4. RESULTS AND DISCUSSION

4.1 THE PHYSICAL SUITABILITY

The physical suitability class is arranged into 5 classes. The most suitable class without limitation is class 1. The permanently not suitable one is class 4. The moderately suitable and marginally suitable classes are named class 2 and class 3 respectively. The '*nr*' class is the land that was not included in the evaluations. In this study, it is soil unit no. 62.

The physical suitability classes and subclasses matrix proceeded by matching soil data from DLD and the land use requirements from CSR/FAO (1983) as indicated in Appendix Table 11. Some land mapping units attained more than one physical suitability subclass because the of LQ value for each suitability class are not equal when data were obtained from different sources. This is the weakness of using secondary data which is usually reported by the estimated range but not by the specific value. The results showed that more than one physical suitability subclass could be assigned, together with percentage of probability to be in that subclass, for each LMU. For example, the physical suitability subclass of soil unit no. 29B for growing rainfed corn was assigned as 4n = 0.66, 4n/r = 0.33 (Appendix Table 11-2). It means that soil unit no. 29B has probability of 66% to be categorized as subclass 4n and 33% as subclass 4n/r. Some LMU were assigned with too many subclasses such as the soil unit no. 47D for growing rainfed peanut (Appendix Table 11-3). Its subclasses were 4r = 0.3267,

3s/n/r = 0.212454, 3n/r = 0.166518, 3s/n = 0.153846, 3n = 0.120582. Those results are difficult to conclude and/or to use for further operation. This needs further adjustment for some characteristics of land by field checking in order to improve those suitability subclasses. The land use requirements were also modified to be able to evaluate with available data in Phrao agricultural area.

4.1.1 Current Physical Suitability

The current physical suitability is the suitability of land if it used in its present condition without major improvements. Examples of raster images of the suitability classes and subclasses for various cropping systems are shown in Figures 7 to12. The figures show that there was no suitability class 1 in this area. This indicates that if the farmers want to attain the optimum yield, some improvements are necessary.

In the study area, the most severe limitation was nutrient availability especially for growing corn. Nutrient availability can be assessed from three land characteristics, total nitrogen, available P_2O_5 and available K_2O which can be improved by fertilizer applications. Another severity was the flood hazard for growing field crops (corn, peanut and soybean) in the rainy season. This could not be improved in the study area by minor operation. There were some severe limitations caused by the steep slope and the rolling area, surface stoniness and rock outcrops. Bench terraces and contour bunds could improve the suitability level of the steep areas for growing the field crops. Other limitations, such as nutrient retention and rooting condition,

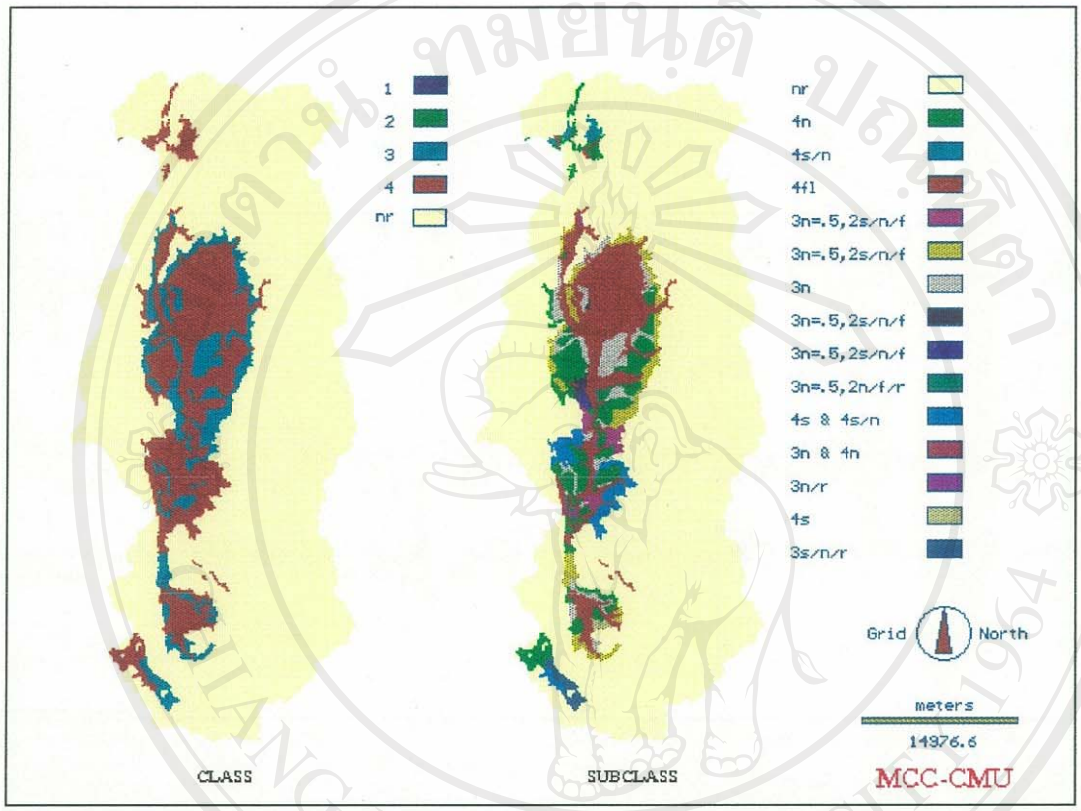

Figure 7. Current physical suitability classes and subclasses for rainfed corn production in Phrao District.

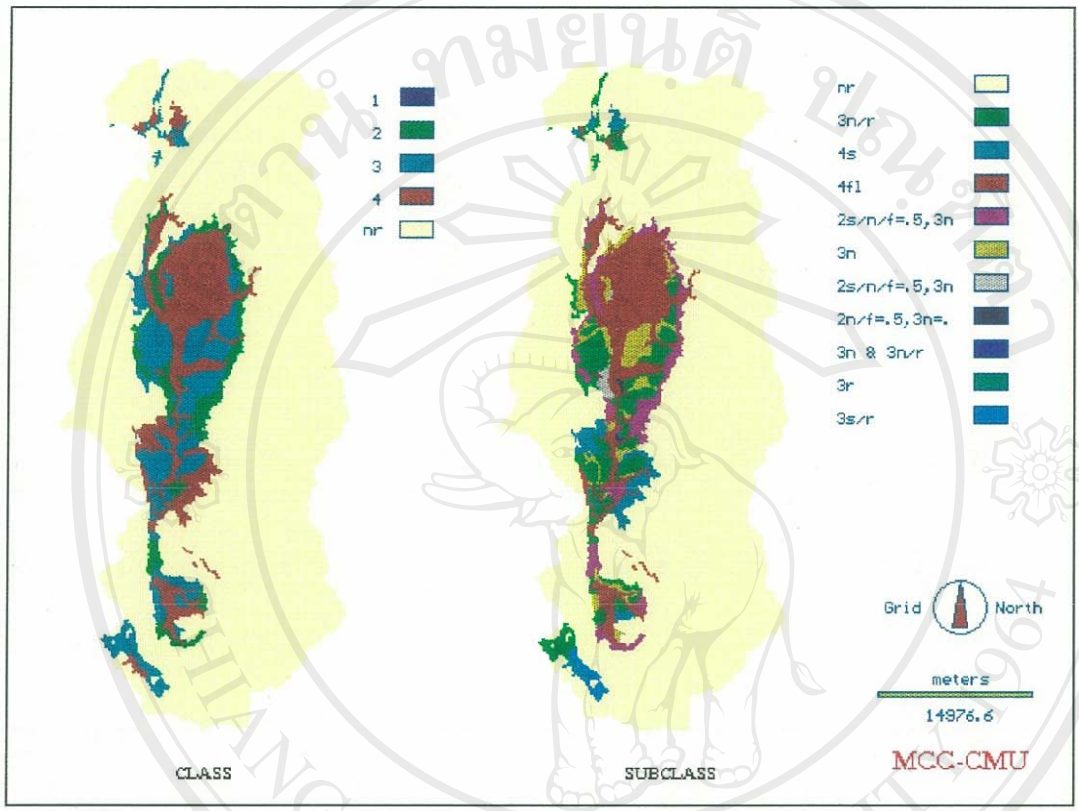

Figure 8. Current physical suitability classes and subclasses for rainfed peanut production in Phrao District.

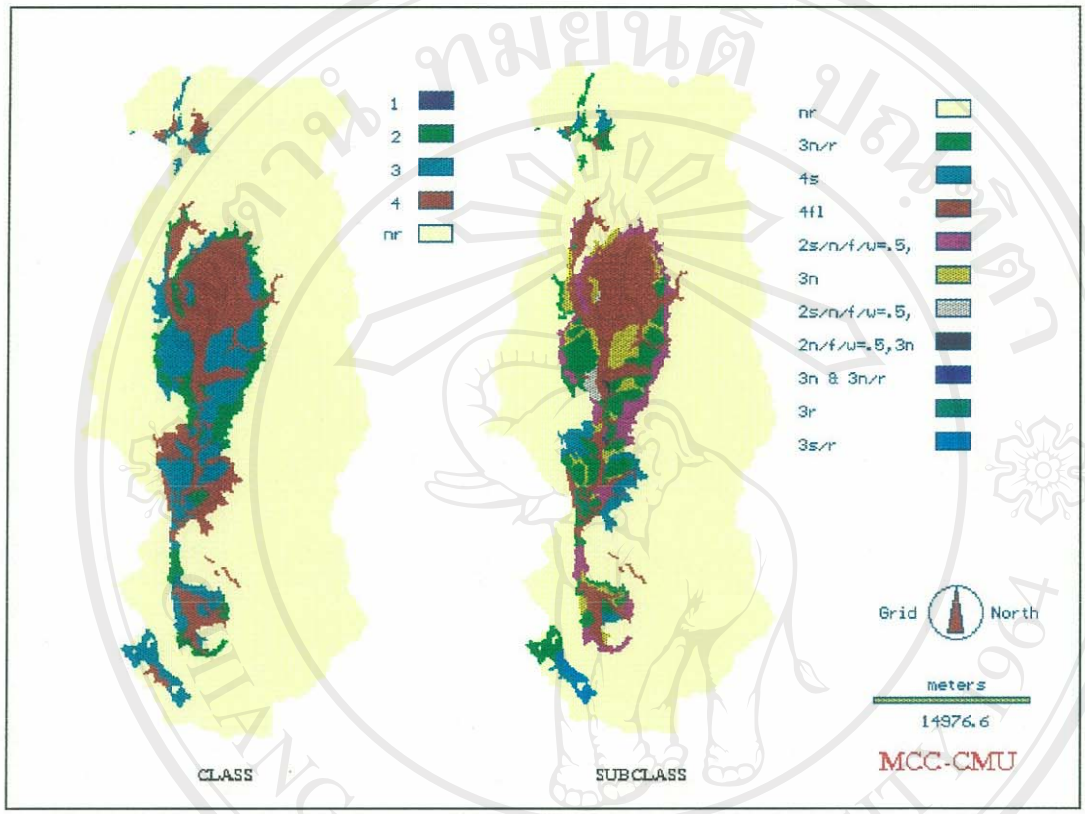

Figure 9. Current physical suitability classes and subclasses for rainfed peanut-peanut production in Phrao District.

