CHAPTER 6

LAND USE CLASSIFICATION AND FACTORS AFFECTING ON LAND USE CHANGE

This chapter deals with results obtained from satellite images classification, land use change analysis, spatial and socio-economic factors that affecting on land use change in the study area.

6.1 Land use classification

Based on information of local inhabitants, land use types can be categorized into 7 classes in the year 1990 and 9 classes in the year 2010. The land use map for 1990 and 2010 were produced from Landsat5 TM images that acquired on 15th January 1990 and on 7th February 2010.

Results of land use classification (Table 6.1) showed that in the year 1990, water bodies cover 41.26 ha, deciduous forest 1,138.28 ha, mixed deciduous forest 1,518.75 ha, fallow 200.09 ha, upland field 300.03 ha, lowland field 57.02 ha and urban area 14.24 ha which constituted of 1.27%, 34.81%, 46.45%, 6.12%, 9.18%, 1.74% and 0.43% of the total area respectively (Figure 6.1) Land use classes in 2010 composed of water bodies about 57.69 ha (1.76%), deciduous forest 1,184.44 ha (36.22%), mixed deciduous forest 976.40 ha (29.86%), fallow 99.56 ha (3.40%), upland field 170.72 ha (5.22%), lowland field 92.77 ha (2.84%), urban area 62.64 ha (1.92%), teak plantation 514.69 ha (15.74%) and mixed fruit orchard 111.03 ha (3.40%) of the total area (Figure 6.2).

Table 6.1 Land use classification in 1990 and 2010

Land use type	1990		2010		Relative change	
	Area (ha)	(%)	Area (ha)	(%)	In (ha)	In (%)
W	41.26	1.27	57.69	1.76	16.43	39.82
DF	1,138.28	34.81	1,184.44	36.22	46.16	4.06
MDF	1,518.75	46.45	976.40	29.86	-542.35	-35.71
Fa	200.09	6.12	99.56	3.40	-100.53	-50.24
UpF	300.03	9.18	170.72	5.22	-129.58	-43.15
LoF	57.02	1.74	92.77	2.84	35.75	62.70
TP	-	-	514.69	15.74	514.69	100
MFO	-	-	111.03	3.40	111.03	100
Ur	14.24	0.43	62.64	1.92	48.40	339.89

Source: From data analysis

Note: W= Water, DF= Deciduous Forest, MDF= Mixed Deciduous Forest, Fa= Fallow, UpF= Upland field, LoF= Lowland Field, TP= Teak Plantation, M.F.O= Mixed Fruit Orchard and Ur= Urban

