CHAPTER IV
RESULTS AND DISCUSSION

This study is to apply Geographic Information System (GIS) integrated with CA-Markovand Potential Surface Analysis (PSA) in order to study changing land use and flood risk areas in Nakhon Si Thammarat Province. The result of this study is as follows.

4.1Land use and land cover classification

The satellite imageries of LANDSAT-5TM and THEOS with supervised classification were used to classify land use pattern. It was classified into 7 categories. The result of land use classification is concluded in table 4-1, figure 4-1, 4-2, 4-3. Land use pattern in 1994 is analyzed by LANDSAT-5 TM image.

The largest area was orchard and para-rubber, covered 2,700.14 km^2 (27.02%) of the total area. Followed by agriculture area, forest, marsh and swamp, aquaculture and water body, built up area, mangrove which covered areas of 2,468.24 km^2 (24.70%), 1,869.44km^2 (18.71%), 1,651.81km^2 (16.53%), 796.96km^2 (7.98%), 410.62km^2 (4.11%), and 94.89km^2 (0.95%) of the total area, respectively.

Land use pattern in 2005 is analyzed by Landsat-5TM image. The largest area was orchard and para-rubber, covered 3,896.30km^2 (38.99%) of the total area. Followed by agriculture area, forest, mash and swamp, built up area, aquaculture and water bodies, mangrove which covered areas of 2,597.64km^2 (26%), 1,671.13km^2 (16.72%), 837.80km^2 (8.38%), 499.48km^2 (5%), 411.74km^2 (4.12%), and 78.02km^2 (0.78%) of the total area, respectively.

Land use pattern in 2011 is analyzed by THEOS image. The largest area was orchard and para-rubber. Orchard and para-rubber were the largest area, covered 4,091.60km^2 (40.95%) of the total area. Followed by agriculture area, forest, built up area, marsh and swamp, aquaculture and water body, mangrove which covered areas of 2,684.47km^2 (26.87%), 1,359.27km^2 (13.60%), 735.4km^2 (7.36%), 541.77km^2

(5.42%), 467.52km^2 (4.68%), and 112.07km^2 (1.12%) of the total area, respectively. This result related with a research of AbdollahBennui (1), which indicates that forest areas converted into rubber plantation also fruit orchards during 1980-2004. This is also related with Kaori A. research (2). It shows that the coastal zone in Nakhon Si Thmmarat Province changed during 1990-2004. Swamp areas have been decreased continuously by changing to building and transportation.

Table 4-1 Land use in Nakhon Si Thammarat Province in 1994, 2005 and 2011.

Land Use Types	Area					
	1994		2005		2011	
	Km^2	%	Km^2	%	Km^2	%
Forest	1,869.44	18.71	1,671.13	16.72	1,359.27	13.60
Mangrove	94.89	0.95	78.02	0.78	112.07	1.12
Marsh & Swamp	1,651.81	16.53	837.80	8.38	541.77	5.42
Orchard &Para-rubber	2,700.14	27.02	3,896.30	38.99	4,091.60	40.95
Agriculture area	2,468.24	24.70	2,597.64	26.00	2,684.47	26.87
Aquaculture & Water Body	796.96	7.98	411.74	4.12	467.52	4.68
Built up area	410.62	4.11	499.48	5.00	735.40	7.36
Total	9,992.10	100	9,992.10	100	9,992.10	100

Source: LANDSAT and THEOS imageries analysis

The accuracy of the land use classification was clarified using 57 ground check points in 2012. The accuracy of land use classification in 1994, 2005, and 2011 is shown in table 4-2.

Table 4-2 Accuracy analysis of land use classification

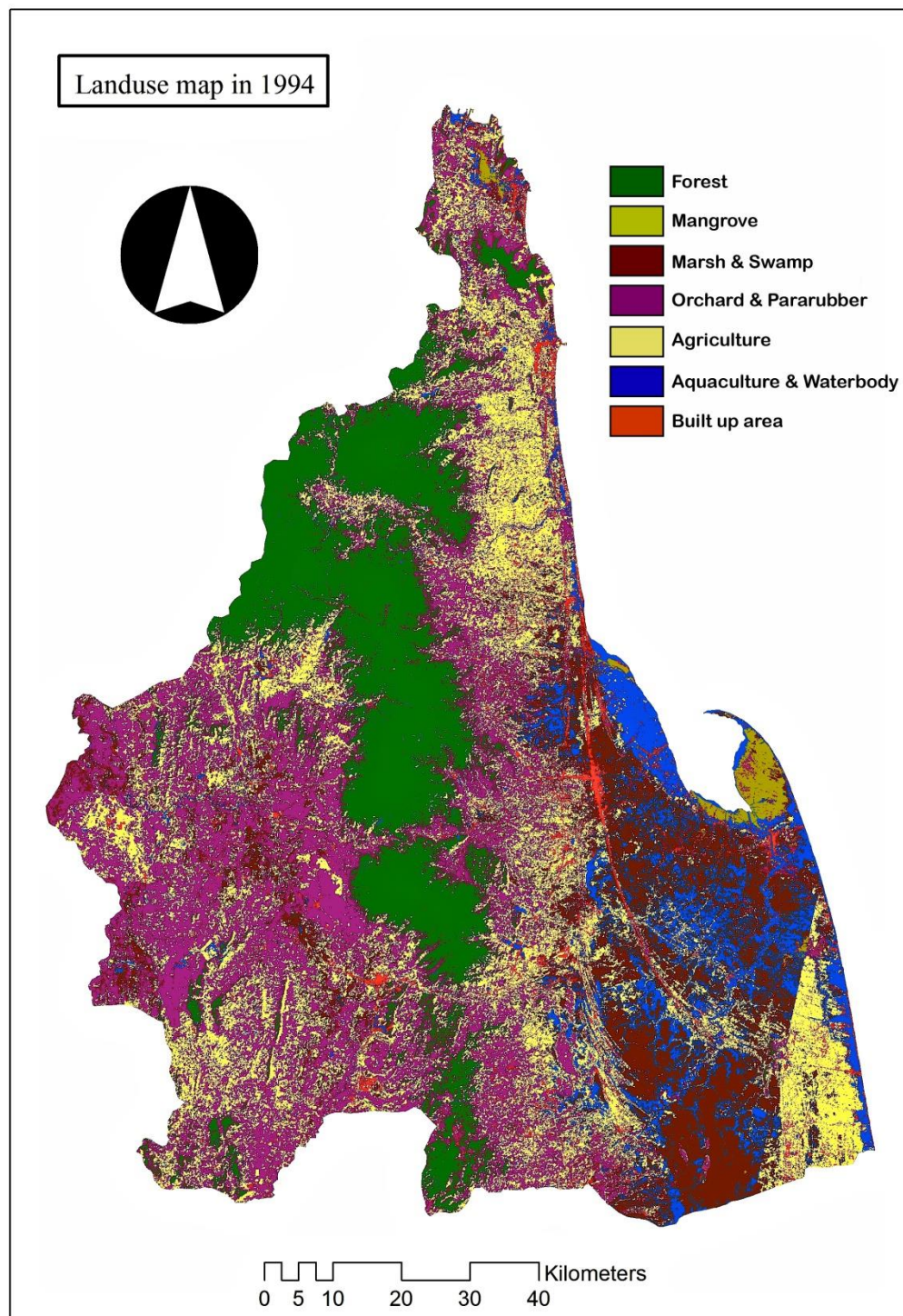|	1994	2005	2011
Number of checkpoint	57	57	57
Accurate classification	42	47	49
Miss classification	15	10	8
Percent of accuracy	73.68	82.45%	85.96%

