CHAPTER 2

LITERATURE REVIEW

2.1 Characterization of Natural Resources

2.1.1 Climatic resources

Luang Prabang province is located in the north of Laos. Its boundary stretches from longitude of 101° 40′ to 103° 30′E and latitude of 19°00′ to 21°00′N, with base altitude of about 305 m asl, ranging to about 1,500 m.

2.1.1.1 Rainfall

The annual rainfall amount, distribution and pattern in Luang Prabang province, as well as in the rest of the country, are mainly influenced by monsoon currents, dividing the year into two distinctive wet and dry seasons. Figure 2.1 shows the rainfall pattern and amount for the province (average from over 20-years of rainfall data 1975-1997). Annual rainfall averages about 1,380 mm. The rainy season starts in May and ends in October. More than 80% of total precipitation falls during the rainy season. July and August are the two wettest months of the year, receiving more than 200 mm month^{-1}.

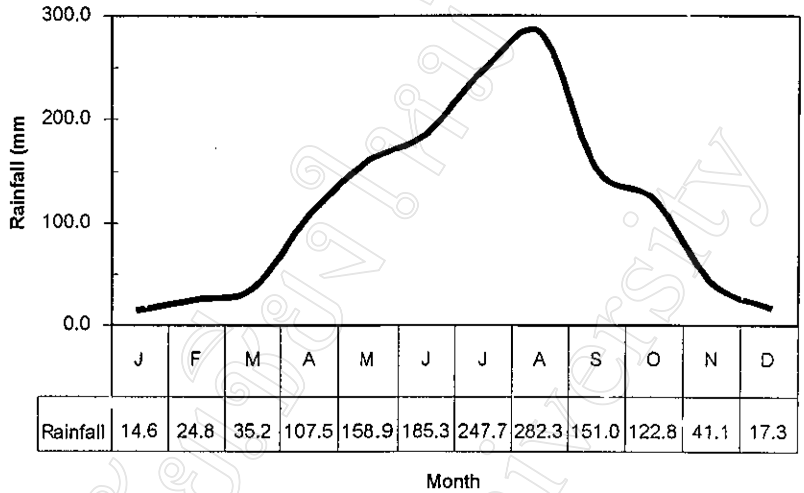
Brown (1969) reported that 1,000 mm of annual rainfall, with 200 mm of monthly rainfall during the growing season, are the minimum requirement for dryland in Latin America. If this statement holds true for the tropics of Southeast Asia, upland rice production might not be suitable to the Luang Prabang conditions. However, daily rainfall is more critical than monthly or annual rainfall. Rainfall of 100 mm $month^{-1}$ distributed evenly, is preferable to 200 mm $month^{-1}$, which falls in just a few days.

There is no predictable pattern between time and amount of rainfall for Luang Prabang province during the last 20 years, and probably for the region as well (Figure 2.2). Regional or global climate change can be the major factors that affect the amount of annual rainfall in the area. Reliable forecasting of weather might help to reduce rice production losses from drought or flooding.

2.1.1.2 Temperature

Average annual temperature was recorded at 25.5°C for the last 20 years, with average minimum of 16.7°C and average maximum of 34.7°C. During cropping seasons (May to October) minimum temperature ranges from 10.4 to 22.2°C, and maximum temperature ranges from 34.5 to 38.5°C.

Considering the optimum temperature requirement for rice growth is between 20 and 33°C, the prevailing average temperature is considered to be favorable. However, high temperature in some years between May to August may depress rice growth, hence reduce rice yield (Figure 2.3).



Month	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall	14.6	24.8	35.2	107.5	158.9	185.3	247.7	282.3	151.0	122.8	41.1	17.3

Figure 2.1 Rainfall pattern for the Luang Prabang Province.

