## Chapter 5

## DISCUSSION

### 5.1 Productive capacity of cropping systems

Suitable farming and good management should make efficient use of resources i.e. light, soil nutrients and water which could contribute to high productivity in term of both quantity and quality. This productive capacity depends on many factors, but in this study, effects of two experimented factors, cropping system and hedgerows will be discussed.

#### 5.1.1 Cropping systems

The valuable combination of a leguminous crop (peanut) in food-crop systems was expected in cropping patterns (Beets, 1990). In the experiment, peanut was a potential representative of leguminous crops. It played a very important role in all aspects of economy, soil conservation as well as farmers' willingness to adopt. It was proven by an average cash yield of 1028.46 kg/ha (pod yield); legume residue or mulch of 6724.78 kg/ha equivalent to 41.23 kg/ha nitrogen, 3.0 kg/ha phosphorus and 5.8 kg/ha potassium per ha returning to soil. It provided a major part of the canopy covered throughout three months from May to July (Appendix Table 10) to protect soil from impact of heavy rain. Besides, unaccountable amount of fine roots in the soil as well as litter of peanut and a micro-organisms could provide positively effect on soil status. The similar results were reported by Huxley (1986), Beets (1990). Given the above performance, peanut showed its high potential and needs to be promoted in the upland farming.

For food crops, cassava provided the highest amount of biomass at the average of 10,410.3 kg/ha as well as the average yield of 17,598.5 kg/ha of fresh roots. Moreover, cassava growth was highly tolerance to environmental variation, such as high rainfall in the early season and serious drought in the later period of the year 1992 (Table 14).

However, if a large amount of cassava was produced in the region, farmers would face problems of poor processing and storage facilities, lack of potential and stable markets and difficulties of transportation. Surveyed data showed that utilization of cassava product in the region varied from upper to lower subregions. The difference was for food: 11.91 %, 21.18 % ; for feed: 42.17 %, 40.11 %; for processing: 11.27 %, 9.55 %; and for sale: 34.65 %, 29.16 % of total cassava product, in the upper and lower subregion, respectively (Binh, et al., 1991).

Continuing with other food crops we found that, though corn produced a smaller food yield compared with other food crop such as cassava (Average 1120.13 kg and 1799.70 kg of residue per ha). However, it is one of the potential crop that need further study due to its nutrition value, and stable yield and easy to cultivate (Table 13).

In peanut-corn sequential systems, the main weakness is that the exposure of soil after harvesting peanut coincides with the peak of rainfall. Soil become vulnerable under the attack of rain, consequently, causes serious soil erosion as estimated of 120 ton/ha/year (Table 19). To resolve this problem, it is hypothesized that corn or upland rice in relay cropping after peanut could provide enough ground cover to minimize soil erosion.

The experimental results have supported the above mentioned hypothesis that there were significant differences in canopy cover percentage in July, August, September and October, between relay and sequential arrangement of corn. The higher canopy cover of alley cropping in these months resulted in lower soil loss. This was proved by the closely negative-relationship between soil loss and canopy cover (Figure 11).

In terms of grain yield, relay cropping produced 15.0 % less grain yield ($P<0.05$) compared to sequential cropping. Causes of reduction in grain yield might be the effect of climatic factors on the developmental stage of corn. It was evidenced by the lower cob number/plant of corn in relay cropping as compared that in sequential cropping system. This is supported by the report of Beets (1990) that time of planting is crucial, since crops have to fit into a very tight schedule to make optimum use of available resource such as rainfall, temperature etc.

For cropping system involving upland rice, the results have shown that upland rice was not a suitable crop in cropping system for poor soil. Under poor soil status, upland rice gave unfilled panicles under drought stress in the 1992.

The highest biomass was obtained from peanut-cassava intercropping and lowest was associated with peanut-corn relay cropping. Comparing among cropping systems, results of the analysis variance showed that capacity in terms biomass productivity depended closely on cropping systems ($P<0.01$) (Table 18). The combination of legume and cereal is a better way to improve productivity. Nourdwijk and Van Andel (1988) stated that multiple crop, in the simple traditional stage it is often practiced to reduce risk, that is reduction of risk by diversity. However, we need to consider carefully about their interaction in given soil condition, climate as well as their management.

### 5.1.2 Alley cropping

The trees in alley cropping are seen as component with two roles: production role which is to increase both economic and biomass yield, and service role which is to sustain production. Production role refers to the physical outputs of the trees whereas the service function refers to the effects the trees have on the annual crops, particularly the effect on sustainability of the system, such as the fertility effect of nitrogen-fixing trees, (Beets, 1990).

