Chapter 4

RESULTS AND DISCUSSION

4.1 Economic development

Socio-economic conditions that relate to land use types and land suitability levels affect the decision and management of land by users in the area. The rapid population during decades in this area led to expansion of cultivation, and infrastructures in the study area. Consequently, this problem is putting a strong pressure on land resource sustainability and the transformation of forestland to cultivated and utility land.

In recently years, a progress trend in economic development of Dinhquan was observed. In 1998, total product in the district was VND 562.49 billion. The income per person was VND 2.64 million (People Committee of Dinhquan district, 1998). In 2002, the growth rate of economic development was 4.83% with total of products in district was VND 8,761.8 billion and the income per person was VND 3.79 million (People Committee of Dinhquan district, 2002). Agriculture and forest are major contributions to this development before industry, tourism and other business.

Perennial crops such as perennial industrial crops (rubber, cashew) and fruit trees (rambutan) were considered as strength. Since 1995, annual crops have been decreased and were replaced by perennial crops. Increasing rate of perennial crop area is 14% per year; in 2003 its area was 19,133 ha because of suitable climate and soil condition. The productivity of perennial crops increased, growth rate were 5% per year. Fruit tree area was maximum in 1996 and 1997, and then it was stabilized by area limitation policy in 1998.

Livestock production has a considerable evolving. Total number of livestock is 8,150 heads and poultry is 35,400 heads. Livestocks and fisheries are continuing to

develop by taking advantages of ponds and semi-flooded areas in Trian pond. At present, areas for livestock and fisheries are 143 ha and attract 1,900 labors.

Total forest product was VND 1,856 millions in 2002, a decreased of 8% from those in 1995 because of over exploitation of forest lead to a reduction of forest area and productivity.

Handcraft, commercial and services also contribute considerably for off-farm income. Tourism is also developing with the discovery of many antiques and diversified landscapes.

Demography and labor

According to statistics of Dinhquan district, population in 2002 was 231,100. Average density was low with 240 people /km^2, compared with other districts (Table 4.1). The whole of district has 46,175 households; or the average of 5 people /household. The growth rate of population is 1.68%.

Table 4.1 Growth rate of population affect to land use from 1998 to 2002

Year	Total of population (people)	Density (people/km^2)
1998	214,855	222
1999	218,808	226
2000	222,834	230
2001	226,795	234
2002	231,100	240

Source: People Committee of Dinhquan, 2002

From 1998 to 2002, population increases by 16,245 people with annual growth rate of 1.8%. In 2002, available labor was 117,861 people, occupying of 51% of total population in the district with majority of labor in agriculture production (84,860 people or about 72% total labor).

Ethnic groups and religion

In Dinhquan, races and religions are very complex and affect farmer's custom and livelihood. There are 36 ethnic groups, Kinh is majority, followed by Han and Ch'ro who distributed in Langa, Tuctrung, Ngocdinh communes. Other ethnic groups such as Dao, Muong and Thai are only the minorities in the study area.

Residents that follow Buddhism are the majority in Dinhquan town and Ngocdinh commune. The second most common religion is Catholicism in Phucuong and Suoinho communes, while Protestantism and Cao Dai religions are distributed scatteredly in the whole district. About 36% populations do not follow specific religion (Table 4.2).

Table 4.2 Ethnic groups and religions in Dinhquan

	No of people (person)	No of households (Hh)	Proportion (%)
Ethnic groups			
Kinh	173,325	34,665	75
Han	39,287	7,857	17
Choro	3,929	786	1.7
Other	14,559	2,912	6.3
Total	231,100	46,220	100
Religions			
Buddhism	73,952	14,790	32.0
Catholicism	67,019	13,404	29.0
Protestantism	3,467	693	1.5
Cao Dai	439	88	0.2
No religion	86,233	17,245	37.3
Total	231,100	46,220	100

Source: People Committee of Dinhquan, 2003

In 2002, the number of labors is 117,861 people (51% total of population). Agricultural sector absorbed most of labors (84,860 labors or 72% total labor).

Infrastructure

In Dinhquan, transportation system consists of 12 main streets with the total length of 156km. About 37 km of highway and Giacanh street are spread with asphalt, the remaining roads are macadamized that cause difficulties in movement of products in the rainy season. Health services and education are still inadequate, local government is improving continuously.

4.2 Assessment of existing land use

Land use in Dinhquan was classified following 01-TK/TCDC format of The General Department of Land Administration (GDLA) of Vietnam for making inventory and establishing existing land utility map since 1995 following the direction No 382/ TC-DC and is applied annually in cadastral agencies. Results of the survey and inventory were used to assess the existing land use map in 2003 of Dinhquan district (Appendix Table 1).

From this survey, land in Dinhquan is classified into 5 major types (the first land unit class): agricultural land, forest land, special land, residential land and unused land. There are 23 types of the secondary land unit class, 9 types of the tertiary land unit class. As the results, 35 unique land units can be coded following regulation of GDLA.

The process was carried out by the support of GIS tools such as digitizer, scanner and 2 GIS sofwares (Microstation and Mapinfo). This is the first time, system of tables following land classification regulation and existing land use maps were completely done.

4.2.1 Change of land use

During 1988 to 2003, agricultural land increased significantly during 1998-2000 (Table 4.3). About 3,000 ha of agricultural land changed from annual to perennial crops. Since 2000, the unused areas were only 2,285 ha and decreased to 1,866 ha in 2003, these areas are mainly river and stream. Special purpose land and residential land in 2003 increased more than in 2000 because there were development programs for ethic communities in this district.

Table 4.3 Change of land use types during 1998 to 2003

LUT	1998		2000			2002			2003		
	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)	Change (ha)	Area (ha)	Proportion (%)	Change (ha)	Area (ha)	Proportion (%)	Change (ha)
Agricultural land	34,811	36.15	38,334	39.66	3,523	38,328	39.66	-6	38,407	39.74	79
Forest land	36,025	37.41	35,578	36.81	-447	35,573	36.81	-5	35,660	36.90	87
Special purpose land	19,498	20.25	19,425	20.1	-73	19,465	20.14	40	19,518	20.19	53
Residential area	1,086	1.13	1,027	1.06	-59	1,034	1.07	7	1,199	1.24	164
Unused land	4,871	5.06	2,285	2.36	-2,586	2,249	2.33	-36	1,866	1.93	-383
Total	96,292	100	96,650	100	358	96,650	100	0	96,650	100	0

Source: People Committee of Dinhquan district, 2002 and 2003

Forest land decreased strongly during the period of 1998-2000 because of the "reclaimation program". During 2000-2003, the increase in a forestation in the 327 program is noticeable, most of unused land were used for forest and specialized land for landscaping and eco-tourism.

Existing agricultural land

Among 5 major land use types, agricultural land is the most diverse and it is necessary to classify in details. Agricultural land in Dinhquan was classified in 5 hierarchical classes (Table 4.4).

The primary class was agricultural land, the second hierarchy was classified according to the length of their seasons and major agricultural land group. They were divided into 4 units, namely annual crop, perennial crop, land for livestock and land for fishery production.

Table 4.4 Classifying existing land use in agriculture

Primary class	Classification of agricultural land			
	2nd Hierarchical class	3rd Hierarchical class	4th Hierarchical class	Cropping system
Agricultural land	1. Annual crop	1.Irrigated paddy rice	1.Double rice	1.Rice (S)-Rice (M)
		2.Rainfed Crop	2. Mono cropping	2. Sugar cane
			3. Double cropping	3. Corn (S)-corn (W)
	2.Perennial crop	3. Mono garden	4. Perennial industrial crop	4. Rubber 5. Cashew
			5. Fruit tree	6. Rambutan
	3. Land for livestock production	4. Pasture	6. Pasture	7. Pasture
	4. Land for fishery production	5. Fresh water	7. Fresh water aquatic production	8. Shrimp extensive farming

Source: Field survey, 2002

Rice (S): summer rice crop (3months from April to June)

Rice (M): main rice crop (4-5 months from August to December or January)

Corn (S): summer corn crop (3months from May to July)

Corn (W): winter corn crop (3 months from October to December)

The third hierarchy was classified based on characteristics of specializing in the growing of plants or combination between crops and livestock. Agricultural land was classified into 4 units (2 types for cultivation, 1 type for livestock production and 1 for fishery production).

The fourth hierarchy was based on numbers of crops in the annual production, major crops of perennial crops and water accessibility for crops. In Dinhquan, there are 5 units (3 types for cultivation, 1 type for livestock production and 1 for fishery production).

The fifth hierarchy (structure of crop and livestock) was based on specific cropping systems, livestock, and the seasons of annual crop. There are 8 agricultural land use types (6 types for cultivation, 1 type for livestock production and 1 for fishery production).

Structure of agricultural land use

Agricultural land still occupies 40% of total land area in the district and are mostly distributed in communes such as Tuctrung, Phutan, Giacanh, Phungoc. Almost 99% total is agricultural land area while 1% is for livestock and fishery production. Perennial cropland occupies half of agricultural land area, this is higher in proportion than other districts therefore the strength in terms of economic value and ability to protect the environment. Perennial crops consist of industrial crops (40% of total agricultural land area) such as rubber and cashew (Table 4.5), fruit trees occupy 9% of total agricultural land area while other perennial crop is very few (1% of total agricultural land area). For annual crops, the double crops of rice are summer rice crop and main rice crop (2,776 ha), which is the dominant food crop of the district. The other system is rice in summer followed by peas, which occupies 2,220ha. Industrial annual cropland consists of corn and sugar cane (11,115 ha) that occupies majority of annual crop land.

Table 4.5 Agricultural land use types in 2003

Land use types	Code	Area (ha)	Proportion (%)
1. Annual crop land	3	17,839	46.40
1.1. Rice-rice, rice-pea	4	4,996	13.01
1.1.1. Summer rice land main rice and	6	2,776	7.23
1.1.2. Main rice and pea crop land	7	2,220	5.78
1.2. Other annual crop land	12	12,843	33.44
1.2.1. Crop and industrial annual crop land	13	11,115	28.94
1.2.2. Vegetable land	14	9	0.02
1.2.3. Other annual crop land	16	1,719	4.48
2. Complex orchard land	17	1,291	3.36
3. Perennial crop land	18	19,132	49.81
3.1. Perennial industrial crop land	19	15,391	40.07
- Rubber	19/CS	3,021	7.87
-Cashew	19/D	9,898	25.77
-Other	19/K	2,472	6.44
3.2. Fruit tree land	20	3,364	8.76
3.3. Other perennial crop land	21	377	0.98
4. Pasture for livestock	23	2	0.01
4.1. Natural pasture land	25	2	0.01
5. Water surface land for fishery	26	143	0.37
5.1. Breeding fish land	27	143	0.37
Total of agricultural land		38,407	100.00

Source: Synthesizing from procedure of establishing existing LUT map of Dinhquan, 2003.

