4. RESULTS AND DISCUSSION

4.1 Rice Production Areas

Chiang Mai Provincial Statistical Office (1998) reported that total rice production area in Chiang Mai was about 91,215 hectares, the highest among cultivated crops in the province (Table 4.1). The wet season rice made up about 91 percent of total rice produced while only 19 percent of rice were produced from the dry season rice.

Table 4.1 Cultivated areas in Chiang Mai by types of crop

Crops	Cultivated Areas (ha)		
	1988	1993	1998
Rice	113,977	106,846	91,215
Field crops	19,658	23,475	19,833
Vegetable crops, Flowers and ornamental plants	8,895	14,117	12,981
Perennial trees/Para rubber	28,299	55,676	67,199
Pasture	146	546	10
Forestry	3,967	498	209
Other	4,960	5,663	4,040
Total	179,903	206,820	195,487

Source : Chiang Mai Provincial Statistical Office (1998)

Most paddy fields are distributed along the major valleys in the province. The largest paddy areas are in Chiang Mai valley which extend from Mae Tang, Mae Rim, San Kamphaeng, Hangdong and San Patong districts (Figure 4.1). Other major paddy areas are found in river valleys in Fang, Mae Aei, Phrao, Chiang Dao and Wiang Hang. The rest of the paddy fields are small ones and distributed in the small valleys on the highlands in Màe Chaem, Chomthong and Omkoi districts.

4.2 Rice Mill Distribution

The number of mills in Chiang Mai province was reportedly declined by Office of Agricultural Economics (Table 4.2). Unfortunately, from year 1986 the report was given only in number of mills not their capacity. In 1985 there were 1028 small-scale, 194 medium-scale and 20 large-scale mills in Chiang Mai.

Table 4.2 Number of rice mills in Chiang Mai during 1988 to 1997.

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
No. of Rice mills	899	896	895	893	891	889	887	887	886	920

Rice mills are also distributed along the major valleys in the province (Figure 4.2). The medium-scale mill in the area surrounding Muang district decreases while the number of medium-size mills in Fang and Mae Aei districts increases. However, the large-scale mill remains relatively unchanged. It was found that thirty four medium-scale mills were clustered in Fang and Mae Aei districts and 20 mills were located in Muang, Sarapi, Hangdong, San Patong, San Sai and Chomthong districts (Table 4.3).

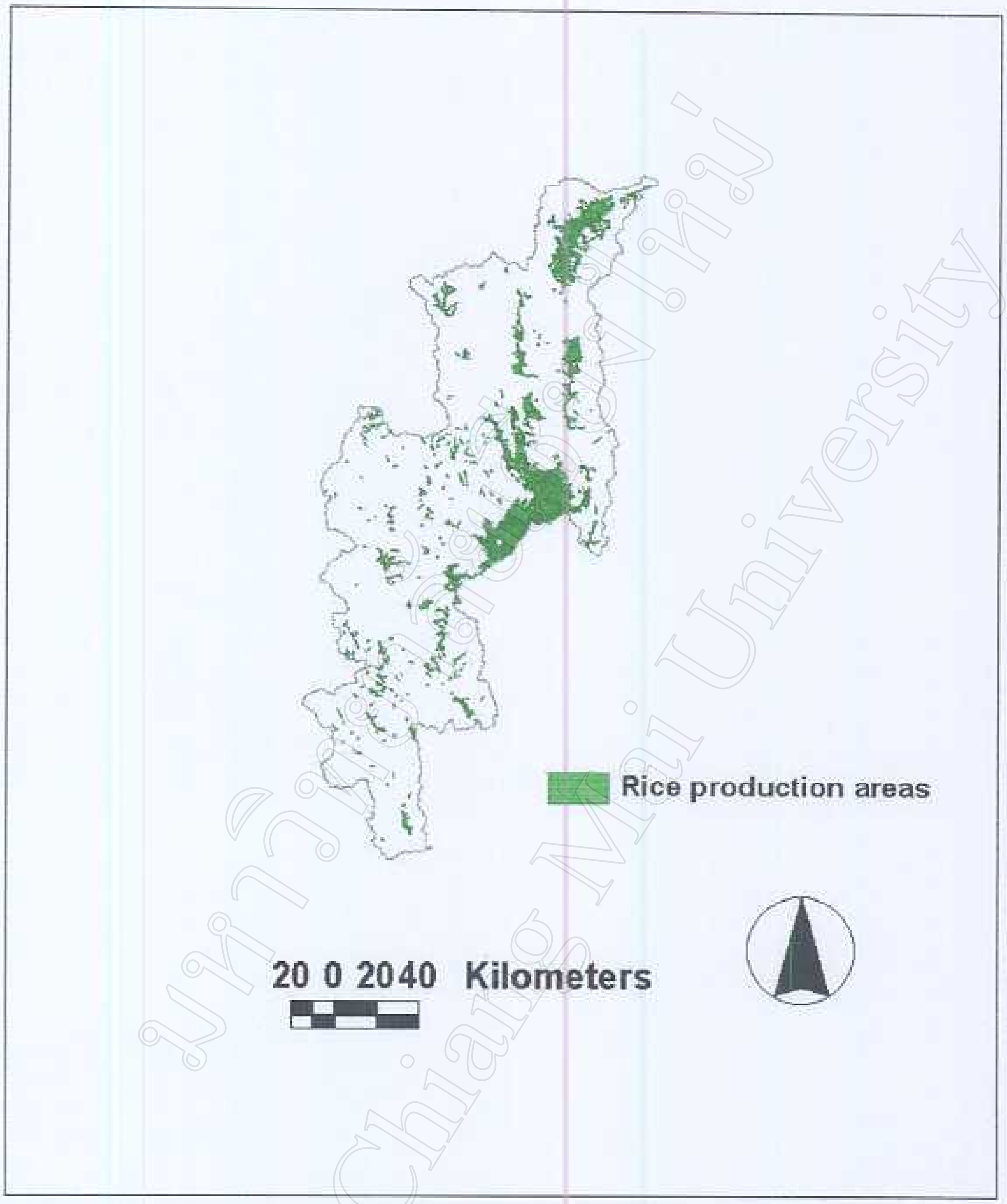

Figure 4.1 Rice production areas in Chiang Mai province.

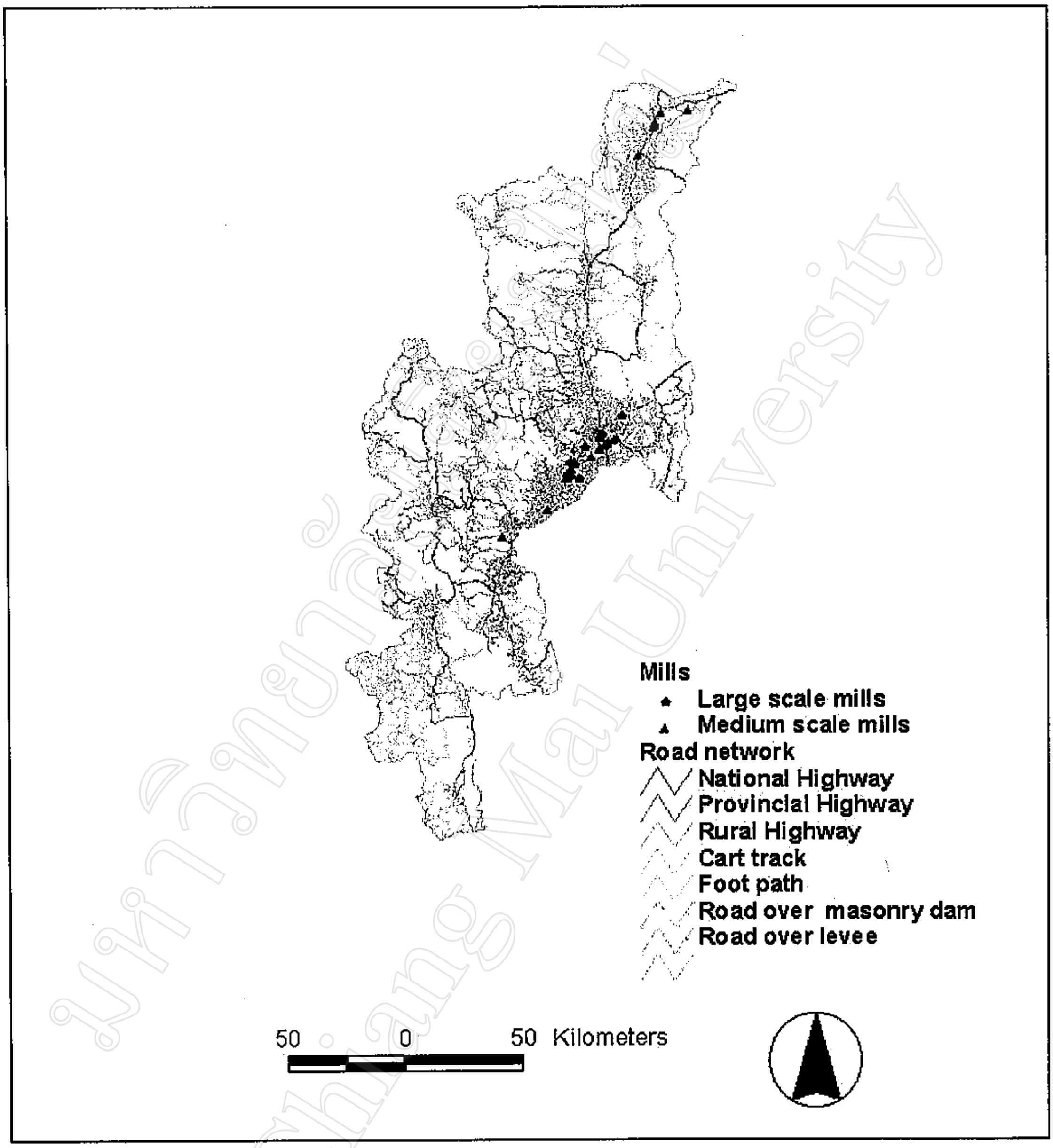

Figure 4.2 Rice mills in Chiang Mai province.

