systems unsustainable as soil quality (due to nutrient depletion and erosion) is worsening, weed pressure and labour inputs are increasing and yields are declining with the end result being lower returns on productivity and increased poverty. This is supported by numerous surveys where farmers report that rice yields are declining and rice deficits are increasing. Since rice sufficiency is strongly associated with well-being, poverty is increasing as a result of short fallows (ADB, 2001). In upland rice systems short falls are resulting in a heavy investment in weeding. Farmers need to weed up to five times per season when the fallow is two years or less, compared with twice in a ten-year fallow (figure 2). Weeding alone accounts for about 50% of the total labour requirement of rice (150 person days/yr or more).

These issues have created a demand from farmers and government agencies for alternative agricultural solutions. Such solutions could either be:

- Improved rice production systems
- Alternative cash crops that allow for income generation and cash to buy rice.

Experiences from other Asian countries suggest that farmers are much more likely to diversify into other crops once they have achieved self-sufficiency in rice. Thus rice sufficiency is a platform for diversification. Lao-IRRI and NAFRI have been working together since 1991 to develop sustainable rice based systems. Research has focused on improving productivity and developing highland paddies (discussed by Pandey et al., in this book) as well as upland rice based systems. The following paper discusses the problems, challenges and progress to developing improved upland rice based systems.

Intensification of rice based systems

Land use and labour intensify as systems move from traditional slash-and-burn systems with forest fallows to annual cropping systems (figure 3). In Laos, traditional upland rice production practices have not changed despite shortening fallows, and this
Shifting Cultivation and Poverty Eradication in the Uplands of the Lao PDR has led to declining productivity. Research is necessary to identify improved cropping systems that are sustainable under the current land management practices.

Where villages have undergone land allocation, farmers typically have three plots of land; therefore the maximum fallow is two years. In alignment with this policy, research has focused on developing alternative upland rice based systems for zero (annual cropping) to two-year fallows. A multifaceted research approach is used that combines the development of suitable varieties with alternative rice based cropping systems (figure 3).

Alternatives for short fallow systems

**Varieties**

Traditional upland rice varieties are grown extensively in the uplands of Laos, in fact, there are no known improved upland varieties being grown. The diversity of varieties is high with most villages growing 10 to 20 different varieties and a single farmer growing two or three varieties on average (Appa et al., 2002). These varieties have been selected for long fallow conditions and are generally not suited to the short fallows that many farmers are currently experiencing.

Since 1991, the Lao-IRRI project has been collecting and preserving traditional Lao rice varieties. There are currently over 13,000 accessions in the Lao gene bank, with about half of these being upland rice varieties. The variety improvement program is screening these varieties to identify early and medium duration varieties that are suited to short fallsows. Final testing and evaluation of varieties is done through participatory variety selection (PVS) trials under farmer management. Such trials have been conducted in all the northern provinces of the Lao PDR. Through this programme, two upland rice varieties (Nok and Makhinsoung) have been identified which yield 0.3 - 0.5t/ha more than local check varieties which is an 18-27% increase in yield (figure 4). Nok is an early duration variety that has good yields and receives high farmer preference ratings due to its large seed and panicle, ability to perform in poor soils and high quality (aroma and softness). Makhinsoung is a medium duration variety that also receives high farmer preference ratings although the grain quality is lower than Nok.

While much of the research has focused on glutinous rice varieties, the programme has started evaluating non-glutinous rice varieties that may be more preferable to certain ethnic groups. These varieties come both from Laos and other countries. On-farm testing began in 2003.

**Cropping systems**

For systems with only two or three-year fallows to be sustainable, some form of fallow enrichment is required. Shrubby legumes are often suggested as possibilities as they add nitrogen to the system by nitrogen fixation and other nutrients due to deep rooting depths.

Farmer participatory research began in 2001 by testing a number of promising fallow species:

- leucaena (*Leucaena leucocephala*)
- pigeon pea (*Cajanus cajan*)
paper mulberry (*Broussonetia papyrifera*).

crotalaria (*Crotalaria anagyroides*).

All are legumes except paper mulberry, which was included since it is an indigenous fallow crop in northern Laos. Crotalaria and pigeon pea performed the best in the first year (data only available for fallow species establishment) but farmers preferred paper mulberry and pigeon pea because of the potential economic benefits, especially paper mulberry (table 1). Based on these results, the requirements of a good fallow or rotational species are that it:

- Provides some economic benefit.
- Is easy to grow and maintain.
- Requires minimum labour.
- Maintains or improves rice yields (presumably through nutrient replenishment and reducing nematode pressure).