4.2.2 Change of agricultural land during the period of 1998-2003

Annual crop land: Since 1998, annual crop land area slightly decreased from 20,108 ha to 17,839 ha in 2003. Paddy rice area was maintained as double rice crop, paddy rice area always is the priority area in local economic policy aiming to keep the local food security. Almost upper slope area where ethnic people grew cassava and medicinal plants about 140ha in 1998 changed into other crop (cashew) in 2003 because this land use type is low efficiency, easy to degradation of land quality (erosion). Field crop and industrial crop land was 11,115 ha in 2003, major crops were sugar cane (about 3200 ha) and corn.

Perennial crop land: Perennial crop land area increased significantly during 1998-2003. In 1998, the area was 13,743ha but increased to 19,133 ha in 2003. Perennial crop land area occupied the highest proportion in agricultural area (50% of total agricultural land and 20 % of the whole district). However, the rapid increase in perennial crop land caused a pressure on the land, unbalancing distribution of crop production. Farmers focused on increasing perennial cropland area and cashew is a major crop (about 9,989ha). In some areas, previous coffee trees were replaced by cashew (Figure 4.2).

Complex orchard: In 2000, complex orchard area increased 1,344 ha comparing with 1998, and area decreased slightly in 2002 (1,298 ha), and in 2003 (1,291 ha). Majority complex orchard is low economic value because the crops are so diverse that they can only supply for family demand.

Pasture for breeding: this occupies small area and concentrated around the edge of Trian pond serving for number of cows in the program of "one crop and one livestock", its area increased only about 50 ha.

In summary, agricultural land increases slightly, in which annual cropland is decreasing and transformed into perennial crops. Within the perennial crop, rubber area is very stable, cashew and fruit tree lands are increasing quickly but coffee land decreases significantly because of unstable market price (Figure 4.1 and Table 4.4).

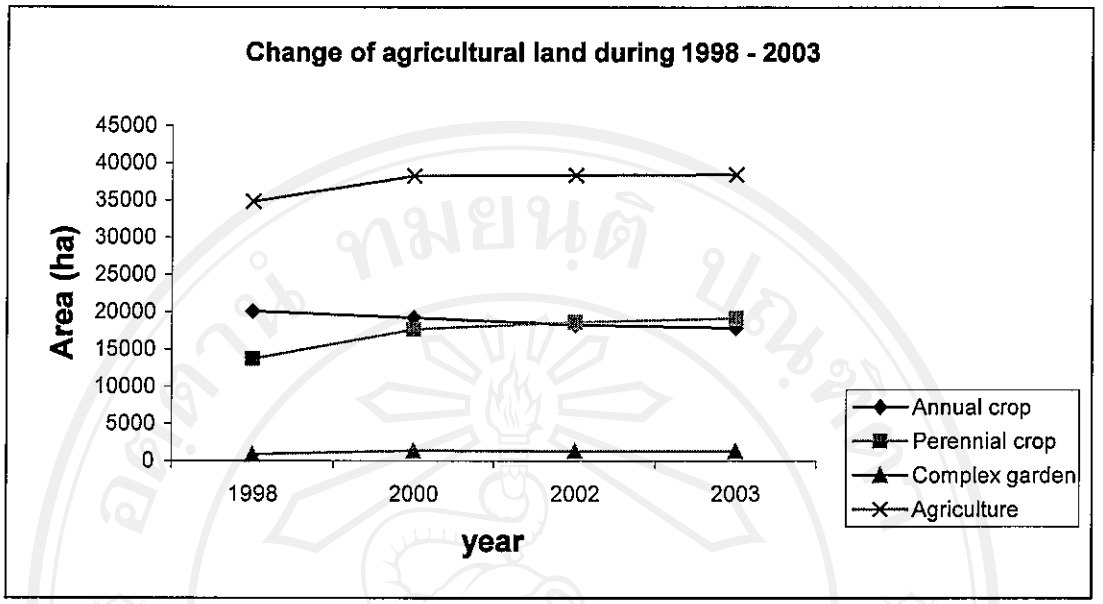

Figure 4.1 Change of agricultural land during 1998-2003

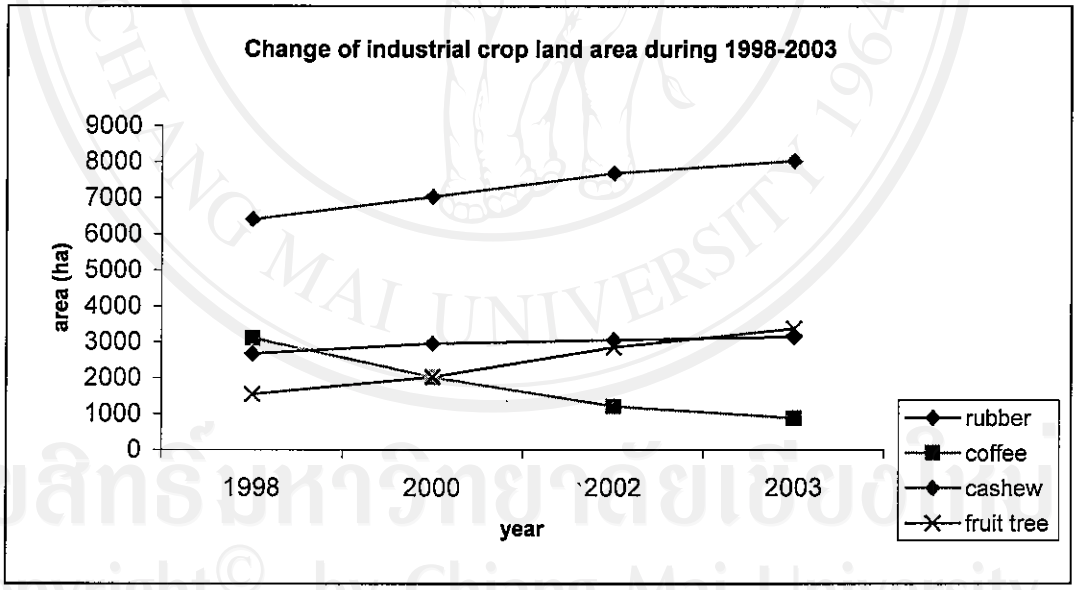

Figure 4.2 Change of industrial crop area during 1998-2003

Results of household interview and survey expressed economic value for each land use type (Table 4.6). Level of management differs according to the resources availability on farm. Gross margin analysis was used to generate total variable cost, net benefit for rice-rice, corn-corn and sugar cane cropping systems. Discounted cash

flow analysis was used for generating total variable cost, income and net benefit for rubber, cashew and rambutan because values of perennial crops relate to net present value (NPV).

Results of surveying agricultural land use showed that majority of farmers have adopted the monoculture/mono-cropping system due to insufficient poor soil status for annual crop land.

Table 4.6 Economic return for land use types in agriculture

Cropping system	Total variable cost	Total income	Total net benefit
	1000 VND/ha	1000 VND/ha	1000VND/ha
1.Rice (S)-rice (M)	7,285	12,389	5,104
2. Sugar cane	7,931	12,426	4,495
3. Corn (S)-corn (W)	8,150	13,500	5,350
4. Rubber	5,653	11,124	5,476
5. Cashew	3,449	5,933	3,483
6. Rambutan	6,177	15,539	9,471

Source: Synthesizing from field survey, 2002

Note: Rice (M): main rice crop, rice (S): summer rice crop,

Corn (S): summer corn crop, corn (W): winter corn crop

Economic values for LUTs in Dinhquan were based on ranges of rating of total variable cost, income and net benefit in Table 4.7. These classifications for LUTs had been done in Dongnai province in 2000 by economic experts (Report of socio-economic development of Dongnai province, 2000).

For annual crop, summer corn and winter corn produce higher profit than the double crops of rice (summer rice crop and main rice crop) and sugar cane. For perennial crop system, rambutan has highest net return (9,471,000VND/ha) and give positive environmental effect while rubber has medium net profit, and cashew has the lowest profit. However, cashew is easy to grow and investment requirement is very low, they can be grown in poor quality soil therefore the growing area is expanding (Table 4.6).

Table 4.7 Classification of assessing economic effect

Assessing class	Classifying (*1000VND/ha/year)		
	Total cost	Total income	Net Benefit
Low (L)	<4,000	<8000	<4,000
Medium (M)	4,000-6,000	8000-12000	4,000-6,000
High (H)	6,000-8,000	12000-16000	6,000-8,000
Very high (VH)	>8,000	>16000	>8,000

Source: People Committee of Dongnai province, 2000

4.3 Land evaluation

4.3.1 LMU and LC

The LMU had been generated from procedure of soil classification by Department of Land Administration of Dongnai province and soil scientists, their distribution and attributes are shown in Appendix 3 and Appendix 4 respectively. The map of LMU is shown in Figure 4.3.

The number of LMU established was 77 units. Each unit will be described following characteristics of soil types, soil drainage, slope, stoniness, depth and composition of soil chemical properties and rainfall.

LMU No. 41, 47 occupies 8% and 9% respectively the highest proportion of the study area, they are chromic grey soil types with relative fertile and differentiated soil depth.