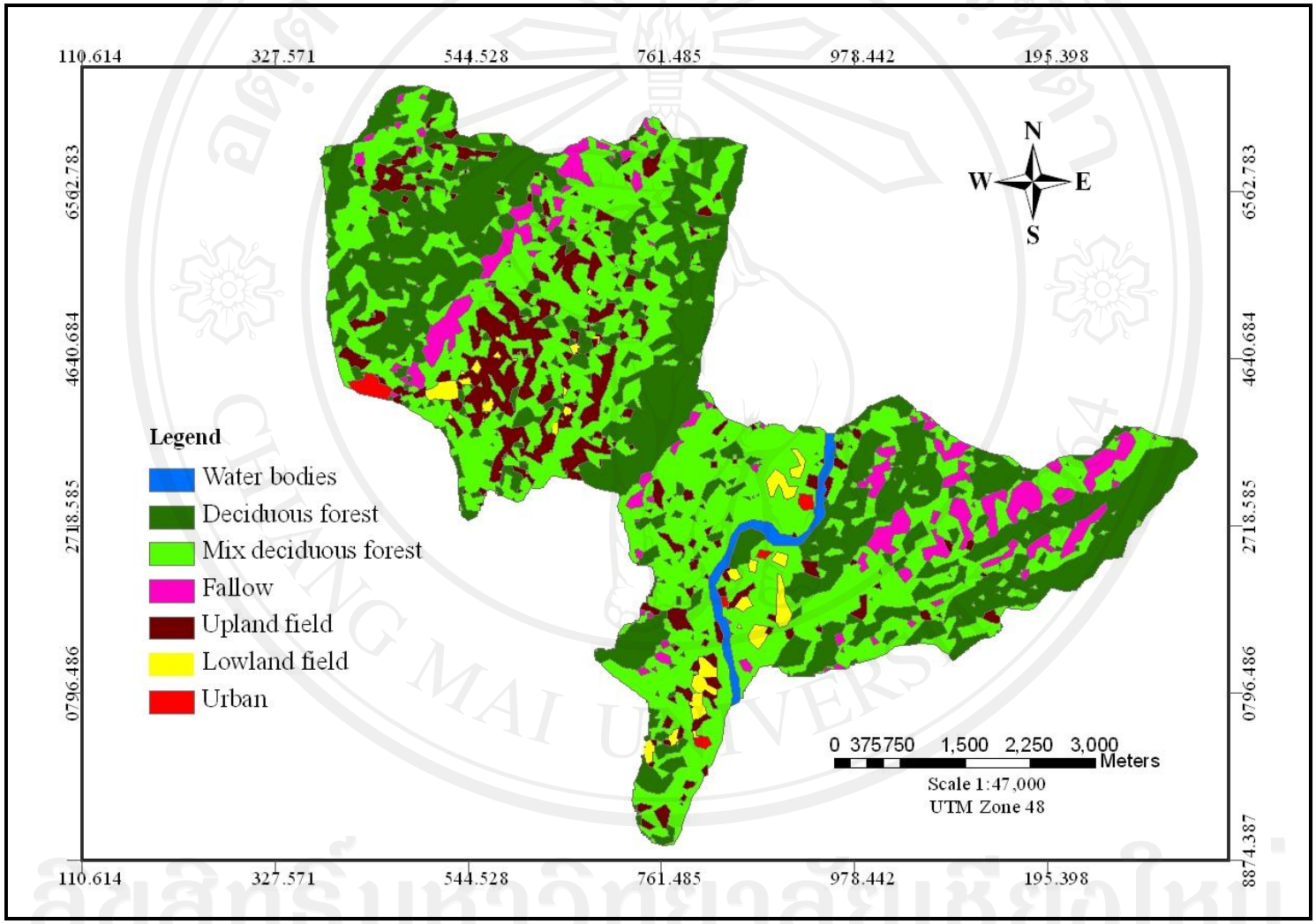

Figure 6.1 Land use and land cover in the year 1990

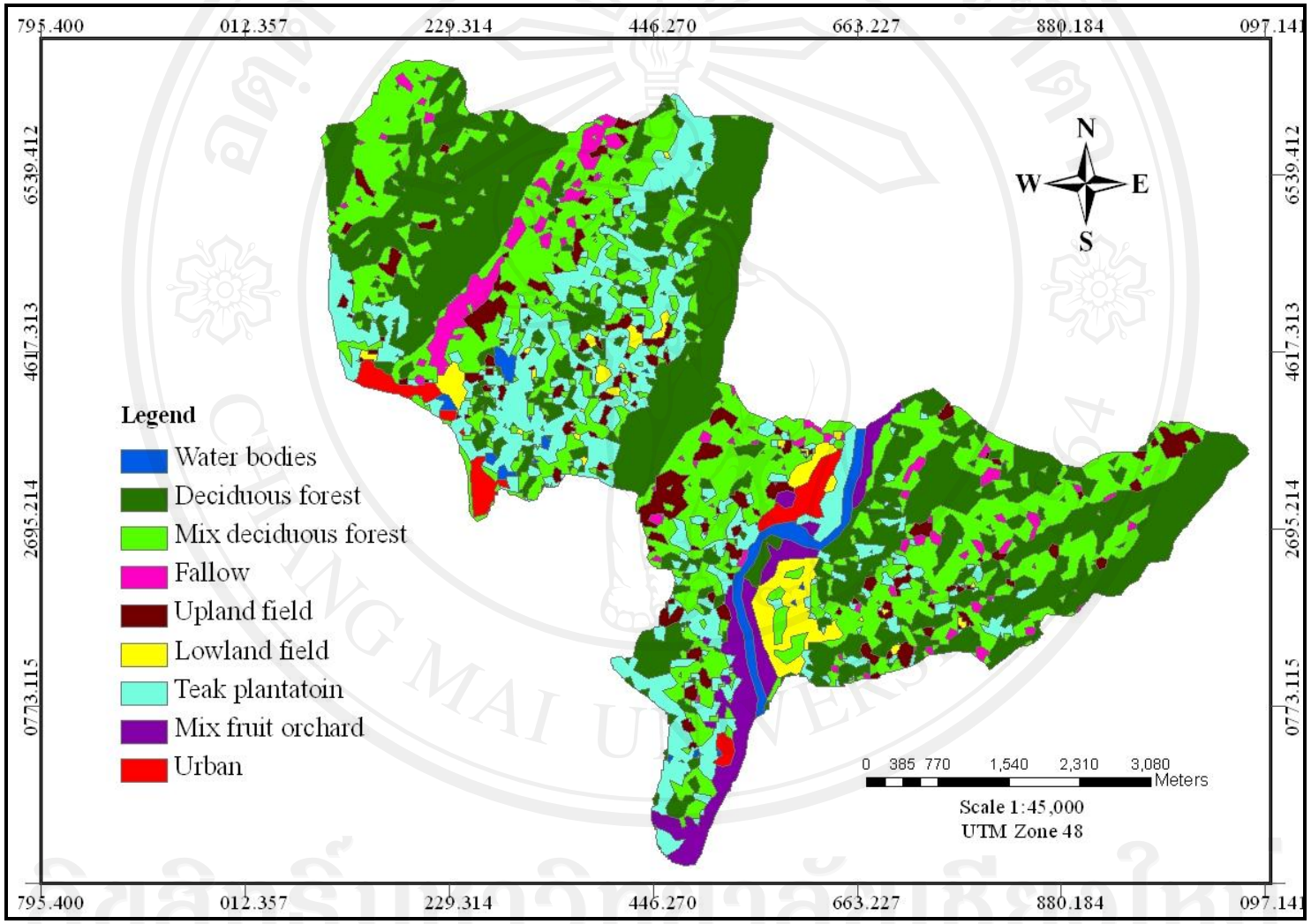

Figure 6.2 Land use and land cover in the year 2010

6.2 Accuracy assessment of land use classification

Accuracy assessment was critical for a map generated from remote sensing data. Error matrix is in the most common way to present the accuracy of the classification results. Overall accuracy; user's, producer's accuracies and the Kappa statistic were then derived from the error matrices. Results of accuracy assessment found that the overall accuracy of the land use classification for 1990 was 89.96% and 84.38 % for 2010. The kappa indices of about 0.88% and 0.83% for 1990 and 2010 respectively (Table 6.2 and 6.3). Based on the results of accuracy assessment showed that land use map of 1990 and 2010 is highly acceptable.

Table 6.2 Accuracy assessment of land use classification in 1990

Land use type	W	DF	MDF	Fa	UpF	LoF	Ur	Total	UA (%)	PA (%)	kappa
W	14	0	0	0	0	0	0	14	100	100	0.92
DF	0	84	9	0	0	0	0	93	90.32	94.38	0.85
MDF	0	4	92	0	4	0	0	100	90	87.61	0.85
Fa	0	0	2	18	0	0	0	20	90	85.71	0.89
UpF	0	1	2	0	14	2	0	19	73.68	77.77	0.81
LoF	0	0	0	3	0	12	0	15	80	85.71	0.86
Ur	0	0	0	0	0	0	8	8	100	100	1
Total	14	89	105	21	18	14	8	269	89.14	90.17	0.88
Overall Accuracy = 89.96%											

Source: From data analysis

Note: W= Water, DF= Deciduous Forest, MDF= Mixed Deciduous Forest, Fa= Fallow, UpF= Upland field, LoF= Lowland Field, TP= Teak Plantation, M.F.O= Mixed Fruit Orchard and Ur= Urban.

Table 6.3 Accuracy assessment of land use classification in 2010

Land use type	W	DF	MDF	Fa	UpF	LoF	Ur	TP	MFO	Total	UA (%)	PA (%)	Kappa Stat.
W	17	0	0	0	0	0	0	0	0	17	100	100	1.00
DF	0	67	11	0	2	0	4	0	0	84	79.76	91.78	0.73
MDF	0	6	52	2	3	0	1	0	0	64	81.25	76.47	0.75
Fa	0	0	1	12	0	2	0	3	0	18	66.66	80	0.72
UpF	0	0	0	1	12	0	2	0	0	15	80	70.58	0.78
LoF	0	0	0	0	0	9	0	0	0	9	100	81.81	0.81
Ur	0	0	4	0	0	0	41	0	0	45	91.11	85.41	0.86
TP	0	0	0	0	0	0	0	8	0	8	100	72.72	0.83
MFO	0	0	0	0	0	0	0	0	9	9	100	100	1
Total	17	73	68	15	17	11	48	11	9	269	88.75	84.31	0.83
Overall Accuracy = 84.38%													

Source: From data analysis

Note: W= Water, DF= Deciduous forest, MDF= Mixed deciduous forest, Fa= Fallow, UpF= Upland field, LoF= Lowland field, Ur= Urban, TP= Teak plantation, MFO= Mixed Fruit Orchard

6.3 Nature and location of change in land use from 1990 to 2010

The land use change was analyzed by identifying the substitution patterns among classes during the period of 1990-2010. A transition matrix was created using cross-tabulation tools provided in ArcGIS version 9.3 software package and regular spreadsheet software. The quantity of anticipated land use changes from each existing category to other categories over the time period allows to identify the transitions between land use classes.

From land use change analysis, the results are summarized for the years 1990 and 2010 with their relative change in each class (Figure 6.3). An important aspect of change detection is to determine what is actually changing to what, for example: which land use class is changing to the other. This information will reveal both desirable and undesirable changes and classes that are relatively stable overtime. In terms of location of change, the emphasis is on each class. Looking at the nature of change under stability for example: areas with no change and instability-loss or gain by each class between 1990 and 2010 particularly in the change in hectares as observable in (Table 6.4 and Figure 6.4), stability seems to be a relative term as no class is actually stable during the last 2 decades and (Figure 6.5) shows the comparison of change in land use between 1990 and 2010.