The challenge for research is to not only identify species that suit these criteria but ones that also address the long term challenge of sustainability so that yields are maintained, soil fertility is replenished, weeds remain under control and soil erosion is reduced. Further research on short fallows has focused on paper mulberry, pigeon pea and rattan (also an indigenous fallow crop) in one to two year rotations with rice (figure 3).

**Rice - Paper mulberry rotations**

Paper mulberry has become an important cash crop in northern Laos. The inner bark is harvested and used for paper production. Paper mulberry is an indigenous fallow species and research has focused on the feasibility of intensifying paper mulberry as a rotational crop between rice crops. After establishing paper mulberry into upland rice the paper mulberry will continue to grow after the rice has been harvested. The paper mulberry is harvested 1.5 to 2 years after establishment and harvesting can continue until the next rice crop, at which time all the paper mulberry is harvested and the trees cut down in order to prepare the field for rice. The paper mulberry will regenerate from roots and stems during the rice growing season to continue the next cycle. Research on rice-paper mulberry rotations has focused on the following aspects:

- Paper mulberry establishment into upland rice fields: Three planting materials were tested (seedlings in polybags, root suckers and root cuttings). Survival and growth was best for the seedlings followed by root suckers (table 2). In all cases, paper mulberry growth was slow during the first year of establishment and did not reduce rice yields. However, due to this slow initial growth, weeding is still necessary after rice harvest until the paper mulberry has become fully established.

- Estimation of paper mulberry bark yield: A survey of 17 farmers was conducted which included crop cuts for above ground biomass (ranging from 1.5 to 27t/ha) and bark yields (ranging from 0.1 to 1.9t/ha). From this data a model was developed from plant height, stem diameter, and stem density that explains 95% of variation in bark yield (figure 5).

\[
\ln(\text{Bark yield}) = 0.82 \times \ln(\text{Height} \times \text{Diameter}^2 \times \text{Density}) - 7.02
\]
Rice production in a regenerated paper mulberry field: When paper mulberry regenerates from its roots and stems it is highly competitive with rice, unlike during the initial establishment phase. In order to sustain rice yields, the regenerated paper mulberry needs to be carefully managed by keeping it at a low density and at a lower height than the rice canopy. Densities of more than 1 plant/4m² have been shown to reduce rice yields (figure 6).

Nutrient cycling: Current research is studying nutrient cycling in these systems to determine if such systems are sustainable in terms of maintaining or building soil fertility. As of yet results are not available.

While the rice - paper mulberry system is indigenous to Laos, few farmers have attempted to intensify the system by planting and closely managing the paper mulberry. Instead they let a few trees come up and then harvest those. As long as the market remains good for paper mulberry this system has potential. It is also attractive in that most of the labour requirements for paper mulberry are during periods when labour demand for rice production is low. The main limitation to this system is livestock control. Cows and buffaloes graze on paper mulberry leaves and prevent good establishment unless the area is protected.

**Rice - Pigeon pea**

Pigeon pea has been evaluated as a potential rotational crop with rice since 1991. It has shown good promise in terms of its ability to suppress weeds, reduce nematodes (Roder et al., 1998) and maintain rice yields. It also has economic potential, although this has yet to be fully realized due to limited market potential. Where there is market potential farmers have shown strong interest.

The system is described as follows. Pigeon pea is planted three to four weeks after rice at a spacing of 1.25m x 1.25m. The late planting and wide spacing reduces competition with rice. The pigeon pea grows along with the rice and continues to grow after the rice has been harvested. Pigeon pea is a perennial and pods can be harvested once a year - usually in March and April. Grain yields range from 0.3 to 1.0 t/ha. The pigeon pea remains in the field (it can survive for two to three years) until the field is ready to be prepared for the next rice crop when it is then cut. When planting the next rice crop, pigeon pea will need to be planted again.

A good review of work conducted by Lao-IRRI up to 1996 on this system can be found in Roder et al. (1998). Here they report on pigeon pea variety and management trials. Roder et al. (1998) report that rice yields decline when pigeon pea is established with rice. However, this is most likely due to the high pigeon pea density used in those trials (plant spacing of 1.0 x 0.25m) and that pigeon pea and rice were planted at the same time. In more recent studies a lower pigeon pea density (1.25 x 1.25m) has been evaluated. When planted at this density three weeks after rice, rice yields are not reduced and pigeon pea yields average 0.5t/ha.