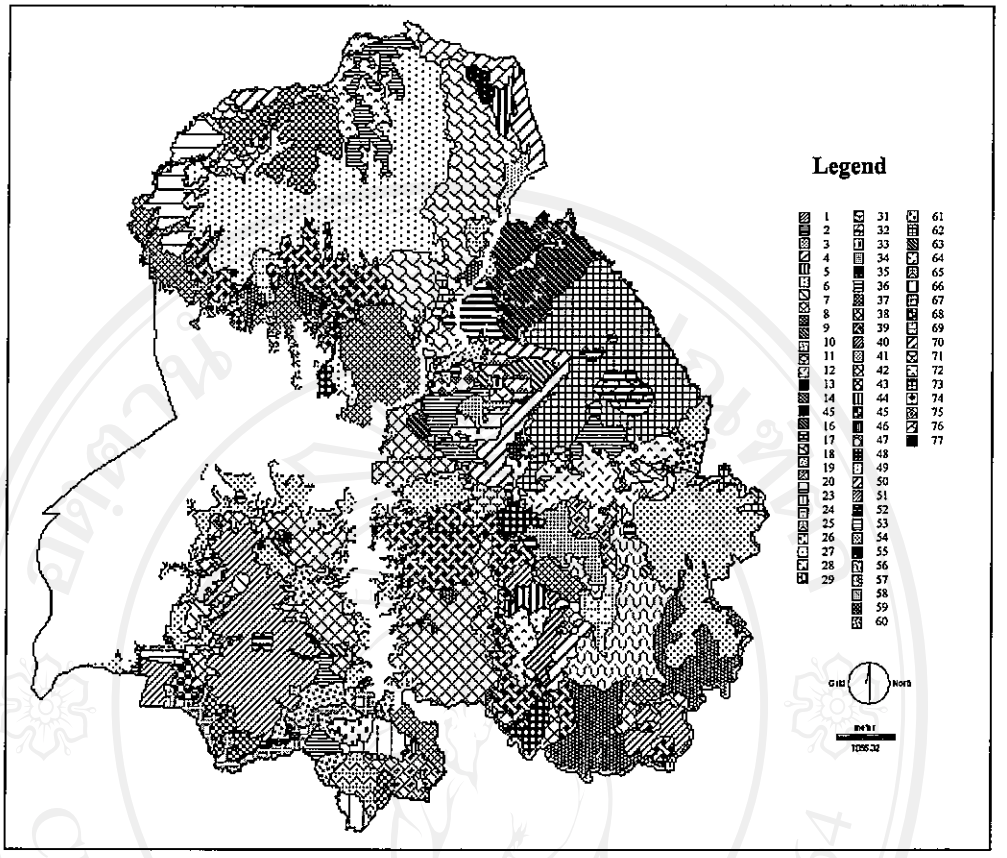

Figure 4.3 Land Mapping Unit map of Dinhquan district

The descriptions of soil units are followed:

Acrisols. This is a main soil group in this area (49,962ha) occupying the highest proportion (63.4%). It has 4 soil units: Chromic Acrisols, Ferlic Acrisols, Gley Acrisols, Arenic Acrisols and 4 soil subunits. Chromic Acrisols is highest proportion with area of 40,108ha, which is developed from Schist, and Granite, poor humus, low easy absorbed nutrients, acid soil, and low exchanged cation capacity. Soil texture is ranged from light to medium.

Andosols. This soil unit has area of 427ha, occupies about 0.54% and consists of only one subunit (Haplic Andosols). It was derived from Basalt; soil layer has mixing stones, sometimes clotting. Because of stones on the effective layer this soil group is not used in agricultural production.

Ferrasols. The soil occupies the area of 10,798ha (13.17%). It has 2 soil units: Rhodic Ferrasols and Xanthic Ferrasols and 9 soil subunits. The soils are created from basalt with thick soil layer, heavy textural composition, tattered particles, rich in nitrogen, high phosphate and exchanged cations.

Gleysols. The gleysols occupies only 0.77% with area of 609ha. It consists of one soil unit (Umbric Gleysols) and 2 soil subunits. Majority of the area are used for sugar cane and annual crop. In a few places, farmer tried to make beds to grow fruit trees but the cost is very high.

Luvisols: This is the second main soil type in Dinhquan after Acrisols with area of 16,987ha, occupied 21.86%. There are 4 soil units: Ferric Luvisols, Gleyic Luvisols, Haplic Luvisols, Chromic Luvisols and 9 soil subunits. It is also developed from basalt, which has characteristics of rich in nutrients and easily absorbed nutrients, especially, high P_2O_5, Ca and Mg.

Attributes of LMUs are characteristics of soil types and in each soil type, soil characteristics are assumed to be homogenous.

4.3.2 Land use types for land evaluation

The first step in land evaluation starts with the decision of alternative LUTs to be evaluated. Land Use Type is a technical term used to represent common term "land use" (Rossiter, 1994). Major LUTs evaluated consist of rice – rice cropping system (irrigated summer rice crop and main rice crop), and corn – corn systems (rainfed summer corn crop and winter corn crop), sugarcane, rubber, cashew and rambutan in rainfed condition. The result of socio-economic data collected from the secondary source and informal interview are used for identifying LUT (Table 4.4). The descriptions of each LUT including varieties and growing period were listed in Table 4.8.

Table 4.8 Some key operations for of major LUTs

	Rice-rice	Corn-corn	Sugar Cane	Rubber	Cashew	Rambutan
Variety	IR66, Nho chum, Sarri,	Local variety,MT 12, BM235	Xuan Dieu	CSK23, DN	Local variety, DT66, India	Local variety, troc
Growing period	100-110 days (April-Jun) 120-150days (Aug-Dec or Jan)	105-120days (May-July) 100-110 days (mid of Sep-Dec)	240-270days(May-Jan or Feb)	1-4.5 (1^{st} stage) 5-40 years (harvest)	1-4 (1^{st} stage) 4-30 years (harvest)	1-3(1^{st} stage) 3-40 years (harvest)

Selected irrigated paddy rice system was summer rice crop and main rice crop. Growing time for summer rice crop is 100-105 days, starting from the end of April to June while main rice crop lasts from 120 to 150 days during August to December or January. Selected variety is short-strawed and high yielding cultivars. This cropping system was distributed in flat and even land, beside streams and rivers to access water supply easily. There are no seasonal or annual shortages of water. Irrigation system in Dinhquan was appraised well for watering and drainage because of a good irrigation system diverting water from Dongnai and Langa rivers. "Nho chum" and IR66 varieties were used for short-term rice (summer rice crop) and Sarri variety for long-term rice (main rice crop). Capital was invested for this LUT at low level. Farmer used animal-drawn farm implements, high labor intensity. There are 95% freehold farms, 5% tenants. Harvested rice serves for subsistence and domestic markets.

Corn, sugar cane, rubber, cashew and fruit tree are major rainfed crops in the study area. Summer corn crop followed by winter corn crop system is also the main annual crop in Dinhquan. Most corn was grown in the land where average slope is 0-10^0 on the low hills. In the study area, growing time for rainfed corn is 105-120 days for summer corn crop and 100-110 days for the winter corn crop. The first crop starts

from May to July (summer season) and the second crop starts from the middle of September to middle of December (winter season). According to farmers and experts, rainfall amount is suitable for double crop of corn in the study area but for winter corn crop, BM235 variety was grown to reduce the growing time and limit water shortage. After harvesting, corn is sold to go to companies of feed processing for livestock in industrial zones in Dongnai province.

Sugar canes were grown in the rainfed areas using Xuandieu variety. Ratoons last until the third crop, anticipated yields on the highly suitable land varied from 45.0 ton/ha for the first crop to 40.0 ton/ha for the third ratoon. Langa Sugar Company in joint venture with government was the outlet for sugar cane farmers to meet domestic requirements. At the beginning of rainy season, sugar cane crop was harvested in January or February. Harvesting sugar method involves labor for hand cutting, but mechanization was used for tillage, loading and transportation.

Rubber tree was a perennial crop grown in the rainfed areas. In the first stage of growth, rubber is was mainly cultivated at the beginning of the rainy season (at the beginning of April). At the end of the fourth year, rubber started to produce latex. Time for harvesting rubber latex lasted about 40 years after the first stage. Average yield of rubber was 1.0 ton/ha. The average farm size for rubber was about 0.4 ha.

Rambutan was the most commonly grown fruit trees. According to the interview, at the first stage (1^{st}- 3^{rd} year), water is essential for establishment of the orchard. And cost for this stage was very high because of planting, fertilizing and weeding. Productivity of rambutan was highest in basalt red land (11ton/ha) while on the other types of land, productivity was 9 to 10 ton/ha. The problems that rambutan growers often face were labor shortages in the harvesting season and limited market expansion.

Another crop that had been cultivated entirely on rainfed was cashew. In the first stage, cashew was also grown at the beginning of the rainy season but it requires less water than rambutan. After the first rainy season, cashew can establish and grow better than rambutan. Cashew can be harvested in the 4^{th} year, and productivity is

about 0.9 ton/ha. In Dinhquan, cashew was a dominant crop, resource-poor farmers can grow it even they do not have capital to invest. This crop is the priority crop for protecting environment and adding income. Cashew was sold to cashew nut processing planting in Tuctrung commune. Harvesting of cashew was often done at the end of dry season (from March to April), the quality of cashew nut also depended on whether the rain season occurred early or late. The price was relatively stable and increases slightly in the recently years. This encourages farmer to expand cashew areas in unused land or low productivity land.

4.3.3 Land use requirements of LUTs

Land use requirement was used to describe the requirement for successful and sustainable practices of a given LUT. They are expressed in term of land qualities grouped from land characteristics (LC). The LQ in LUR of particular LUT reflected crop requirement, management requirement and conservation requirement. In the assessment process, LC and LQ would be matched for each LUT. The criteria for selecting LUR based considered effect on the use, occurrence of critical value, obtainable of information and significance. The value was derived from the opinion of researchers, local agricultural officers and farmers who involved in this study, the relative weight of each factor for different LUT are shown in Table 4.9 and Table 4.10.