In this experiment, *T. candida* performed both functions. For production role it provided green matter of an average 6165.47 kg/ha (equivalent 42.21 kg/ha nitrogen, 4.62/ha kg phosphorus and 6.48 kg/ha potassium) *in situ* to return to the soil and considerable amount of firewood for an average of 1318.33 kg/ha (Table 17).

Concerning the underground part of trees in hedgerows, Huxley (1986) discovered from detailed study of the carbon budgets of selected tree species that a considerably higher proportion of dry matter could be allocated to root growth and respiration, especially fine-root turnover, than was previously thought (in some cases 40 - 60 % of total carbon fixed was allocated to root growth and respiration). This discovery implied that amount of organic carbon being returned to the soil through fine-root death and decomposition could potentially be as high as that expected from leaf litter. Thus an uncounted mass of *T. candida* roots, where many nodules with a high nitrogen content are located, was an important source.

Evaluation of the effects of *T. candida* hedgerows on cropping systems, indicated that it had positive effects on crop in which it produced leguminous residues, (Kang et al., 1985), canopy cover in July and August, and soil conservation (Huxley, 1986). However its negative effects were found on corn biomass at 30 DAS, and grain yield of corn; upland rice biomass at 20, 80 and 110 DAS; biomass of cassava from growing date to 110 DAS; $K_2O$ in corn seeds (Appendix Table 11).

## 5.2 Evaluation on soil conservation

Aspects of soil conservation of cropping systems are return residues to the soil (particularly nitrogen-fixing crops or trees which provide residues of high nitrogen content in both of tops and roots), soil cover, a barrier to break run-off and the nutrient cycling. Pedro, (1987) suggested the soil-agroforestry hypothesis as appropriate agroforestry system improve soil physical properties, maintain soil organic matter, and promote nutrient cycling.

In terms of residues, we should consider the quality of residues among treatments. For peanut-cassava cropping systems although higher non-leguminous residues are produced, only a small part of the leaves and young shoots of cassava could return to the soil, the rest of cassava stems was often removed for fire wood by farmers.

Glover and Beer (1986) emphasized the significance of the amounts of other nutrients added by litter or residue. The short-term effects of applying plant residue to the soil can be considered, particularly in the promotion of root growth and the activity of crop plants as well as living micro-organisms in the soil through maintaining both the timeliness and availability of water and nutrients in top soil (especially in drought and poor soil cases). Treatments with hedgerows revealed greater advantage than ones without hedgerows (6156 kg/ha/year of green manure of *T. candida*) (Table 17).

For soil cover, comparing among cropping systems, with the presence of cassava throughout the growing seasons in peanut-cassava intercropping systems provided the best soil cover (Figure 8). Corn and upland rice in relay cropping also played a significant role in soil cover. We should regard two types of mulches which consist of canopy cover (live mulches) and residue cover (death mulches). The multi-layer crop canopy would provide better soil cover than monoculture in terms of covered area and covered time period. Cropping system +H3 once again attained the advantage by providing the high values of soil cover in both dead mulch cover of 6506.78 kg/ha and living cover of an average percentage of 76.8 % of the total area (this is obtained by counts during the peak period of the rainy season from June to September), therefore, the erosion was reduced. Mulch not only creates a better root environment, but also improves soil fertility and protects soil from erosion. Besides, mulches also lead to higher water use efficiency of rainfed crops via controlling evaporation (Lal, 1984).

Moreover, results also show that soil movement was affected by canopy structure and certain crop practice. In upland rice systems, there was no relationship between canopy cover percentage and soil loss. This was shown by high erosion of average 116.6 ton/ha/year while its canopy cover was also relatively high. Two reasons for this problem might be used to explain. First, cultivating factor, such as the surface of upland rice area was relatively more smooth than those of others (Earth mounding practice was not done in upland rice as it was in corn or cassava production). Lal (1976) recorded similar results in effect of aspects of slope on soil movement. More serious erosion was noted if the barriér of hedgerows is not established to block the run-off such as in the case of peanut-upland rice relay cropping without hedgerows (-H2). Soil loss was 133 ton/ha/year, which was 33.13 % greater than that with barriers of hedgerows (+H2). Second, the canopy structure of upland rice might also contribute to this increased erosion because of its vertical leaf arrangement offers insufficient protection from the attack of raindrops.

The last aspect of soil conservation is to block run-off (Lal, 1976). Two things might contribute to this function: Contouring rows of hedgerows, and field practices. In cropping systems with presenting by corn or cassava, earth mounding practice was taken place which caused lesser runoff than the cropping systems with upland rice which was not done earth mounding. In relay systems contouring hedgerows of *T. candida* is a good barrier for blocking run-off. However, this role is not able to evaluate within one year. Hence, further study need to be investigated.