The mills in Fang and Mae Aei districts process paddy rice from Fang, Mae Aei and Phrao district, and those from Chiang Rai province. The other mills are supplied by paddy rice from the production areas surround their locations, Lampang and Lampoon provinces.

Table 4.3 Distribution of medium and large-scale mills by districts.

Districts	Large-scale mill	Medium-scale mill
Muang	3	1
Hangdong	3	6
Doi Saket	1	-
Sarapi	1	3
San Patong	1	1
San Kampaeng	-	2
Fang	-	3
Mae Aei	-	30
Total	9	45

4.3 Rice Transportation Network

Once the road networks have been constructed, the centroids of 1410 paddy fields of various sizes were snapped to the road segment to form a node. These nodes are now part of the transportation network. Similarly, points that represent the mills were snapped to the road network and the nodes are formed (see Figure 4.3). The complete transportation network in Chiang Mai is illustrated in Figure 4.4.

Nodes that represent paddy areas are now connected to each node representing the rice mill. Since the length of each segment of the roads can be easily computed in GIS, a distance matrix (1410×54) between paddy fields and a rice mill can be constructed and expressed as traveling time in minute (Table 4.4). The shortest route from any particular rice mill to a specified paddy field can be traced (Figure 4.5). This route indicates the least cost involved in transporting rice from that particular rice field to the rice mill of interest.

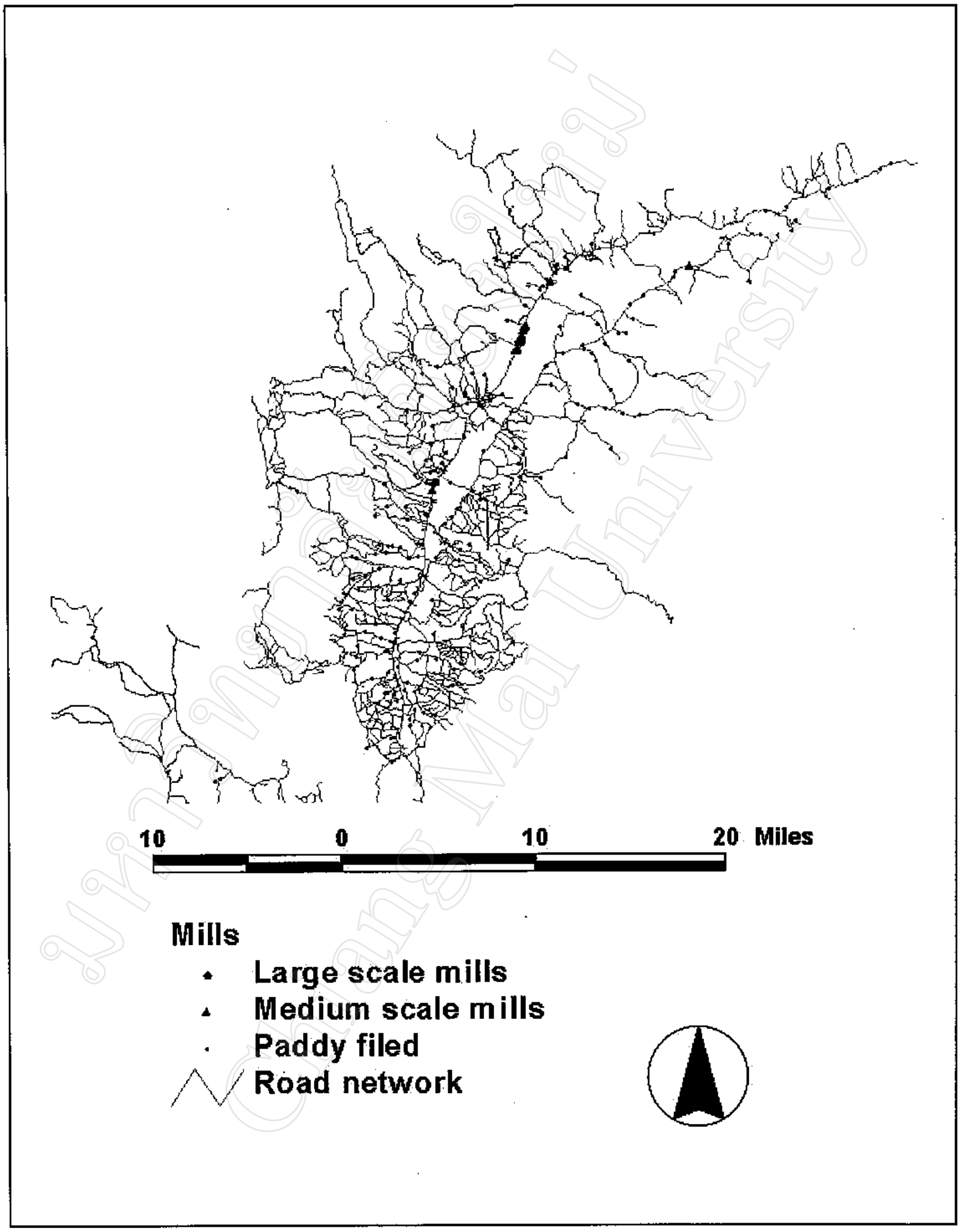

Figure 4.3 Nodes representing paddy and rice mills in transportation network.

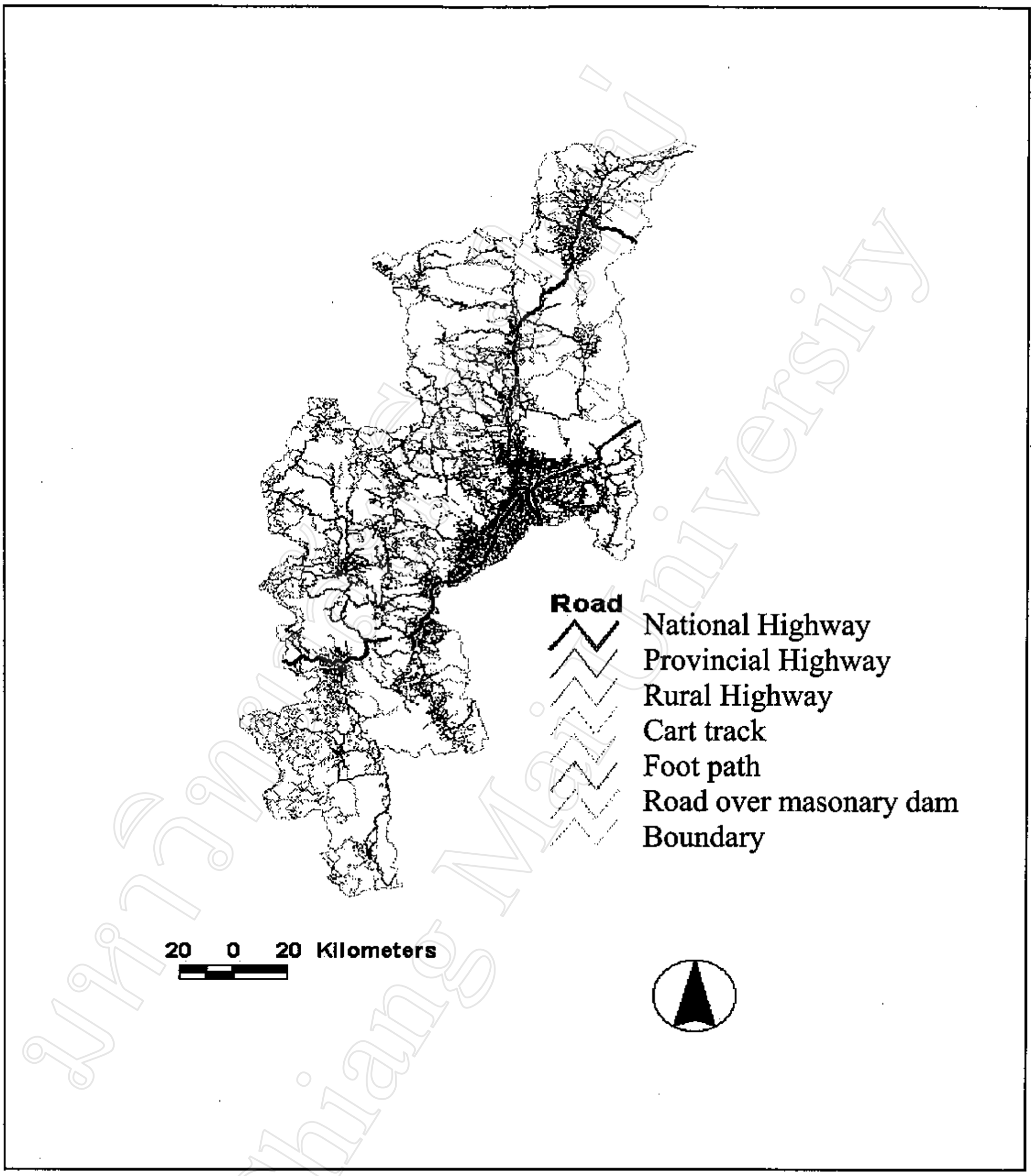

Figure 4.4 A transportation network in Chiang Mai province.