Table 4.9 Relative weights of each factor for irrigated rice-rice

Land characteristics	Rice-rice
Soil drainage	0.2
Soil depth	0.14
Slope	0.2
pH	0.16
Stoniness	0.12
OM	0.18
Overall	1

Table 4.10 Relative weights of each factor for rainfed LUTs

Land characteristic	Corn-Corn	Sugar-cane	Rubber	Cashew	Rambutan
1.Soil drainage	0.15	0.14	0.13	0.14	0.13
2. Soil depth	0.1	0.12	0.17	0.2	0.18
3. Annual rainfall	0.2	0.2	0.15	0.14	0.16
4. Slope	0.1	0.12	0.14	0.15	0.14
5.Surface soil pH	0.14	0.14	0.1	0.1	0.07
6. OM	0.18	0.16	0.16	0.13	0.17
7. Stoniness	0.13	0.12	0.15	0.14	0.15
Overall score	1	1	1	1	1

4.3.4 Land quality

The specific sequence of steps used to create factor images depended on data in decision wizard of Idrisi. Before they were combined, factors must be standardized with fuzzy method by selecting suitable membership function shape (mononicallly increasing, mononically decreasing, and Symetric) and membership function types (sigmoidal, linear and user defined). The raw values in Appendix Table 4 were

standardized to have membership values (μ(x)) ranging from 0-1.0. For each LUT, the membership functions were selected for rainfall, soil drainage, OM, pH, slope, and stoniness, they are summarized in Table 4.11.

The shape of sigmoidal membership function is shown in Figure 4.4 both monotonically decreasing and monotonically increasing. In the monotonically increasing case, the value given for inflection points b, c, and d are identical. Similarly, in the monotonically decreasing function, a, b and c have identical values. These function types were applied for standardizing factors of organic matter, slope, and stoniness. (Table 4.11)

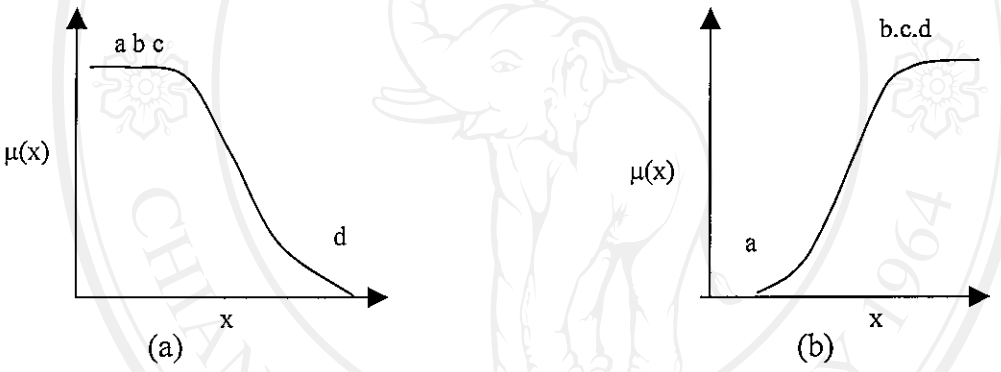

Figure 4.4 Sigmoidal membership function with monotonically decreasing (a) and monotonically increasing (b)

The Figure 4.5 below shows the linear function and its variants, along with the position of the inflection points. The factors that were standardized by the linear function type were pH and depth with symmetric and monotonically increasing shape respectively (Figure 4.5(a) and Figure 4.5(b)). The values of control points of these factors for LUTs were presented in Table 4.11.

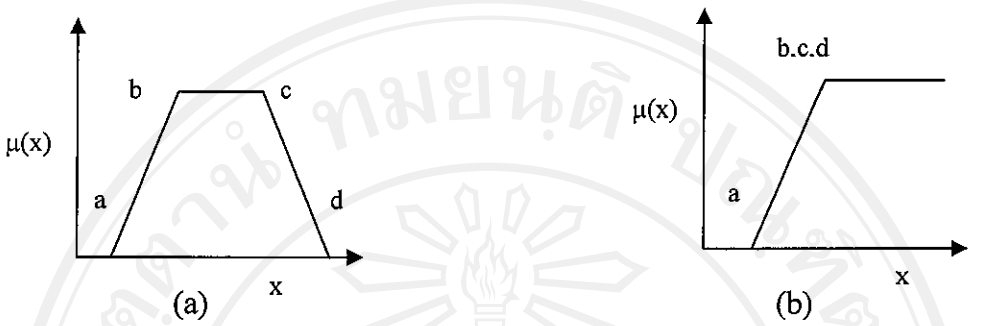

Figure 4.5 Linear membership function

The user-defined function is applied for soil drainage factor because the relationship between the value and fuzzy membership does not follow any of the main functions. The control points used in this function can be as many as necessary to define the fuzzy membership curve. The fuzzy membership between any two-control points is linearly interpolated, as in the Figure 4.6 below. In this study, soil drainage related to yield of LUTs according to mentions of effects of soil drainage to yield of crops for the south-eastern region in Vietnam (Pham, 1995). The percentages of yield were standardized to obtain the scores corresponding with the values of drainage levels. (Table 4.11)

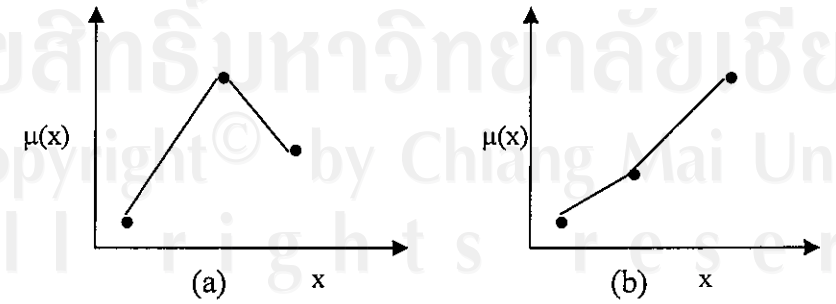

Figure 4.6 The user defined function

Table 4.11 Membership function of factors

LUTs	Function	pH	OM	Drainage	Slope	Rainfall	Depth	Stoniness
Rice-rice	Type Shape VCP	LI SY a=4.5, b=5 c=7 , d=8.5	SI MI a=1.5, b=3	User defined Poor=1 Moder=0.6 Well=0.4	SI MD c=0, d=8	SI MI a=1200, b=2000	LI MI a=30, b=80	SI MD c= 0 , d=10
Corn-corn	Type Shape VCP	LI SY a=4 , b=5.5 c=7 , d=8.5	SI MI a=0.5 , b=2	User defined Poor= 0.4, Moder=1 well= 0.6	SI MD c=0, d=25	SI MI a=600, b=1200	LI MI a=40, b=100	SI MD c= 0, d=15
Sugar cane	Type Shape VCP	LI SY a=4.5 , b=5.5 c=7 , d=8	SI MI a= 1, b=2.5	User defined Poor= 0.4, Moder=1 Well= 0.7	SI MD c=0 , d=20	SI MI a=900, b=1600	LI MI a=40, b=100	SI MD c=0 , d= 10
Rubber	Type Shape VCP	LI SY a=3.5 , b=5.5 c=6.5 , d=8.5	SI MI a=2 , b=3.0	User defined Poor= 0.4, Moder=1 Well= 0.7	SI MD c= 0, d=10	SI MI a=1200 , b=1700	LI MI a=50, b=100	SI MD c= 0, d=8
Cashew	Type Shape VCP	LI SY a=3 , b=5 c=7 , d=9	SI MI a=1.5, b=2.5	User defined Poor=0.5, Moder=1, Well= 0.7	SI MD c=0, d=15	SI MI a=1000 , d= 1500	LI MI a=50, b=100	SI MD c=0 , d=20
Rambutan	Type Shape VCP	LI SY a=3 , b=6 c=7 , d=8	SI MI a=1.5, b=3.0	User defined Poor= 0.3, Moder=1, Well= 0.7	SI MD c=0 , d=10	SI MI a=1300 , d=1800	LI MI a=50, b=100	SI MD c=0,d=10

Note:
Shape: LI: linear, SY: Symmetric, SI: Sigmoidal
Type: MI: monotonically increasing, MD: Monotonically decreasing, SY: Symmetric
VCP: value of control points

The rainfall factor was still considered for all of LUTs but for irrigated rice-rice, the effect of rainfall was assumed to be ineffective because of adequate irrigation water. After standardizing factors by fuzzy method, each membership value represents land quality for each LUT and the values range from 0 to 1.0.

The constraints were required to mask out the non-arable land. In this study the non-arable land was defined as roads, water bodies, planning constructions of local government, forest area and villages. The constraint area was about 57,367 ha

consisting of 17,621ha of Trian Hydroelectricity Plant, 35,660ha of forest, 1,503 ha of roads, 1,199ha of residential areas and 1,384ha of streams and rivers (Figure 4.7).

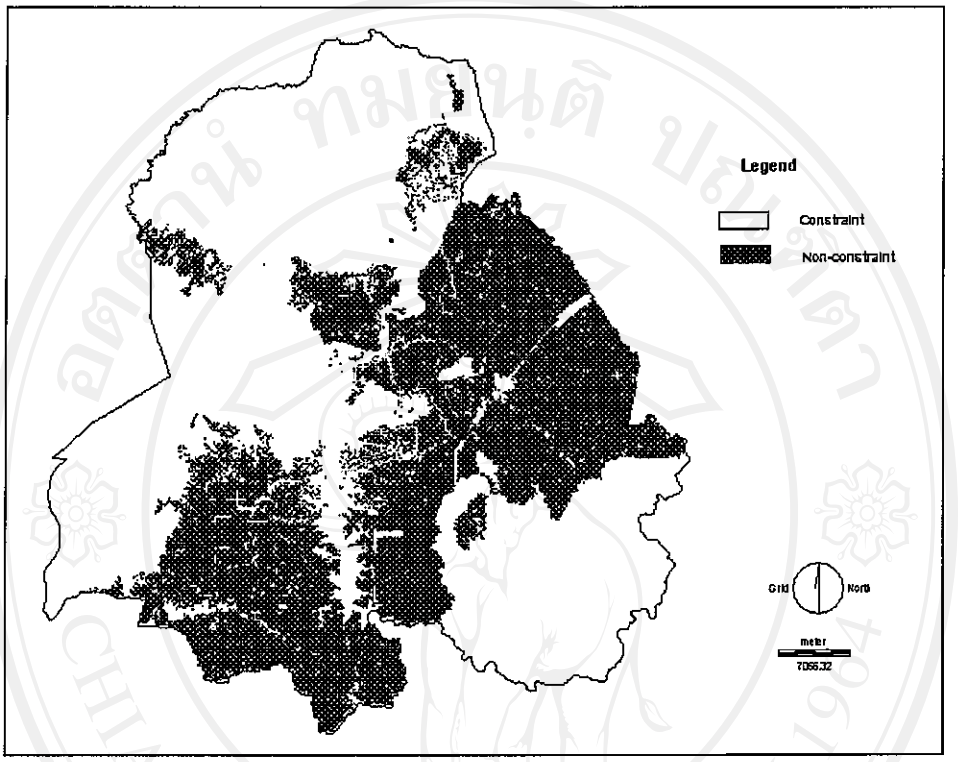

Figure 4.7 The constraint map in the study area

For irrigated rice-rice, the constraints showed non-arable land and the rainfed area (Figure 4.8). The area of rice- rice cropping system evaluated was 4,996 ha.