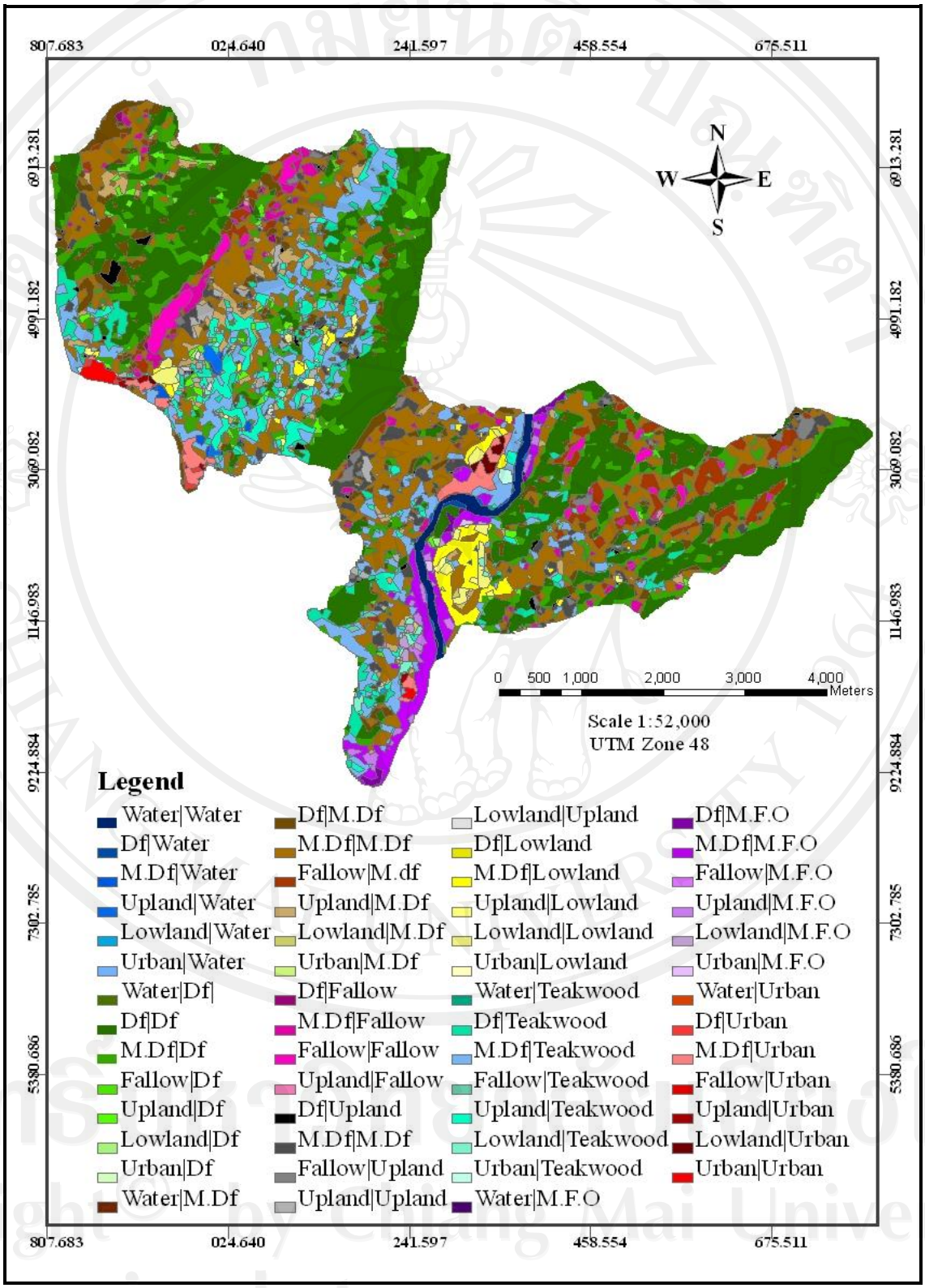

Figure 6.3 Map of land use change in the period from 1990-2010

Table 6.4 Land use change matrix in the period from 1990-2010

Land use 1990	Land use 2010									Total 1990
	W	DF	MDF	Fa	UpF	LoF	Ur	TP	MFO	
W	36.07	1.53	0.03	-	-	-	0.7o	0.72	2.21	41.26
DF	3.33	821.89	173.12	5.58	15.73	1.91	-	107.51	9.21	1,138.28
MDF	9.98	303.06	610.09	43.49	99.62	56.79	40.35	278.93	76.44	1,518.75
Fa	-	11.26	111.92	48.71	22.14	-	0.34	4.28	1.44	200.09
UpF	7.12	44.99	75.59	1.78	30.46	12.16	4.41	107.99	15.80	300.30
LoF	0.88	1.52	5.53	-	2.77	21.65	6.90	12.05	5.72	57.02
Ur	0.31	0.19	0.12	-	-	0.26	9.94	3.21	0.21	14.24
	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-
Total 2010	57.69	1,184.4	976.4	99.56	170.72	92.77	62.64	514.69	111.03	3,269.94
Change (ha)	16.43	46.16	-542.35	-100.53	-129.58	35.75	48.40	514.69	111.03	
Change (%)	39.82	4.06	-35.71	-50.24	-43.15	62.70	339.89	100	100	

Source: From data analysis

Note: W= Water, DF= Deciduous forest, MDF= Mixed deciduous forest, Fa= Fallow, UpF= Upland field, LoF= Lowland field, Ur= Urban, TP= Teak plantation, MFO= Mixed Fruit Orchard

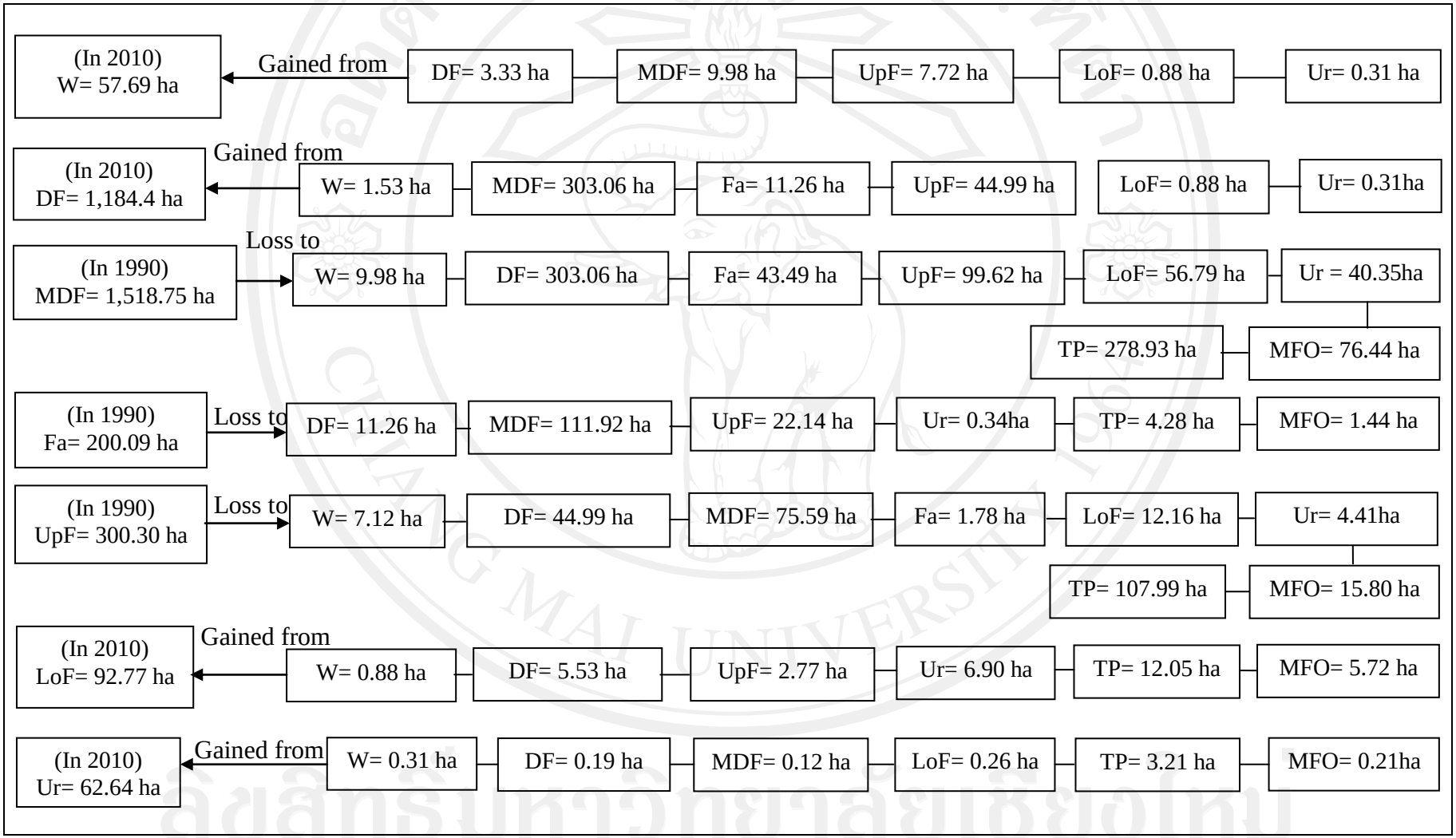

Figure 6.4 Diagram of land use change from the year 1990-2010

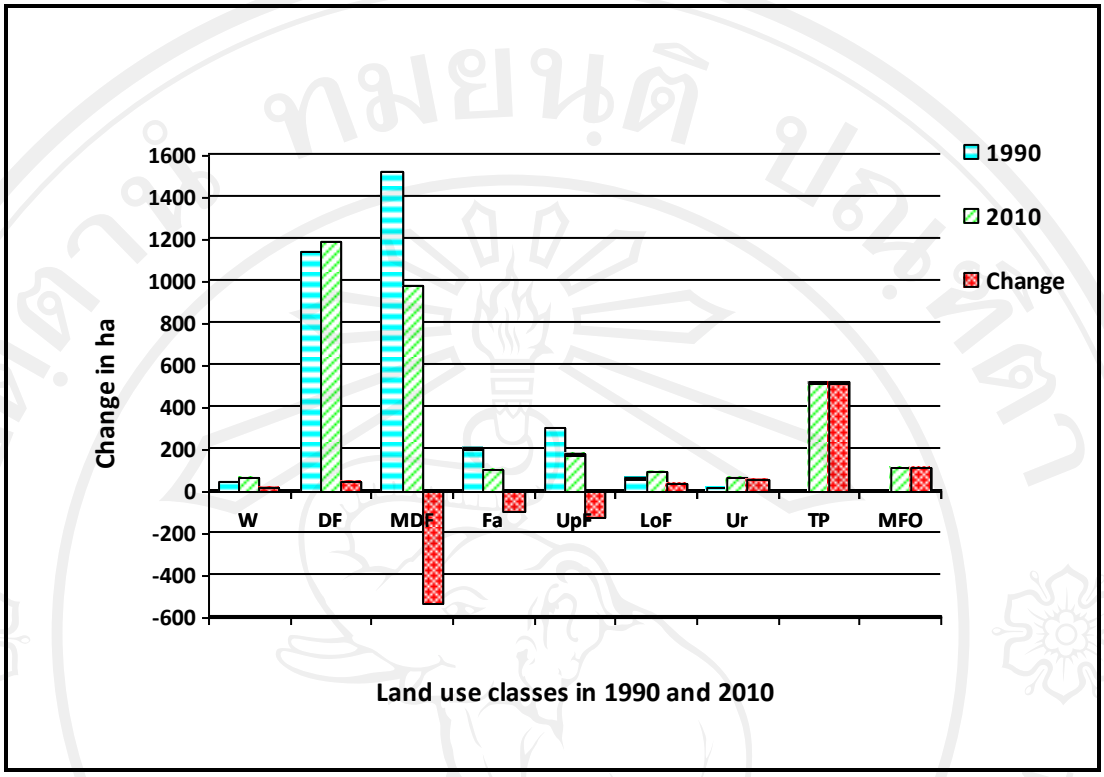

Figure 6.5 Comparison of land use change in 1990 and 2010

Results of land use change are summarized in (Table 6.4) and showed that water bodies in the year 2010 was increased from 41.26 ha in the year 1990 to 57.62 ha which was 33.3, 9.98, 7.12, 0.88 and 0.31 ha gained from deciduous forest, mixed deciduous forest, upland field, lowland field and urban area respectively. This is because the local farmers converted some of those land use types to fish ponds for aquaculture and small dam for crops production.