Table 4.4 Part of a distance matrix (expressed as traveling time in minute) between different pairs of paddy field and rice mill. The full matrix is 1410 paddy fields × 54 mills.

Paddy_ID	Mill4	Mill5	Mill61
2589	20.38	23.67	34.36
2592	20.51	25.51	34.48
2720	20.56	26.04	34.53
2725	19.91	25.22	33.88
2835	21.35	30.32	33.34
3209	20.15	43.35	21.98
3221	21.02	38.42	23.11
3235	20.38	43.58	21.95
3239	20.21	43.41	20.48
3273	21.19	44.39	20.46
3293	20.19	38.21	22.02
3299	21.29	39.31	23.12
3321	21.33	37.52	23.16
3324	21.04	40.81	22.87
3326	21.39	44.59	21.55
3373	20.70	43.90	18.19
3376	20.17	43.37	17.66

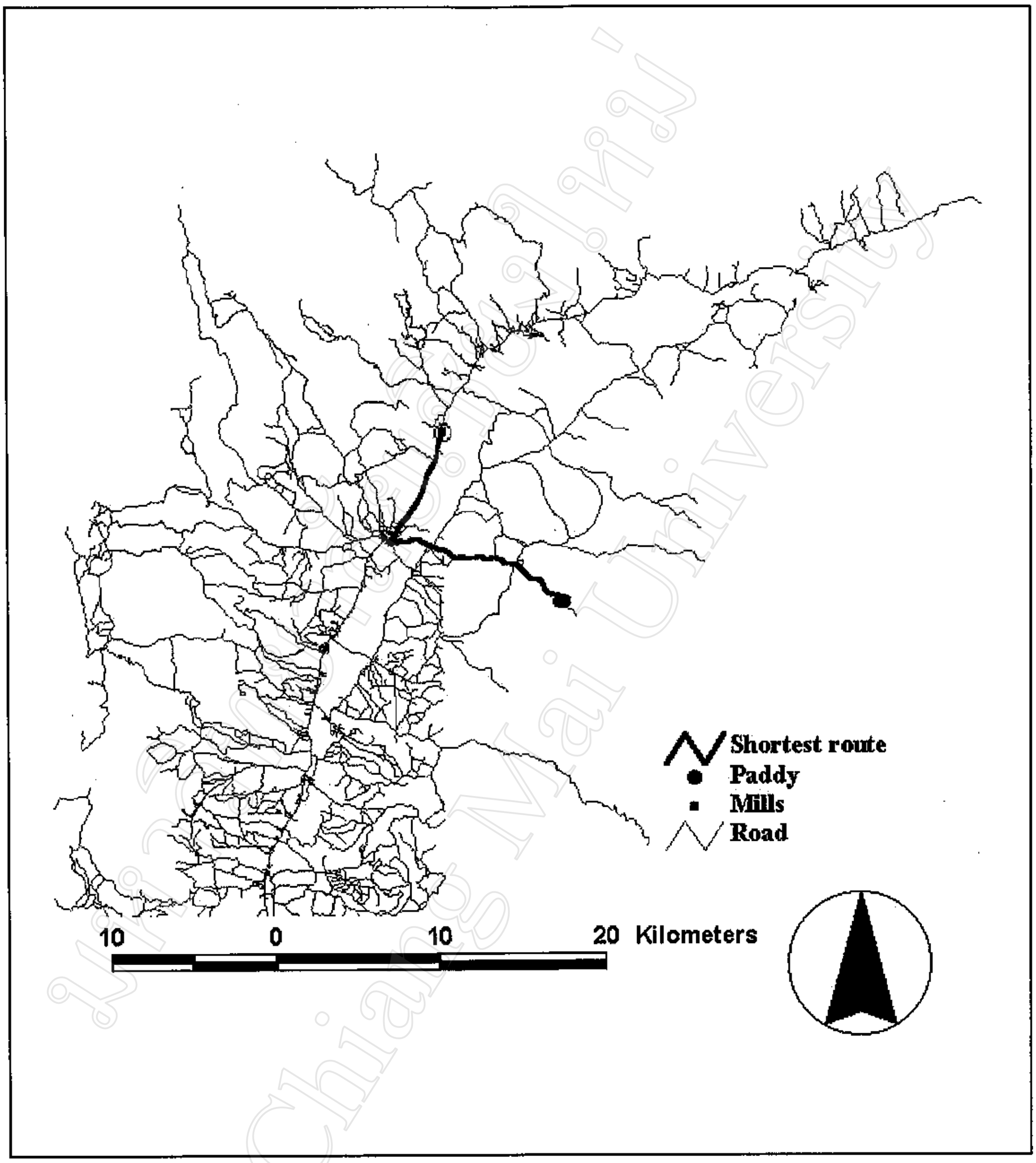

Figure 4.5 The shortest route from rice mill number 39 to the target paddy in Fang district.

4.4 Accessibility of Rice Production Areas

Table 4.5 shows one part of the accessibility index matrix of each paddy field. The higher the values in this matrix, the more accessible of the paddy field from all rice mills. The paddy with the high value in this matrix indicates that rice produced from that paddy field will have a high chance of trading with the surrounding rice mills. The values in this table can be linked to the attribute table of RICE shapefile in ArcView. The expected trading activities area for each paddy field can then be displayed as a map to be discussed in the next section.

Accessibility index (AI) also depends on the value of decay-function exponent (β). The higher the value of β, the more weight is given to traveling time (or distance) in the calculation of AI. Hence, AI is higher if β increases for the same paddy field (Table 4.5).

Table 4.5 A part of standardized accessibility index matrix computed from distance decay function using β of 0.5, 1.0 and 1.2.

Paddy_ID	**Standardized Accessibility Index**		
	β = 0.5	**β = 1.0**	**β = 1.2**
1	2.45	3.98	5.08
2	2.42	3.85	4.85
3	2.43	3.89	4.92
7	2.47	4.10	5.29
10	2.48	4.12	5.33
15	2.52	4.32	5.71
17	2.54	4.46	5.98
23	2.70	5.59	8.41
25	2.28	3.30	3.93
26	2.80	6.55	10.72
27	2.41	3.81	4.77
28	2.49	4.19	5.46
31	2.75	6.06	9.51
32	2.67	5.34	7.84
33	2.55	4.53	6.11
37	2.87	7.34	12.77
45	2.50	4.24	5.56
46	2.94	8.41	15.72
56	2.51	4.28	5.63
59	3.05	10.20	21.03
60	3.01	9.47	18.81

4.5 Spatial Interactions

In the analysis of spatial interactions, production of each paddy field is taken into consideration apart from attractiveness index of the rice mill. The higher the values of rice production and attractiveness, and the lower traveling time (or distance) will give rise to the higher value of I_{ij} in the spatial interaction matrix (Table 4.6). Conversely, if I_{ij} is high, the trading activities between them are expected to be high.

The cumulative probability of the occurrence of I_{ij} was computed by sorting I_{ij} descendently and part of the resulting matrix is shown in Table 4.7. The values from the whole matrix were linked with RICE shapefile to create attribute values of spatial interactions and probability of the occurrence of different levels of interactions. These values are essential information to generate trade areas at different cumulative probability levels to be discussed in the next section.

Table 4.6 Interaction matrix between selected paddy fields and three rice mills using β value of 1.0.

Paddy_ID	Mill4	Mill5	Mill61
2589	0.09088493	0.06947678	0.03714197
2592	0.35780861	0.24381937	0.14735357
2720	0.38962321	0.25788170	0.16089927
2725	0.08689263	0.05685496	0.03456426
2835	0.77320871	0.43376822	0.36116549
3209	0.11822772	0.03597743	0.09665555
3221	0.65123061	0.25298071	0.52826469
3235	0.22128277	0.06841254	0.18553825
3239	0.25312556	0.07735005	0.23841078
3273	0.05311351	0.01730172	0.05500569
3293	0.05118197	0.01850171	0.04186897
3299	0.27062778	0.10445252	0.22480699
3321	0.12709356	0.05244927	0.10562830
3324	0.52505311	0.18841169	0.43474664
3326	0.79135456	0.26092948	0.75461390
3373	0.13347568	0.04215312	0.16939118
3376	0.05557781	0.01693630	0.07171689
3407	0.03646986	0.01115218	0.04698227
3432	0.53770739	0.16657748	1.04008355
3456	0.26303752	0.08494517	0.29467739

Table 4.7 A matrix of cumulative probability of interaction between selected paddy fields and three rice mills, using β value of 1.0.