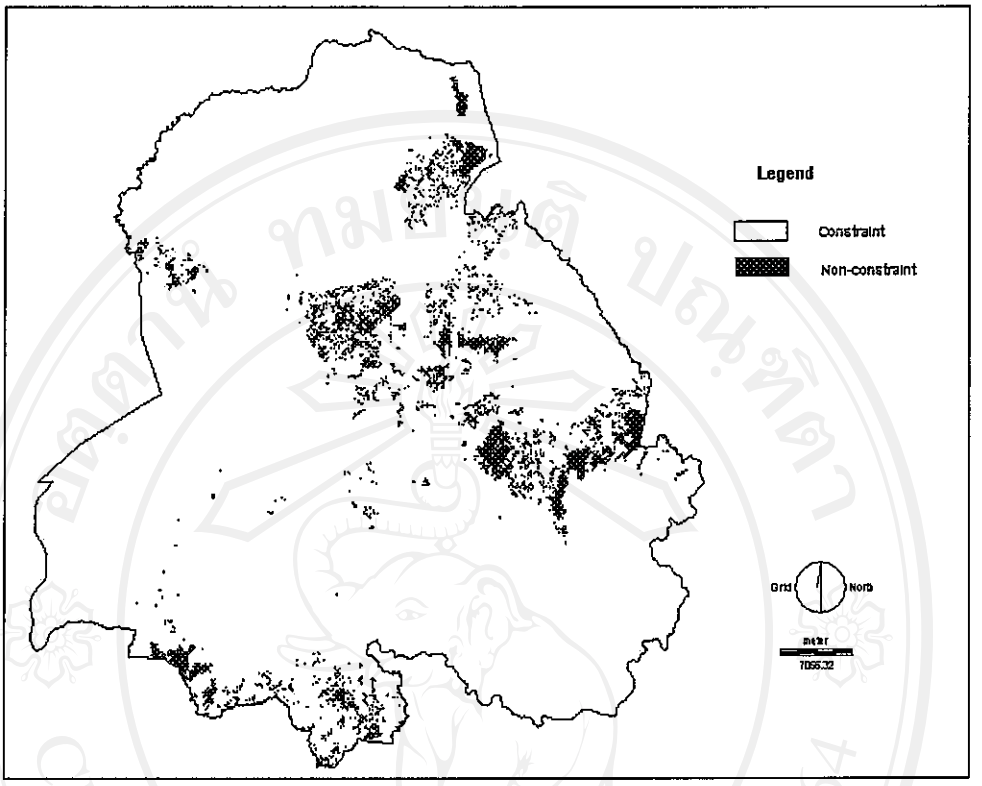

Figure 4.8 Constraint map of irrigated rice-rice cropping system

4.3.5 Physical suitability

The weighted linear combination method was used to combine land quality maps of LUTs. The physical suitability index was calculated by the following formula:

$$Si = \Sigma \mathbf{Wi} * \mathbf{Xi} * \Pi \mathbf{Cj}$$

Where, $\boldsymbol{S}$ = *suitability scores*

$\mathbf{w_i}$ = *weight of factor* i

$\mathbf{x_i}$ = *criterion score of factor i*

$\mathbf{c_j}$ = *criterion score(0 or 1) of constraint j*

$\prod$ = *product*

The relative weights (Wi) were calculated from pair-wise comparison of the AHP for each factor as in Table 4.9 and Table 4.10. The criterion score for each land quality of each LUT (Xi) was standardized by the fuzzy method. For irrigated rice-rice, the constraints (Cj) of irrigated rice- rice include rainfed and non-arable area while for the rainfed LUTs the constraint (Cj) includes only non-arable area.

The result of multi criteria evaluation for physical suitability was expressed as suitability index. The higher the value, the more suitable the land is, and vise versa. The suitability index ranges between 0-1.0. The score of 1.0 means highest suitability and value 0 is non-suitable. The suitability class according to FAO classification (1976) is defined from the suitability index as shown in Table 4.12 following S1, S2, S3 and N. The relative suitability class maps for irrigated rice-rice, rainfed corn-corn, sugar cane, cashew, rubber and rambutan are shown in Figure 4.9 to Figure 4.14.

Table 4.12 Suitability class for crops

Value	**Class**	
0-0.25	Non suitable	N
0.25-0.50	Marginally suitable	S3
0.5-0.75	Moderately suitable	S2
0.75-1.00	Highly suitable	S1