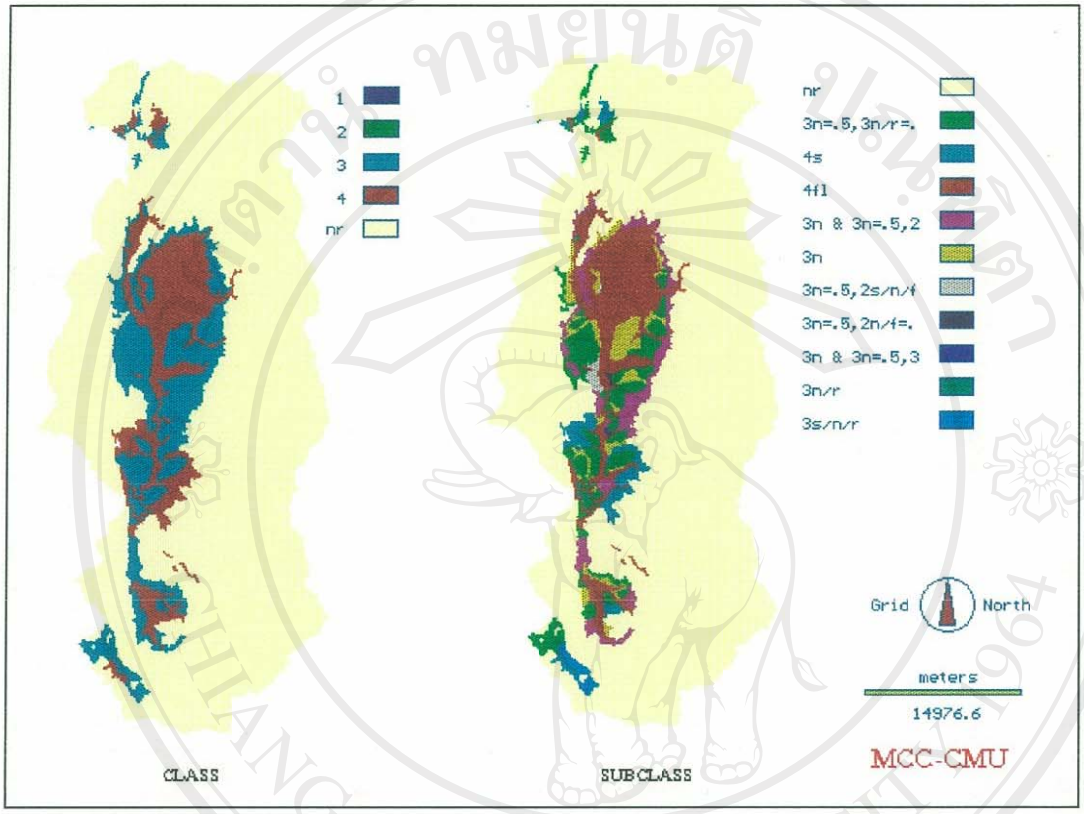

Figure 10. Current physical suitability classes and subclasses for rainfed soybean production in Phrao District.

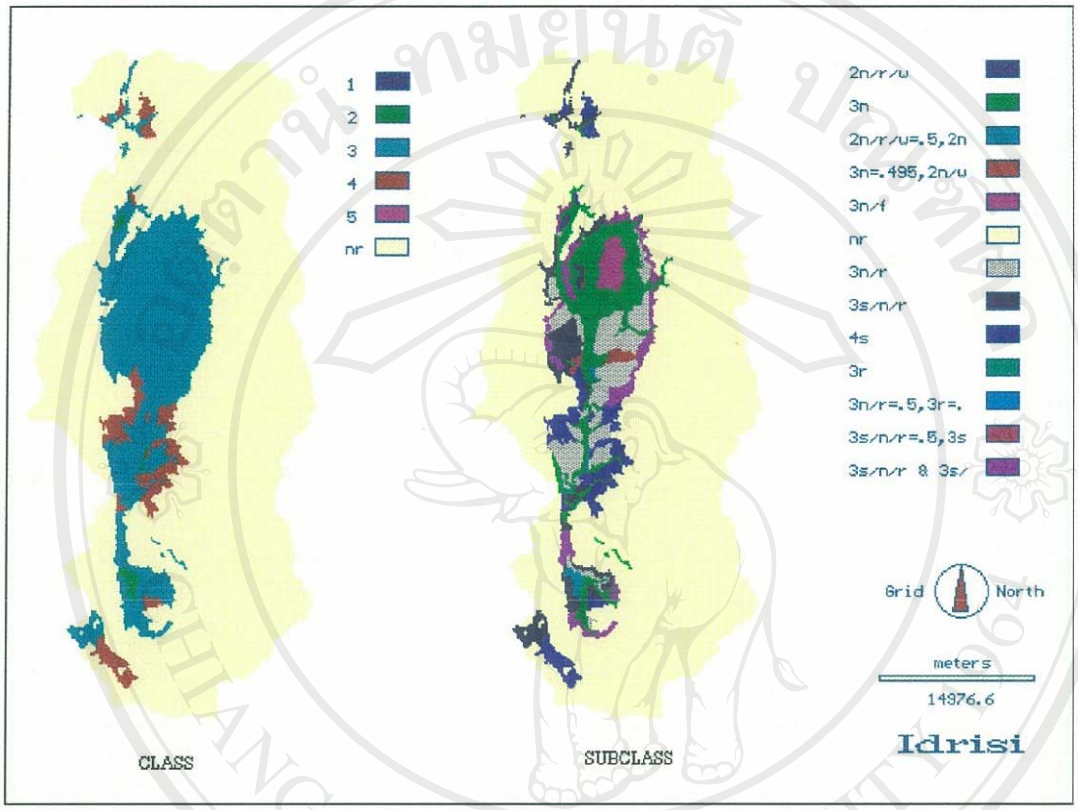

Figure 11. Current physical suitability classes and subclasses for rainfed rice production in Phrao District.

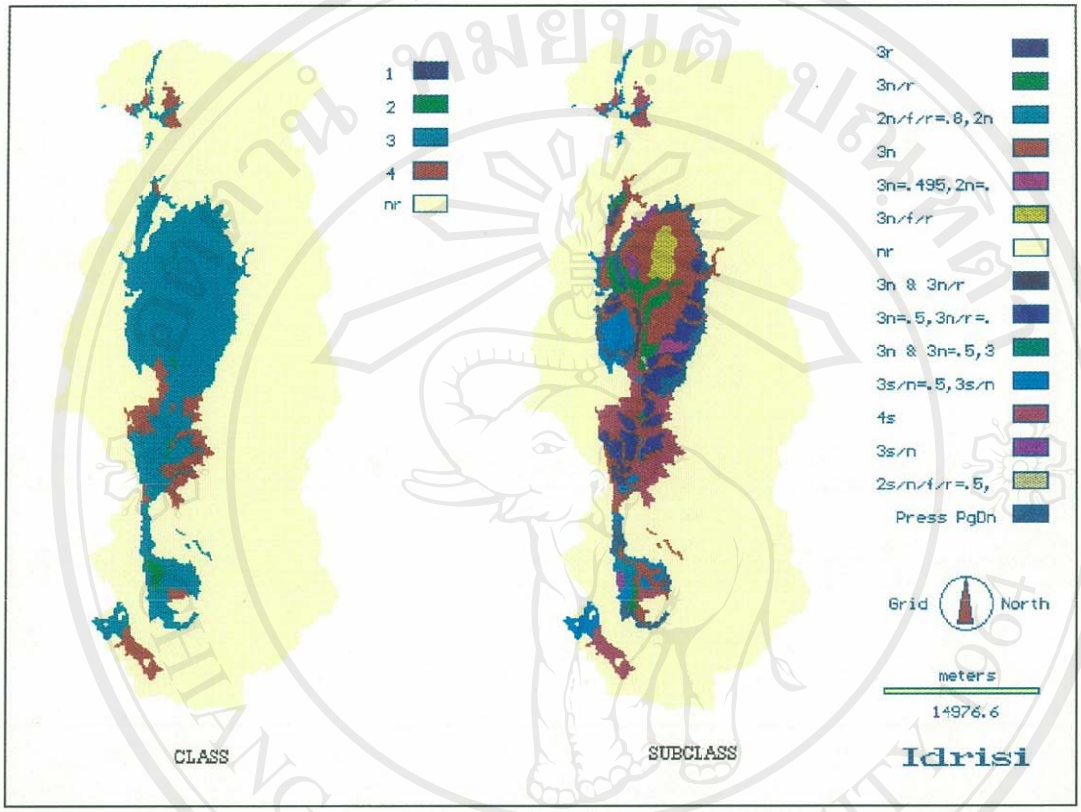

Figure 12. Current physical suitability classes and subclasses for irrigated rice-soybean production in Phrao District.

rarely occurred in the area. There were no limitations on water availability and temperature regime.

As mentioned earlier, the highest value of severity level of LQ determined the most severe limitation for using that LMU if maximum limitation method was used for land evaluation. Physical suitability classes evaluated by ALES using maximum limitation method resulted in class N2 being assigned to most of agricultural area in Phrao district. It means that those lands could not be used to grow those crops in the current status and it was uneconomic for the given use (FAO, 1976). Nevertheless, some LQs (i.e., nutrient availability, terrain, nutrient retention) could be improved overtime through changes in some economic and social conditions. Hence, the most severe LQs would neither cause the physical suitability subclass to be class 4 nor class N2 if economic suitability is assessed. To reclassify the physical suitability subclass, the maximum limitation method of all selected LQs could not be done but it was easily obtained when reconstructing the decision trees.