Deciduous forest occupied 1,138.28 ha in 1990 with a positive change of 46.16 ha or 4.06% of the total area. This class was gained from water 1.53 ha because of changed in water flow direction and emerged of new land close to river bank, gain from mixed deciduous forest 303.06 ha, fallow 11.26 ha, upland field 44.99 ha, lowland field 1.52 ha and urban area 0.19 ha.

Lowland field occupied 57.02 ha in 1990, increased to 92.77 ha in 2010 with a positive change 35.75 ha constituted a 62.70% of the total area. The change of lowland field during the last 20 years was gained from deciduous forest 1.91 ha, mixed deciduous forest 56.79 ha, upland field 12.16 ha and urban area 0.26 ha. This may be due to increasing of population and needed of sufficient rice for home consumption.

Urban area also increased in 1990. It just occupied only 14.25 ha and increased to 62.64 ha in 2010. From 1990-2010 water, mixed deciduous forest, fallow, upland field, lowland field were converted to urban about 0.7 ha, 40.35 ha, 0.34 ha, 4.41 and 6.9 ha respectively. The severe changes of urban area during the last 20 years because of increasing population and demand for residential area for living, the government policy on relocation small villages and merging them to cluster village development and emerging of small industrial factories such as metal, tobacco, baked clay and oxygen factories in the study area.

Teak plantation and mixed fruit orchard were considered as severe changes during the last two decades. These two types of land use did not existing in 1990. The change of teak plantation in 2010 occupied 514.69 ha or 100% increased from 1990. Most types of land use were converted to teak plantation; water bodies 0.72 ha, deciduous forest 107.51 ha, mixed deciduous forest 278.93 ha, fallow 4.28 ha, upland 107.99 ha, lowland 12.05 ha, and urban 3.21 ha respectively. This is because the government's policy on forest and land allocation since 1990 to 1995 to strengthening of forest recovers and also falls within teak plantation boom era of 1993 to 1997. This attracted a lot of people to the area thus contributing to the physical expansion of teak plantation area for long term benefits as evident in its increased.

Mixed fruit orchard was also considered as severe change with increased 111.03 ha in 2010 or 100% increased from 1990. This is due to in 2010 water bodies converted to mixed fruit orchard 2.21 ha, deciduous forest 9.21 ha, mixed deciduous forest 76.44 ha, fallow 1.44 ha, upland field 15.8 ha, lowland field 5.72 ha and urban area 0.21 ha respectively. This due to the need of permanent agricultural production to increase productivity, agricultural production for commercial and market oriented.

On the other hands mixed deciduous forest, fallow and upland field area considered as negative change. They were decreased and converted to other types of land use in 2010. In 1990 mixed deciduous forest occupied 1,518.75 ha constituted 46.45%, in 2010 occupied only 976.40 ha (29.86%) with negative changed of 542.35 ha constituted 35.71%. This is because of mixed deciduous forest converted to other types of land use such as loss into water 9.98 ha, deciduous forest 303.06 ha, fallow 43.49 ha, upland field 99.62 ha, lowland field 56.79 ha, urban 40.35 ha, teak plantation 278.98 ha and mixed fruit orchard 76.44 ha respectively.

Fallow in 1990 covered 200.09 ha or 6.12% of the total area which is decreased 100.53 ha or 50.24% from 1990 and remain 99.56 ha in 2010 constituted 3.40%. Fallow was also converted to deciduous forest 11.26 ha, mixed deciduous forest 111.92 ha, upland field 22.14 ha, urban 0.34 ha, teak plantation 4.28 ha and mixed fruit orchard 1.44 ha.

Upland field in 1990 occupied 300.30 ha (9.18%) of the total area. In 2010 remain 170.72 ha (5.22%) with negative changed of 129.58 ha constituted 43.15%. Upland field has been converted to water bodies 7.12 ha, deciduous forest 44.99 ha, mixed deciduous forest 75.59 ha, fallow 1.78 ha, lowland field 12.16 ha, urban 4.41 ha, teak plantation 107.99 ha and mixed fruit orchard 15.80 ha respectively.

6.4 Transition matrix of land use change in each village

When separate the land use change matrix in each village it can be helpfully more understand and clearly about the situation of land use changes and can be seen the different in each village.

6.4.1 Land use change of Phonsavang village

The results of land use change in Phonsavang village was summarized in (Table 6.5) and showed that water bodies in the year 2010 was not much increased from 26.22 ha in the year 1990 to 27.48 ha which was 2.09, 31.2, 0.61 and 0.0045 ha gained from deciduous forest, mixed deciduous forest, upland field and urban area respectively.

Deciduous forest occupied 444.90 ha in the year 1990 to 460.14 ha in the year 2010 with a positive change of 15.24 ha or increased of 3.43%. This class was gained from water 1.53 ha, mixed deciduous forest 95.03 ha, fallow 7.36 ha, upland field 4.51 ha and lowland field 0.91 ha.

In the year 1990, mixed deciduous forest occupied 618.15 ha, in 2010 it occupied only 448.72 ha with negative change of 169.43 ha constituting 27.41% decrease. It was converted to other types of land use such as converted into water 3.12 ha, deciduous forest 95.03 ha, fallow 17.04 ha, upland field 55.52 ha, lowland field 47.97 ha, urban 17.83 ha, teak plantation 58.66 ha and mixed fruit orchard 28.05 ha respectively.

Table 6.5 Land use change matrix of Phonsavang village from the year 1990-2010

Land use 1990	Land use 2010									Total 1990
	W	DF	MDF	Fa	UpF	LoF	Ur	TP	MFO	
W	21.66	1.53	-	-	-	-	0.70	0.72	1.61	26.22
DF	2.09	350.8	59.68	1.44	4.42	0.28	-	19.98	6.21	444.90
MDF	3.12	95.03	294.93	17.04	55.52	47.97	17.83	58.66	28.05	618.15
Fa	-	7.36	80.16	16.85	18.22	-	-	1.03	1.44	125.06
UpF	0.61	4.51	11.28	0.91	4.77	3.68	-	7.62	4.17	37.55
LoF	-	0.91	2.67	-	-	14.98	6.13	1.43	1.16	27.28
Ur	0.0045	-	-	-	-	0.27	-	2.80	2.00	5.07
Total 2010	27.48	460.14	448.72	36.24	82.93	67.18	24.66	92.24	44.64	1,284.23
Change (ha)	1.26	15.24	-169.43	-88.82	45.38	39.90	19.59	92.24	44.64	
Change (%)	4.82	3.43	-27.41	-71.02	120.85	146.26	386.39	100	100	

Source: From data analysis

Note: W= Water, DF= Deciduous forest, MDF= Mixed deciduous forest, Fa= Fallow, UpF= Upland field, LoF= Lowland field, Ur= Urban, TP= Teak plantation, MFO= Mixed Fruit Orchard

Fallow in 1990 covered 125.06 ha. It was decreased by 88.82 ha during 1990-2010 and remained at 36.24 ha in 2010 constituted a 71.02% decrease. Fallow was converted to deciduous forest 7.36 ha, mixed deciduous forest 80.16 ha, upland field 18.22 ha, teak plantation 1.03 ha and mixed fruit orchard 1.44 ha.

Upland field in the year 1990 occupied only 37.55 ha but in the year 2010 increased to 82.93 ha constituted 45.38% increase. Upland field has been expanded and gained from deciduous forest 4.42 ha, mixed deciduous forest 55.52 ha, fallow 18.22 ha. This is due to the increase of population because of Ban Luang and Phoncheang village were clustered to this village, farmers have less land for permanent agriculture so they need to expand more upland field for rice cultivation.

Lowland field in 1990 occupied 27.28 ha but increased to 67.18 ha in 2010 with a positive change 39.90 ha constituted a 146.26% increase. The change of lowland field during the last 20 years was gained from deciduous forest 0.28 ha, mixed deciduous forest 47.97 ha, upland field 3.68 ha and urban area 0.27 ha.

Urban area in 1990 just only occupied 5.07 ha but increased to 24.66 ha in 2010. From the year 1990-2010 water, mixed deciduous forest and lowland field were converted to urban about 0.70 ha, 17.83 ha, 6.13 ha respectively. The changes of urban area of Phonsavang village during the last 20 years may caused by increased population and demand for residential area for living, the government policy on relocation small villages and merging them to cluster village development.

Teak plantation and mixed fruit orchard were considered as major changes in this village during the last two decades. These two types of land use did not existing in 1990. In 2010, it occupied 92.24 ha or 100% increased from 1990.

Most types of land use were converted to teak plantation; it gained from water bodies 0.72 ha, deciduous forest 19.98 ha, mixed deciduous forest 58.66 ha, fallow 1.03 ha, upland 7.62 ha, lowland 1.43 ha, and urban 2.80 ha respectively.

Mixed fruit orchard increased to 44.64 ha in 2010 or 100% increased from 1990. This is because of in 2010 water bodies converted to mixed fruit orchard 1.61 ha, deciduous forest 6.21 ha, mixed deciduous forest 28.05 ha, fallow 1.44 ha, upland field 4.17 ha, lowland field 1.16 ha and urban area 2.00 ha respectively.