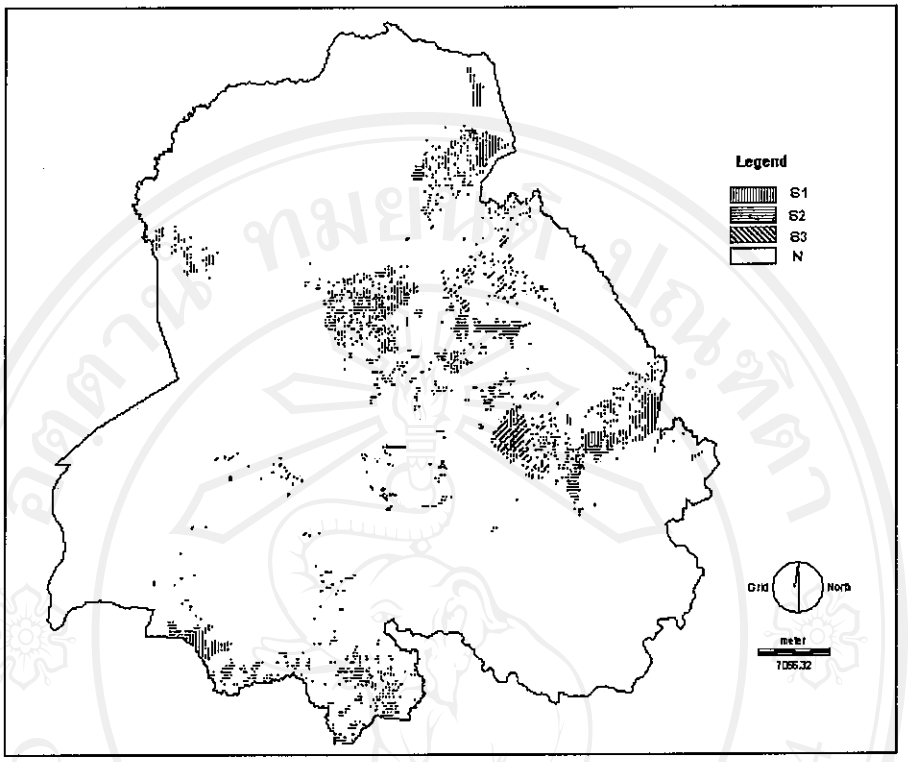

Figure 4.9 Physical suitability for irrigated rice-rice cropping system

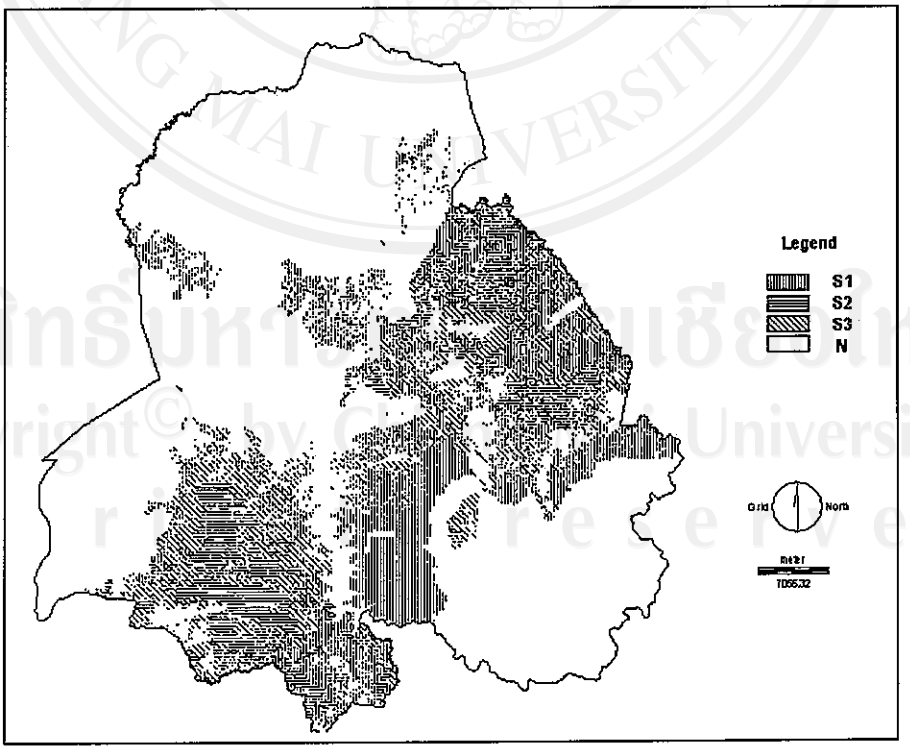

Figure 4.10 Physical suitability for rainfed corn-corn cropping system

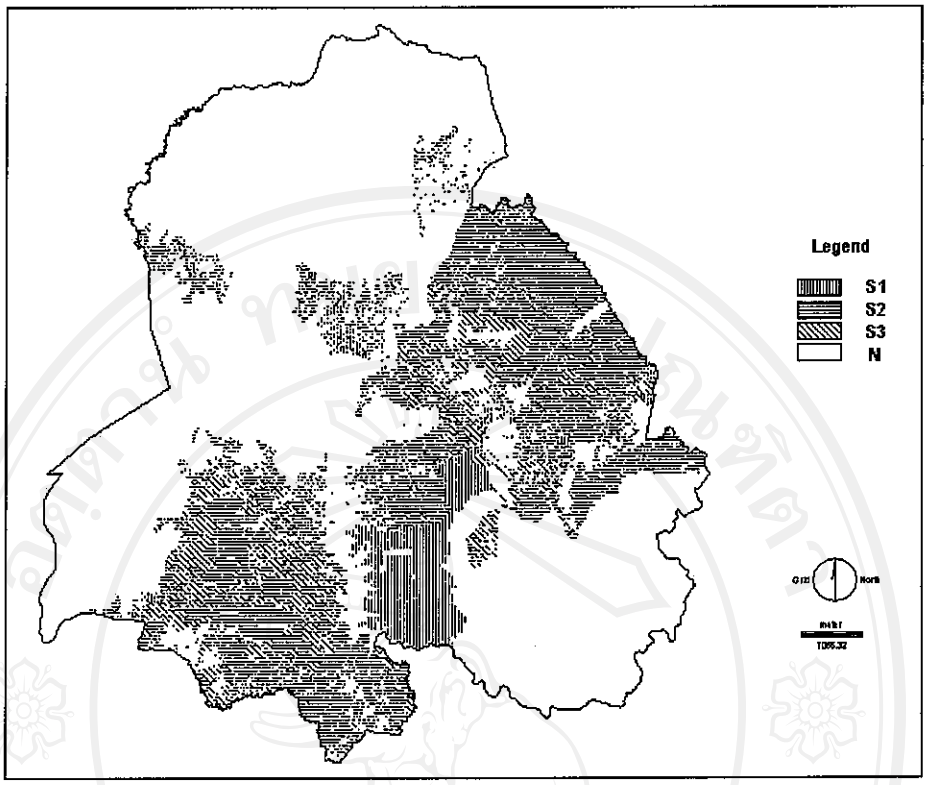

Figure 4.11 Physical suitability for sugar cane

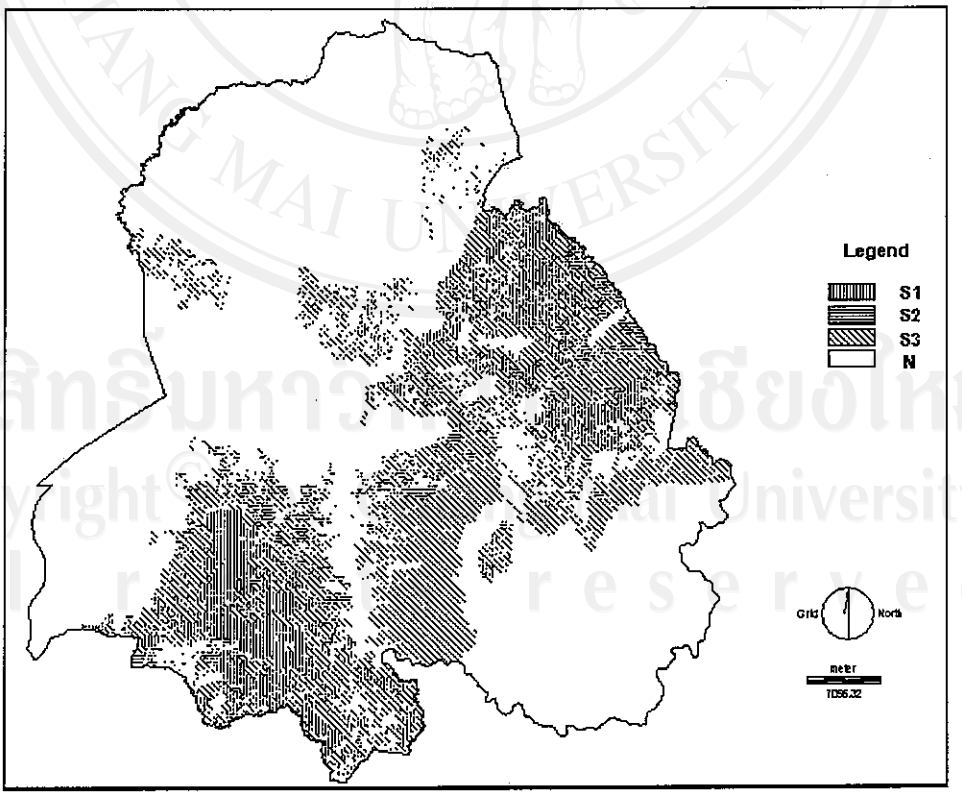

Figure 4.12 Physical suitability for rubber

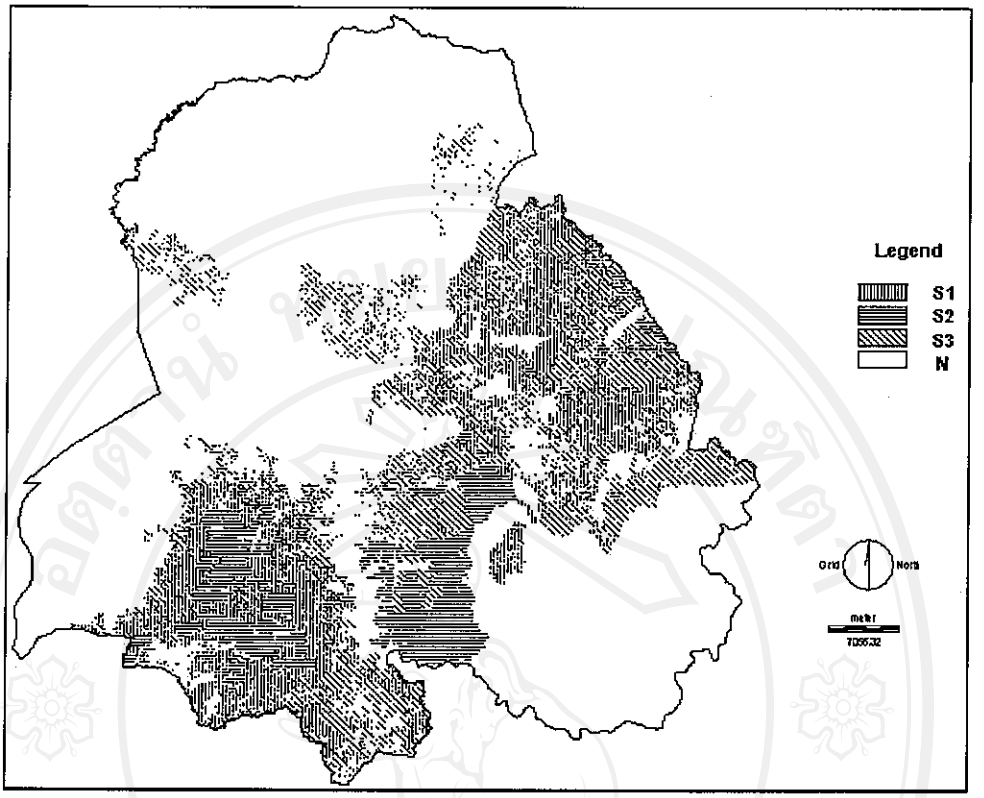

Figure 4.13 Physical suitability for cashew

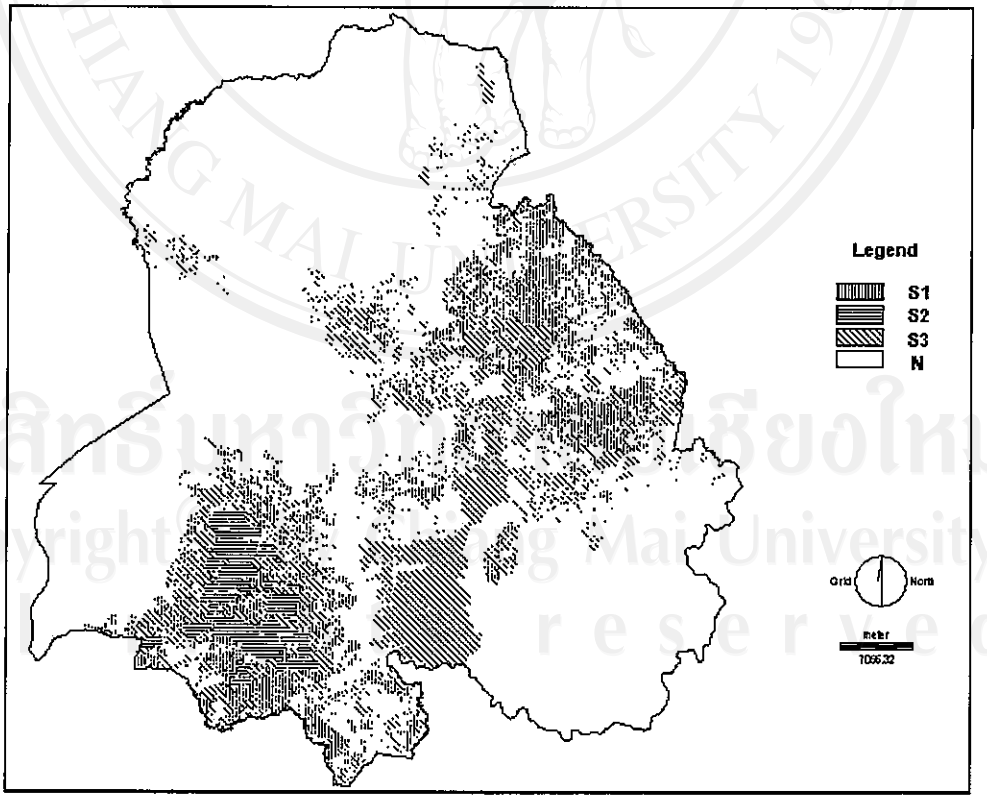

Figure 4.14 Physical suitability for rambutan

After reclassifying each suitability map of LUT into S1, S2, S3 and N, the distribution of physical land suitability are tabulated as shown in Table 4.13.