4.1.2 Potential Physical Suitability

The decision tree allows the model builders to use alternative criteria to determine class of physical suitability. Therefore, the physical suitability of class 4 for the improvable LQs were shifted to class 3 for further consideration on the economic suitability rating. The results of computations by traversing decision trees are displayed in Figures 13 to18. This can be considered as the classification of the potential suitability for a defined use after specified major improvements (FAO, 1976). The results

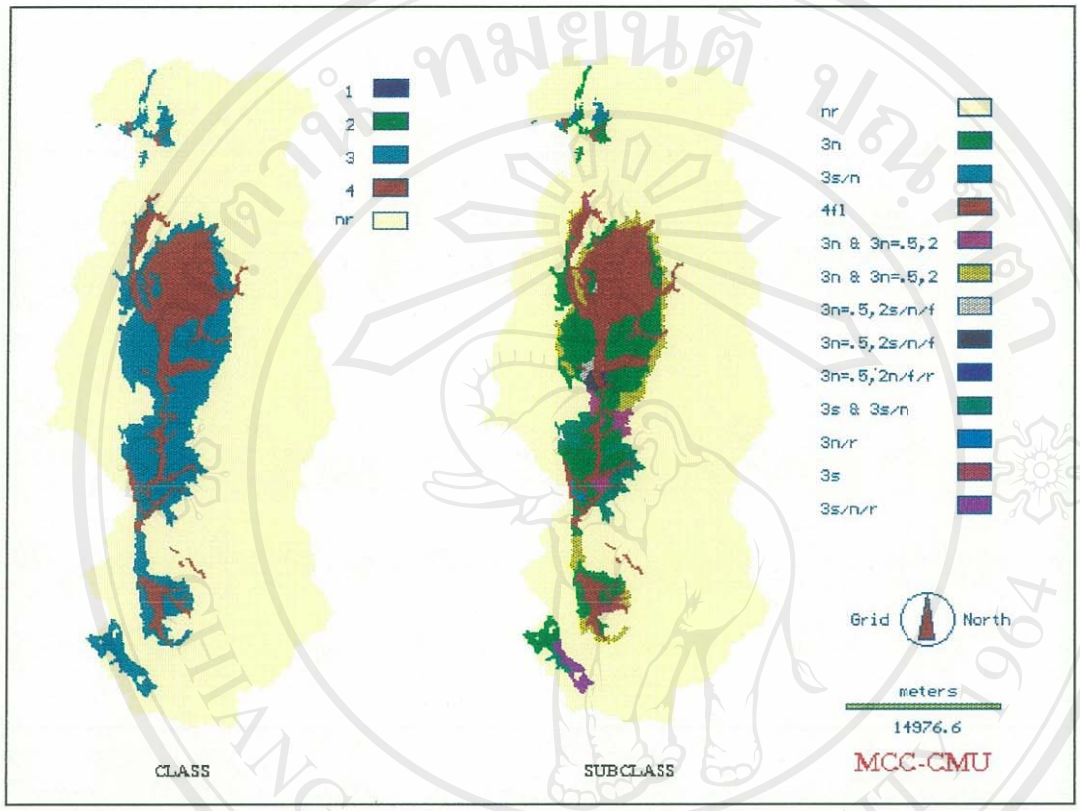

Figure 13. Potential physical suitability classes and subclasses for rainfed corn production in Phrao District.

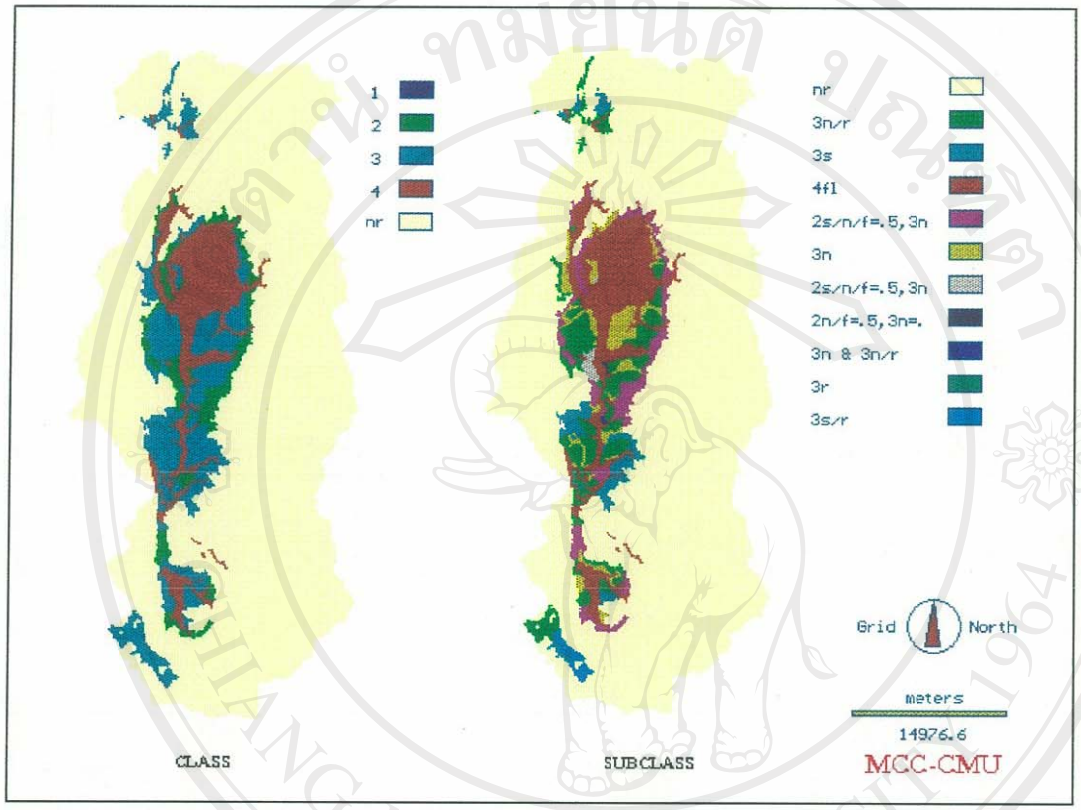

Figure 14. Potential physical suitability classes and subclasses for rainfed peanut production in Phrao District.

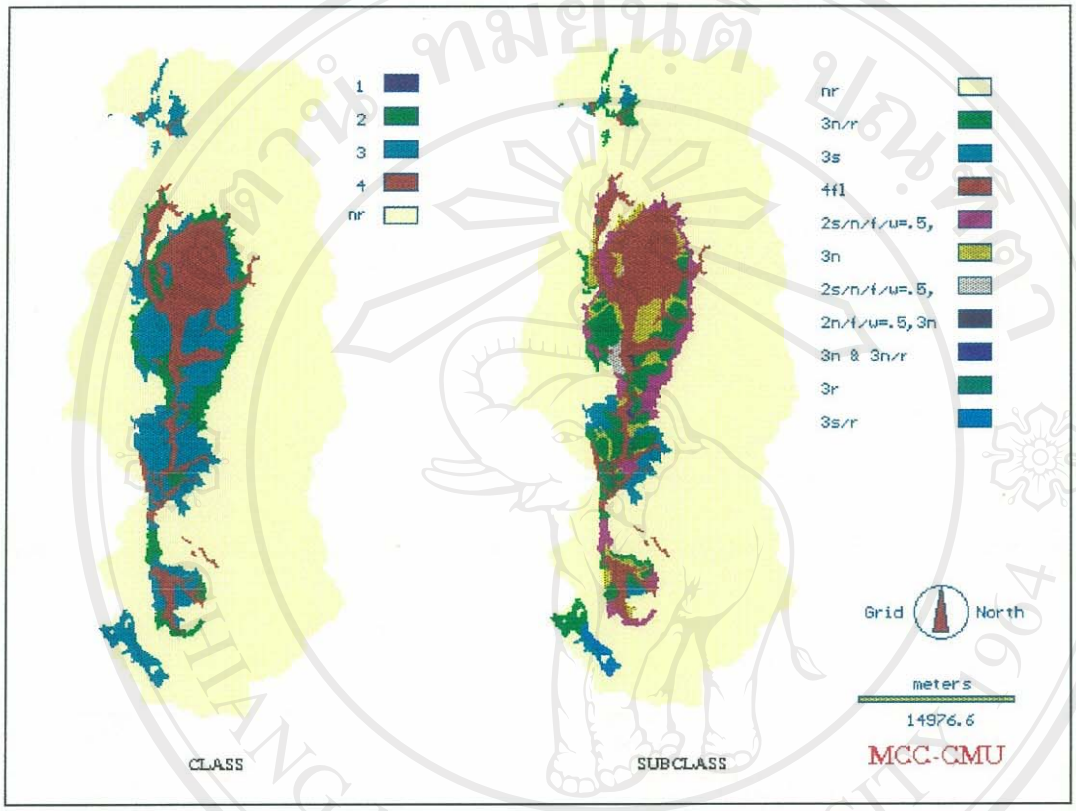

Figure 15. Potential physical suitability classes and subclasses for rainfed peanut-peanut production in Phrao District.

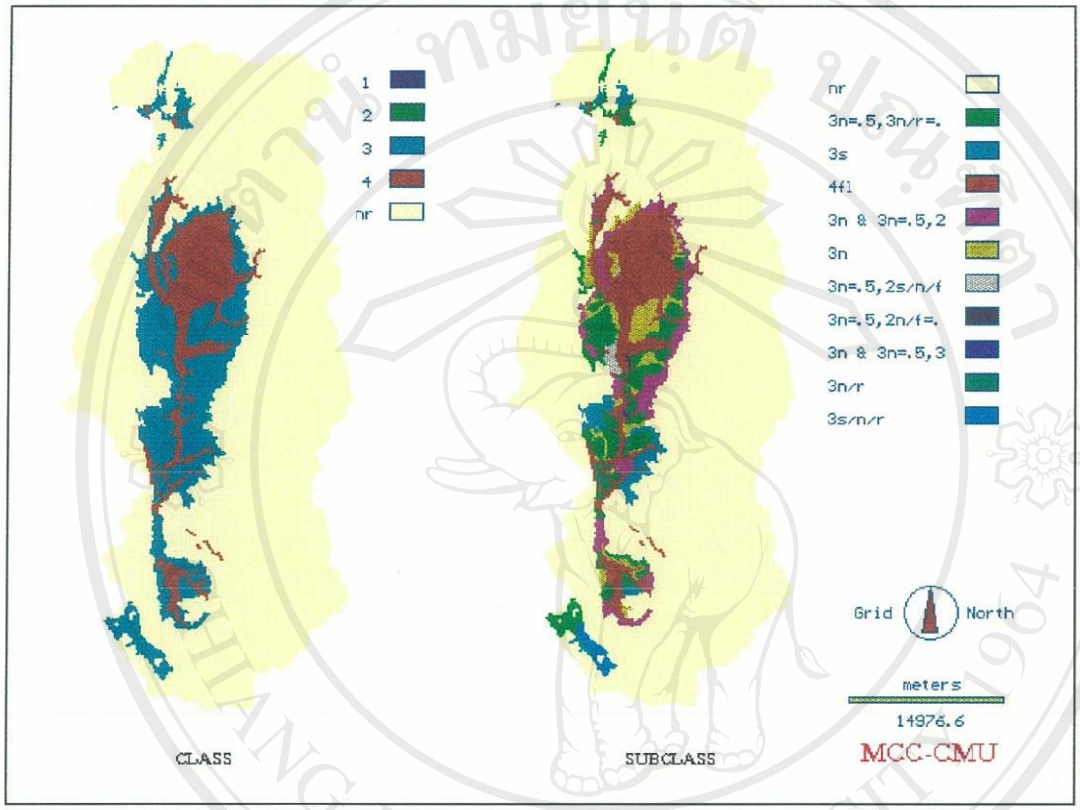

Figure 16. Potential physical suitability classes and subclasses for rainfed soybean production in Phrao District.