6.4.2 Land use change of Sanghai village

Land use change of Sanghai village was summarized in (Table 6.6) and the results showed that in the year 1990 water bodies did not exist except Mekong River. In the year 2010, it was increased to 12.97 ha, gaining area from deciduous forest 1.23 ha, mixed deciduous forest 5.69 ha and upland field 6.05 ha. This change was due to the farmers converted land to fish pond and small dam for crop irrigation.

Deciduous forest covered an area of 635.90 ha in the year 1990, increased 674.26 ha in the year 2010 with a positive change of 38.36 ha or 6.03% increase. It gained area from mixed deciduous forest 191.01 ha, fallow 3.58 ha, upland field 40.18 ha, lowland field 0.41 ha and urban area 0.19 ha.

Mixed deciduous forest in the year 1990 occupied 708.48 ha, in 2010 occupied only 459.67 ha with negative change of 248.81 ha or 35.12% decrease. Mixed deciduous forest was converted to other types of land use such as water bodies 5.69 ha, deciduous forest 191.01 ha, fallow 25.61 ha, upland field 31.50 ha, lowland field 8.82 ha, urban area 16.09 ha and teak plantation 168.12 ha.

Table 6.6 Land use change matrix of Sanghai village from the year 1990-2010

Land use 1990	Land use 2010									Total 1990
	W	DF	MDF	Fa	UpF	LoF	Ur	TP	MFO	
W	-	-	-	-	-	-	-	-	-	-
DF	1.23	438.89	107.23	4.13	10.64	1.62	3.67	68.49	-	635.90
MDF	5.69	191.01	261.64	25.61	31.50	8.82	16.09	168.12	-	708.48
Fa	-	3.58	30.15	31.54	3.11	-	0.34	1.52	-	70.24
UpF	6.05	40.18	59.49	0.64	22.78	8.47	3.62	88.23	-	229.46
LoF	-	0.41	1.04	-	2.60	6.67	0.63	3.37	-	14.72
Ur	-	0.19	0.12	-	-	-	8.06	0.36	-	8.73
Total 2010	12.97	674.26	459.67	61.92	70.63	25.58	32.41	330.09	-	1,667.53
Change (ha)	12.97	38.36	-248.81	-8.32	-158.83	10.86	23.68	92.24	-	
Change (%)	100.00	6.03	-35.12	-11.85	-69.22	73.78	386.39	100	-	

Source: From data analysis

Note: W= Water, DF= Deciduous forest, MDF= Mixed deciduous forest, Fa= Fallow, UpF= Upland field, LoF= Lowland field, Ur= Urban, TP= Teak plantation, MFO= Mixed Fruit Orchard

In the year 1990, fallow covered 70.24 ha but decreased 8.32 ha during 1990-2010 and remained 61.92 ha in 2010, constituting 11.85% decrease. Fallow was converted to deciduous forest 3.58 ha, mixed deciduous forest 30.15 ha, upland field 3.11 ha, urban area 0.34, teak plantation 1.52 ha.

Upland field in the year 1990 occupied 229.24 ha but in the year 2010 decreased to 70.63 ha constituting 158.83% decrease. Upland field has been changed to water bodies 6.05 ha, deciduous forest 40.18 ha, mixed deciduous forest 59.49 ha, fallow 0.64 ha, lowland 8.47 ha, urban area 3.62 ha and teak plantation 88.23 ha.

Lowland field in 1990 occupied 14.72 ha but increased to 25.58 ha in 2010 with a positive change 10.86 ha constituting a 73.78% increase. The increase of lowland field was gained from deciduous forest 1.62 ha, mixed deciduous forest 8.82 ha, upland field 8.47 ha.

Urban area in 1990 was just only 8.73 ha but increased to 32.41 ha in 2010 or increased 23.68 ha constituting 386.39% increase. From the year 1990-2010, deciduous forest, mixed deciduous forest, fallow, upland and lowland were converted to urban area (3.67 ha, 16.09 ha, 0.34 ha, 3.62 ha and 0.63 ha respectively). The change of urban area of Sanghai village is due to the government's trade and investment policy. Many factories emerged in this area.

Teak plantation was considered as major changes in this village because of this type of land use did not exist in 1990. In 2010, it occupied 330.09 ha or 100% increased from 1990. Teak plantation gained area from deciduous forest 68.49 ha, mixed deciduous forest 168.12 ha, fallow 1.52 ha, upland field 88.23 ha, lowland 3.37 ha and urban 0.36 ha respectively.

6.4.3 Land use change of Thinchaloen village

Land use of Thinchaloen village was similar to Phonsavang village in term of teak plantation and mixed fruit orchard but differ in other classes which have been decreased as summarized in Table 6.7. The results showed that water bodies in the year 1990 was only 0.53 ha. In the year 2010, it was 1.31 ha. This change due to the farmers converted forest land, upland and lowland fields to fish pond for aquaculture.

Deciduous forest covered 60.88 ha in the year 1990 but increased to 50.38 ha in the year 2010. This type of land use has a negative change of about 10.50 ha during the period or 17.25% decrease. This land use was converted to mixed deciduous forest 6.04 ha, teak plantation 19.02 ha and mixed fruit orchard 3.00 ha.

Mixed deciduous forest of this village in the year 1990 occupied 186.96 ha but in 2010 covered just about 67.80 ha with negative change of 119.16 ha or 63.74% decrease. Mixed deciduous forest was converted to other types of land use such as converted to deciduous forest 16.94 ha, upland field 12.25 ha, urban area 2.75 ha, teak plantation 52.13 ha and mixed fruit orchard 48.27 ha.

In the year 1990, fallow covered 4.81 ha but decreased 3.44 ha during 1990-2010 and remained 1.37 ha in 2010 constituting 71.52% decreased. Fallow was converted to deciduous forest 0.32 ha, mixed deciduous forest 1.63 ha, fallow 0.32 ha, upland field 0.82 ha and teak plantation 1.72 ha.

Table 6.7 Land use change matrix of Thinchaloen village from the year 1990-2010

Land use 1990	Land use 2010									Total 1990
	W	DF	MDF	Fa	UpF	LoF	Ur	TP	MFO	
W	-	-	0.01	-	-	-	-	-	0.52	0.53
DF	0.01	32.12	6.04	0.02	0.67	-	-	19.02	3.00	60.88
MDF	0.03	16.94	53.46	0.81	12.57	-	2.75	52.13	48.27	186.96
Fa	-	0.32	1.63	0.32	0.82	-	-	1.72	-	4.81
UpF	0.10	0.79	4.82	0.22	2.90	-	0.79	12.13	11.59	33.37
LoF	0.86	0.21	1.82	-	0.18	-	0.13	7.26	4.55	15.00
Ur	0.31	-	-	-	-	-	1.87	0.04	0.11	2.33
Total 2010	1.31	50.38	67.80	1.37	17.14	-	5.54	92.30	68.04	303.88
Change (ha)	0.78	-10.50	-119.16	-3.44	-16.23	-	3.21	92.30	68.04	
Change (%)	141.17	-17.25	-63.74	-71.52	-48.64	-	137.77	100	100	

Source: From data analysis

Note: W= Water, DF= Deciduous forest, MDF= Mixed deciduous forest, Fa= Fallow, UpF= Upland field, LoF= Lowland field, Ur= Urban, TP= Teak plantation, MFO= Mixed Fruit Orchard

Upland field in the year 1990 occupied of about 33.37 ha but in the year 2010 remained only 17.14 ha constituting 16.23 ha or 48.64% decrease. Upland field has been converted to mixed deciduous forest 4.82 ha, teak plantation 12.13 ha and mixed fruit orchard 11.59 ha.

Urban area of Thinchaleon village in 1990 covered just 2.33 ha but increased to 5.54 ha in 2010 or an increase of 3.21 ha. From the year 1990-2010, urban area was gained from mixed deciduous forest, upland field and lowland about 2.75 ha, 0.79 ha, 0.13 ha respectively.

Teak plantation in this village was a major change in land use in this village because of it did not exist in 1990. The change of teak plantation in 2010 covered 92.30 ha or 100% increased from the year 1990. Teak plantation gained from deciduous forest 19.02 ha, mixed deciduous forest 52.13 ha, fallow 1.72 ha, upland field 12.13 ha and lowland 7.26 ha.

Mixed fruit orchard was a major change in land use increasing to 68.04 ha in 2010 or 100% increase from 1990. It gained areas from mixed fruit orchard 0.52 ha, deciduous forest 3 ha, mixed deciduous forest 48.27 ha, upland field 11.59 ha, lowland field 4.55 ha and urban area 0.11 ha respectively.

It can be concluded that the changes of land use in three villages were similar in some types of land use and different in another types. The changes in water bodies, mixed deciduous forest, teak plantation and urban area among three villages during the last twenty years were the same in term of an increase in land use. Deciduous forest of Phonsavang and Sanghai were similarly increased but Thinchaleon's deciduous forest was decreased. Upland field still increased only in Phonsavang village while in other villages it was decreased. In the year 2010, there was no

lowland field of Thinchaleon village, all lowland fields has been converted to teak plantation and mixed fruit orchard. Sanghai has highly changed in teak plantation and urban area; most of industrial factories were built in this village's area. Mixed fruit orchard was major land use change and occurred only near the Nam Seung river bank of Phonsavang and Thinchaleon village.