Source: THEOS imageries analysis and ground check

Figure 4-1 Land use pattern of Nakhon Si Thammarat Province in 1994
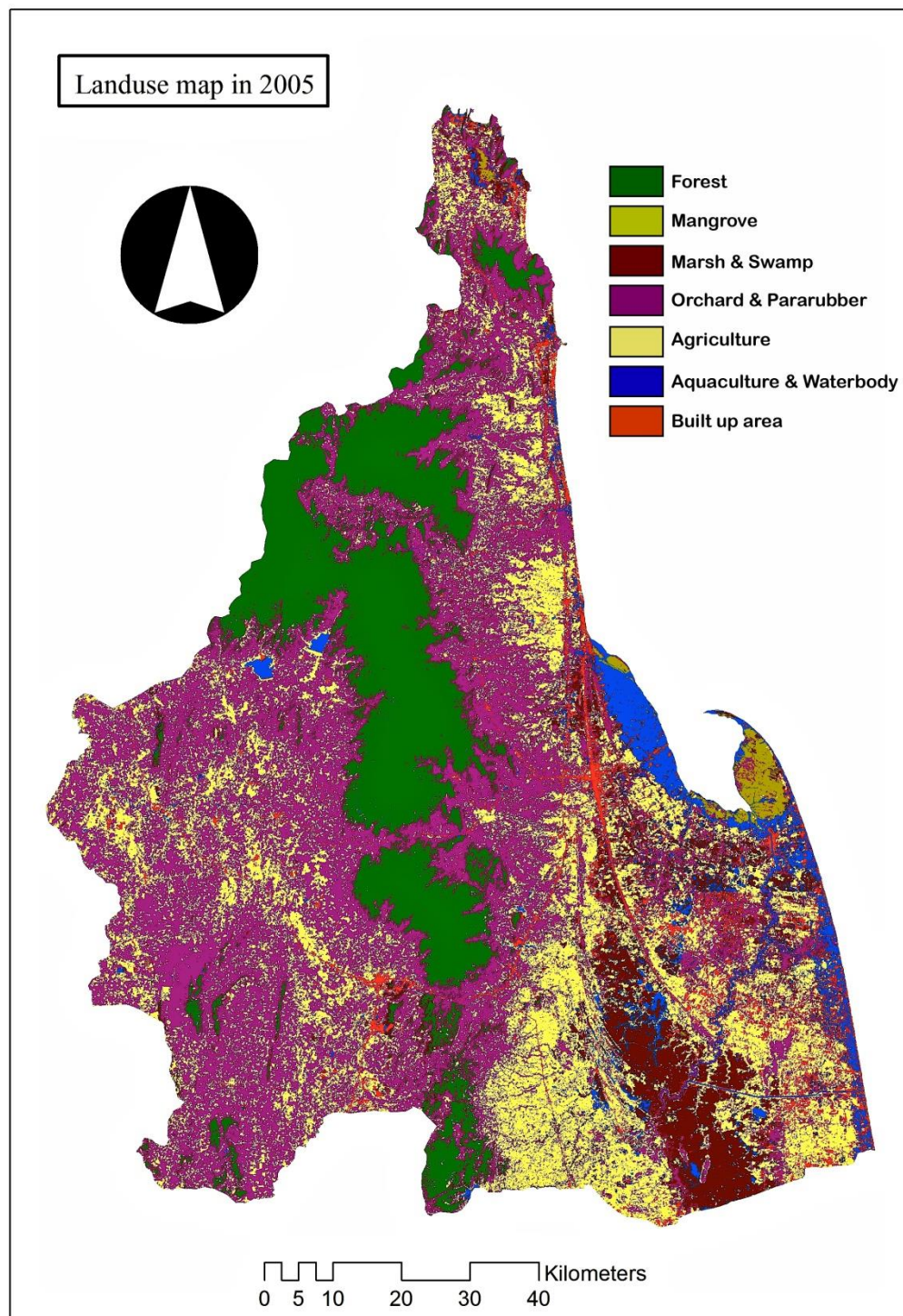
Source: LANDSAT-5TM imageries analysis