Paddy_ID	Mill4	Mill5	Mill61
2589	74.46	79.18	89.18
2592	35.29	52.82	66.13
2720	34.19	51.33	63.96
2725	75.26	82.96	90.04
2835	16.20	38.03	39.95
3209	67.63	89.73	74.79
3221	21.13	51.83	29.67
3235	49.92	79.80	59.08
3239	46.55	76.78	52.83
3273	84.96	95.46	84.53
3293	85.38	94.99	87.93
3299	43.67	70.20	53.97
3321	66.04	84.42	73.69
3324	26.74	59.94	33.98
3326	15.43	50.81	19.63
3373	64.60	87.30	62.65
3376	84.15	95.61	80.14
3407	89.73	97.46	86.92
3432	24.62	61.18	14.34
3456	45.01	74.84	48.36

4.6 Analysis of Trade Areas

One advantage of the network analysis in this type of problem is that once the basic matrices of distance, accessibility and spatial interactions are computed, trade areas may be generated using GIS capability. Three examples will be presented here to illustrate how trade zones for selected rice mills can be identified in GIS.

Example I. Using distance matrix

The simplest way to create a trade zone is to use traveling time (distance) matrix (Table 4.4). In this case, the trade zone is identified from the maximum traveling time (transportation cost) that can be born by the rice mill owner or the trader. This traveling time and specific rice mills can be selected as a condition for spatial query in GIS. All paddy fields that fall within the travelling time to the selected rice mills can be identified and shown as a map in GIS. Figure 4.6 illustrates the trade zones of rice mill no.4 (Chaiwiwatana), no 5. (Roungtong), and no. 61 (San Patong Cooperatives) as the results of spatial query in ArcView using traveling time of 20 minutes. It is noted that trade zones of rice mill no. 4 and 61 are slightly overlapped indicating the possible competition for rice at that location between the two rice mills if maximum 20 minutes travelling time are used by these mills for trading.

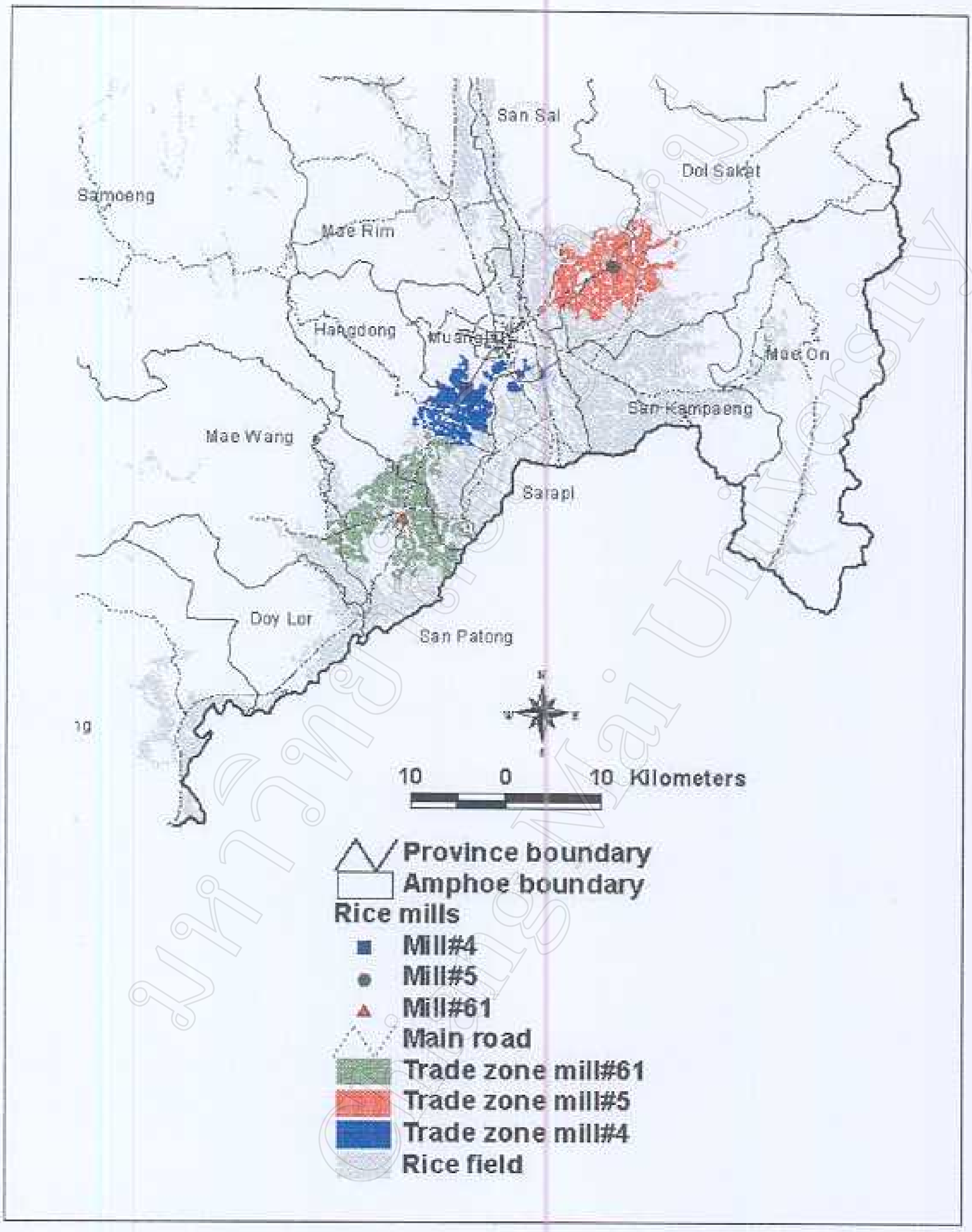

Figure 4.6 Trade zones of 3 rice mills generated from traveling time (distance) matrix.

Example II. Using accessibility index matrix

If accessibility index is used to suggest the trade zones, the results would be different since not only distance is considered but also attractiveness of each rice mill will affect how trading activities would occur. Figure 4.7, 4.8 and 4.9 demonstrate the trading activities which were generated from standardized AI of the paddy fields. The higher the value of standardized AI, the higher competition among rice mills for production of the same paddy field. The competing areas for rice trading also depends on the exponential value (β) of decay function used. The higher the β value, the higher AI value will be next to the vicinity of rice mill (Figure 4.9). If β value selected is low, expected trading activities would occur in the paddy fields at the further distance from rice mills (Figure 4.7).

Example III. Using spatial interaction matrix

In this case, the trading zone depends on attractiveness of rice mill, traveling time, and the decay function exponent (β) and production of each paddy field. Figure 4.10, 4.11 and 4.12 display trade zones of rice mill no. 4, 5, 61 respectively when making a query for paddy fields with cumulative interaction probability of 20 percent and using β value of 1.0. If the value of β is increased from 1.0 to 1.2, the radius of trade zones around these rice mills will be reduced as shown in Figure 4.13, 4.14, and 4.15 for mills no. 4, 5 and 61 respectively. The results using this method will be different from what have been obtained in Example I and II. However, the trade zones generated from spatial interaction matrix are conceived to be more realistic because locations with large paddy field have higher opportunity for trading activities.