6.5 Spatial relationship between land use change and physical land characteristics

To achieve the second objective on determining factors affecting on land use change of the study area, the spatial logistic regression model was performed since land use changes are discrete phenomena and logistic regression is an adequate statistical method to analyze them (Millington et al, 2007). Logistic regression model was used when the dependent variable is dichotomous. The relationship between the dependent variable and independent variables is nonlinear. The physical land characteristics consisted of 5 independent variables that related to dependent variable. Table 4.5 showed the complete list of variables.

Table 6.8 List of spatial variables included in the logistic regression model

Variable	Meaning	Nature of variable
Dependent Y	0= No land use change, 1= Land use change	Dichotomous
Independent		
X_1	DEM (meter)	Continuous
X_2	Slope (%)	Continuous
X_3	Distance from road (meter)	Continuous
X_4	Distance from urban (meter)	Continuous
X_5	Distance from water (meter)	Continuous

6.5.1 Independent variables

A Digital Elevation Model (DEM) was obtained from provincial geographic office as Luang Prabang provincial digital elevation model map with the elevation ranged between 270- 562 meters from mean sea level. Figure 6.6 shows the raster maps of the independent variables. Five design variables denoted as X_1, X_2, X_3, X_4 and X_5 representing as spatial variables which were elevation, slope, distance from road, distance from urban and distance from water respectively.

Slope or gradient: is one of a spatial that describes its steepness to represent the characteristics of terrain which has the unit in degree or percentage. The slope map was created from (DEM) by using slope analysis in spatial analysis function in ArcGIS version 9.3 and according to geographical characteristics of Lao PDR, slope was reclassified into 5 levels which ranged from 0-12%, 13-36%, 37-45%, 46-60% and more than 60%. Slope has a negative influence in all processes,

since steeper areas are less suitable for housing construction and agricultural practices.

Distance from roads: This variable was calculated as a series of buffers of 35 m (1 pixel) expanding from each arc of the road network. Most of the roads in the study area are gravel roads and a pave road. Road quality largely depends on maintenance efforts and is highly variable in time. Each road segment was therefore treated as equally suitable for transport of goods and people.

Distance from urban: The distance to the nearest settlement was calculated as a series of buffers of 35 m, expanding from each centre. Only the official registered village centers were taken into account as well as industrial factories that are located in the study area. Although not real settlements, the factories provided job opportunities for the local people as well as possibilities to trade locally.

Distance from water: Accessibility to permanent water sources is highly valued. Besides permanent rivers and artificial water holes and fish pond with permanent water were also mapped. Temporary rivers and seasonal water points were not taken into account. Distance to water was calculated as a series of buffers of 35 m, expanding from each arc of the river or from each point.

6.5.2 Dependent variable

The spatial distribution was modeled for period 1990-2010 and the land use and land cover change map was segmented in zones with different dominant land uses based on the interpretation of the landscape patterns on the 2010 Landsat5 TM image and supported by field survey data. Figure 6.7 shows the map of land use change from 1990 to 2010 which serves as the dependent variable Y.

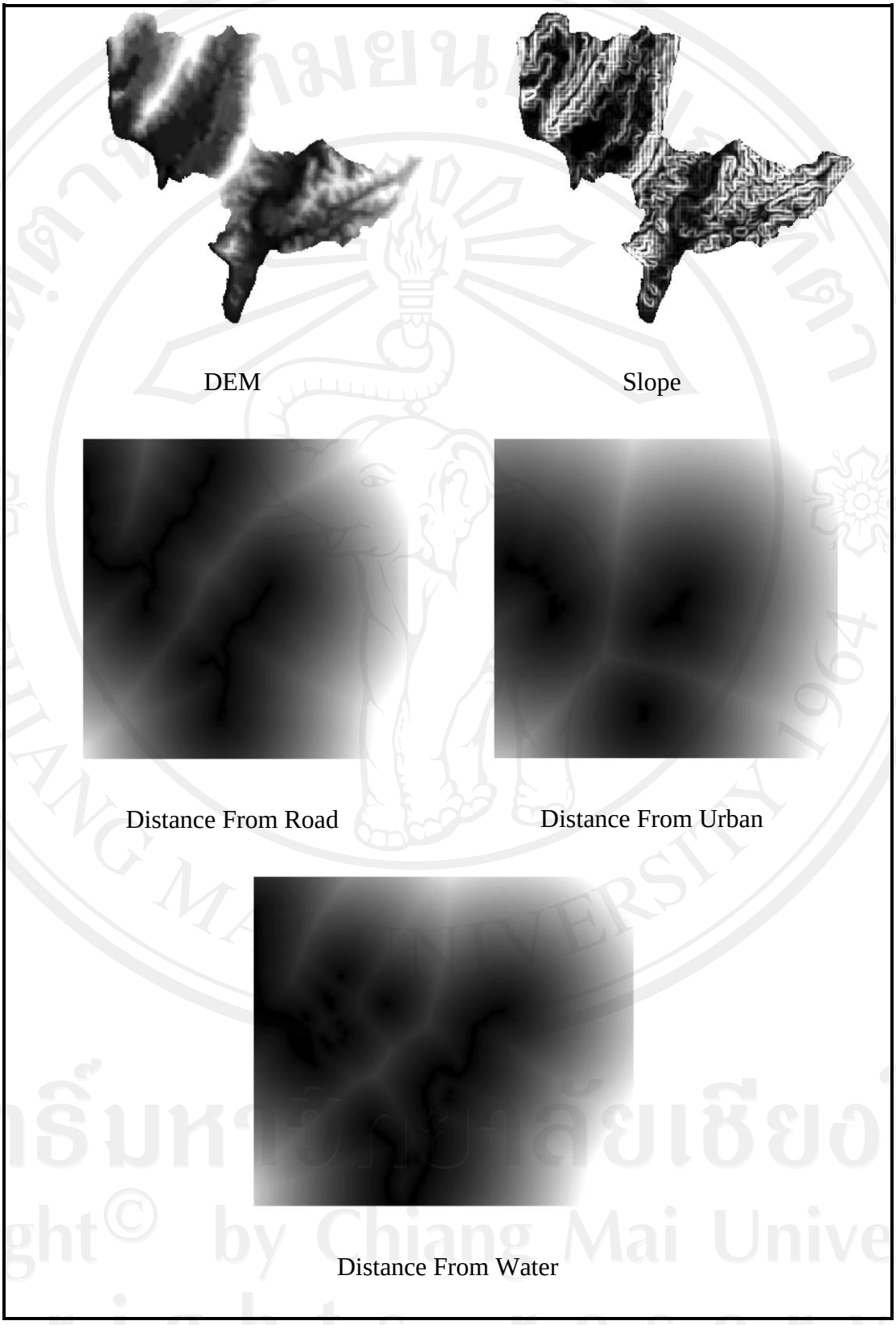

Figure 6.6 Raster layers of independent variables for logistic regression model.