Figure 4-2 Land use pattern of Nakhon Si Thammarat Province in 2005
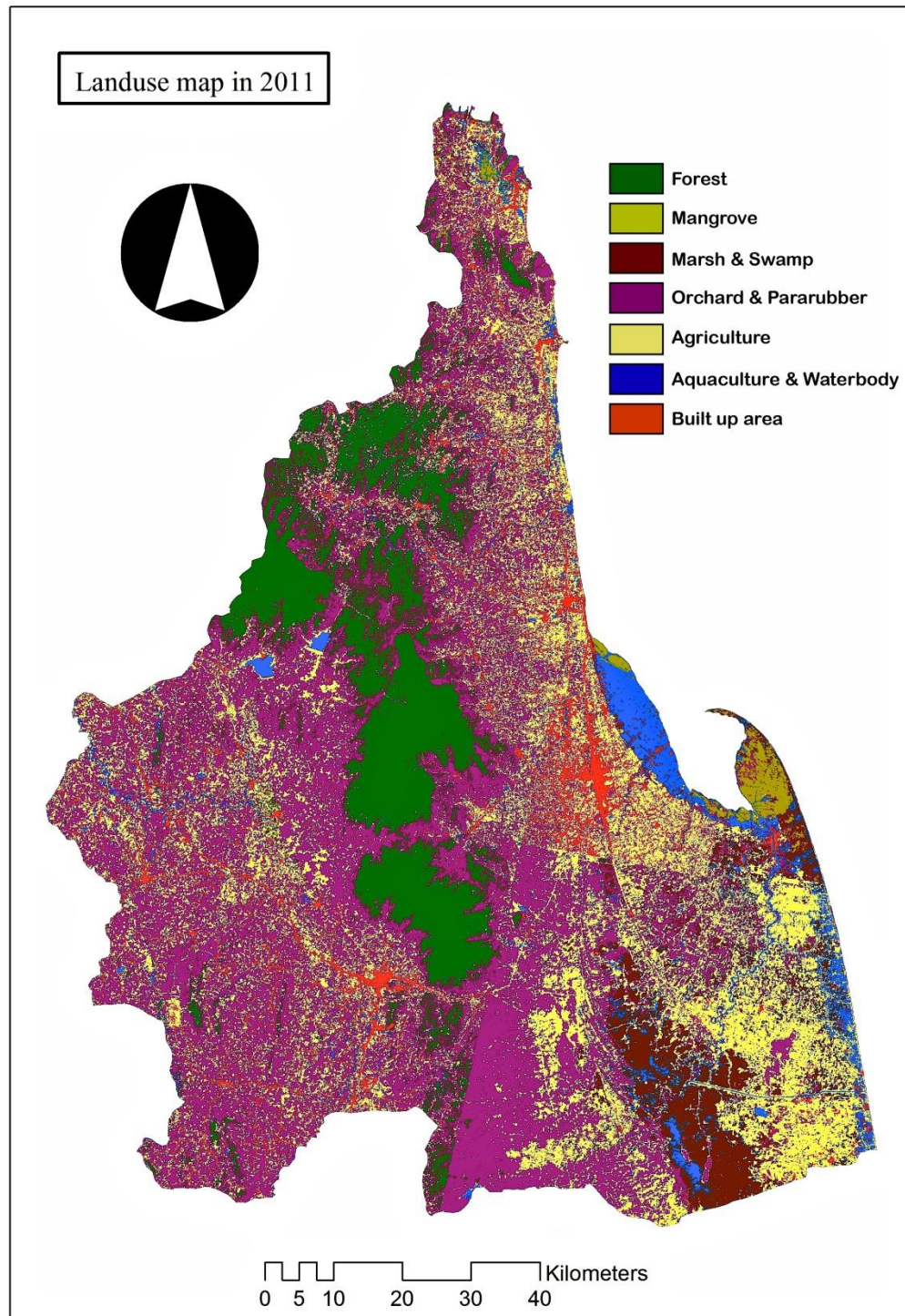
Source: LANDSAT-5TM imageries analysis

Figure 4-3 Land use pattern of Nakhon Si Thammarat Province in 2011

Source: LANDSAT-5TM imageries analysis

4.2Land Use Prediction

Land use was predicted for future (in 2017) using GIS technique integrated with CA-Markov by using land use data in 2005 and 2011 to be baseline data. MARKOV model was used to calculate probability value (Table 4-3) and transition values (Table 4-4). Those values were applied to CA-MARKOV to predict the land use change in 2017.The land use pattern in 2017 is shown in figure 4-4.

Table 4-3 Probability of changing

Year 2011 / Year 2005	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
Class 1	0.7287	0.0089	0.0017	0.2007	0.0410	0.0097	0.0093
Class 2	0.0232	0.7979	0.0760	0.0476	0.0240	0.0265	0.0047
Class 3	0.0308	0.0177	0.3753	0.2111	0.2370	0.0789	0.0492
Class 4	0.0300	0.0066	0.0107	0.6410	0.2256	0.0187	0.0675
Class 5	0.0083	0.0041	0.0337	0.3587	0.4669	0.0329	0.0953
Class 6	0.0128	0.0098	0.0917	0.0722	0.1807	0.5932	0.0395
Class 7	0.0037	0.0053	0.0621	0.1415	0.3638	0.0798	0.3437

Source: Markov model.

Remark: Class 1 = Forest   Class 2 = Mangrove

Class 3 = Marsh and Swamp   Class 4 = Orchard andPara-rubber

Class 5 = Agriculture   Class 6 = Aquaculture & water body

Class 7 = Built-up area

Table 4-4 Transition area

Year 2005 \ Year 2011	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
Class 1	1617055	19825	3818	445356	90948	21455	20555
Class 2	5129	176524	16816	10527	5320	5859	1049
Class 3	27783	15951	339035	190732	214128	71256	44461
Class 4	190022	41778	67954	4062383	1429654	118258	427778
Class 5	34963	17077	140946	1502543	1955724	137994	399295
Class 6	11151	8469	79635	62731	156938	515053	34284
Class 7	4556	6554	76213	173807	446656	98041	422065

Source: Markov model.