Beets (1990) stated that throughout the tropics soil losses from erosion were far too high. It should be realized that maximum weathering or natural soil formation was less than 0.5 mm/year. This is equivalent to about 12 ton/ha/year. Thus acceptable soil losses through erosion would be about 10 ton/ha/year. In most farming systems losses far in excess of 100 ton/ha/year is common. Previous research in Thailand recorded an average of 112 ton/ha/year soil movement in soybean, and peanut with *L. leucocephala* in hedgerows (Amarueckachoke, 1992).

In recent years there has been interest in minimum tillage, particularly in combination with mulching (as case of peanut-corn relay cropping). Excessive tillage destroys soil structure whereas keeping the soil covered with a mulch tends to reduce the oxidation of organic matter and erosion (Lal, 1989). The ideal system would be one where live mulch replaces the fallow period, fixed nitrogen, competes against weeds and adds organic matter to the soil (Voelkner 1979). The treatments of corn or upland rice relay cropping seemed to meet these criteria.

On aspects of the nutrient cycling, the deep roots of woody perennial trees (*T. candida*) might result in an increase of nutrients pumped up (Beets, 1990) from the subsoil which helps maintain stability of fertility (Table 20 and Appendix Table 12a, 12b). Getahun and Jamma (1986) stated that nutrient status of the surface soil distinctly improved in the alley cropped plot compared with the control plot. Soil pH, N, P, K, Ca, and Mg increased with an increase in tree density. In Kenya, the similar result was also observed by Getahun and Jamma (1986). On the other hand, more residue supply leads to change in soil structure and contained organic matter. However, in short experimental time (one year), there was no significant data to support these statements.



Excess water leads to run off which not only causes mechanical damage in the form of erosion but also results in nutrient loss, (Table 19). However nutrient loss is not only by lateral run off, but also causes leaching through downward movement of water-containing nutrients (Beets, 1990). Matthews (1992) reported that loss of nutrients though leaching by heavy rain was highly likely. This concept might be used to explain the sharp reduction of potassium in this study (Table 20, Appendix Table 12).

Getahun and Jama (1986) stated that the nutrient status of the surface soil distinctly improved in the alley cropped plot compared with the control plot, in which soil pH increased over time. The soil nutrient status (N,P,K,Ca,Mg) was improved with an increase in tree density. Kang et al. (1984) reported that pH, organic matter increase in pruning of *L. leucaena* increase. Jou and Lal (1977) compared the effect of *L. leucaena* and brush fallow in which results showed there was significant increasing in Ca, K exchangeable and other cation. The analysis results of soil, pH, N %, $P_2O_5$ % in this experiment are in accordance with the above report (Table 20).

### 5.3 Farmers' willingness to adopt different cropping systems

In order to introduce and expand a new technology, its feasibility should be determined in terms of farmers' economic, social condition and perception as well.

There has been a wide gap between researchers and farmers' perceptions and believe, for example the erosion problem in this area. Though farmers knew that their crop yields have been decreased, and soil fertility was decreasing over time, they did not know the cause of the problem (Table 9). Similar result has been reported by Cator (1990) in the case study in Nan province, Thailand. Farmers focus only on rice production as their self-sufficiency food. Their needs for government´s support their priorities were on subsidy of fertilizers, insecticides, and seeds of new varieties of lowland rice. Upland farming was not their main concern.

The experiment on cropping systems were set up upon the basic of farmers ´ prevailing crops such as cassava, corn, upland rice (for food) and peanut (for both food and cash). Field practices of these crops are well known by farmers. Somewhere, cultivation of these crops is done though in very small area, however, the productivity as well as advantage have not fully been evaluated yet. Therefore, the lack of this information could not convince farmers to adopt these cropping systems.

In addition, according to Beets (1990), the principles of cropping system are to improve productivity in a sustainable manner by having outputs that satisfy most of the farmers´ needs; at the same time nutrient cycling is enhanced, soil erosion is prevented and soil moisture is conserved. The main consideration in rational crop selection are matching crop requirements with agro-ecological condition as well as the state of both the rural and the national economics and, particularly, the degree of subsistence production. Results of the survey indicated that 79.17 % farmer are willing to adopt peanut-cassava intercropping as well as peanut-corn sequential cropping (Table 11) and

60.42 % adopt alley cropping, once technical guidance and seed supplies are given (Table 10).

### 5.4 Cropping systems development

To evaluate the advantages as well as disadvantages of the cropping systems trial, some main indicators are calculated in relative percentages which are displayed in Figure 12 and Appendix Table 14. Circle of 100 % shows the mean in percentage of all treatments. The thick polygon line is a combination of all percentages of indicators. If the boundary of the polygon is outside 100 % circle it indicates advantages of total biomass, leguminous residue, canopy cover, food yield and return to labor cost, otherwise, within 100 % cycle expressing the relative disadvantages of the treatment comparing to other treatments. However, in case of soil loss, opposite interpretation should be done i.e. when the boundary of this polygon beyond 100 % circle, it denotes the relative disadvantage of treatment in soil conservation and vice versa.