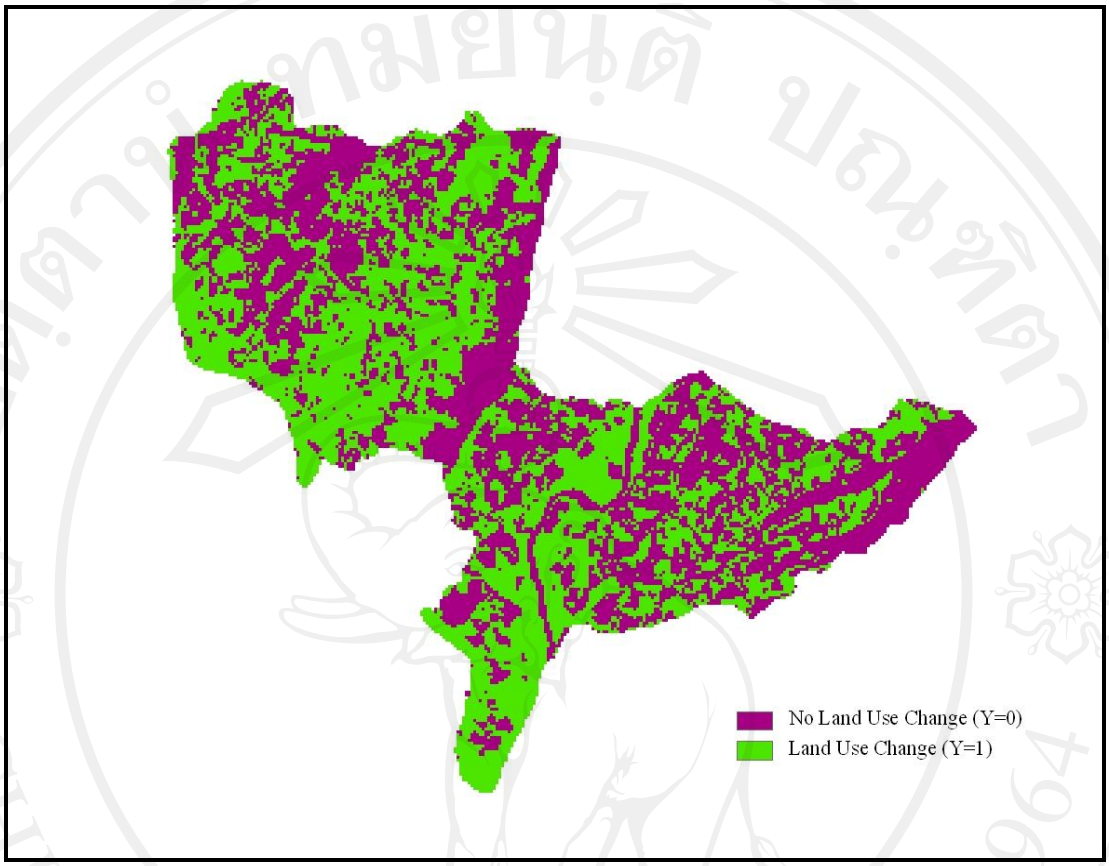

Figure 6.7 Dependent variable Y= land use change from 1990 to 2010

6.5.3 Land use change prediction

Logistic regression model was performed with 5 independent variables (X_1-X_5) in the support of IDRISI GIS. All the raster layers at the resolution of 35 m data set (35 m pixel size) were converted into ASCII format. It should be noted that the dependent variable Y has binary nominal values with 1 representing the change from non-land use change to land use change and 0 no such change. Land use change tend close to 1 is the slope (X_2) has a coefficient 0.00657036 and distance from urban 0.00003700 (Table 6.9) indicate that both variables have a high probability change than other 3 variables.

Logistic regression equation predicting land use change occurrence was obtained: logit (LUC) P = 2.2979 + (-0.005178 dem) + 0.006570 slope + (- 0.00035 1road_dist + .000037 urban_dist + (-0.000074water_dist).

Table 6.9 Estimate means, coefficient and standard error for the logistic regression

Variable	Coefficient	Standard Error
DEM	-0.00517756	5007.547852
Slope	0.00657036	4830.664551
Distance from road	-0.00035104	1410.892944
Distance from urban	0.00003700	1365.153687
Distance from water	-0.00007407	1244.546753

Pseudo R square = 0.5054

According to (Clark and Hosking, 1986) stated that if pseudo R square is equal to 1, it indicates a perfect fit, where as pseudo R square equal to 0 indicates no relationship. However, if pseudo R square greater than 0.2 is considered a relatively good fit. So land use change in this model indicating a good fit of the model. The pseudo R square value of the full model is 0.5054 indicating a good fit of the model.

When classification of cases and odds ratio by using the new threshold found that the observation of no land use changes Y=0 was increased to 53244 pixels counted for fitted_0 and decreased to 4855 pixels counted for fitted_1. The observation for Y=1 was also increased to 4855 pixels counted for fitted_0 and decreased to 9046 pixels counted for fitted_1 (Table 6.10).

Table 6.10 Classification of cases and odds ratio by using the new threshold

Observed	Fitted_0	Fitted_1
0	53244	4855
1	4855	9046

Adjusted Odds Ratio = 20.4338

True Positive = 99.7684%

False Positive = 8.3564%

The results also showed the adjusted odds ratio of the new threshold is 20.433, true positive cells which are predicted as land use change 99.768% and false positive cells 8.356%.

Relative operating characteristic (ROC) was used to validate the logistic regression model. Recently the ROC method was brought to the field of land use and cover change modeling to measure the relationship between simulated change and real change (Pontius, 2000; Schneider & Pontius, 2001). ROC method is an excellent method to evaluate the validity of a model that predict s the occurrence of an even t by comparing a probability image depicting the probability of that event occurring and a binary image showing where that class actually exists.

In this case, the ROC method offers a statistical analysis that answers one important question: ‘‘How well is land use change concentrated at the locations of relatively high suitability for the change?’’ Mode l validation using ROC reported a summary ROC value. A ROC value of 1 indicates that there is a perfect spatial agreement between the actual land use change map and the predicted probability map.

A ROC value of 0.5 is the agreement that would be expected due to chance, i.e., the cells values on the predicted probability image were assigned to random locations. For this study a relative operating characteristic (ROC) is 0.9281.

The ROC value ranges from 0 to 1, where 1 indicates a perfect fit and 0.5 indicates a random fit. A ROC value between 0.5 and 1 indicates some association between the X variables and Y. The larger the ROC the better the fit.

The map of predicted probability of land use change is shown in Figure 6.8. The lighter tones indicate higher probabilities of land use change. Some new emerging clusters far from existing land use areas can be seen. Most probable areas for land use change are closer to slope and existing urban clusters.

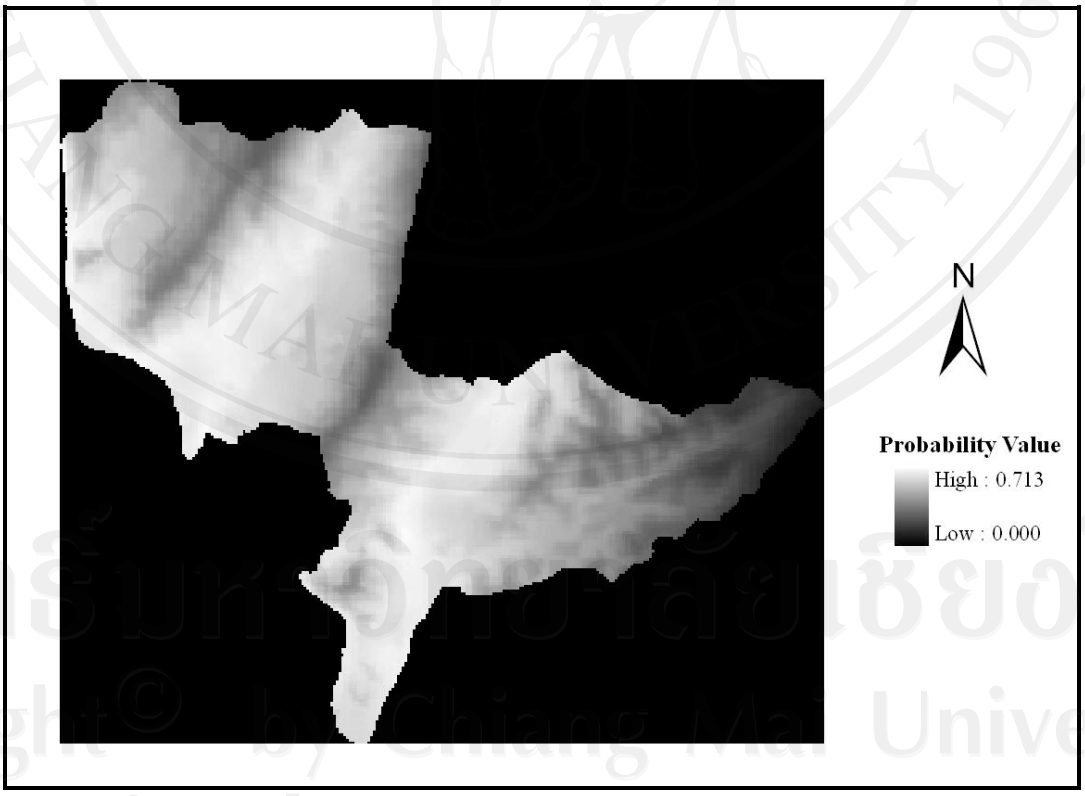

Figure 6.8 Land use change probability map of the study area. Lighter tones indicate higher probabilities of Land use change

6.5.4 Trend in future of land use change

There is a variety of both spatial and socio-economic factors that drive land use changes in the study area described either by statistical or modeling approach. The statistical analysis revealed that the land use change is influenced by a set of variables declared by DEM, slope, distance from road, distance from urban and distance from water is correlated with the change of land use. In the future trend of land use change seem to be highly increased in urban, lowland field and mixed fruit orchard this is due to the increasing of population, it relies on initial number of population in the year 1990 changed in number population in 2010. This factor is linked to the change of land use such as the need of land parcel for residential, setting of industrial factories and demand of cultivable land for food production.

6.6 Socio-economic factors affecting on land use change

This section examines the relationship between socio-economic factors affecting on land use change, the factors such as demographic factors that are supposed to influence land use change in the study area. Land use and cover changes are often influenced by several factors among which the socio-economic factors play a great role (Lambin & Geist, 2002). As stated by (Verburg et al, 2004), land use change can be described by the complex interaction of behavioral and structural factors associated with other variables such as demand, capacity, social relations and nature of environment.

To point out the relevant socio-economic variables that affect land use change in the study area, the statistical package SPSS was used and the logistic regression analysis has been computed to estimate the correlation between land use change events and factors affecting on land use. For this purpose, the analyses were focused on the variables derived from socio-economic survey on household. This step attempts to identify underlying 12 variables or factors that explain the pattern of correlations within a set of observed variables.