The rice - pigeon pea system is being evaluated for different length fallows. In two separate three-year studies involving one-year fallow systems (one year between rice crops) rice yields after pigeon pea were highest compared to all the other treatments, including natural and enriched fallows (Figures 7 and 8).
**Rattan**

An upland rice-rattan system was observed in Luangnamtha where rattan is an indigenous fallow crop between rice crops. In this system, rattan is harvested just before slashing the fallow vegetation in preparation for burning and land preparation. The rattan survives the cutting and burning and farmers allow it to regenerate during the upland rice cropping period. After the rice is harvested, the field returns to its natural fallow vegetation where rattan remains as one of the species. Due to the short fallows the rattan is harvested for edible shoots (as opposed to furniture material). Only certain species of rattan can survive both cutting and burning and this deserves more research, however, it is thought that *Daemonorops jenkinsiana* is one such species.

**Alternatives for annual cropping**

Development of improved annual upland rice based systems presents a unique challenge compared to other cereal crops grown in similar environments. Rice yields decline rapidly when continuously cropped for reasons that are not well understood. In a five-year experiment conducted in Luangprabang, upland rice yields declined from over 3t/ha to 0.5t/ha when rice was grown every year (figure 9). Such results are seen elsewhere in Laos (Figures 7 and 8), Asia (George et al., 2002) and South America (Evenson et al., 1995; Sanchez, 1983). Yields declined even when nitrogen (N) fertilizer (30kg N/ha at booting) was applied or when rice was grown between legume hedgerows (legumes were planted in rows at 1.5m spacing with four rows of rice grown in between) (figure 9). Results of other studies also indicate that nutrient limitations (including phosphorus) are not responsible for the rapid yield declines observed when rice is grown continuously (George et al., 2002; Evenson et al., 1995; Sanchez, 1983). Increased weed pressure associated with successively cropped fields may be a cause of declining rice yields, however, it is unlikely to be the sole cause. Even when weeds are well controlled (as in the experiments above) rice yields continue to decline. There is some evidence that the cause of the problem may be nematodes (*Meloidogyne graminicola*) (Prot and Matias, 1995). Indeed, nematode numbers and nematode infected roots are higher in successively planted rice (Roder et al., 1998). While it is still not clear, the cause of declining rice yields may be a combination of the above factors and current research is focusing both on understanding the cause as well as developing sustainable upland rice based systems.

**Varieties**

There has been limited research testing varieties under continuous cropping conditions. However, some upland rice varieties appear to do well under such conditions. In an experiment conducted in Luangprabang on a field in its third rice cropping cycle, several varieties produced yields of between 1.4 and 2.0t/ha while the other varieties yielded only 0.5t/ha or less. Research is ongoing to screen Lao varieties based on names farmers have given them which may suggest an ability to do well under continuous cropping (i.e. 'garden rice' and 'win over weeds'). While choice of variety will be an important component, these will still need to be integrated into appropriate farming systems.
Cropping systems

Little research has been conducted on intensively cropped annual upland rice systems. Based on this research the following points can be made.

Crop rotations

Rotation with other crops is necessary for sustainable systems. However, research to identify rotational crops is not promising. Limited research has shown that rice yields continue to decline when cowpea, maize and stylo are used as rotational crops (figure 8). The most promising species studied to date has been pigeon pea, which has shown promise as a one-year fallow species (Figures 7 and 8). Research is continuing to study the potential of rice and pigeon pea in more intensive annual systems. Pigeon pea is not a host for nematodes (Roder et al., 1998) and, if planted properly, can limit the growth of other weeds that may be alternative hosts for nematodes.

Nutrient replenishment

Nutrient replenishment is necessary in any intensive cropping system where crop products are annually removed. Under slash-and-burn systems the long fallow period allows time for natural soil replenishment. In annual systems, such enrichment can come from crops being rotated with rice (such as cover crops, green manures or hedgerows) or from fertilizers. These are discussed separately below. Pot studies on a limited number of soils show that upland soils are primarily deficient in N and P (Lao-IRRI, 2001).

Nutrient replenishment from companion crops

Growing rice continuously in hedgerow systems is not a sustainable option as rice yields decline when grown between leucaena, crotalaria or gliricidia hedgerows (figure 9). However, if alternative crop rotations are used between hedgerows, the hedgerows may provide a valuable source of plant nutrients.