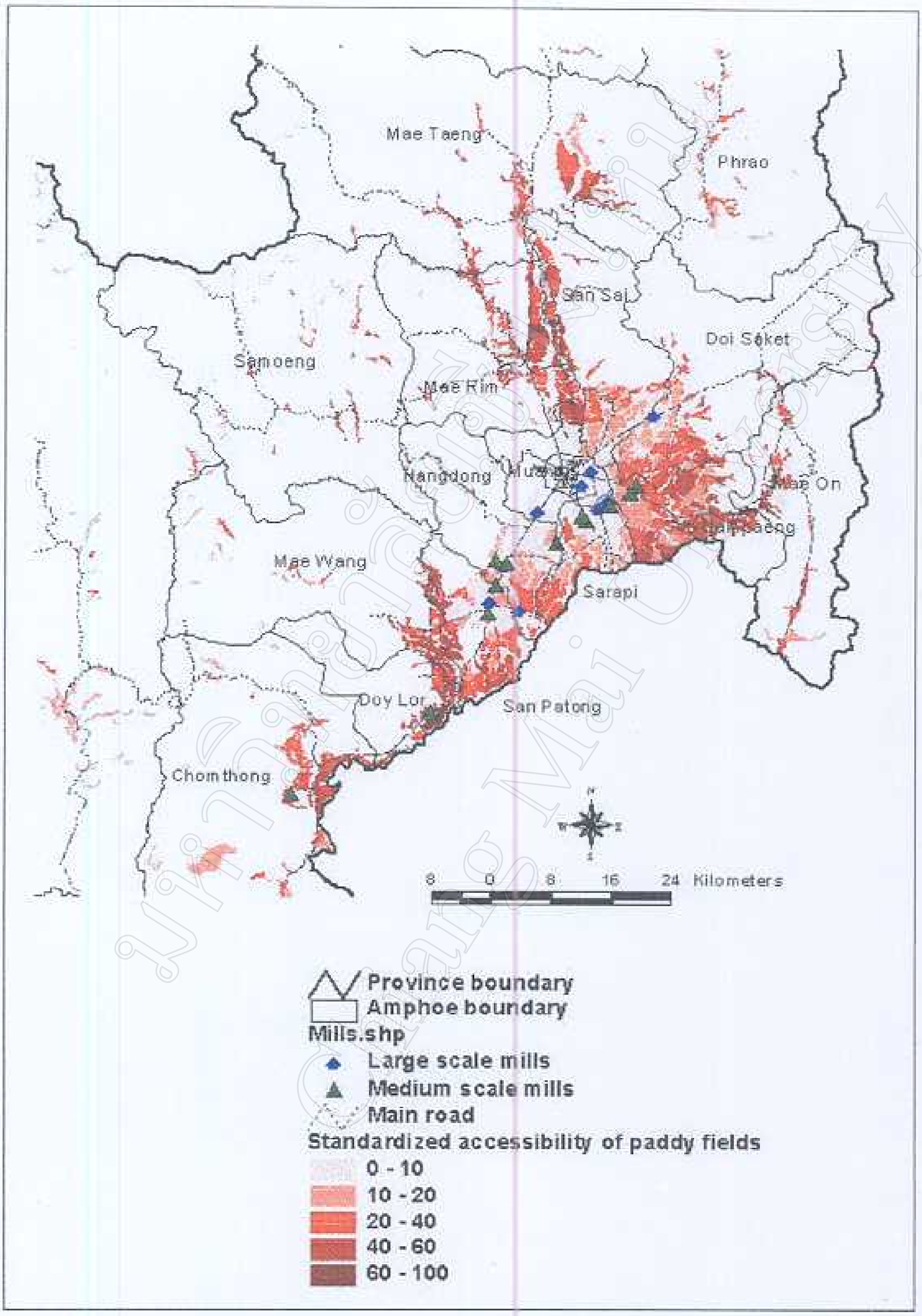

Figure 4.7 Standardized accessibility of paddy fields in Chiang Mai valley using β value of 0.5.

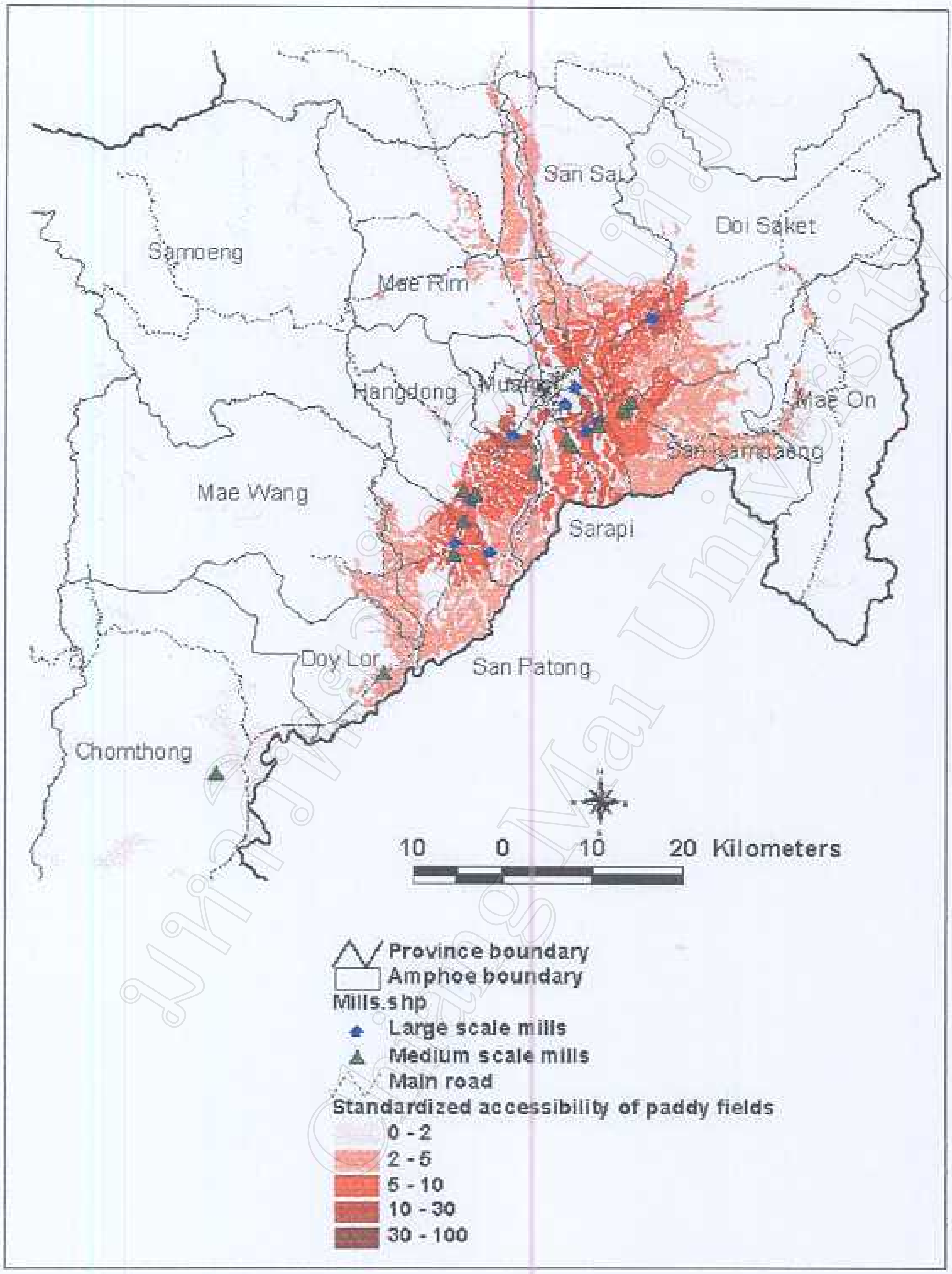

Figure 4.8 Standardized accessibility of paddy fields in Chiang Mai valley using β value of 1.0.

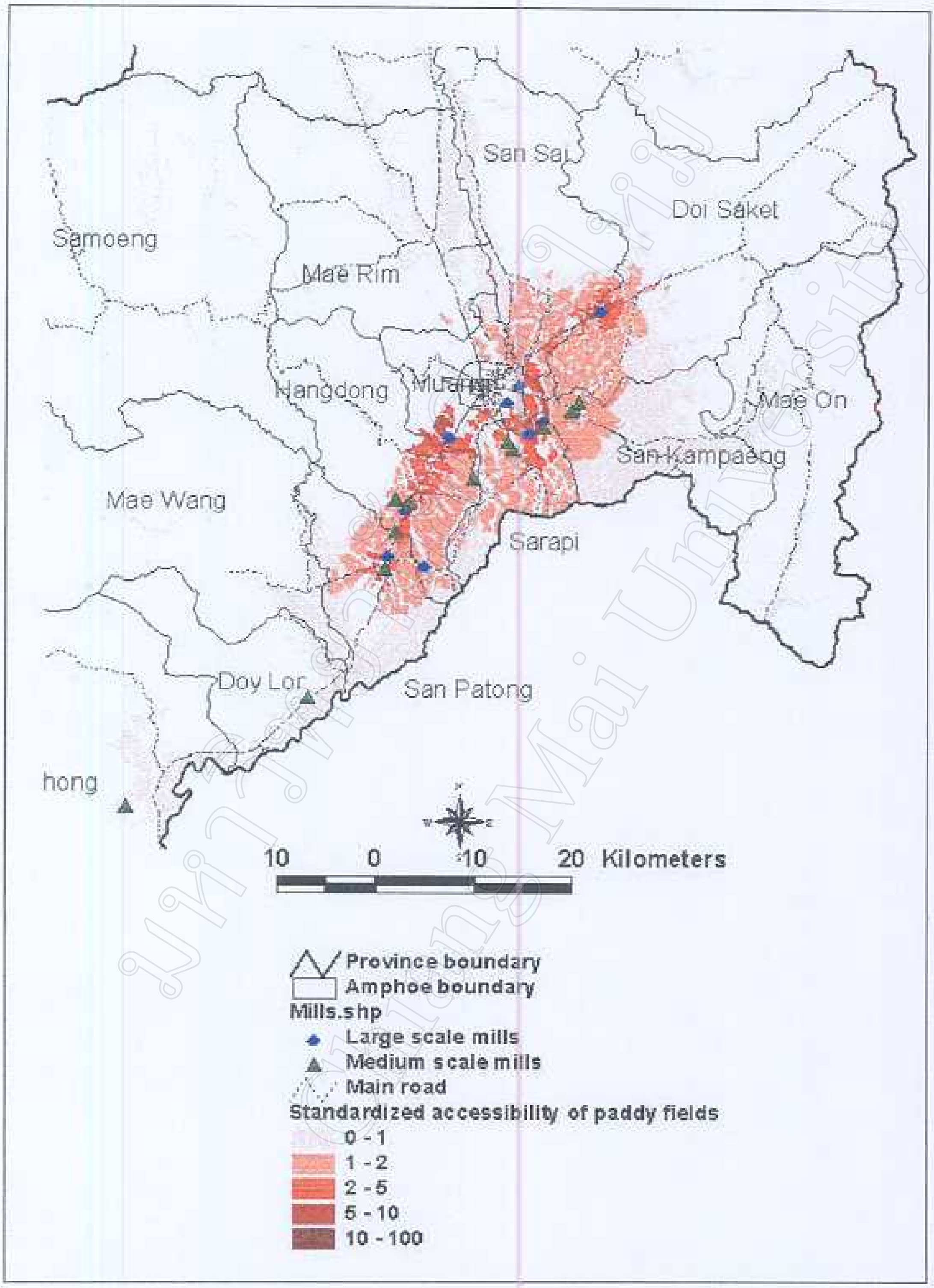

Figure 4.9 Standardized accessibility of paddy fields in Chiang Mai valley using β value of 1.2.