Remark: Class 1 = Forest   Class 2 = Mangrove

           Class 3 = Marsh and Swamp   Class 4 = Orchard andPara-rubber

           Class 5 = Agriculture   Class 6 = Aquaculture & water body

           Class 7 = Built-up area

Table 4-5 Land use pattern of Nakhon Si Thammaratprovince in year 2017

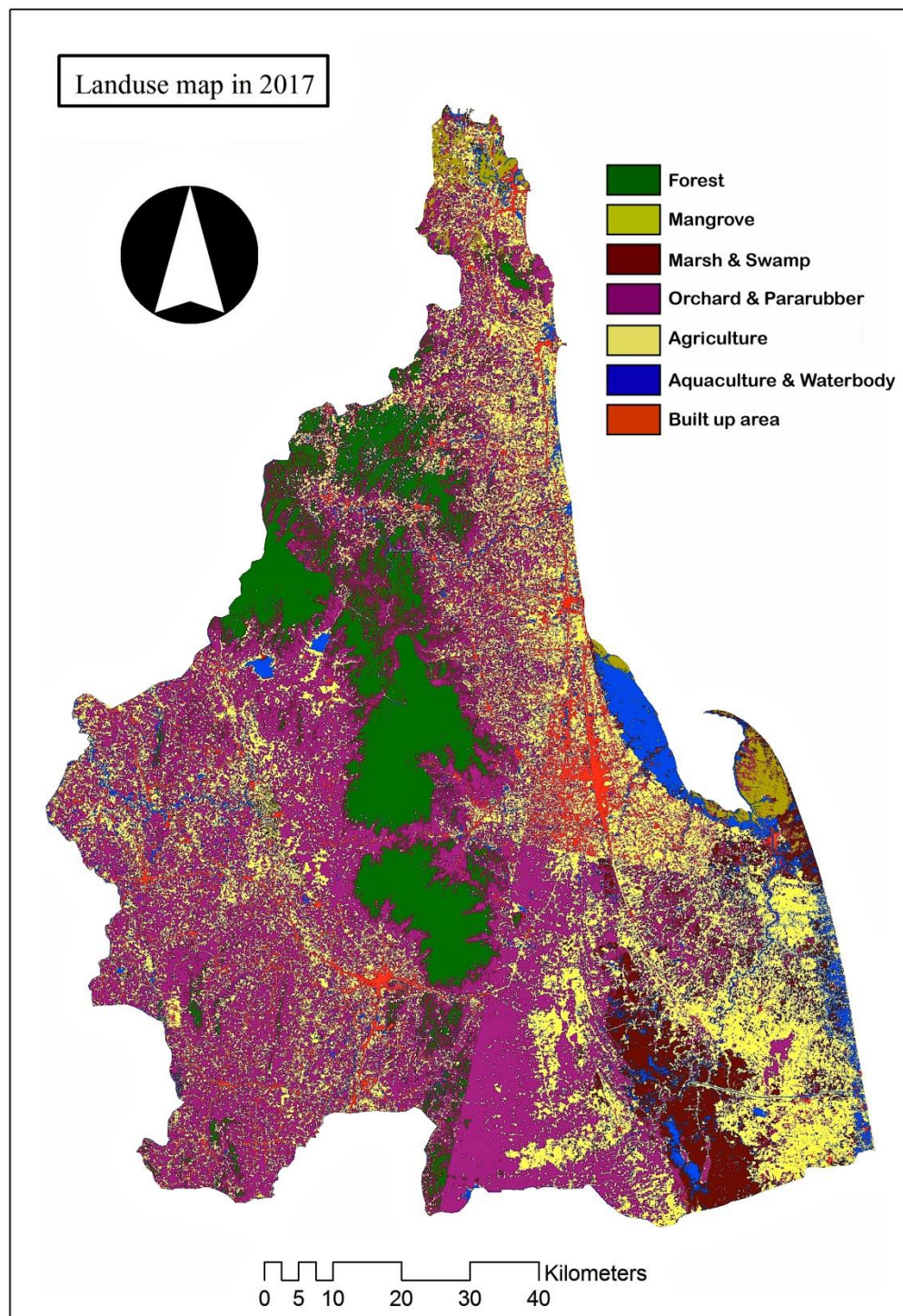| Land Use Type	Area	
	km^2	%
Forest	1,337.56	13.39
Mangrove	172.50	1.73
Marsh and Swamp	553.49	5.54
Orchard andPara-rubber	3,712.64	37.16
Agriculture area	2,872.36	28.75
Aquaculture and Water body	589.92	5.90
Built-up area	753.63	7.54
Total	9,992.10	100.00

Source: Analysed

Figure 4-4 Land use pattern of Nakhon Si Thammarat Province in year 2017

Source: CA-Markov model

4.3 Land Use Changes

The results of changed land use are as follows:

4.3.1 Land use change between 1994 and 2005

The result was found that the highest increasing of the areas is orchard and para-rubber. It was increased by 1,196.16km^2. Followed by agriculture area, built-up area was increased by 129.40km^2, and 88.86km^2 respectively. Meanwhile, the largest decreases are marsh and swamp that were decreased by 814.01km^2. Aquaculture and water bodies, forest, and mangrove were decreased by 385.22km^2 198.31 km^2, and 16.87 km^2 respectively. The result of changing land use between 1994 and 2005 is concluded in Table 4-6.

Table 4-6 Land use pattern comparison between 1994 and 2005

Land Use Type	Area : km^2		
	1994	**2005**	**Different**
Forest	1,869.44	1,671.13	(-198.31)
Mangrove	94.89	78.02	(-16.87)
Marsh and Swamp	1,651.81	837.80	(-814.01)
Orchard andPara-rubber	2,700.14	3,896.30	1,196.16
Agriculture area	2,468.24	2,597.64	129.40
Aquaculture and Water body	796.96	411.74	(-385.22)
Built-up area	410.62	499.48	88.86

Source: CalculatedRemarks: A number with negative value (-) was defined as decreasing area

4.3.2 Land use change between 2005 and 2011

The results were found that the highest increasing area is built-up area. The built-up area was increased by 235.92km^2. Followed by orchard and para-rubber, agriculture area, aquaculture, water body, and mangrove increased by 195.30km^2, 86.83km^2, 55.78km^2, and 34.05km^2 respectively. Meanwhile, land use patterns which highest decreasing area is forest followed by mash and swamp, which decreased by 311.86km^2, and 296.03km^2 respectively. The result of land use change between 2005 and 2011 is concluded in Table 4-7.