Table 4.13 Distribution of physical suitability class for crops

Suitability rate	Rice-rice		Corn-corn		Sugarcane		Rubber		Cashew		Rambutan	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
S1	2,031	40.7	8,023	20.4	6,231	15.9	6,875	17.5	7,850	20.0	4,523	11.5
S2	1,523	30.5	8,037	20.5	7,231	18.4	7,965	20.3	8,632	22.0	5,261	13.4
S3	1,023	20.4	18,236	46.4	8,652	22.0	7,036	17.9	12,361	31.5	10,351	26.4
N	419	8.4	4,987	12.7	17,169	43.7	17,407	44.3	10,440	26.5	19,148	48.7
Total	4,996	100	39,283	100	39,283	100	39,283	100	39,283	100	39,283	100

The process of land suitability classification involves appraising and specific types of land use in terms of their absolute or relative suitability for a specific kind of land use (FAO, 1976). The suitability map distinguishes different classes for crop production: highly suitability (S1), moderately suitability (S2), marginally suitability (S3) and non- suitability (N) on the basis of level of limitations associated. In the "non suitability" (N) class, no further distinction between "current non suitability "(N1) and "permanently non suitability" (N2) were made because this group constitutes natural land marks (ponds, forest and high hills) and built-up areas. It was also observed during the field survey that some areas with steep slope were heavily eroded resulting into unsuitable for crop cultivation. Based on the physical parameters, the study area delineated according to suitability classes for rice-rice, corn-corn, sugar cane, rubber, cashew and rambutan production.

Spatial analysis showed that as much as 40.7% of total irrigated area is highly suitable for paddy rice production. Likewise, 30.5% and 20.4% are of moderate and marginal suitability, respectively and the area under non- suitability category is 8.4%.

Land suitability analysis for corn-corn cropping system indicates that S1, S2, S3 and N categories for corn production accounted for 20.4%, 20.5%, 46.4%, and 12.7% of total arable area respectively.

For sugar cane, spatial analysis showed that 15.9% of total arable area is highly suitable for sugar cane production. About 18.4% and 22.0% of total arable area are grown on the moderately and marginally suitable land respectively. The non-suitable area (N) is 43.7%.

Land suitability for rubber suggested that about 17.5%, 20.3%, 17.9 and 44.3% of total arable area in suitability class S1, S2, S3, and N respectively.

About 20.0% of arable area was found highly suitable for cashew growing where as 22.0% and 31.5% area are classified as moderate and marginal suitability.

The proportion of area under S1, S2, S3 and N category according to rambutan suitability analysis accounted for 11.5%, 13.4%, 26.4%, and 48.7% of total arable area respectively. Rambutant is a crop requires high land quality and it is difficult to grow when having soil limitation leading to more N areas than other perennial crops.

4.3.6 Land allocation for selected crops

Gross margin analysis for annual crops (paddy rice, corn, sugar cane) and discounted cash flow analysis (net present value) for rubber, cashew and rambutan were used to calculate net benefit-cost ratio. Rambutan generated the highest net return of 9,471,000VND/ha. Other important crops were paddy rice, corn, sugar cane, rubber and cashew with a net return of 5,104,000VND, 5,350,000VND, 4,495,000VND, 5,476,000VND and 3,483,000VND, respectively (Table 4.6). Net benefit-cost ratio (NBCR) of rambutan were (1.53:1), cashew (1.01:1) and rubber (0.97:1) are higher than annual crops (paddy rice (0.70:1), corn (0.66:1) and sugar cane (0.57:1)) (Table 4.14).

Table 4.14 Net benefit-cost ratio (NBCR) of selected crops

Cropping systems	NBCR
Rambutan	1.53
Cashew	1.01
Rubber	0.97
Rice (S)-rice (M)	0.70
Corn (S)-corn (W)	0.66
Sugar cane	0.57

NBCR of each crop was used to assign weights (W_j) for setting up priority for land allocation. The standardized values of weights for selected crops are shown in Table 4.15. However, according to local government, the existing rice-rice cropping system area must be maintained for food security policy of local subsidy demand. Thus, the significance of this LUT was defined clearly, weight value for rice-rice cropping system is not necessary to calculate.

Table 4.15 The economic priority expressed as weights standardized from NBCR

Kind of crops	Relative weight
Rambutan	0.32
Cashew	0.21
Rubber	0.21
Corn (S)-corn (W)	0.14
Sugar cane	0.12
Total	1.00

The product of economic priority and physical suitability index of major crops were used to obtain the land allocation for crops. The process was carried out in the attribute table of suitability land allocation for LUTs, the table was exported to Excels software. The attribute table contained records and fields indicating LMU and physical suitability indices of each LUT respectively. The physical suitability index in each cell of each LUT was multiplied by value of economic weights of each crop. A Max_crop field was created as the new field in the attribute table. The value in each cell of this field was the result of selecting the maximum value among of crops in a row. A code_crop field was also created to code the name, which has maximum suitability. The resulting attribute table was imported into Idrisi and linked with the map to display the final relative suitability and LUTs which were allocated to each LMU (Figure 4.15).

The land allocation for crops was calculated and shown in Table 4.16. The results indicate that crops (rambutan, rubber and cashew) are still the most important crops that were allocated in the study area. The areas allocated to perennial crops and annual crops were 51.6% and 46.5 % of total assessed area respectively.

Table 4.16 The result of land allocation in the study area

Land use types	**Area (ha)**	**Proportion (%)**
Cashew	10,238	26.06
Corn (S)-corn (W)	10,803	27.50
Rambutan	6,689	17.03
Rice (S)- rice (M)	4,577	11.65
Sugar cane	2,881	7.33
Rubber	3,346	8.52
Non suitable	749	1.91
Total assessed area	39,283	100
Constraint area	57,367	
Total area	**96,650**	

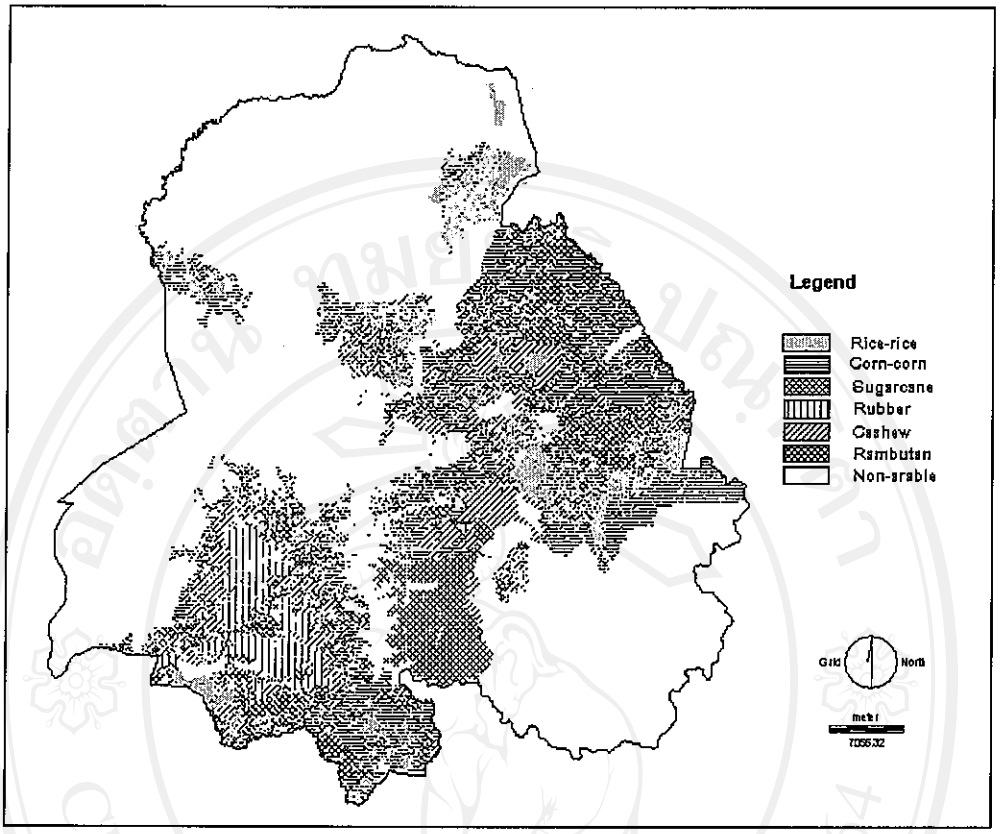

Figure 4.15 Land allocation for selected crops in the study area

Land allocation areas for crops were overlayed on the existing land use map to see how selected crop areas used in the land evaluation study match with results of land allocation. Land use types in land allocation were recoded differently from values of the existing land use types before overlaying together to gain the matched areas. The values of matched areas were grouped before calculating areas. The results are shown in Table 4.17. For rubber and corn-corn cropping system, the proportion of matched areas with existing land use were 0.99% and 0.96% respectively. Allocating land for these two LUTs were very similar to the existing areas. For other LUTs, proportional areas of agreement varied from 0.86 to 0.91 for rambutan, cashew, sugar cane, rice-rice cropping system. It clearly shows that rambutan can be expanded to meet land potential and obtain more efficient use.

Table 4.17 Matched areas between land allocation and existing land use

Land use types	Land allocation areas (ha)	Existing land use areas (ha)	Matched areas (ha)	Proportion of matched area
Cashew	10,238	9,898	8,546	0.86
Corn (S)-corn (W)	10,803	7,915	7,563	0.96
Rambutan	6,689	3,364	2,895	0.86
Rice (S)- rice (M)	4,577	4,996	4,532	0.91
Sugar cane	2,881	3200	2,881	0.90
Rubber	3,346	3,021	3,005	0.99

The study provides information on both physical suitability for each crop of and relative suitability of major crops for each LMU. This offers alternative cropping systems for farmers and policy makers to select LUT according to their objectives. The areas have inherently low nutrient status so that the cashew and corn are suitable and cover extensively in the study area. According to the land qualities in the area, the principal limiting factors are the soil depth and stoniness and rock outcrop and fertility for rainfed crops. The results indicate that the highly suitable area is allocated to rambutan, paddy rice and rubber. It is also observed that the moderately suitable and the marginally suitable area for cashew occupy the marginally suitable area of the rubber and rambutan; and moderately suitable area for corn occupies the moderately and marginally suitable area of paddy rice and sugar cane.

The alternatives for agricultural land use are dynamic and varied according to the market prices of the products. The process of developing alternatives for the study area requires proper economic and goal of stakeholders. The decision maker can make the proper decision given clear economic and environmental goals. The GIS layers established can support to achieve the goals set by the stakeholders.