(Source: Provincial Agriculture Service of Luang Prabang 1997)

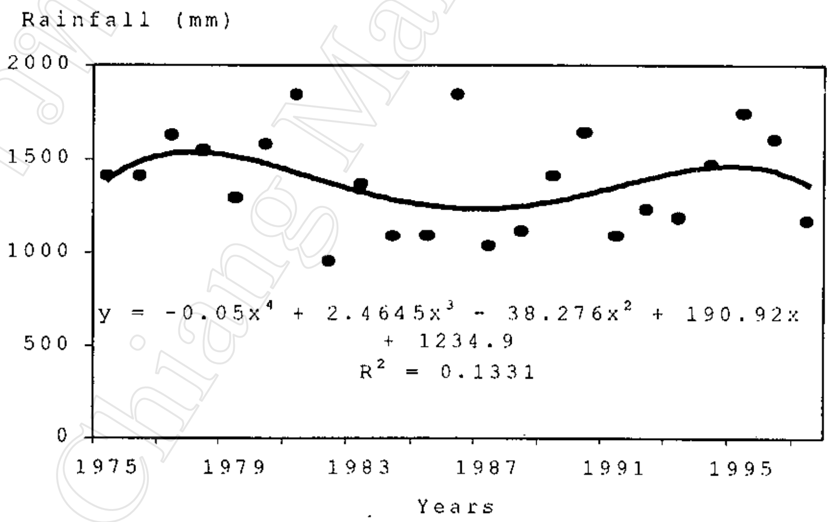


Figure 2.2 Trend in Amount of Rainfall for Luang Prabang Province over the last 20 Years.

(Source: Provincial Agriculture Service of Luang Prabang, 1997)

2.1.1.3 Solar Radiation

Solar radiation is the primary energy source for crop growth and profoundly affects temperature and evaporation. Quantitative information on radiation in upland rice growing regions in Laos is limited, mainly because reliable equipment to measure it is relatively expensive compared to instruments for measuring rainfall and temperature. Only the measured sunshine duration (actual sunshine hours) can be obtained.

Figure 2.4 shows monthly radiation intensity (MJ m^{-2} d^{-1}) for Luang Prabang province, mathematically converted from the actual sunshine measured over the last 20 years. The calculation is based on the Angstrom formula (eq. 2.1) (Berkhout and Keulen, 1986) as follows:

$$Ri = Ra\{a+b(n/N)\} \qquad \text{(eq. 2.1)}$$

Where,

Ri = received radiation (J m^{-2} s^{-1})

Ra = Angot's values

n = observed daylength (hours)

N = potential daylength (hours)

a and b = the constant for the tropical region, 0.29 and 0.42, respectively.

Calculated daily radiation is 13.2 MJ m^{-2} day^{-1}. Radiation intensity actually starts to increase in the beginning of August, which is favorable to rice growth during the reproductive phase. However, increased solar radiation cannot help increase rice yield if the crop is seriously affected by water and/or nutrient stresses, pests, or diseases.

2.1.2 Edaphic resources

2.1.2.1 Landscape and soils

The province of Luang Prabang is located in the hilly area of Northern Laos. Because of mountainous topography, the area available for lowland rice production is limited. Most of the areas used for upland agriculture are at altitudes ranging from 350 to 800 m. However, Some ethnic groups, Hmong and Yao, live above 1,000 m and cultivate up to 1500 m (Soukhaphonh et al., 1992.)

Land use maps based on slope gradient is presently unavailable for the whole province. Phouaravanh (1993), however, reported that most of upland rice production in Northern Laos is concentrated on sloping land. Slope gradient range from 0 to 120% with most ranging between 15 to 60%.

Upland soils in the province are classified as Orthic Acrisols (red-yellow podsolic and red-brown lateritic soils) with sandy loam to sandy clay topsoil (FAO, 1986). They are generally heavily leached, fairly acid, with low CEC, low available P content, and have a depth varying from 0.4-1.0 m (Roder et al., 1992) (Table 2.1).