Table 4-7 Land use pattern comparison between 2005 and 2011

Land Use Type	Area : km²		
	2005	**2011**	**Different**
Forest	1,671.13	1,359.27	(-311.86)
Mangrove	78.02	112.07	34.05
Marsh and Swamp	837.80	541.77	(-296.03)
Orchard andPara-rubber	3,896.30	4,091.60	195.30
Agriculture area	2,597.64	2,684.47	86.83
Aquaculture and Water body	411.74	467.52	55.78
Built-up area	499.48	735.40	235.92

Source: Calculated

Remarks: A number with negative value (-) was defined as decreasing area

4.3.3 Land use change between years 2011 and 2017

The trend of land use changes from 2011-2017 was found slightly increased in agriculture area, aquaculture and water bodies, mangrove, built-up area, marsh and swamp which increased by $187.89km^2$, $122.40km^2$, $60.43km^2$, $18.23km^2$, and $11.72km^2$ respectively. Meanwhile, orchard and para-rubber, and forest were decreased by $378.96km^2$ and $21.71km^2$ respectively (Table 4-8).

Table 4-8 Land use pattern comparison between 2011 and 2017

Land Use Type	Area : Km²		
	2011	**2017**	**Different**
Forest	1,359.27	1,337.56	(-21.71)
Mangrove	112.07	172.50	60.43
Marsh and Swamp	541.77	553.49	11.72
Orchard andPara-rubber	4,091.60	3,712.64	(-378.96)
Agriculture area	2,684.47	2,872.36	187.89
Aquaculture and Water body	467.52	589.92	122.40
Built-up area	735.40	753.63	18.23

Source: CalculatedRemarks: A number with negative value (-) was defined as decreasing area

4.3.4 Comparison of land use changed in 1994, 2005, 2011, and 2017

Land use change during years 1994 to 2017 was found agriculture area; built-up area, mangrove, orchard and para-rubber are steadily increased. Meanwhile, forest, marsh and swamp are steadily decreased. An overview of land use change during 1994 to 2017 is shown in the figure 4-5.
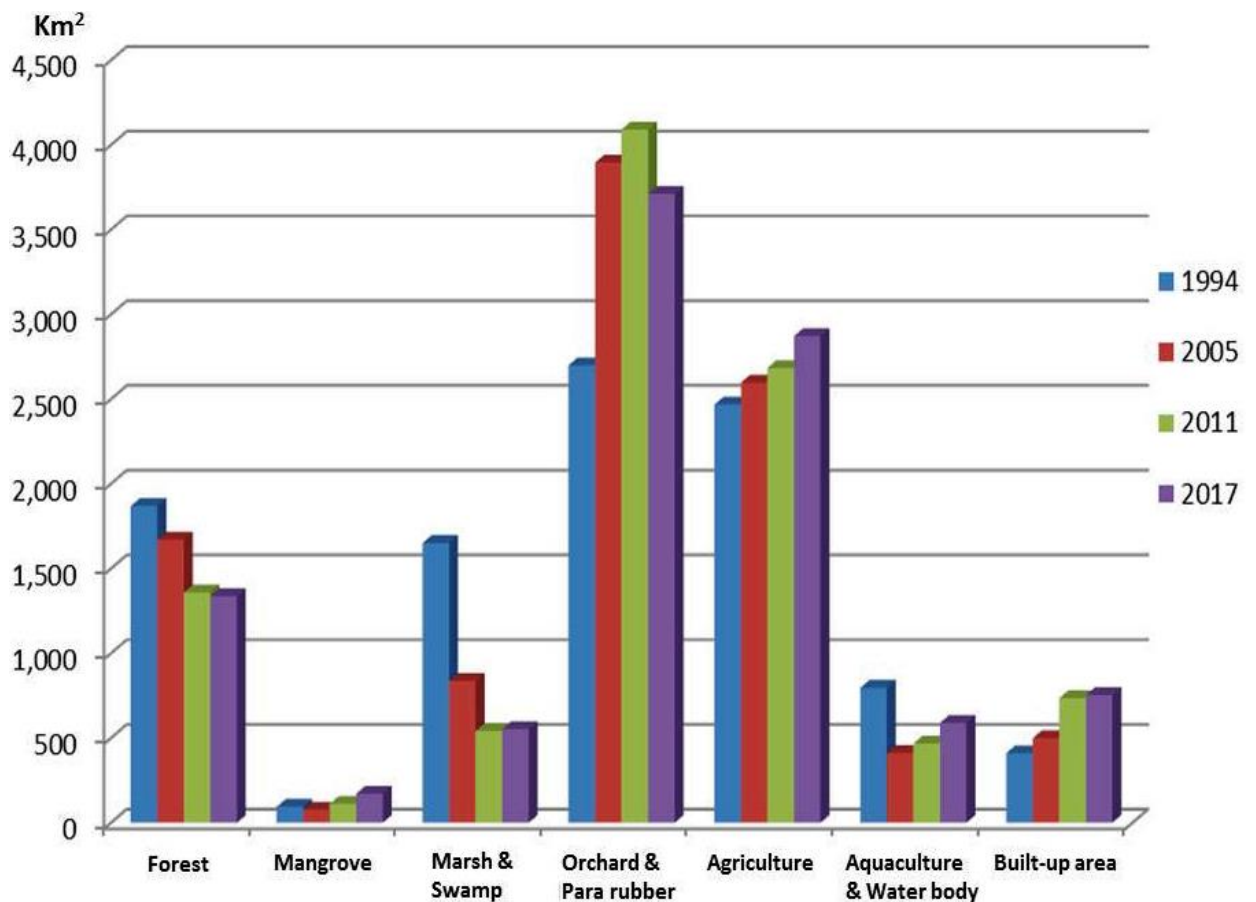

Figure 4-5 Comparison of land use change during 1994 to 2017
Source: Calculated

4.4. Flood risk areas

This study of flood risk was applied GIS integrated with Potential Surface Analysis (PSA) in order to study flood risk areas in Nakhon Si Thammarat Province. The result of flood risk area is as follows:

4.4.1 Flood risk factors

This study uses 5 flood risk factors, including daily rainfall, elevation, slope, soil drainage ability, and land-use.