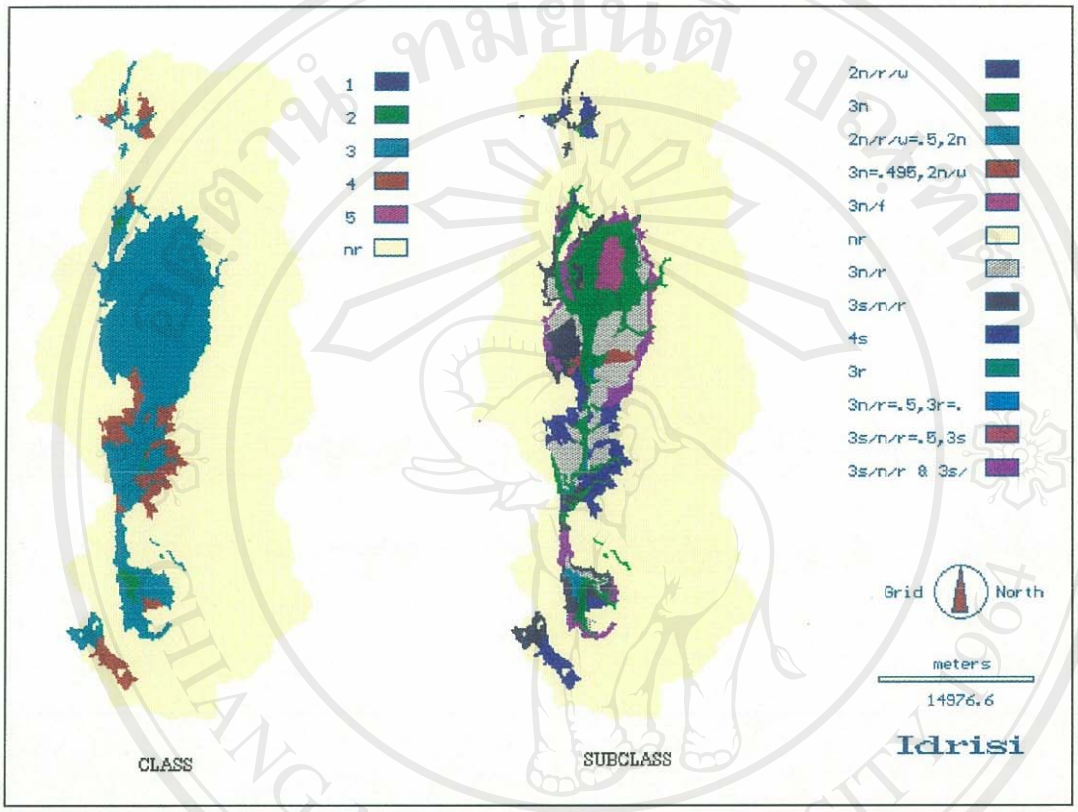

Figure 17. Potential physical suitability classes and subclasses for rainfed rice production in Phrao District.

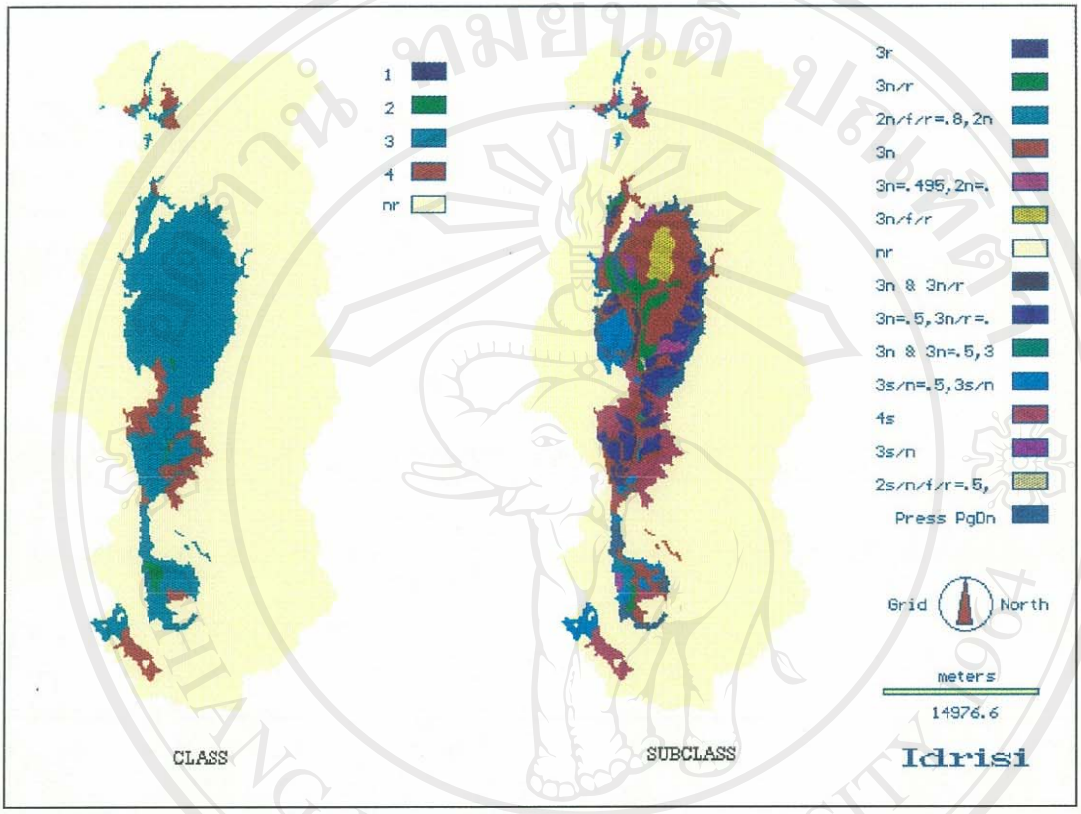

Figure 18. Potential physical suitability classes and subclasses for irrigated rice-soybean production in Phrao District.

showed that the flooded areas could not be used to grow field crops and the sloping areas were not allowed to grow rice. In contrast, rice could be grown in flooded areas and field crops could be cultivated on the sloping areas.

Comparison was made on the percentage of the agricultural area in Phrao district of each class based on current physical suitability (Table 9) and potential physical suitability classification (Table 10). The land evaluation for field crops indicate that significant amount of lands were moved from subclass 4 to subclass 3 when the nutrient availability and terrain were considered as the improvable LQs. In addition, the economic suitability could be further assessed. However, rice in subclass 4 as limited by steep terrain could not be improved by minor operation. Therefore, results of the potential physical suitability rating in those areas are the same as in the current one.

Table 9. Area (percentage) of different current physical suitability subclasses of the evaluated crops.

Subclass	Corn	Peanut	Peanut-Peanut	Soybean	Rice	Rice-Soybean
1	-	-	-	-	-	-
2	-	15.0	15.0	-	1.6	1.4
3	29.4	39.5	39.5	54.5	83.4	83.6
4	70.6	45.5	45.5	45.5	15.0	15.0

Table 10. Area (percentage) of different potential physical suitability subclasses of the evaluated crops.

Subclass	Corn	Peanut	Peanut-Peanut	Soybean	Rice	Rice-Soybean
1	-	-	-	-	-	-
2	-	15.0	15.0	-	1.6	1.4
3	63.1	48.0	48.0	63.1	83.4	83.6
4	36.9	37.0	37.0	36.9	15.0	15.0

4.2 Comparison of the Evaluation Results

The physical suitability classes, both current and potential ones as computed by ALES, were compared to the suitability classes assessed by the DLD method (DLD, 1990). The comparison was made also to the present land use in Phrao district that was surveyed by DLD in 1992.

4.2.1 Comparing the ALES Physical Suitability Classes with the Land Suitability Class by DLD.

The land suitability classes by DLD (including 4 crops of rainfed corn, rainfed peanut, rainfed soybean and rainfed rice) are displayed in Figure 19 to 22.

The DLD method classified the land into three physical suitability classes namely suitable, moderately suitable and not suitable. The limitations defined by DLD for soil units in Phrao are shown in Table 11.

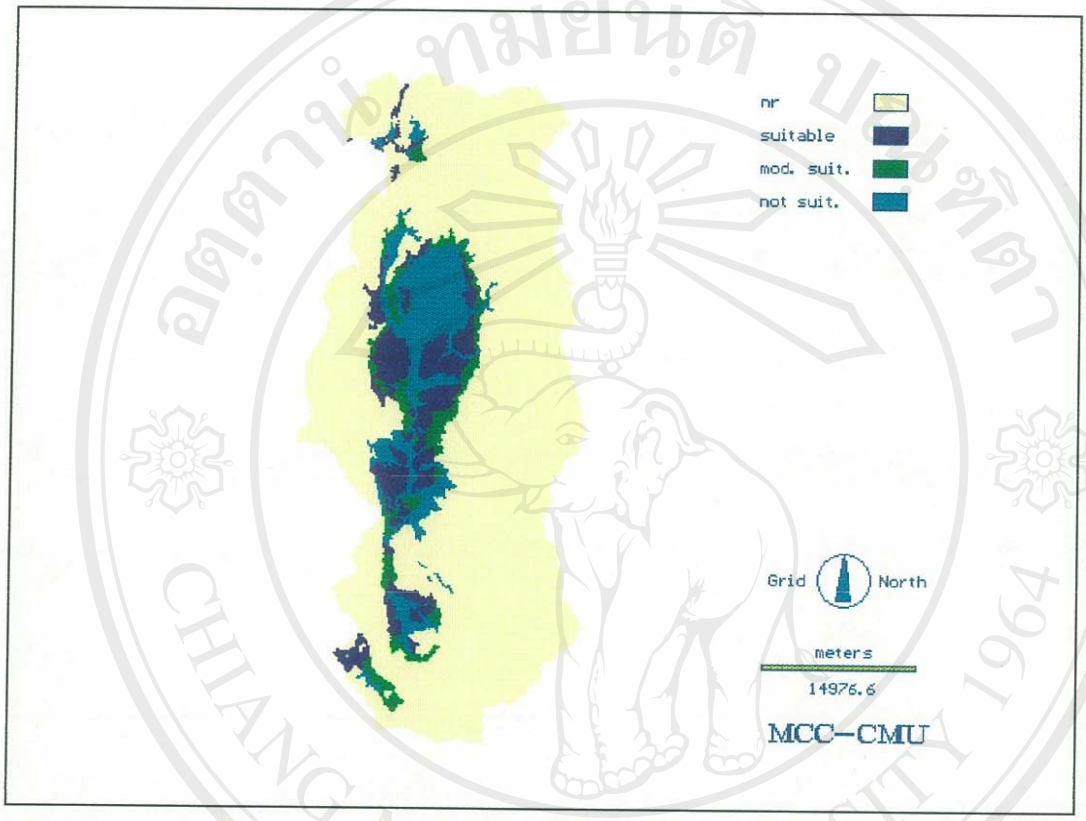

Figure 19. Land suitability classes by the DLD method for rainfed corn production in Phrao District.