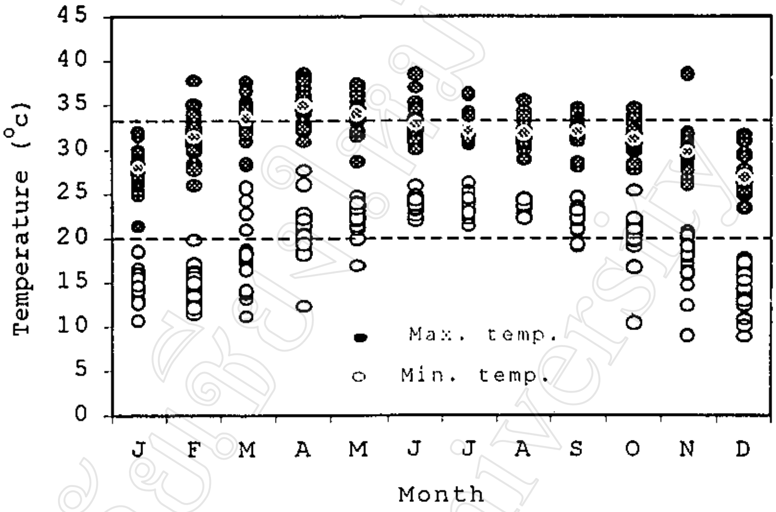


Figure 2.3 Maximum and minimum temperatures in Luang Prabang province for the last 20 years (1975-1997)

(Source: Provincial Agriculture Service of Luang Prabang, 1997)

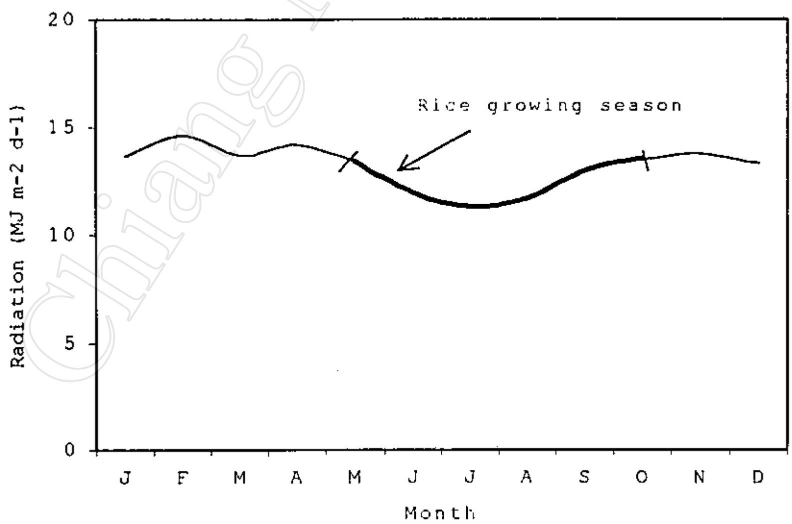


Figure 2.4 Radiation intensity (MJ m^{-2} day^{-1}) for Luang Prabang province

(Source: Provincial Agriculture Service of Luang Prabang, 1997)

Table 2.1 Characteristics of soils in Luang Prabang province.

Parameter	Depth (cm)					
	0-3	3-10	10-25	25-50	50-75	75-100
pH	5.59	4.76	4.56	4.61	4.73	4.83
Organic matter (%)	6.48	4.23	2.90	1.97	1.53	1.24
Total P (ppm)	758.0	609.0	523.0	469.0	447.0	424.0
Available P (ppm)	28.40	8.90	4.60	4.60	2.90	2.50
Available K (ppm)	358.0	162.0	91.0	60.0	41.0	37.0
Exch. Ca (meq/100g)	4.16	1.30	0.71	0.50	0.47	0.48
Al (meq/100g)	0.45	2.32	3.62	4.09	3.88	3.58
CEC (meq/100g)	14.90	11.90	10.30	9.80	9.10	8.40

(Source: Soukhaphonh et al., 1992)

2.1.3 Upland rice cultural practices

2.1.3.1 Shifting cultivation

Shifting cultivation has long been practiced by Lao upland farmers. Because of hilly topography, it may be the best option for farmers to produce rice from shifting cultivation. The shifting cultivation is practiced by all ethnic groups (Lao Loum, Lao Theung, and Lao Sung). The practice consists of cutting the vegetation (trees, shrubs) during the dry season (January, February), allowing it to dry and burning shortly before the onset of the rainy season. Seeds are dibbled in May or early June. Rice, mostly glutinous varieties, is the most important crop. However, Lao upland farmers often plant a large variety of non-rice crops with upland rice on the same plot (Soukhaphonh et al., 1992).