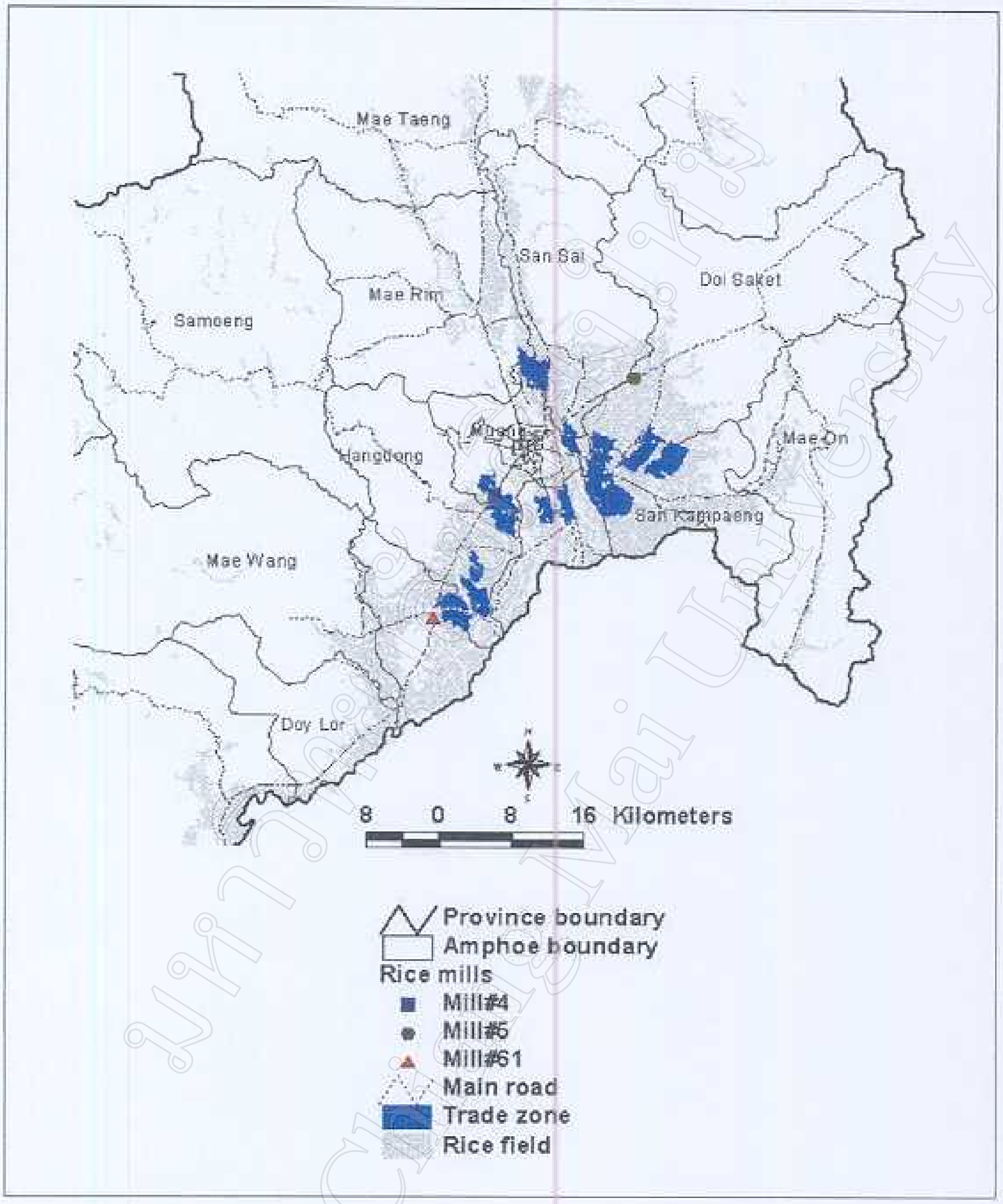

Figure 4.10 Trade zone of rice mill number 4 generated from paddy fields with cumulative interaction probability of 20%, using β of 1.0.

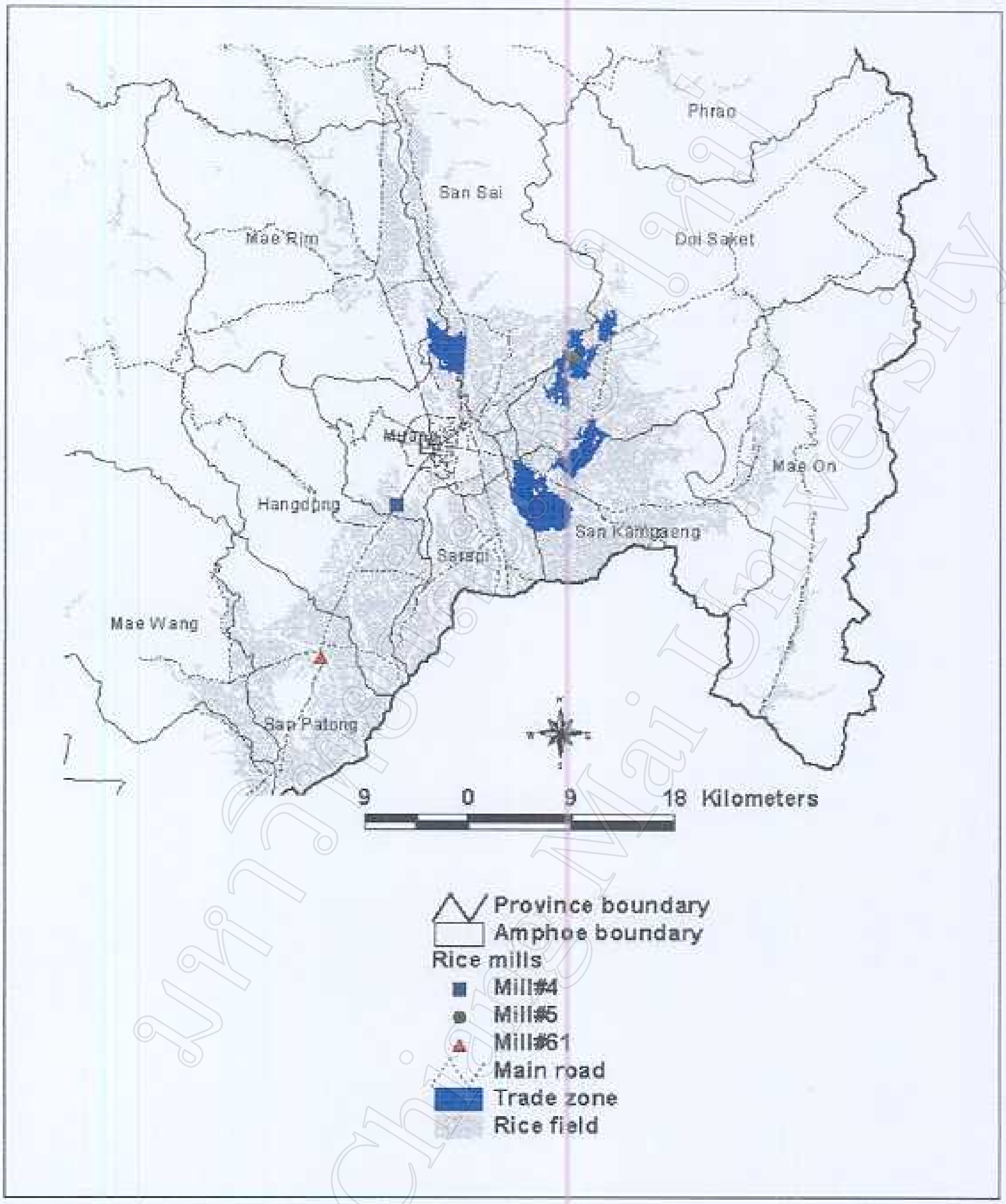

Figure 4.11 Trade zone of rice mill number 5 generated from paddy fields with cumulative interaction probability of 20%, using β of 1.0.