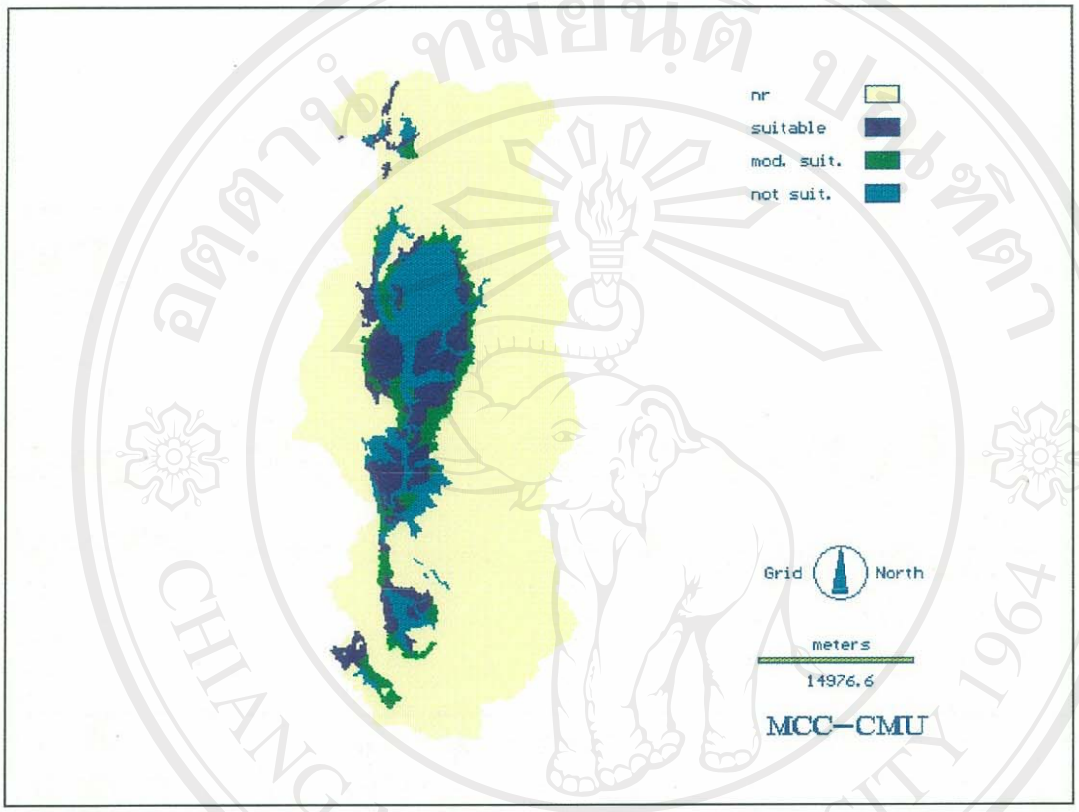

Figure 20. Land suitability classes by the DLD method for rainfed peanut production in Phrao District.

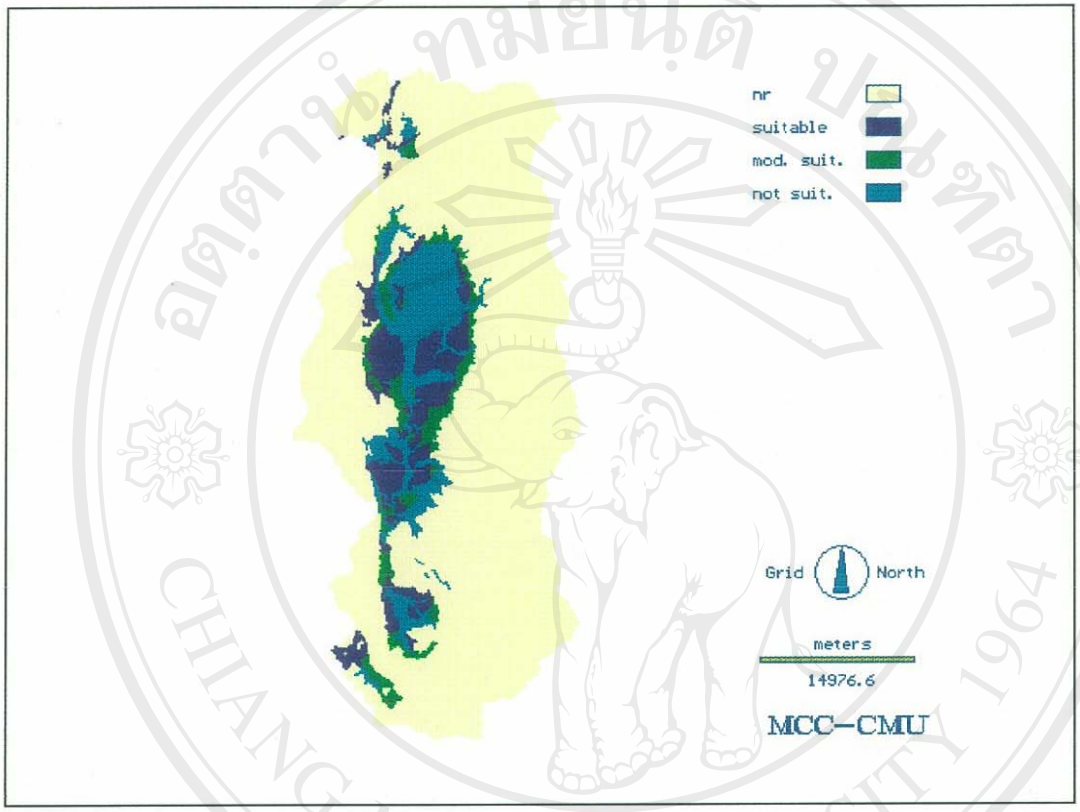

Figure 21. Land suitability classes by the DLD method for rainfed soybean production in Phrao District.

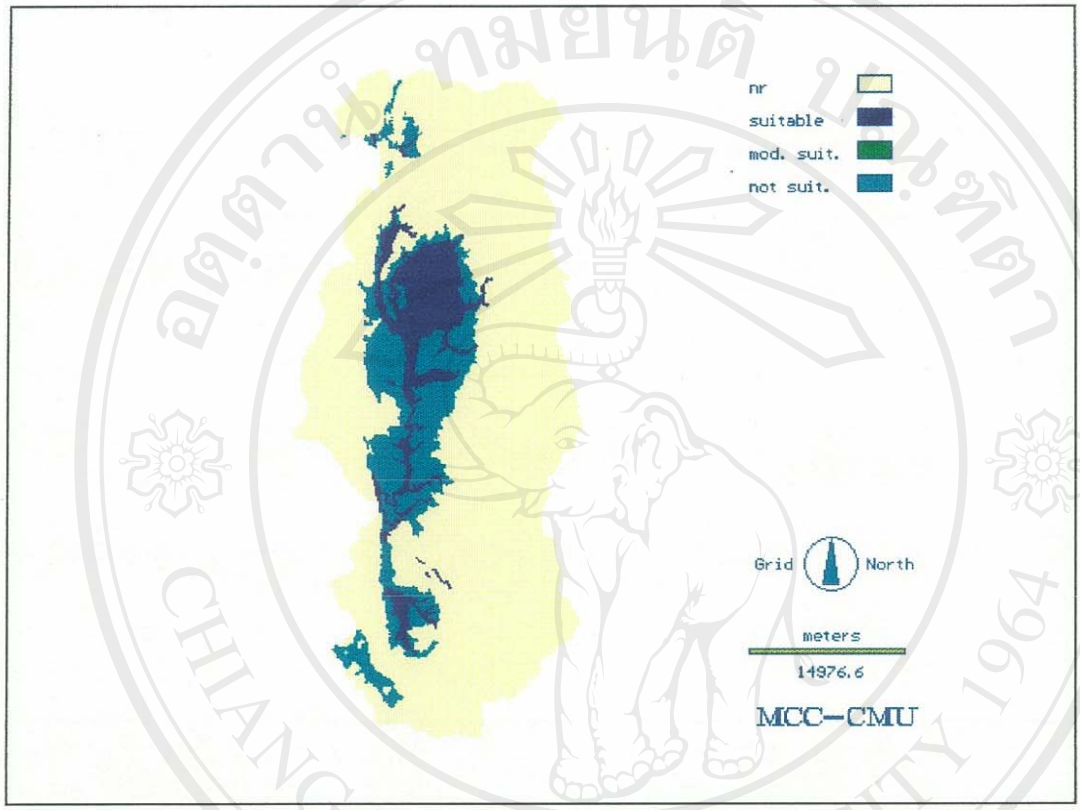

Figure 22. Land suitability classes by the DLD method for rainfed rice production in Phrao District.

Table 11. Land suitability classification defined by DLD (1990).

Soil unit	Corn	Peanut	Soybean	Rice
4	3f	3f	3f	1
5	3f	3f	3f	1
6	3f	3f	3f	1
7	3f	3f	3f	1
15	3f	3f	3f	1
21	3f	3f	3f	1s
22	3f	3f	3f	1s
59	3f	3f	3f	1s
29B	1t	1t	1t	3t
29C	1t	1t	1t	3t
29D	2t	2t	2t	3t
29E	3t	3t	3t	3t
35B	1s	1s	1s	3t
35C	1s	1s	1s	3t
47B	2g	2g	2g	3t
47D	2t	2t	2t	3t
48C	2g	2g	2g	3t
48D	2g	2g	2g	3t
48E	3t	3t	3t	3t
56C	1t	1t	1t	3t
56D	2t	2t	2t	3t
56E	2t	2t	2t	3t

Remark: 1 = suitable
2 = moderately suitable
3 = not suitable
f = flood hazard
g = surface rockiness/stoniness
s = problem on texture or structure of soil
t = terrain

The suitability classes of corn, peanut and soybean by the DLD method were the same. The severe limitations of the area for growing those crops were flood hazard and terrain. The slight limitations were texture or structure of the soil and surface rockiness/stoniness. The severe limitation for growing rice was terrain and the slight limitation was soil texture or structure.

The limitations used by the DLD method were quite different from the ALES method. The DLD method did not take nutrient availability as one factor of limitations. However, other LQs such as flood hazard to field crops and the limitations due to terrain for growing paddy rice were used by both methods.

About 36% of agricultural area were assessed to be suitable for field crops, 19% of the area were moderately suitable and 45% was not suitable. About 37% of agriculture land were classified as suitable for growing rice and the remaining 63% of the agricultural land were not suitable for rainfed rice.

The comparisons between the outputs of land evaluation based on the ALES method and DLD method were made by KHAT statistics and the results are illustrated in Table 12.

The current physical suitability rating assessed by ALES for rice and corn were different from those evaluated by the DLD method. The overall Kappa value of 0.19 for rice and of 0.52 for corn indicated that the two methods were agree at level 19% and 52% greater than that expected by

chance, respectively. Appendix Table 13 illustrated that some suitable areas calculated by ALES method for rice were defined as not suitable one by the DLD method (5,202 pixels). On the other hand, certain areas that were not suitable for corn when using ALES model were determined as the suitable areas by DLD method (2,715 pixels). Overall Kappa values when comparing the current physical suitability between the two methods were 1.00 for peanut and soybean. It could be concluded that both methods showed perfect agreement to each other (Carstensen, 1987). However, nutrient availability (one of land quality) did not greatly affect leguminous crop in this area therefore the results of the evaluation of these LUTs were similar (see Appendix Table 13).

Table 12. Overall Kappa between ALES and DLD.

Land Utilization Type		Kappa
Current Physical Suitability	Rice	0.19
	Corn	0.52
	Peanut	1.00
	Soybean	1.00
Potential Physical Suitability	Rice	0.19
	Corn	0.82
	Peanut	0.82
	Soybean	0.82

In matching potential physical suitability computed by ALES with the DLD one, the agreement of both current condition and potential condition for growing rice in Phrao agricultural area are the same due to the fact that

rice has to be grown in the low lying. The overall Kappa value of corn shows better agreement in potential condition. It could be explained by comparing between Appendix Table 12 and 13. The number of pixels of suitable and not suitable areas calculated by ALES method in potential situation match well with the number of pixels of those evaluated by DLD method (5,897 pixels of suitable area, and 3,990 pixels of not suitable area). The improvements by fertilizer applications and terrace constructions on some unsatisfactory land can be used for increasing the suitable area of corn. The overall Kappa value of 0.82 for peanut and soybean indicates good agreement, but not perfect, between both methods of potential suitability ratings. Appendix Table 13 shows that 924 pixels were classified as not suitable area by DLD for growing those crops but classified as suitable area by the ALES method.