Neither inorganic nor organic fertilizer is presently used by Lao upland farmers. The only chemical pesticides used occasionally are sevin for seed treatment against ants and zincphosphide for rat control.

Reduced fallow periods and increased cropping intensities have substantially increased labor requirements for weed control. Upland farmers, however, customarily weed their rice field, hence weeds are more a constraint to labor rather than to rice yields. To produce 1 ha of upland rice requires total labor inputs of about 300 man day^{-1} ha^{-1}, in which over 50% of the total labor inputs are used for weeding (Roder et al., 1994). To be sustainable and optimize return on labor upland rice production under slash and burn systems required large land resources.

2.1.3.2 Negative effects of shifting cultivation on upland rice environment

Traditional slash and burn systems are believed to be sustainable and well adapted to hilly conditions, such as those prevailing in Northern Laos (Ruthenberg, 1980; Warner, 1991; Brady, 1994). The fallow length plays a significant role in sustaining productivity of the traditional systems. Traditionally, Lao slash and burn farmers used to fallow their lands as long as 30 years or longer after a period of 1-3 years of upland rice cultivation (Roder, 1994).

Fallow periods have recently been shortening, because of government regulations on land use in the uplands and rapid population growth. To meet the growing rice demand production has to be increased from limited land areas. Short fallow period deteriorates upland rice productivity and sustainability, encouraging soil degradation, and weed infestation. Shifting cultivation or slash and burn agriculture has been known as a destructive method of food production that creates negative impacts on environment and society rather than benefits.

Shifting cultivation is associated with soil nutrient declines through leaching, runoff and erosion during the cropping phase (Jordan 1985; Tulaphitak et al., 1985), although burning slashed vegetation produces ash rich in essential nutrients for plants and serves to temporarily neutralize acidic soils. Continuation of burning and cultivation result in deterioration of soil nutrient status and physical conditions, loss of porosity, thus reducing infiltration rate, increasing runoff, and often increasing soil erosion (Hernani et al., 1987; Weeraratna, 1984).

Shifting cultivation is also associated with decrease in soil macrofauna after burning (Watanabe and Ruaysoongnern, 1984), hence a decrease in decomposition rate of soil organic matter, which is the main stock of essential plant nutrients.

Subsequently, shifting cultivation or slash and burn agriculture entails an immense destruction to environment that one cannot easily estimate quantitatively. Examples of the catastrophe that can be obvious to us are land degradation, extinction of plant species and wild life, river sedimentation and increase flood in the plains.

2.2 Factors affecting upland rice environment and research priorities

Table 2.2 shows factors that affect upland rice environment in Luang Prabang province and the ongoing research priorities. The research priority was highly given towards farmer practices. Upland rice productivity and stability can not be maintained without improving cultural practices. Improving cultural practices that are suitable for shorter fallow periods and increase efficiency of farm resources will satisfy the present government policies and also help farmers to accumulate capital that facilitate their future food production. Hopefully, the developed technology should be appropriate to local farmers, especially the poor ones.

Meanwhile, other production factors (e.g., climatic resources, and edaphic resources) are low and medium priorities.

Table 2.2 Factors affecting upland rice environment and research priority

Factors	Upland rice environments		Research priority
	Not favorable	Favorable	
1. Climatic resources			
* Rainfall	✓		*

Table 2.2 Factors affecting upland rice environment and research priority (cont')

Factors	Upland rice environments		Research priority
	Not favorable	Favorable	
* Temperature		✓	*
* Solar radiation	✓		*
2. Land resources			
* Landscape	✓		**
* Inherent soil fertility	✓		**
3. Farmer practices			
* Slash and burn systems	✓		***

Note: * Low, ** Medium, *** high.

2.3 Rice/pigeon pea intercroping for upland rice-based cropping systems in Northern Laos

Pigeon pea (*Cajanus cajan*) is well adapted to the soil and climatic conditions in northern Laos (Roder et al., 1998). Lao upland rice farmers often grow a few plants in their ricefields near their temporary shelters or along paths and borders and consume the green pods as a minor vegetable food. There is presently no market for pigeon pea seed and farmers have no incentive for growing this crop on a larger scale. Extension and development agencies who work with hill farmers, however, have recommended that pigeon pea be an alternative crop to improve natural short fallows.