1.) Daily Rainfall This study uses daily rain fall data in 2011. Inverse Distance Weighting (IDW) method was used to divide rainfall data into 2 cases as normal case (average daily rainfall) and extreme event (maximum daily rainfall). The data of daily rainfall is shown in Table 4-9, Figure 4-6, and Figure 4-7.

Table 4-9 Daily rain fall in Nakhon Si Thammarat Province.

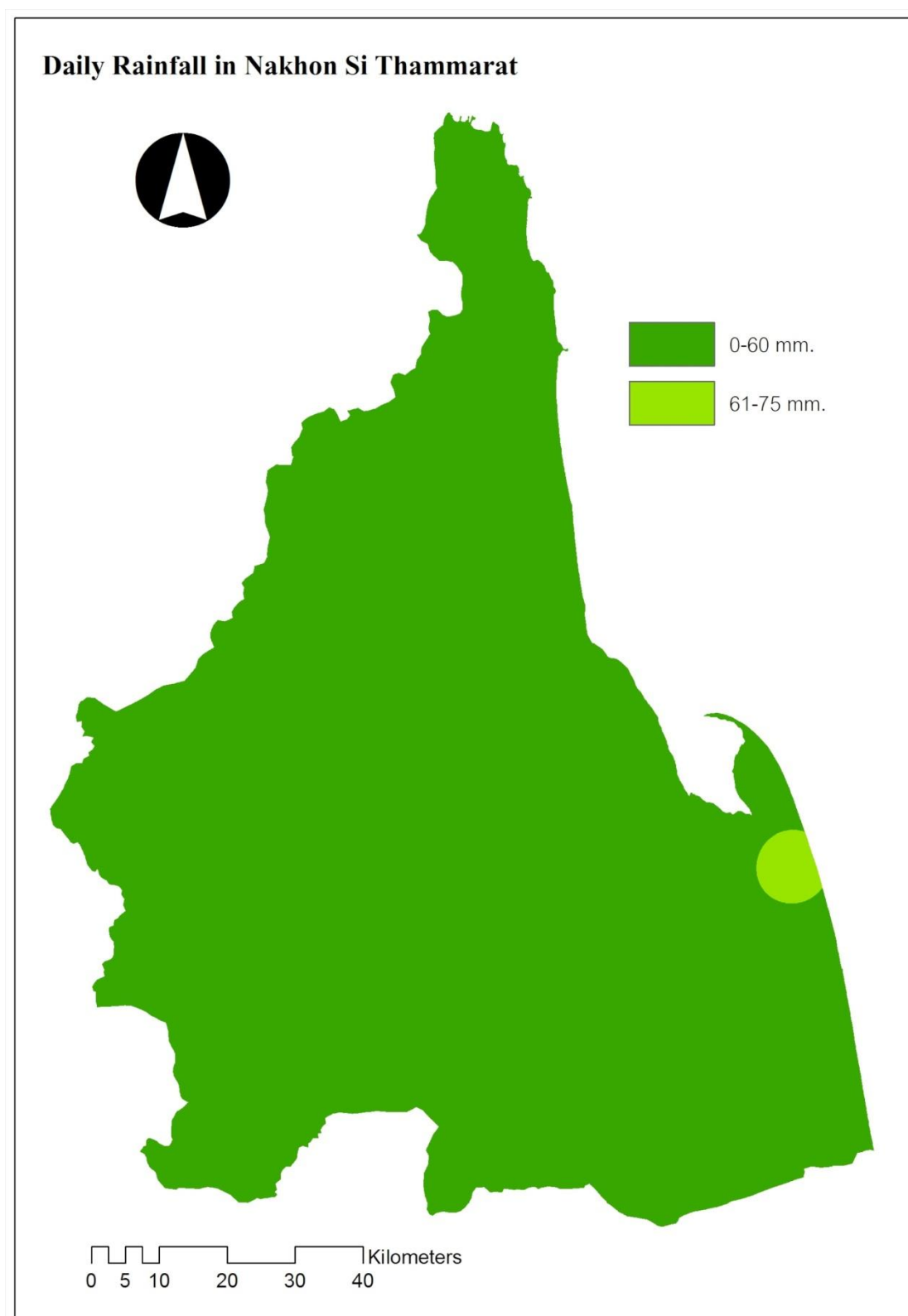| Level	Normal Case (Average Daily rainfall)		ExtremeEvent (Maximum Daily rainfall)	
	Km^2	(%)	Km^2	(%)
> 100 mm.	-	-	7399.89	74.06
76 – 100 mm.	-	-	1,712.96	17.14
61 – 75 mm.	78.95	0.79	555.75	5.56
0 – 60 mm.	9,913.15	99.21	323.50	3.24
Total	**9,992.10**	**100.00**	**9,992.10**	**100.00**