4.2.2 Comparing the ALES Physical Suitability Classes with Land Use in 1992.

The most recent official land use map in the study area was published in 1992. It was compared with those results from ALES model for field crop area and rice land (see Figures 23-25).

In 1992, field crop occupied only 26% of all agricultural area and about 32% of that area were paddy land. More than 40% was used for other crops or other purpose for example orchards, urban, and forest (see Figure 23 and Table 13). It could be said that only 60% of agricultural area in Phrao district defined by DLD was used to grow rice and field crops. The remaining 40% that have potential for growing those crops were used for other purposes.

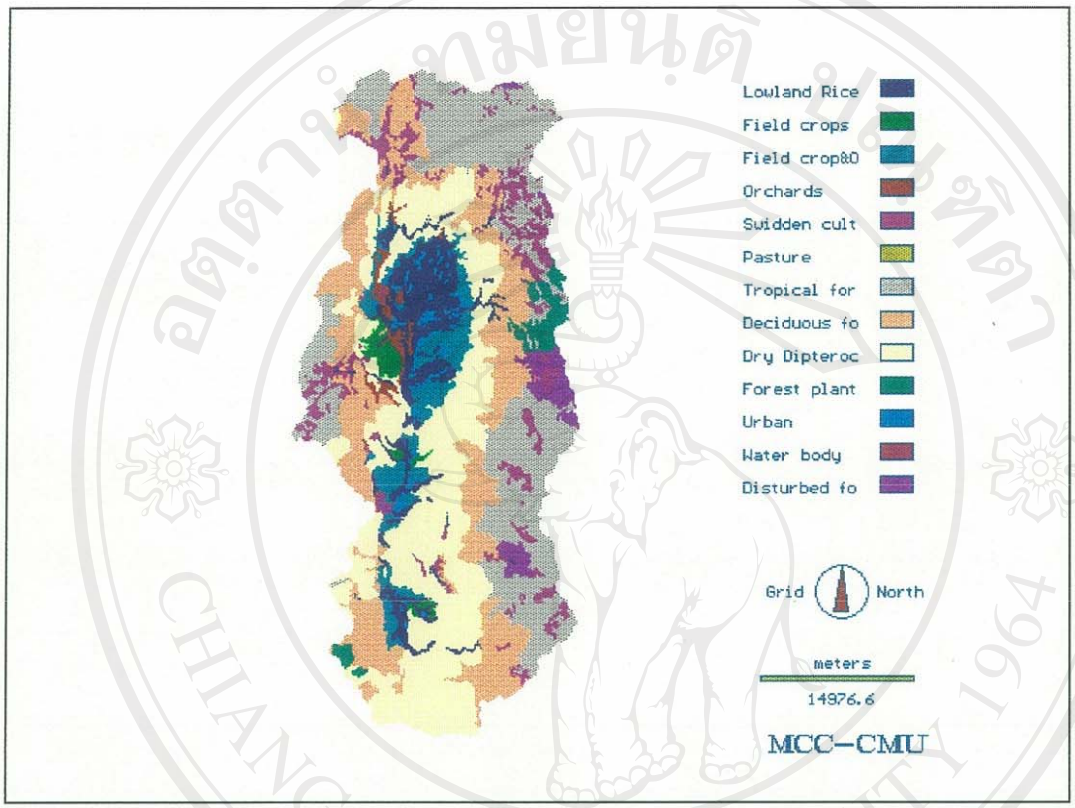

Figure 23. Land use in 1992, Phrao District.

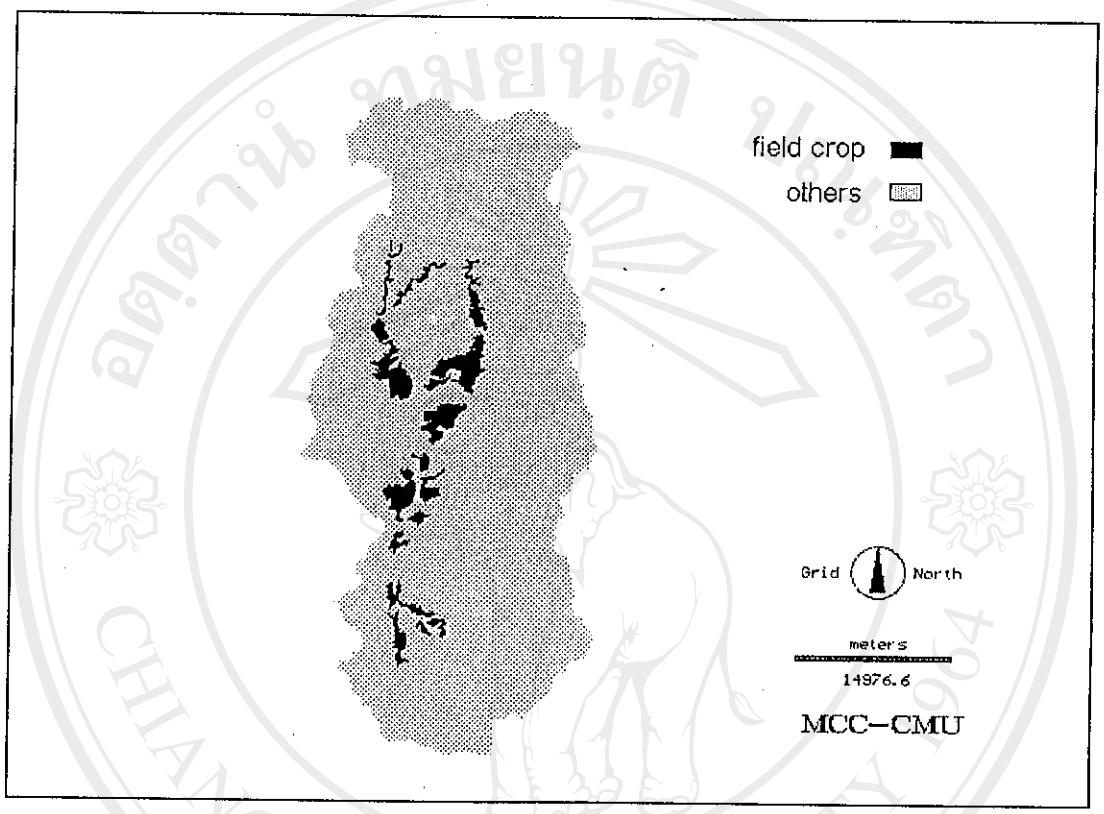

Figure 24. Field crop area in 1992, Phrao District.

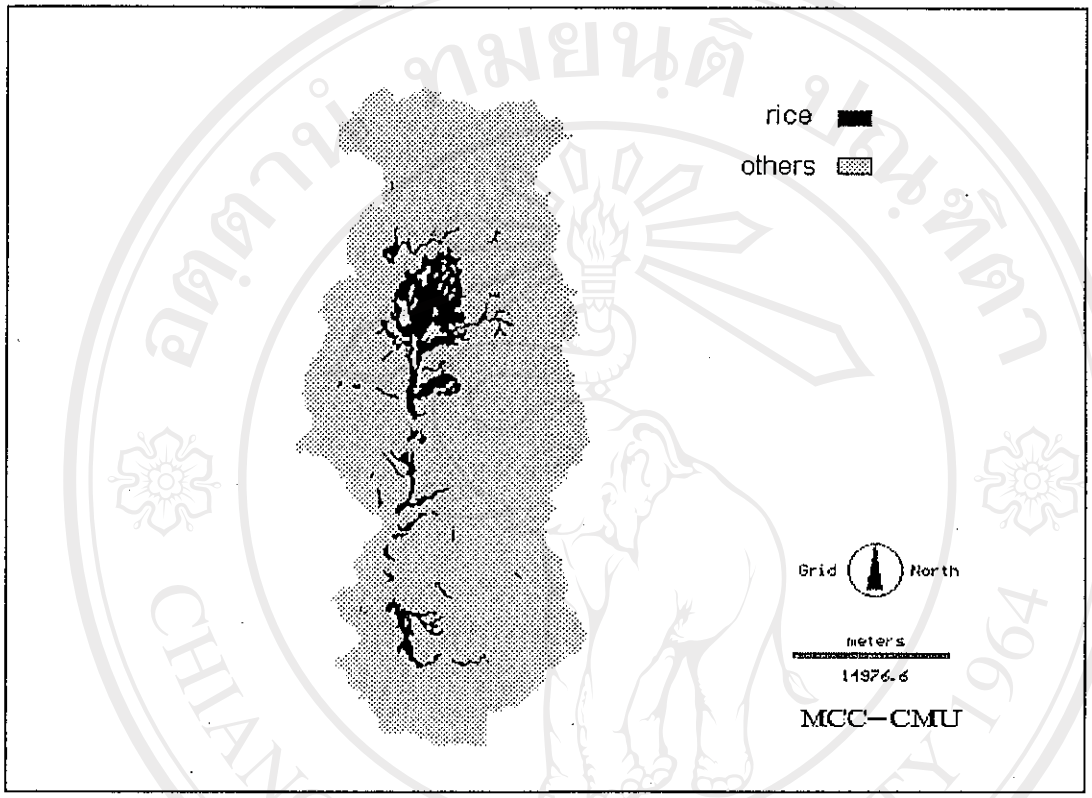

Figure 25. Paddy rice area in 1992, Phrao District.

Table 13. Land use in 1992, Phrao study area.

Land use type	Area (ha)	Area (%)
Field crop	7290.88	26.3
Rice	8760.32	31.7
Orchards	1438.72	5.2
Swidden cultivation	778.24	2.8
Urban	2099.20	7.6
Dry dipterocarp	5519.36	20.0
Tropical forest	43.52	0.2
Decidious forest	1088.00	3.9
Disturbed forest	181.76	0.6
Forest plantation	337.92	1.2
Water body	135.68	0.5

Source : DLD (1992)

Tables 14 shows the results of the test of agreement between the suitability maps produced by ALES method and present land use map produced by DLD in 1992. ALES method was agree with the actual land use in 1992 at level 16% for rice, 40% for field crops at current condition and 28% for field crops at potential uses greater than those expected by chance. The suitability rating of field crops as computed by ALES method were more similar to the land use in 1992 than that of rice. Appendix Table 14 and Appendix Table 15 denote that most cultivated rice in 1992 were located in the suitable area suggested by ALES model (the 3,361 pixels of the total 3,422 pixels). The remaining rice crops were grown in the unsuitable land as classified by ALES (61 pixels). Some suitable areas for rice were used for other purpose i.e., urban area. Most field crops area in 1992 were the suitable area realized by ALES model too. Although the overall Kappa value

were small (0.40 to 0.28) when comparing the suitability rating of field crops, it was found that field crops were mainly grown in the current suitable area as computed by ALES model. Only small portion of land (206 pixels in the Appendix Table 15) were used to grow field crops in the not suitable area as assessed by ALES method.