In the following table (Table 6.11) is given the completed list of all the variables used to compute in the logistic regression analysis. This table shows in total 1 binary dependent variable and 12 independent variables used. Among these last, six (6) are continuous and six (6) are binary.

Table 6.11 Description of variables used for logistic analysis computation

Variables	Label description	Type	Value
Y	Dependent variable	Binary	0= No land use change 1= Land use change
Independent variables X_1 to X_{12}			
X_1 HHA	Head of household age (Year)	Continuous	Real value
X_2 ETH	Ethnicity	Binary	0= Lao; 1= Khmu
X_3 HHS	Household size (Person)	Continuous	Real value
X_4 ED_1	Secondary School	Binary	0= Otherwise 1= Secondary School
X_5 ED_2	High School	Binary	0= Otherwise 1= High School
X_6 ED_3	Vocational or University	Binary	0= Otherwise 1= Vocational or University
X_7 FL	Family labor (Person)	Continuous	Real value
X_8 OL	Ownership of livestock	Binary	0= No; 1= Yes
X_9 OFIC	On farm income (Lao Kip)	Continuous	Real value
X_{10} NFIC	Non-farm income (Lao Kip)	Continuous	Real value
X_{11} RP	Rice production	Binary	0= No; 1= Yes
X_{12} LSH	Land size holding (ha)	Continuous	Real value

The results from logistic regression analysis of socio-economic factors that affecting on land use change in the study area show that in total 12 variables have 5

variables value were less than 0.05 (95% confidence interval) while other 7 variables value were greater than 0.05 and the constant variable is the intercept term in the equation is also significant as shown in (Table 6.12).

The following equation predicting land use change occurrence was obtained:

Logit (LUC) P= 4.170 + (-.129 HHA) + (-2.099 ETH) + (.290 HHS) + (.904 ED1) + (.620 ED2) + (1.559 ED3) + (-.885 FL) + (-2.194 OL) + (.108 FIC) + (-1.581 NFIC) + (.256 RP) + (-.675 LSH).

Table 6.12 Logistic regression analysis for socio-economic factors on land use change

Variable	B	S.E	Wald	df	Sig.	Exp(B)	95.0% C.I. for Exp(B)	
							Lower	Upper
HHA	-.129	.239	.293	1	.588	.879	.550	1.403
ETH	-2.099	1.001	4.400	1	.036*	.123	.017	.871
HHS	.290	.169	2.941	1	.086	1.336	.959	1.861
ED_1	.904	.824	1.204	1	.273	2.469	.491	12.411
ED_2	.620	.835	.551	1	.458	1.859	.362	9.554
ED_3	1.559	1.241	1.577	1	.209	4.754	.417	54.172
FL	-.885	.351	6.352	1	.012*	.413	.208	.821
OL	-2.194	.755	8.444	1	.004**	.112	.025	.490
OFIC	.108	.284	.144	1	.705	1.114	.638	1.944
NFIC	-1.581	.781	4.101	1	.043*	.206	.045	.950
RP	.256	.623	.169	1	.681	1.292	.381	4.379
LSH	-.675	.172	15.427	1	.000**	.509	.364	.713
Constant	4.170	1.640	6.466	1	.011*	64.743		

Exp (B) shows the predicted change in odds for a unit increase in the predictor.

Wald statistic tests the significance of individual logistic regression coefficients for each independent variable.

Omnibus Tests of Model Coefficients: $\chi^2 = 51.56$ df = 12 Sig. = 0.000

Percentage of correct predictions = 83.30%

Hosmer and Lemeshow's Goodness of Fit Test: $\chi^2 = 5.29$ df = 8 Sig. = 0.726

ns = Not significant level

*Significant at 5% level

**Significant at 1% level

The results of the logistic regression equation show that 5 variables have relationship and influence on land use change. Most two significant predictor variables of land use change is LSH (Land Size Holding) and OL (Ownership of Livestock) both are significant at 99% level of confidence.

The significant of LSH variable is 0.000 with a coefficient (B) of -0.674, the odds ratio score (Exp (B)) of 0.509 meaning that one unit of land size holding will have 0.509 times likelihood of not having land use change (negative coefficient). It means that farmers who have more land is less likely to trickle land use change while farmers who have less of land parcel have a tendency to open and expand more new land to preserve and get the official land certificate for permanent agriculture and long term benefits especially teak wood plantation.

The significant of OL (Ownership of Livestock) is 0.004 with a coefficient of -2.194 and odds ratio score (Exp (B)) of 0.112 that can be interpreted to mean that one unit of OL (Ownership of Livestock) will have 0.113 times likelihood of not having land use change. If farmers who have fewer number of livestock as their family

property and source of income will be more likely to go to open the new land for crops production.

The other three significant predictor variables are the FL (Family Labor), ETH (Ethnicity) and NFIC (Non-Farm Income) they are significant at 95% level of confidence. The significant of 0.012, 0.036 and 0.043 with the coefficient of -0.885, -2.099 and -1.581. The odds ratio score (Exp (B)) of 0.413; 0.123 and 0.206 respectively and can be interpreted as if FML (Family Labor), ETH (Ethnicity) and NFIC (Non Farm Income) increase one unit, it leads to 0.413, 0.123 and 0.206 times less likelihood to influent and affected on land use change.

For the variable FL (Family Labor), the equation indicates a negatively significant relationship with land use change this means that farmers who have smaller number of family labor trend to trickle land use change than famers who have more family labor while this is contrary to common sense, it can be explain that farmers who have more family labor do not necessarily to open and clear some more land for cultivation. The larger family size may force them to seek other occupations and go to work outside such small industrial factories near their village.

Ethnicity was found to have relationship to land use change even though their village have been merged to a cluster. Khmu people have less likelihood than Lao people to clear some of their lands in new village that allocate by the Land and Forest Allocation Program.

For non farm income aspect farmers who have less non farm income will go to open and expand new land for industrial and cash crops production to earn more income from their farm as on farm income.

On the other hand, 7 other variables were not significant such as HHA (Head of Household Age), ED_1 (Secondary School), ED_2 (High School), ED_3 (Vocational or University), HHS (Household Size), OFIC (On Farm Income) and RP (Rice Production) with significance value greater than 0.05 less than 95% confidence.

The omnibus tests of the model coefficient show whether or not all of the variables entered into the regression equation have effect on predicting the dependent variable. The Chi-square value of 51.56 is significant at 0.000 with the 12 variables in the regression equation (Table 6.13). This is indicates that among the 12 variables used in this analysis, 5 are significant in predicting land use change.

Table 6.13 Omnibus tests of model coefficients

Step 1	Chi-square	df	Sig.
Step	51.56	12	.000
Block	51.56	12	.000
Model	51.56	12	.000

In the logistic regression model, a Classification Table compare the predicted value of the dependent variable with the actual observed values in the data as can be seen in the classification table shown in (Table 6.14) the regression equation of 12 independent variables. Overall percent of correct prediction is 83.30%. Specifically, 103 of the 150 samples with land use change and only 22 of the 150 samples with no land use change were predicted correctly.

Table 6.14 Classification of observed in land use change prediction

Observed		Predicted		
		Land use change		Percentage Correct
		No land use change	Land use change	
Land use change	No land use change	22	19	53.7
	Land use change	6	103	94.5
Overall Percentage				83.3

The cut value is .500

The results of model summary in (Table 6.15), shows the -2Log likelihood and the R Square for two different tests (Co & Snell and Nagelkerke). These tests are used to indicate how well the model fits the data. Smaller -2Log likelihood values indicate that the model fits the data better. The perfect model has a value of zero. In this case study, the R Square indicates between 29.1% and 42.1% of the dependent variable (land use change) it can be accounted by all the predictor variables in the equation. R Square value is not so high but it is adequate for the evaluation in the logistic regression model.

Table 6.15 Model summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	125.659 [a]	.291	.421

a. Estimation terminated at iteration number 5 because parameter estimates changed by less than 0.001.

When Hosmer-Lemeshow test is significant, it means that the observed counts and those predicted by the model are not close and the does not describe the data well. When the Hosmer-Lemmeshow test is not significant it means the observed and the predicted counts are close and the model describes the data well. The results of Hosmer-Lemmeshow test in the logistic regression model (Table 6.16) shows the Hosmer-Lemmeshow test is not significant (0.726) it can be concluded that the observed and the predicted counts are close and the model describes the data well.

Table 6.16 Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	5.296	8	.726

All of the results in logistic regression analysis can be concluded that LSH (Land Size Holding), NL (Number of Livestock), FL (Family Labor), ETH (Ethnicity) and NFIC (Non-Farm Income) are influencing factors and affect land use change while HHA (Head of Household Age), ED_1 (Secondary School), ED_2 (High School), ED_3 (Vocational or University), HHS (Household Size) OFIC (On Farm Income) and RYP (Rice Yield Production) have no affect to the land use change.