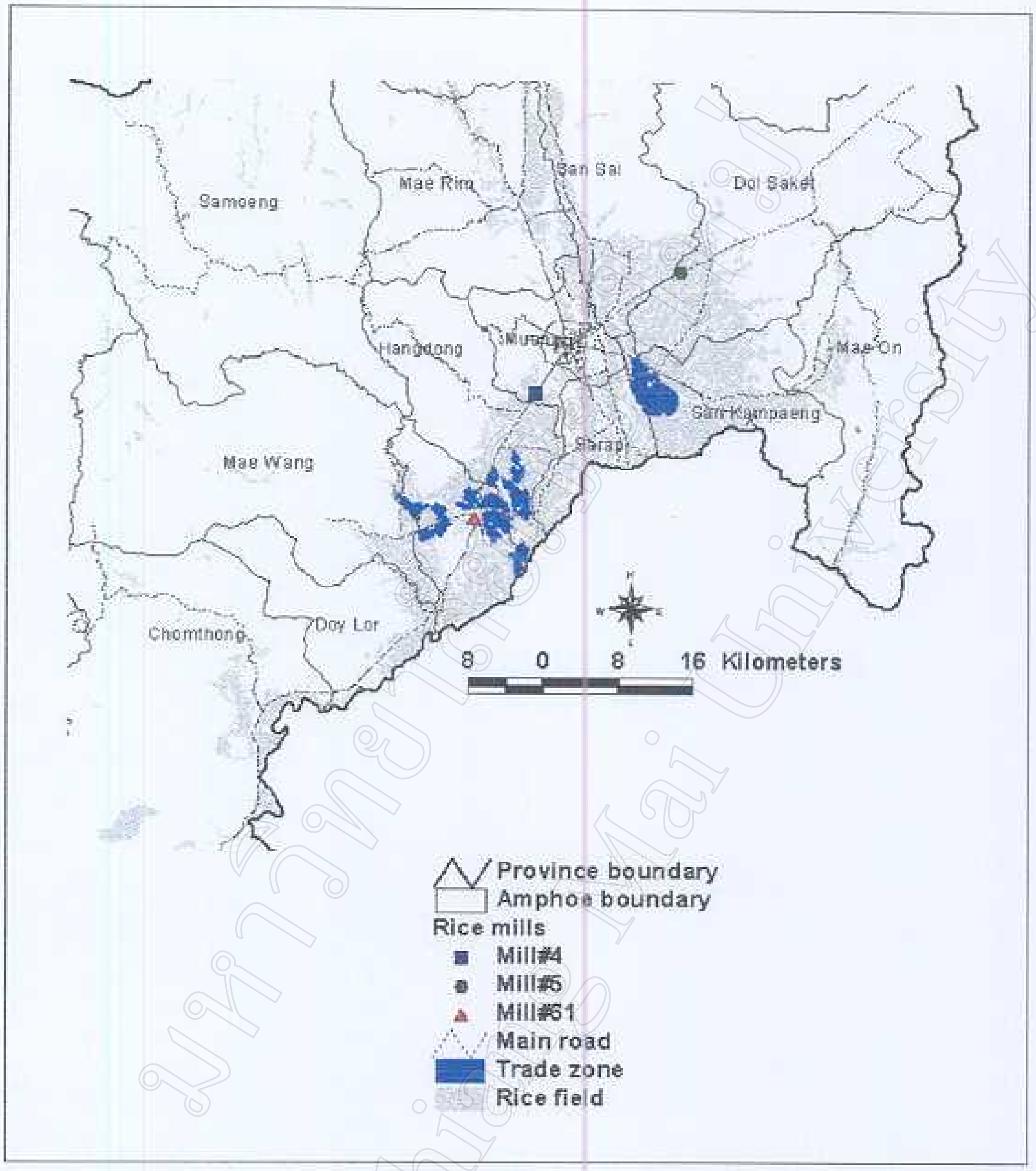

Figure 4.12 Trade zone of rice mill number 61 generated from paddy fields with cumulative interaction probability of 20%, using β of 1.0.

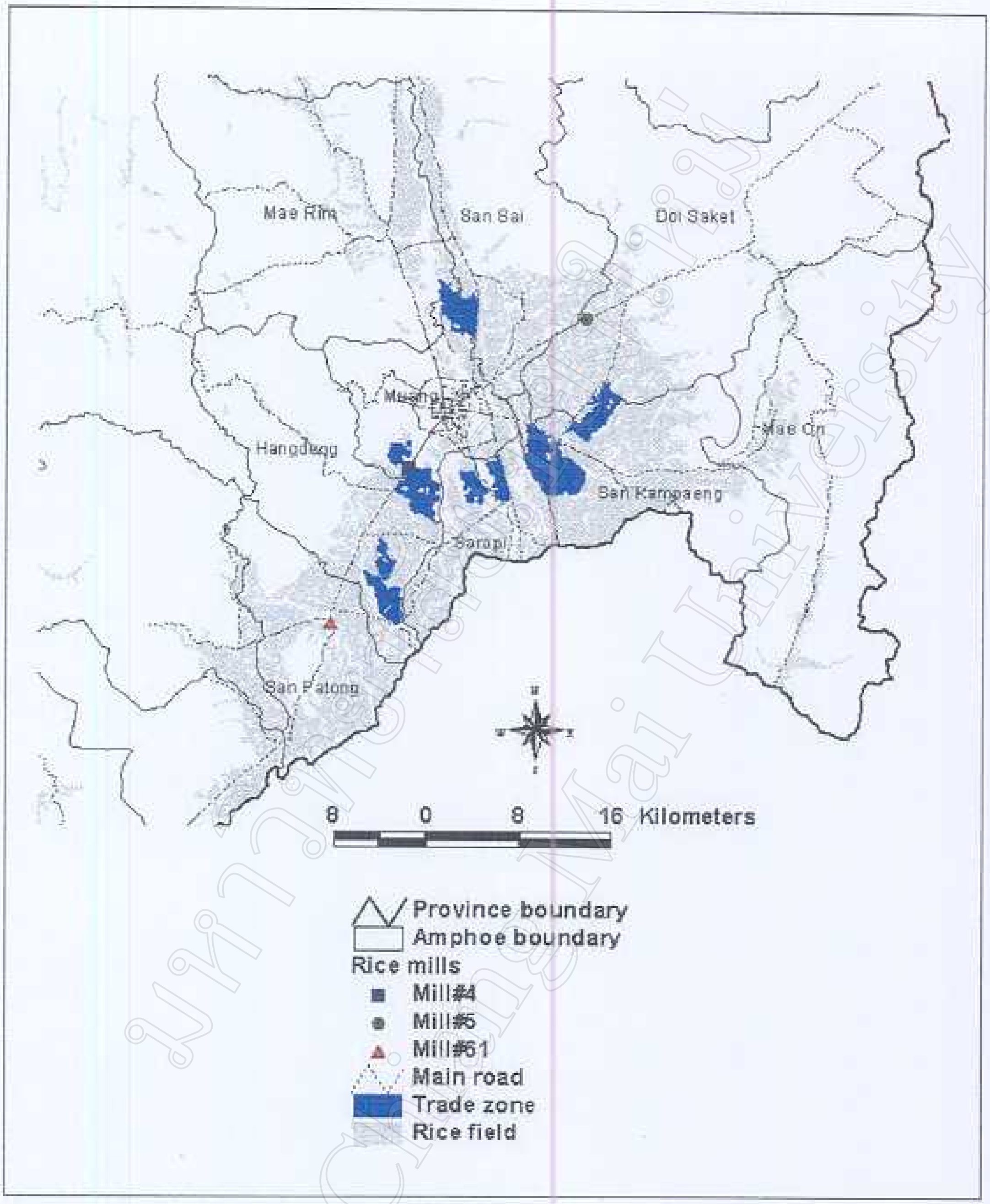

Figure 4.13 Trade zone of rice mill number 4 generated from paddy fields with cumulative interaction probability of 20%, using β of 1.2.