Source: Thai Meteorological Department

Figure 4-6Normal case daily rainfall in Nakhon Si Thammarat Province.
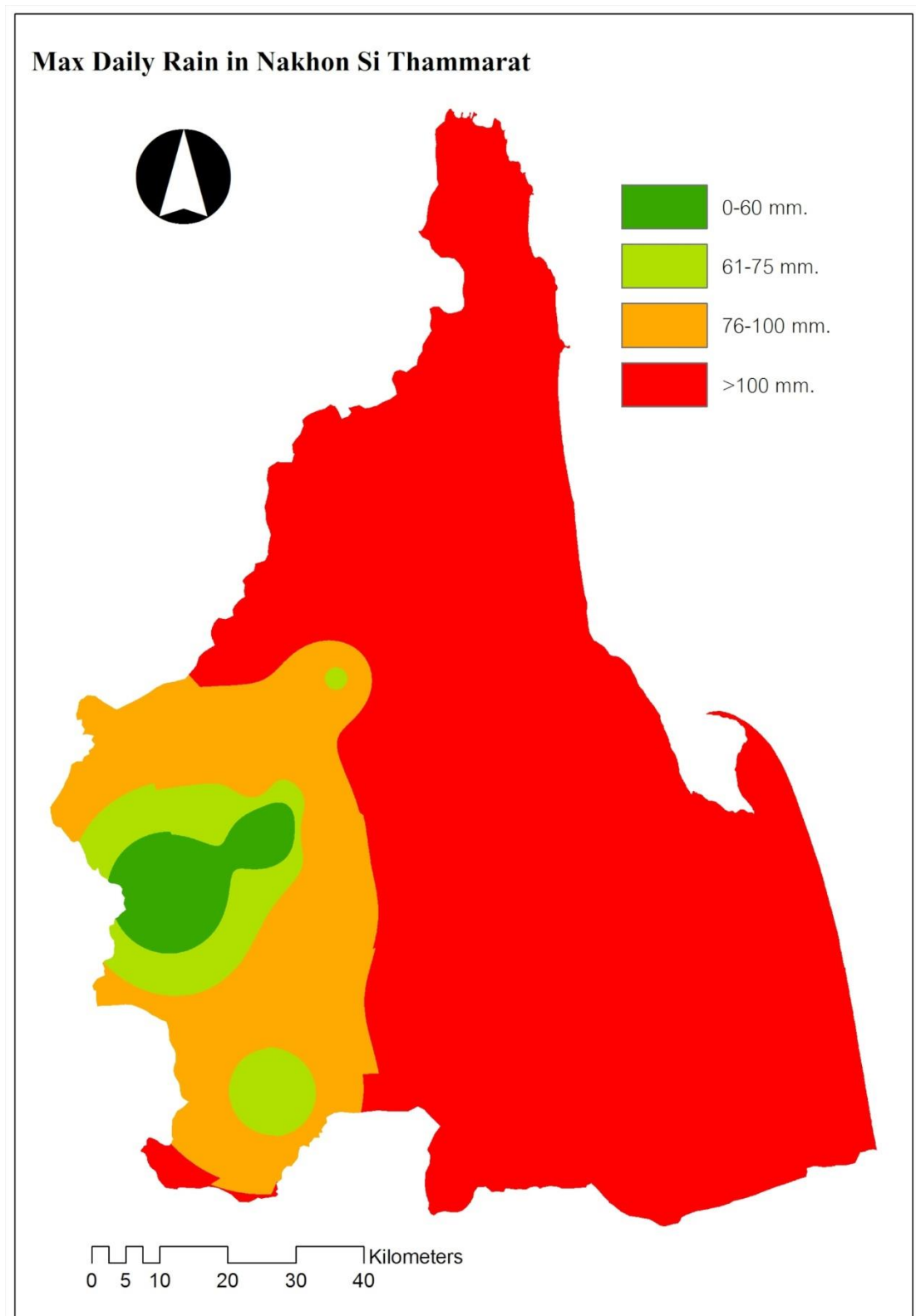
Source: Calculated

Figure 4-7 Extreme event daily rainfall in Nakhon Si Thammarat Province.

Source: Calculated

2.) Slope This study divided slope into 4 levels as (0-5%), (6-10%), (11-1 5 %), and (>1 5 %). That covered area by 4,652.37 km² (46.56%), 1,895.28 km² (18.97%), 700.75 km² (7.01%), and 2,743.70 km² (27.46%) of the total area respectively. The data of slope is concluded in Table 4-10 and Figure 4-8.

Table 4-10 Slopes in Nakhon Si Thammarat Province.

Slope (%)	Areas	
	km²	**(%)**
0-5%	4,652.37	46.56
6-10%	1,895.28	18.97
11-15%	700.75	7.01
>15%	2,743.70	27.46
Total	**9,992.10**	**100.00**