Cover crops have also been considered for upland rice. Again there is little research on the topic but there are several considerations:

- First, care must be taken that the cover crop does not compete with the rice for water, light and nutrients. The most successful crops may be those that can be established into rice late in the growing season and then become a dry season fallow crop.
- Second, as mentioned above for the alternative fallow crops, farmers are not likely to grow a crop that does not itself provide some form of economic benefit.
- Finally, many farmers may not be interested if the cover crops require a lot of labour to establish, manage and harvest.

Scope for fertilizers

Between 1991 and 1998 fertilizer experiments were carried out at 25 sites. Only five of these experiments (20%) gave a significant grain yield response to applied fertilizer. In most of the cases nitrogen (N) was applied alone at a rate of 30kg N/ha and in all cases where there was a significant yield response, the response was to N. In one year 100kg N/ha was applied along with phosphorus (P) at three sites. Yields doubled at two of the three sites when both N and P were applied (there was no response to P only). The site
where there was no response had been in a 15-year fallow. Reasons for poor fertilizer response may be due to:

- The application rates were too low to observe a response given the high field variability. Where higher N rates were applied the yield response was more evident.
- In almost all cases, N was applied alone. N, P and potassium (K) were applied at only 5 of the 25 sites.
- Traditional varieties were used and these are typically not responsive to fertilizer applications.
- Fertilizer uptake may have been low due to run-off.

In 2003 a field experiment was conducted at two sites to compare the application of the following fertilizers to upland rice (table 3):

- Urea.
- Controlled-release urea (CRU).
- CRU + P.
- P.

The data suggests that N was limiting while P was not as there was no yield response to P, although total P uptake increased by 36 and 49% with P and CRU + P applications, respectively. This result is consistent with George et al. (2001) and Roder (2001). Roder (2001) reported that in northern Laos application of P resulted in a 38% increase in uptake of P but with no consistent effect on rice yields. When N was applied in the urea, CRU, CRU + P applications, rice yields increased by 30, 30, and 15%; total biomass by 32, 40, and 33%; and total N uptake by 56, 56, and 55%, respectively. There was no significant difference in these variables with urea, CRU, and CRU + P application methods. Positive responses to N applications (urea, CRU, and CRU + P) were greatest for total N uptake, followed by total biomass, and then rice yield.

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Bibliography


Table 1: Evaluation of potential fallow species to be grown with rice. This evaluation was conducted during the first year when the fallow species were established with rice.

<table>
<thead>
<tr>
<th>Survival-1 mo after planting (%)</th>
<th>Leucaena</th>
<th>Pigeon pea</th>
<th>Crotalaria</th>
<th>Paper mulberry</th>
<th>Natural fallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotational species ht (cm)</td>
<td>73</td>
<td>88</td>
<td>82</td>
<td>35</td>
<td>-</td>
</tr>
<tr>
<td>Rice yields (t/ha)</td>
<td>38</td>
<td>171</td>
<td>165</td>
<td>81</td>
<td>-</td>
</tr>
<tr>
<td>Rice yields (t/ha)</td>
<td>1.61</td>
<td>1.76</td>
<td>1.56</td>
<td>1.83</td>
<td>1.60</td>
</tr>
<tr>
<td>Farmer ranking</td>
<td>68</td>
<td>80</td>
<td>64</td>
<td>124</td>
<td>-</td>
</tr>
<tr>
<td>What farmers said they liked</td>
<td>Eat leaves and pods</td>
<td>Improve soil (dark color and wet)</td>
<td>Improve soil</td>
<td>Sell bark</td>
<td>Use leave as feed for pigs, buffalo</td>
</tr>
<tr>
<td></td>
<td>Improve soil</td>
<td>Eat grain</td>
<td>Suppress weeds</td>
<td>Animal don't like to eat</td>
<td>Doesn't shade the rice</td>
</tr>
<tr>
<td></td>
<td>Fire wood</td>
<td>Fire wood</td>
<td>Fire wood</td>
<td>Can raise stick lack</td>
<td>Improve soil</td>
</tr>
<tr>
<td></td>
<td>Timber for the hut</td>
<td>Animals don't like to eat</td>
<td>Fast growth</td>
<td>A lot of seed</td>
<td>Conserves soil moisture for rice</td>
</tr>
<tr>
<td>What farmers said they did not like</td>
<td>Slow growth</td>
<td>Shade the rice</td>
<td>Can not eat</td>
<td>Can not grow well in some soil</td>
<td>Can not grow well in some soil</td>
</tr>
<tr>
<td></td>
<td>Damage by insects</td>
<td>Lodging</td>
<td></td>
<td>Slow growth if do not plant on time</td>
<td>Slow growth if do not plant on time</td>
</tr>
<tr>
<td></td>
<td>Rats like to eat</td>
<td></td>
<td></td>
<td>Animals like it too much</td>
<td>Animals like it too much</td>
</tr>
</tbody>
</table>