Table 14. Overall Kappa between ALES method and present land use in 1992.

Land Utilization Type		Kappa
Currently Physical Suitability	Rice	0.16
	Field crop*	0.40
Potentially Physical Suitability	Rice	0.16
	Field crop*	0.28

* Aggregated areas of peanut, soybean and corn.

4.3 THE ECONOMIC SUITABILITY RATINGS

The predicted yields and the predicted gross margin of all crops for certain Land Mapping Unit were displayed in the Appendix Tables 16. The economic suitability rating in this study were computed for the LMUs whose potential suitability ratings were in subclasses 1, 2 and 3. For the subclass 4, the quantitative definition is unnecessary since the currently suitability is uneconomic, (FAO, 1976).

Six classes of economic suitability, comprise S1, S2, S3, N1, N2 and NR, were assigned to each LMU according to the suitability classes outlined

by FAO (1976). The values for estimated yield used in the evaluation of the economic suitability classes were based on the proportional yield decision tree as simulated by DSSAT models and limiting yield factors. The results are shown in Figures 26 to 31.

The economic suitability ratings were found to be satisfactory since their estimated yields were in accordance with yield data reported by interviewing and researchers who worked in the area (Shinawatra, et al., 1987; CMFCRC, 1988-1992; Tongsiri, 1990; DOAE et al., 1991 and Schapink, 1992).

The suitability maps resulted from the evaluation at the intermediate input level for crop production in each soil unit revealed that about 20% of agricultural area in Phrao district were classified to be highly suitable for growing rainfed peanut (see Figure 27). About 10% of the area were highly suitable for growing rainfed soybean (see Figure 29). There is no highly suitable area for other LUTs. Most of unflooded areas were evaluated to be moderately suitable for all field crops (corn, peanut and soybean), including the double cropping of peanut-peanut in the rainfed condition. About 60% of the lowland in Phrao with slightly sloping areas were assessed as moderately suitable area for producing rainfed rice and irrigated rice-soybean. The remaining areas were indicated as the permanently not suitable for growing rice.

The economic suitability evaluations give more information for land use planning. The physical suitability classes or subclasses considered land

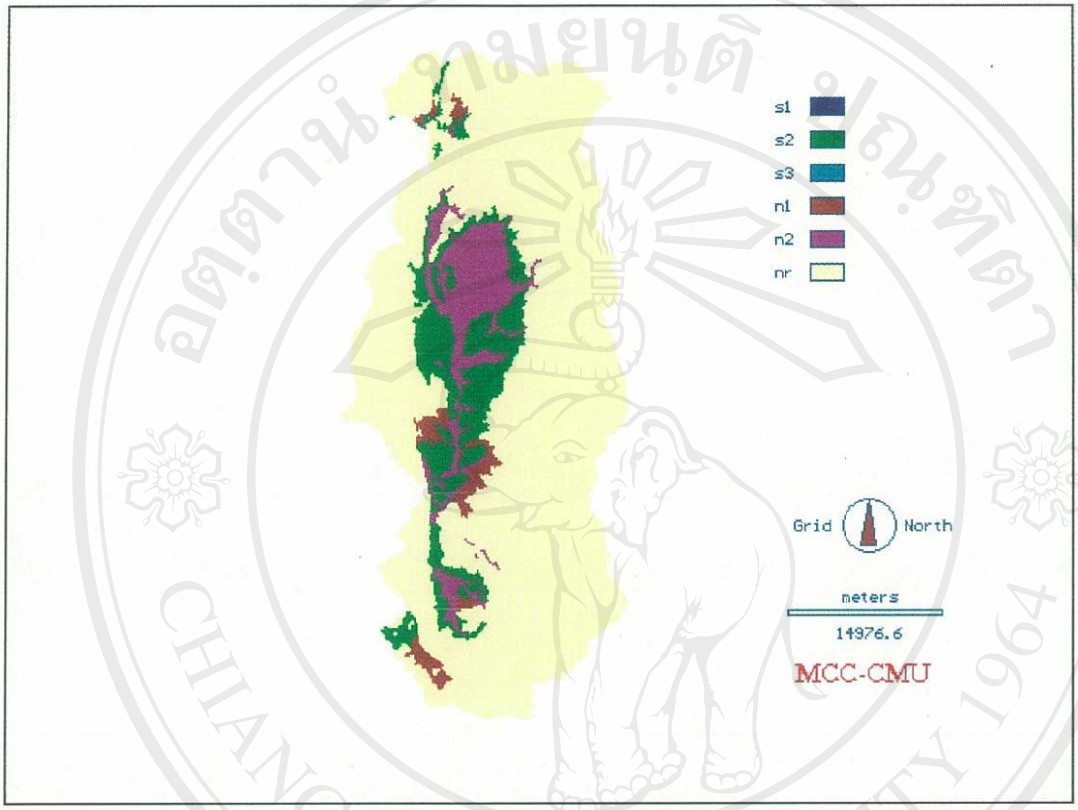

Figure 26. Economic suitability classes as the results of estimating yield for rainfed corn in Phrao District.

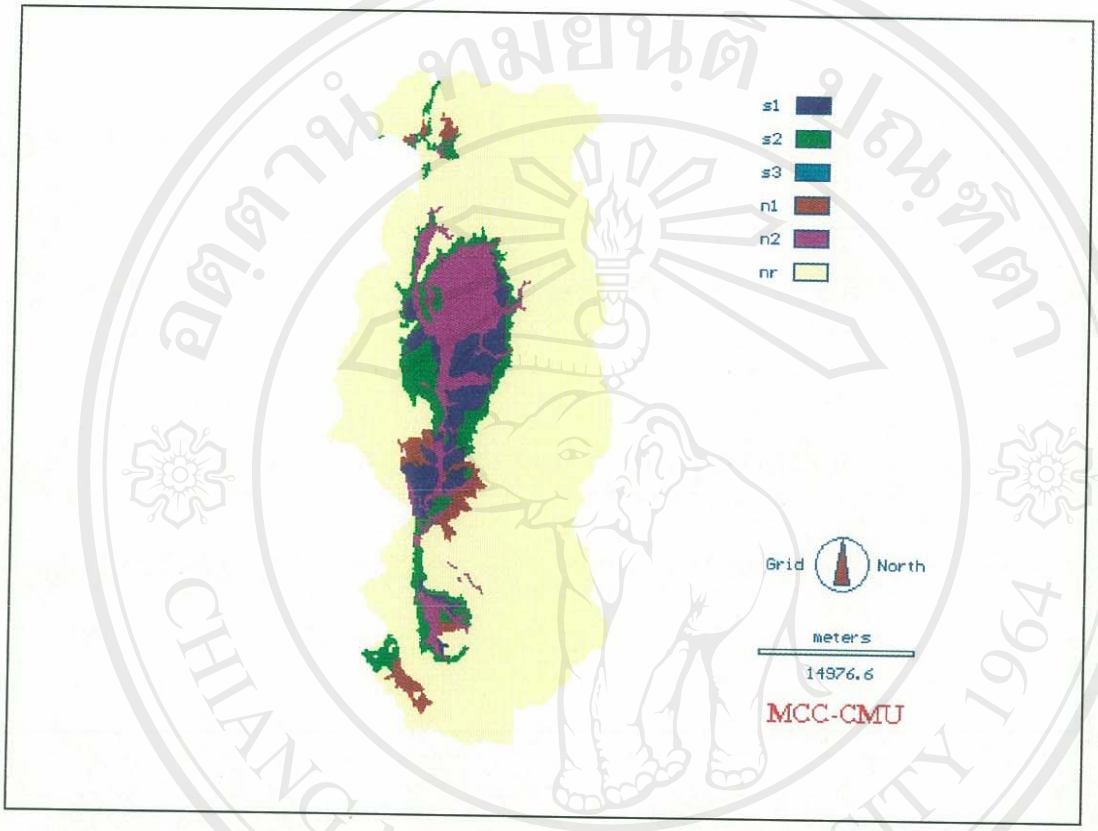

Figure 27. Economic suitability classes as the results of estimating yield for rainfed peanut in Phrao District.

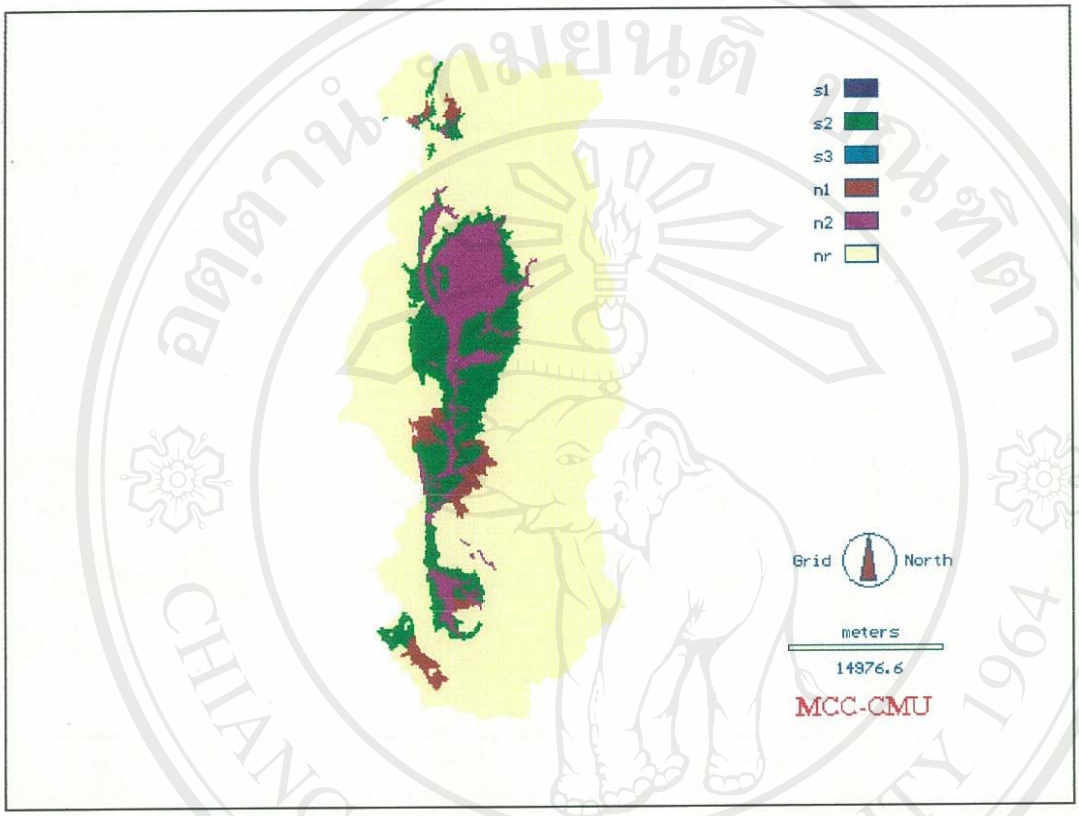

Figure 28. Economic suitability classes as the results of estimating yield for rainfed peanut-peanut in Phrao District.