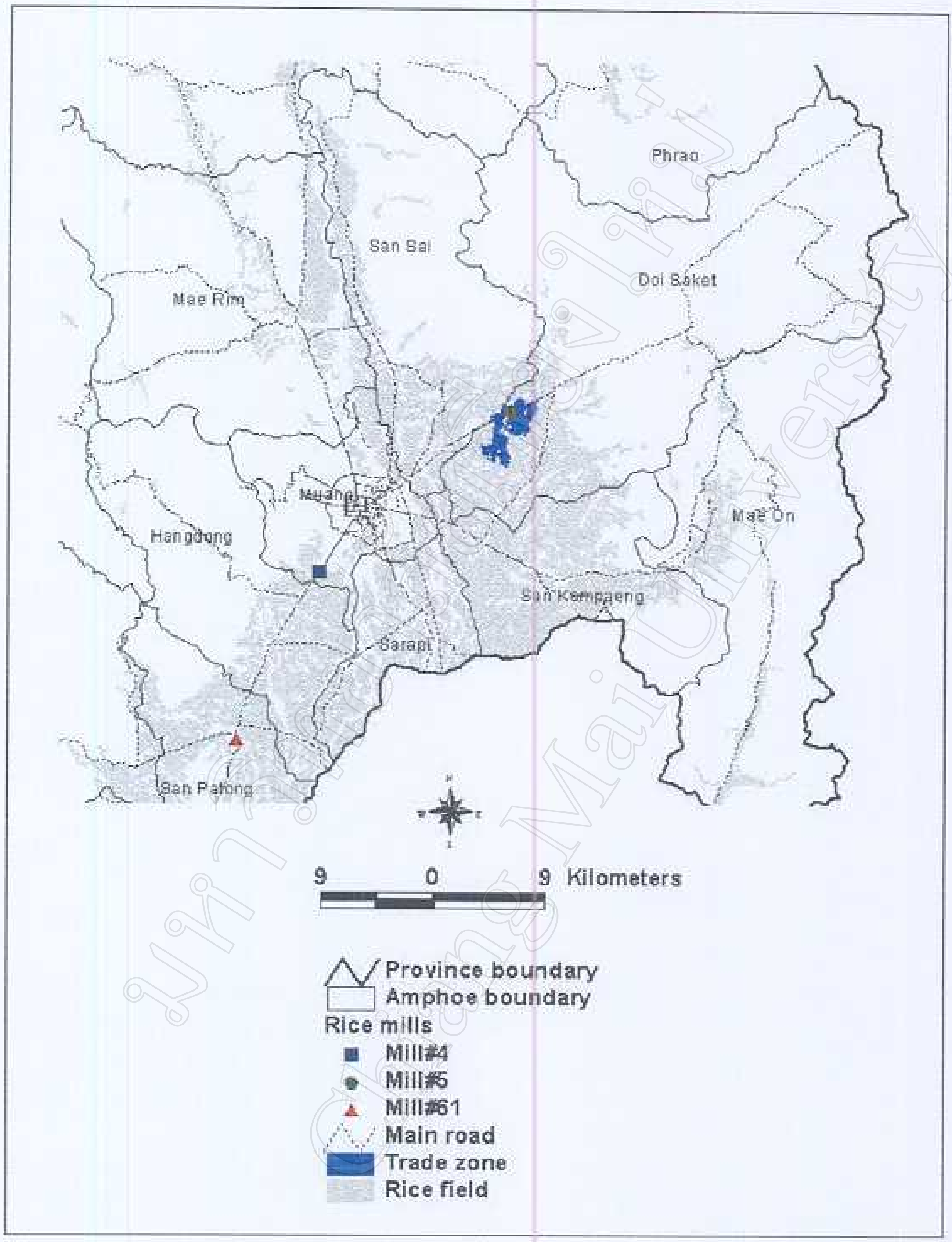

Figure 4.14 Trade zone of rice mill number 5 generated from paddy fields with cumulative interaction probability of 20%, using β of 1.2.

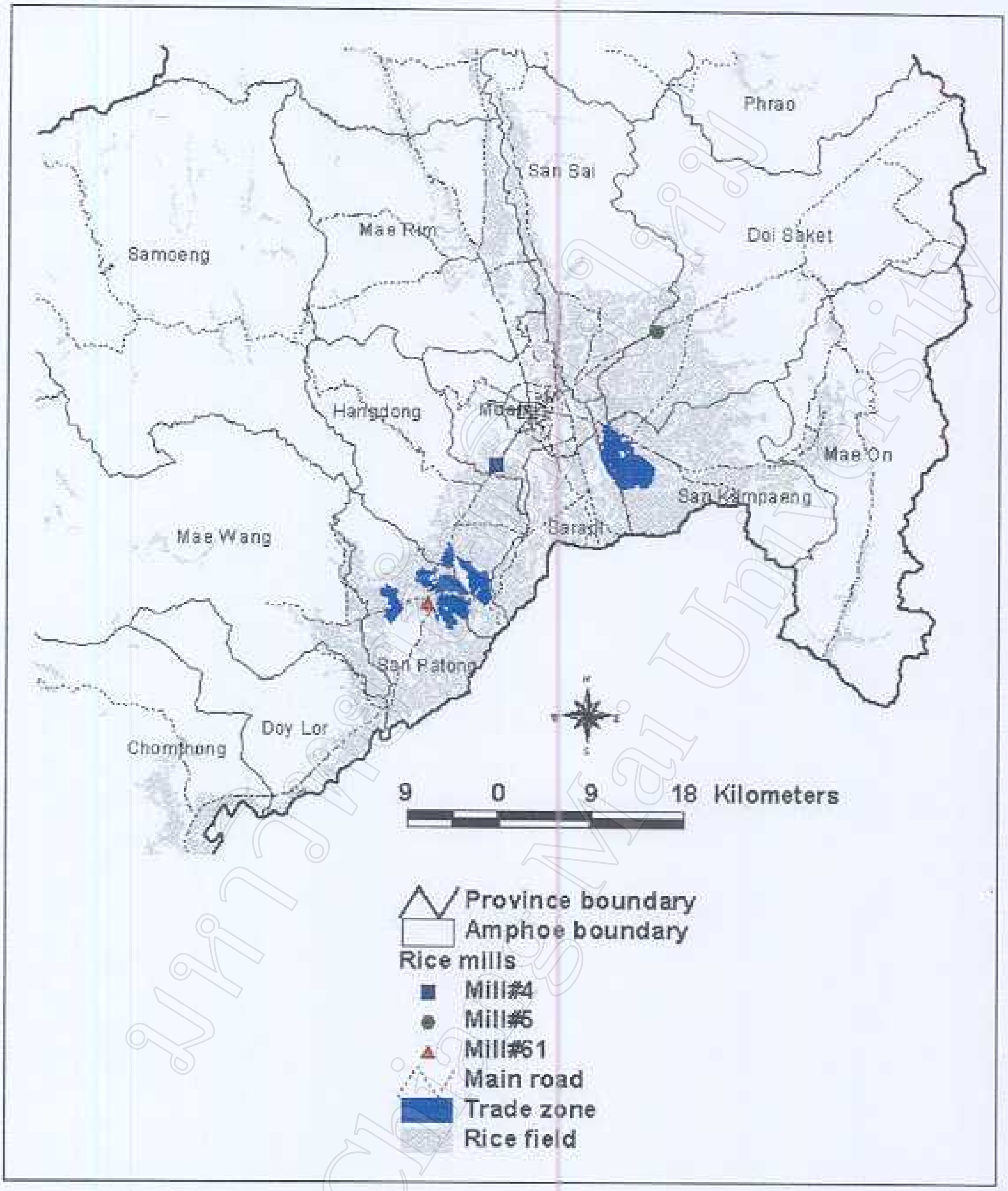

Figure 4.15 Trade zone of rice mill number 61 generated from paddy fields with cumulative interaction probability of 20%, using β of 1.2.

Sensitivity analysis on the effects of selecting different threshold traveling times were also made with these rice mills. It was found that if traveling time was used for determining trading areas, the minimum traveling time for transportation of rice from the paddy fields that can fill up the capacity of mill number 5 and 61 is 20 minutes (Table 4.8). Within this traveling time the paddy areas in the trading zones of mill number 5 and 61 are 39,258 and 53,000 rai respectively, the total rice production in these zones are 15,967 and 23,040 ton. The storage capacity of mills number 5 and 61 are 14,400 and 2,640 ton respectively.

The minimum traveling time to fill up the capacity (28,333 ton) of mill number 4 is 25 minutes since this mill locates in the city. Within this traveling distance, the total paddy areas that have potential for trading activities with Mill4 are 73,407 rai and total production of 30,071 ton.

Sensitivity analysis were also carried out regarding the effect of using different cumulative probability levels of spatial interactions between paddy fields and rice mills. Results from Table 4.9 suggest that for Mill4, using cumulative probability of interaction at the level of 30%, all paddy areas (59,196 rai) in its trading zone can potentially trade 30,191 ton of rice to meet 28,333 ton storage capacity of this mill. However, in order to meet the storage capacity of Mill5 and Mill61, the cumulative probability of interaction at 35% and 15% have to be used for Mill5 and Mill61 respectively.

Table 4.8 Potential trade areas and rice production at different traveling time from selected rice mills.

Traveling time (min)	Rice Mill 4		Rice Mill 5		Rice Mill 61	
	Paddy areas (rai)	Production (ton)	Paddy areas (rai)	Production (ton)	Paddy areas (rai)	Production (ton)
15	10,114	3,879	11,136	4,581	13,522	5,667
20	27,209	11,141	39,258	15,967	53,000	23,040
25	73,407	30,071	80,513	32,272	115,819	50,897
30	156,628	65,204	130,616	52,854	144,852	62,498
35	245,424	102,963	190,356	76,897	179,287	75,943
40	360,460	148,898	259,957	103,858	198,460	83,506
45	406,218	167,636	312,044	126,206	264,959	111,660

Table 4.9 Potential trade areas and rice production at different cumulative probability of spatial interactions for selected rice mills ($\beta = 1.2$).

Cumulative prob. of interaction (%)	Rice Mill 4		Rice Mill 5		Rice Mill 61	
	Paddy areas (rai)	Production (ton)	Paddy areas (rai)	Production (ton)	Paddy areas (rai)	Production (ton)
10	4,858	1,667	2,672	895	6,186	2,546
15	33,316	14,775	6,055	2,407	13,536	6,031
20	44,135	19,422	6,533	2,603	29,730	13,426
25	59,196	25,460	21,619	9,310	35,358	15,790
30	70,616	30,191	31,927	13,913	44,369	19,693
35	93,062	41,274	47,817	20,462	62,532	27,510
40	123,042	53,516	66,783	26,192	81,093	35,250
45	155,699	66,254	86,784	38,195	96,049	42,469
50	182,917	77,093	102,745	45,218	121,524	54,358