Table 2: Survival and growth of different paper mulberry planting materials established in upland rice and subsequent rice yields

<table>
<thead>
<tr>
<th>Planting material</th>
<th>Survival at end of first wet season</th>
<th>Paper mulberry height</th>
<th>Rice yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>cm</td>
<td>t/ha</td>
</tr>
<tr>
<td>Seedling</td>
<td>80 a</td>
<td>139 a</td>
<td>2.13 a</td>
</tr>
<tr>
<td>Root sucker</td>
<td>42 b</td>
<td>85 b</td>
<td>2.05 a</td>
</tr>
<tr>
<td>Root cutting</td>
<td>5 c</td>
<td>51 b</td>
<td>2.13 a</td>
</tr>
</tbody>
</table>

Key: within a column, values with the same letter (a,b,c) are not significantly different (P<0.05)
Table 3: Yield variables of upland rice in response to application of fertilisers in Laos (2003). CRU and P was applied at time of rice planting in the same hill as the rice seed. Urea was applied 30 and 60 days after planting in a trough running along the contour between the rice hills.

<table>
<thead>
<tr>
<th>Category</th>
<th>Rice yield (t ha⁻¹)</th>
<th>Total biomass (t ha⁻¹)</th>
<th>Total N uptake (kg ha⁻¹)</th>
<th>Total P uptake (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.9</td>
<td>3.6</td>
<td>25</td>
<td>5.9</td>
</tr>
<tr>
<td>Urea splits 40kgN ha⁻¹</td>
<td>2.4</td>
<td>4.8</td>
<td>39</td>
<td>7.5</td>
</tr>
<tr>
<td>CRU* 40kgN ha⁻¹</td>
<td>2.4</td>
<td>5.1</td>
<td>40</td>
<td>7.4</td>
</tr>
<tr>
<td>P 30kgP ha⁻¹</td>
<td>2.0</td>
<td>4.3</td>
<td>31</td>
<td>8.0</td>
</tr>
<tr>
<td>CRU 40kgN ha⁻¹, P 30kgP ha⁻¹</td>
<td>2.1</td>
<td>4.9</td>
<td>39</td>
<td>8.8</td>
</tr>
</tbody>
</table>

**Site**
- Site 1 (Pakcheck village) | 2.5 | 5.1 | 39 | 7.6 |
- Site 2 (Pathung village) | 1.8 | 4.0 | 31 | 7.5 |

**Anova summary**
- Treatment | 0.046 | 0.048 | 0.002 | 0.068 |
- Site | 0.003 | 0.043 | 0.027 | ns |
- Treatment x Site | ns | ns | ns | ns |
- LSD⁵⁰⁰₀⁰⁰₉⁰ (treatment main effect) | 0.43 | 1.02 | 7.7 | 2.0 |

*CRU=Controlled-release urea fertilizer.

Figure 1: Lao rice production and rice requirement from 1976 to 2002. ‘South’ includes Vientiane province and all provinces south of it.
Figure 2: The number of weedings required in upland rice grown with different fallow period lengths (from Trosch, 2003).

Figure 3: Pathways for the intensification of shifting cultivation (after Raintree and Warner, 1986) highlighting some of the research areas.
Figure 4: Grain yields of Nok and Makhinsoung compared to local check varieties. Data is from a period of five years and represents over 25 locations in most provinces of northern Laos.

Figure 5: Allometry model to predict paper mulberry inner bark yield based on plant height, stem diameter and stand density.
Figure 6: Relative yields of rice at varying densities of paper mulberry.

Figure 7: Rice grain yields in the third year following either continuous cropping or different types of fallow. Pigeon pea and Leucaena were planted with rice during the first crop at a spacing of 1.25 x 1.25 m. In the third crop Leucaena was cut and allowed to re-coppice and pigeon pea was cut and replanted.
Figure 8: Rice grain yields in the third year of continuous cropping. In each case there was a different crop/fallow in the 2nd year. In the rice-stylo-rice system, rice and stylo were grown together in the first and third year and stylo only in the 2nd year.

Key: columns that have values with the same letter (a, ab, bc, cd, d) are not significantly different (P<0.05)

Figure 9: Rice yields during a five-year cropping period with different shrubby legumes planted with rice. In 1997, rice was planted but there no rice harvest data available.