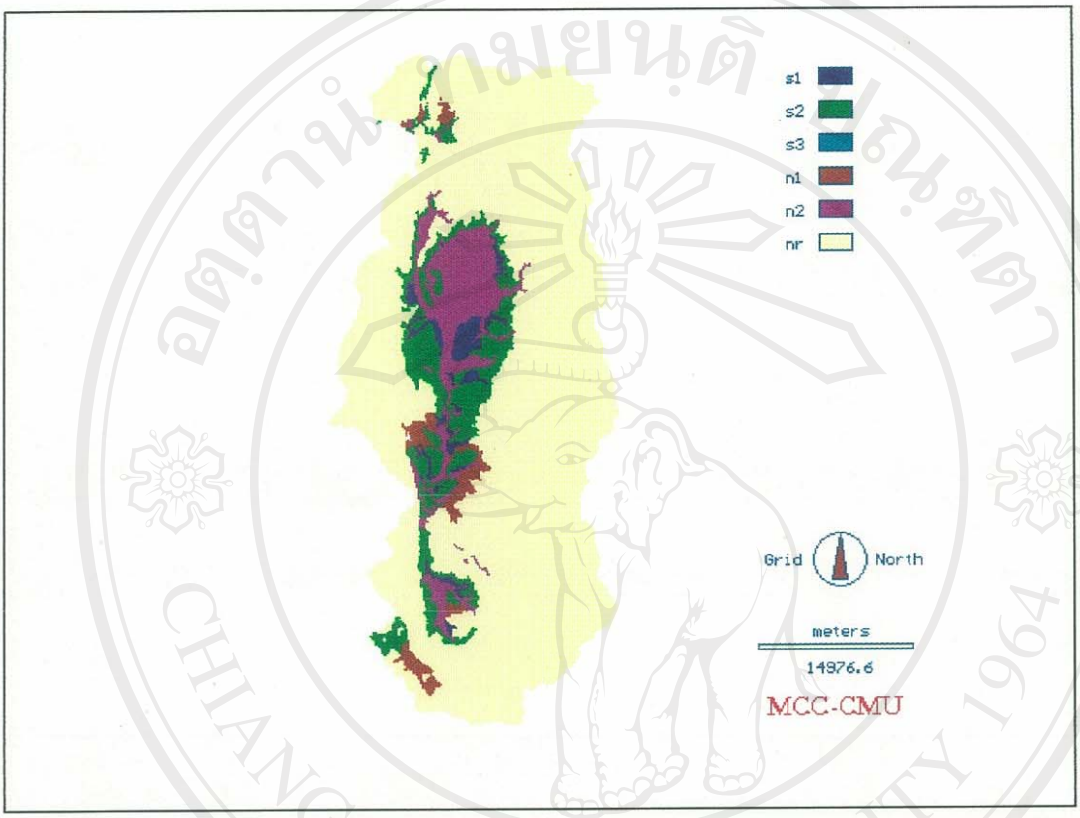

Figure 29. Economic suitability classes as the results of estimating yield for rainfed soybean in Phrao District.

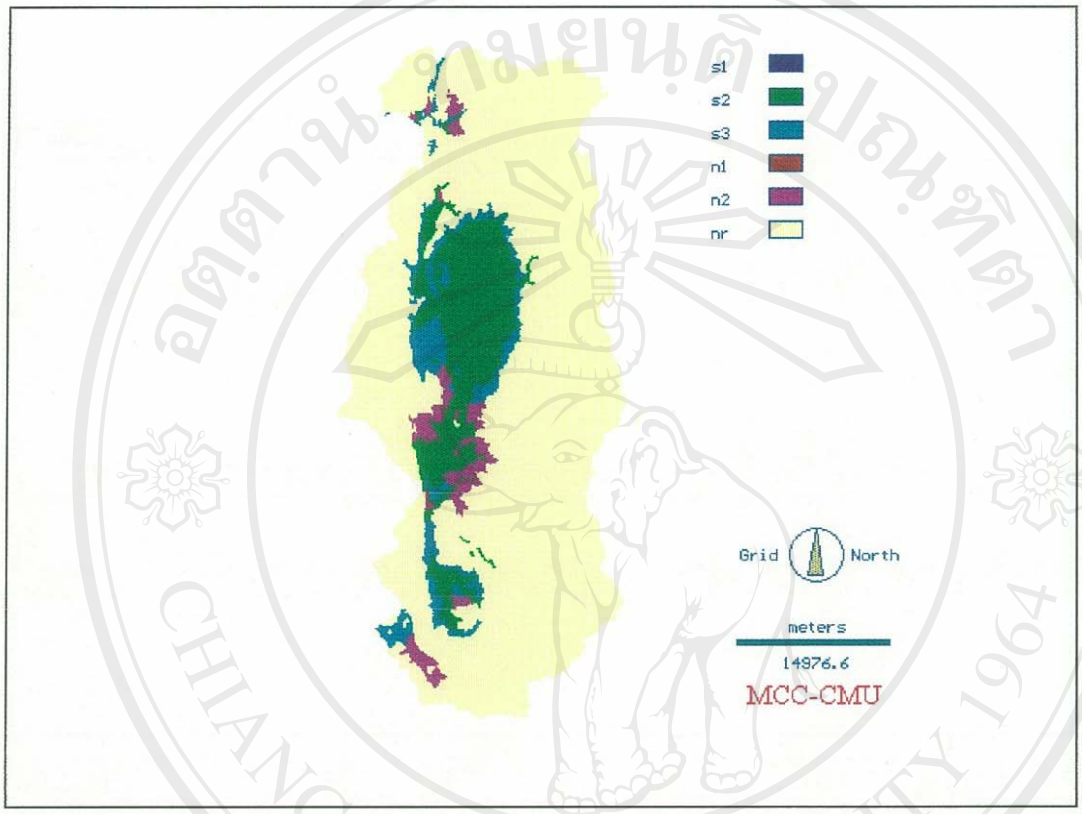

Figure 30. Economic suitability classes as the results of estimating yield for rainfed rice in Phrao District.

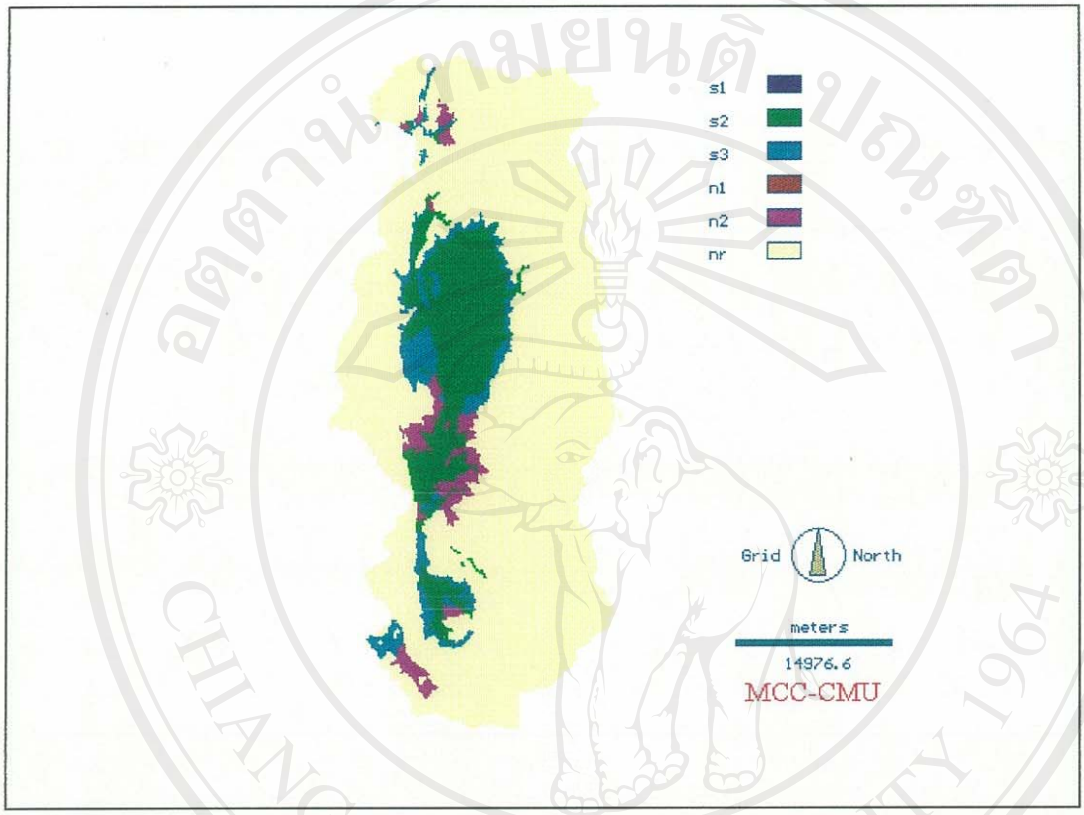

Figure 31. Economic suitability classes as the results of estimating yield for irrigated rice-soybean in Phrao District.

on its capability to use in the present time. Economic suitability classes were able to specify potential areas to be selected for improving income from crop production. For example, Figure 7 shows that about 30% of agricultural land can be used for rainfed corn production at present while Figure 13 demonstrates that about 63.1% of agricultural areas have potential to produce rainfed corn (see Table 15 for more information). The economic suitability rating in Figure 26 and Table 16 reveals further that 52.6% of the area were rating as moderately suitable (S2 class in economic suitability classification) for rainfed corn but the remaining (10.5%) were the currently not suitable one (the N1 class).

Table 15. Area (percentage of agricultural area) in each suitability class of the current physical suitability and the potential physical suitability ratings.

LUT	Suitability Class	Current (%)	Potential (%)
Corn	1	-	-
	2	-	-
	3	29.4	63.1
	4	70.6	36.9
Peanut	1	-	-
	2	15.0	15.0
	3	39.5	48.0
	4	45.5	37.0
Peanut-Peanut	1	-	-
	2	15.0	15.0
	3	39.5	48.0
	4	45.5	37.0
Soybean	1	-	-
	2	-	-
	3	54.5	63.1
	4	45.5	36.9
Rice	1	-	-
	2	1.6	1.6
	3	83.4	83.4
	4	15.0	15.0
Rice-soybean	1	-	-
	2	1.4	1.4
	3	83.6	83.6
	4	15.0	15.0

Table 16. Area (ha and in percentage of agricultural area) in each economic suitability class.

LUT	Economic Class	Area (ha)	Area (%)
Corn	S1	-	-
	S2	14,568.9	52.6
	S3	-	-
	N1	2,892.8	10.5
	N2	10,214.4	36.9
Peanut	S1	6,254.1	22.6
	S2	8,314.9	30.0
	S3	-	-
	N1	2,892.8	10.5
	N2	10,214.4	36.9
Peanut-Peanut	S1	-	-
	S2	14,568.9	52.6
	S3	-	-
	N1	2,892.8	10.5
	N2	10,214.4	36.9
Soybean	S1	2,777.6	10.0
	S2	11,791.4	42.6
	S3	-	-
	N1	2,892.8	10.5
	N2	10,214.4	36.9
Rice	S1	-	-
	S2	16,296.9	58.9
	S3	7,203.8	26.0
	N1	-	-
	N2	4,175.4	15.1
Rice-soybean	S1	-	-
	S2	16,468.5	59.5
	S3	7,063.0	25.4
	N1	-	-
	N2	4,175.4	15.1