Improvement of fallow vegetation by fast-growing species, especially nitrogen-fixing legumes, is a widely recommended technique to maintain crop yields and suppress weeds in slash and burn systems under reduced fallow periods (Fujisaka, 1991; Garrity, 1993; Raintree and Warner, 1986). Gooding (1962) reported that pigeon pea fallows are better than bush fallows of equal duration. Ae et al., (1990) and Adu-Gyamfi et al., (1990) have shown that pigeon pea is more efficient in utilizing the iron-bound P in Alfisols than other crops tested and that it increases total P availability in cropping systems with low available P. An experiment conducted at the Upland Research Center, Houay Khot Station, Luang Prabang province, shown that rice yields increased after pigeon pea cultivation if pigeon pea residues were utilized in situ (Table 2.3).

Agricultural researchers have shown increasing interest in intercropping because of yield advantages, as compared to sole cropping, and greater stability of yields over seasons (Vandermeer, 1989). Intercropping upland rice with grain legumes could increase total grain production by 60-80% over sole rice. Pigeon pea was found to be the best companion crop to rice in terms of biomass and crop value in various tropical environments (ICRISAT 1992).

A three-year experiment conducted at the Upland Crop Research Center, Houay Khot Station, Luang Prabang province, revealed that intercropping pigeon pea into upland rice could actually sustain soil fertility, as it could improve rice yields (Figure 2.5). At the same time rice/pigeon pea intercropping could reduce weed biomass. In the third year of the experiment, intercropping reduced weed biomass by 33 % compared to continuous rice cropping and by 31 % compared to rice after fallow (Lao IRRI Project, 1993; 1994). Pigeon pea as a rotated or intercroped crop significantly could reduce nematode infestation when compared with continuous rice cropping (Roder et al., 1998). Rice/pigeon pea intercropping systems, therefore, should be an effective and productive technology to improve upland rice production.

Introducing pigeon pea into upland rice-based cropping systems could also provide more feed to animals, especially for poultry and pigs (animals commonly raised by the local farmers). Consequently, rice/pigeon pea intercropping could help farmers to accumulate capital, which is essential for them to move to more intensive and permanent farming systems.

Table 2.3 Effects of pigeon pea on rice yield.

Treatment	Rice yield (Mg ha^{-1})
1. Slashing and burning pigeon pea residues	1.16 ab
2. Slashing and removing pigeon pea residues	0.65 c
3. Slashing and mulching pigeon pea residues	1.46 a
4. No pigeon pea	0.93 bc
ANOVA (PR>F)	0.02
CV%	14.3

(Source: Lao IRRI Project, 1993)

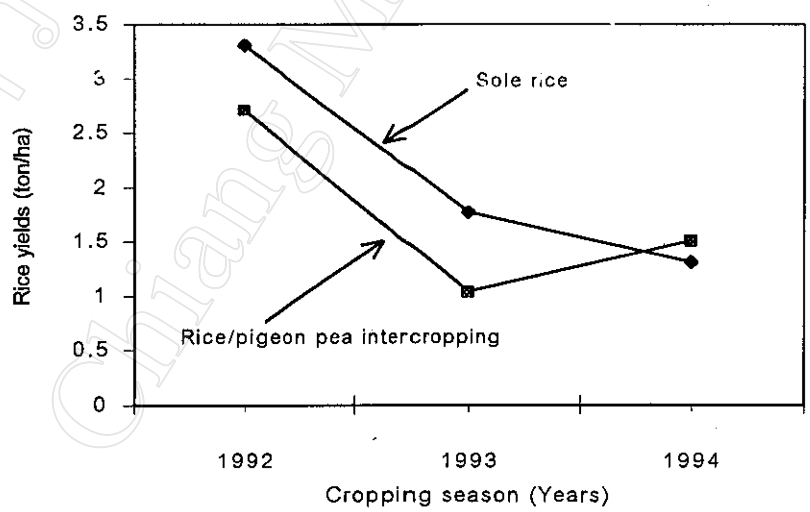


Figure 2.5 Effect of rice-pigeon pea intercropping on rice yields.

(Source: Lao IRRI Project, 1993; 1994)