4.4 Examples of scenarios for land use planning

Dinhquan is one of the areas that the government intends to use for developing agricultural production in Dongnai province. The majority of products can be contributed to raw material area for processing factories in the industrial zone. Some farmers already have enough capital or supported credits from the agricultural bank of the district. They are encouraged to grow rambutan aiming to increase the income and maintain the ground cover to protect environments of a district in the upper zones of Dongnai and Langa watersheds.

In order to support the plan, two scenarios were created and land evaluation technique was implemented to assess and visualize the results of these two scenarios.

Scenarios I. The policy makers decide to decrease corn production area by 20% (1,583 ha) in order to reduce environmental effects due to soil erosion.

Scenario II. The policy makers decide to expand rambutan-growing area by 50% (1,682 ha) in order to boost productivity of the district.

The solution started with the physical suitability classes of corn and rambutan using above land evaluation technique, then find the most suitability land that meet the target areas according to the scenario.

Modules GROUP and AREA were used to calculate cumulative areas to meet the target areas for corn and rambutan set in scenarios. Module GROUP was used to determine contiguous grouping of the identical integer value for cells in physical suitability grids of corn and rambutan. Cells belong to the same contiguous grouping were given a unique integer identifiers numbered consecutively in the order found (Eastman, 2001). AREA module was used to calculate the area of each group in hectares unit. In the scenarios, the target area for reduction of corn is 1,583 ha and for expanding rambutan is 1,682 ha while the existing areas for corn and rambutan were 7,915 ha and 3,364 ha, respectively.

Corn areas were reclassed and extracted from existing land use and overlayed with physical suitability index for corn. The Image Calculator module was used to select the areas from the lowest to the highest suitability index to gain the areas that meet the target area of corn (1,583 ha).

For rambutan, the expanding areas were identified from the rainfed areas that are currently used for other annual crops and have high suitability index for rambutan. Before overlaying with physical suitability index for rambutan, existing rambutan areas were reclassed as 0 to exclude them from the analysis. GROUP and AREA modules were used to support the sorting of the areas from highest to lowest suitability index until the area reaching nearest value of 1,682 ha.

The Figure 4.16 and Figure 4.17 present the distribution of the target areas for reducing corn and expanding rambutan cultivation in the study area according to scenario I and II respectively.

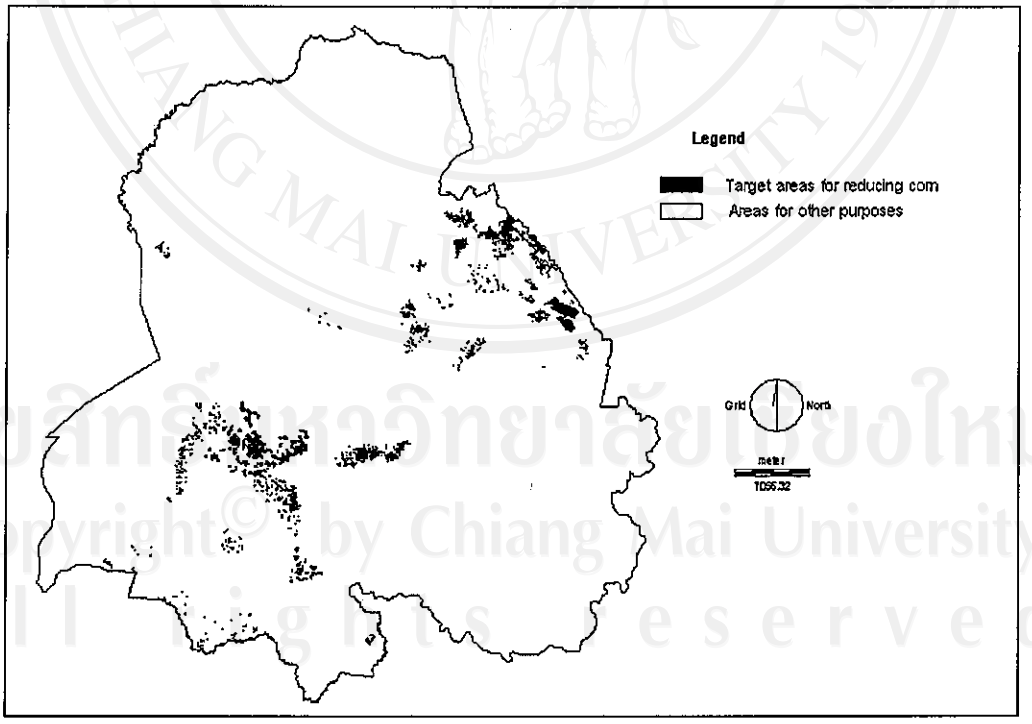

Figure 4.16 Target areas for reducing corn production in the study area according to the Scenario I

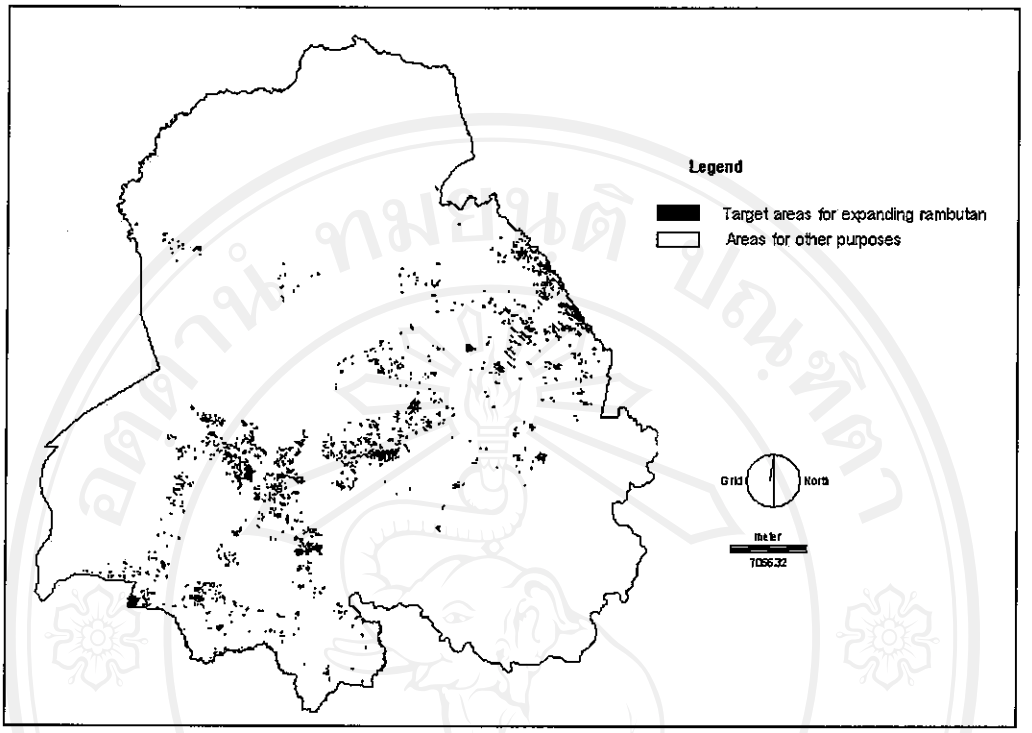

Figure 4.17 Target areas for expanding rambutan production in the study area according to the Scenario II

To define which LUTs will occupy the reducing corn area, the LUTs which have the highest suitability index for the LMUs that coincide with the reduced areas were selected. Target area for reducing corn was overlayed with land allocation for selected crops to obtain the alternative crops to replace corn. Areas for LUTs that will be most suitable to replace 1,583 ha of corn are shown in Table 4.18 and Figure 4.18. It was found that 623 ha of cashew and 960 ha of rambutan were selected.

Table 4.18 LUTs selected to replace corn in the scenario I

Planned LUT	Replaced LUTs areas (ha)	
Reduced corn areas (ha)	Cashew	Rambutan
1,583	623	960

For the scenario II, the expanding areas of rambutan (1,682 ha) occupy 720 ha and 962 ha of existing cashew and corn.

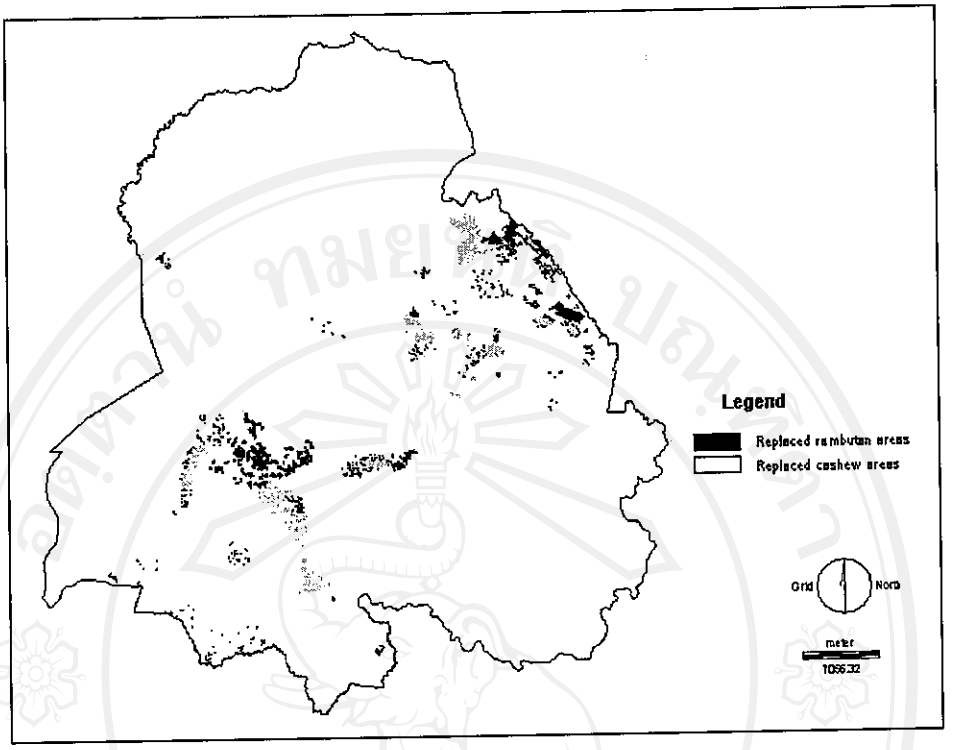

Figure 4.18 Areas of cashew and rambutan replace for reducing corn areas