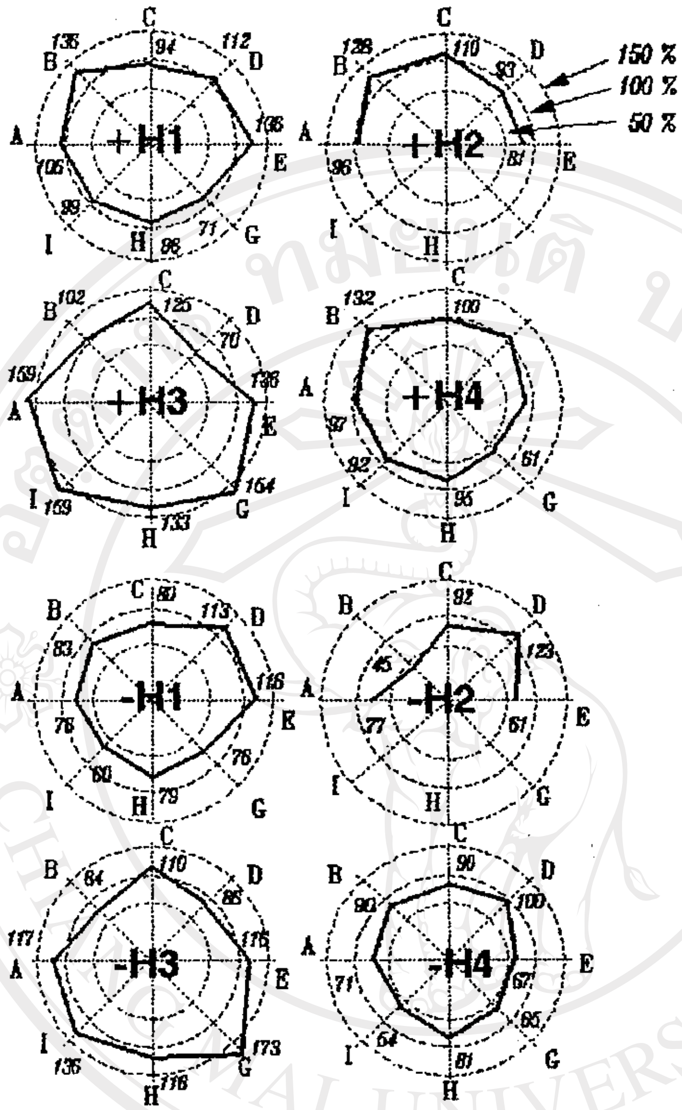

Figure 12: Combined effects of the productivity,economic returns, soil conservation and farmers' willingness to adopt different cropping systems (A = biomass; B = leguminous residues; C = canopy cover; D = soil loss; E = farmers willingness to adopt; G = food yield; H = return to labor cost; and I = gross margin)



In treatments of +H3 and -H3, the area of the polygons, which represent total biomass, leguminous residue, canopy cover, food yield, and gross margin, return to material cost and return to labor cost are bigger than those of other treatments. This implies that +H3 and -H3 treatments have advantages in the above mentioned aspects. The advantage of soil conservation of these treatments is also displayed by the thick lined boundary of soil loss section being inside the 100 % circle.

This research has shown that some cropping systems such as peanut-cassava intercropping with hedgerows of *T. candida* have considerable advantages. It does not only increase productivity in both economic and residues yield, but also provides more soil cover that can decrease soil movement, and reduce labor requirements.

Furthermore, for the upland agriculture, improvement in production can not be isolated from the conservation of natural environment. Combining trees with annual crops as in certain cropping systems brought some certain important environmental benefits (Beets, 1990).

Finally, it is necessary to assert that under certain conditions diversified cropping systems can have several economic and social benefits. The economic benefits include reduction in the incidence of total crop failure, which is common in monoculture systems (for instance in the case of failed upland rice) - if one crop fails the others might succeed; and increases in the total amount of food produced. Moreover the social benefits includes improvements in nutrition and rural health due to increased quantities of food, with improved quality and greater choice; improved living standards of rural people from increasing employment opportunities, higher incomes, decreased walking distance for fuel wood collection etc. However, it is necessary to further study in more detail the existing and new cropping systems to understand more clearly about the advantages and disadvantages of various systems. On-farm experiment also needs to be conducted to validate promising cropping systems so that we could gain certain basic concept for property arrangement as well as having suitable management for upland farming.