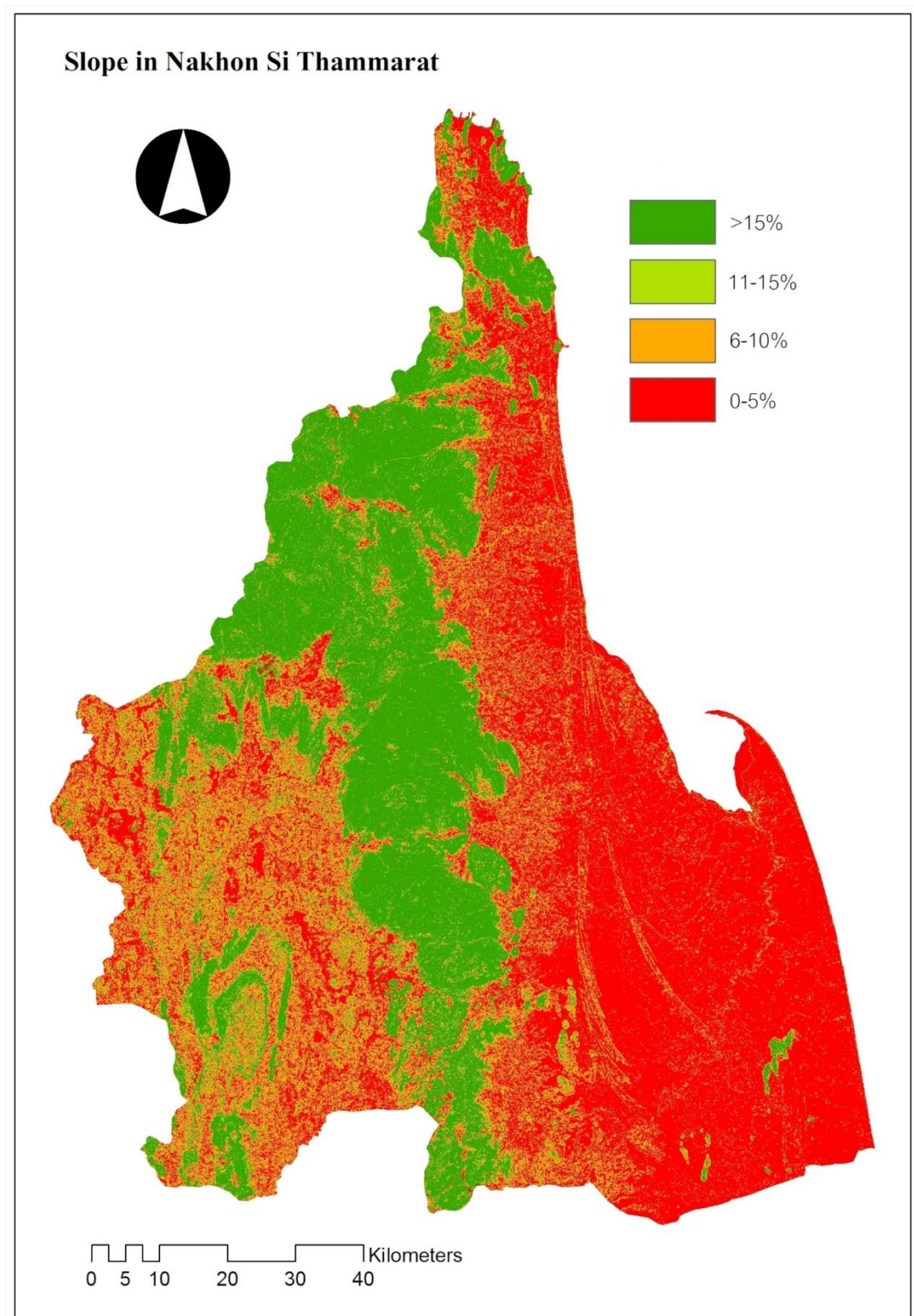Source: Royal Thai Survey Department

Figure 4-8 SlopeinNakhon Si Thammaratprovince.

Source: Calculated

3.) Elevation This study divided elevation into 4 levels as (0 − 100 m.), (101–300m.), (301–500m.), (> 500m.). That covered area by $7,098.29 km^2$ (71.04%), $1,401.17 km^2$ (14.02%), $589.38 km^2$ (5.90%), and $903.26 km^2$ (9.04%) of the total area respectively. The data of elevation were concluded in Table 4-11, Figure 4-9.

Table 4-11 Elevation in Nakhon Si Thammaratprovince.

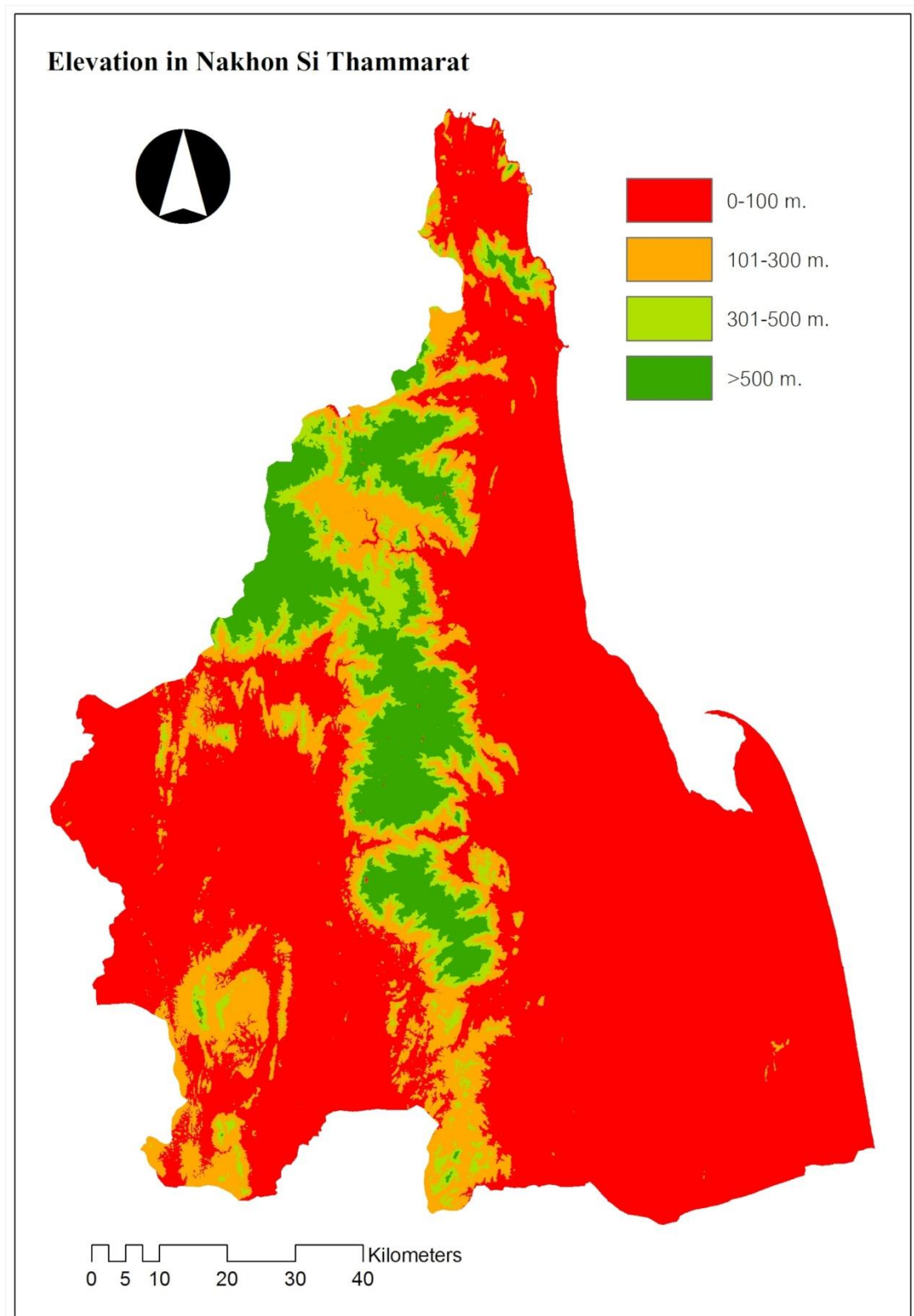| Slope	Areas	
	Km^2	**(%)**
0 – 100 m.	7,098.29	71.04
101 – 300 m.	1,401.17	14.02
301 – 500 m.	589.38	5.90
> 500 m.	903.26	9.04
Total	**9,992.10**	**100.00**

Source: Royal Thai Survey Department

Figure 4-9 Elevation in Nakhon Si Thammaratprovince.

Source: Calculated

4.) Soil drainage ability This factor divided in to 4 levels from very poorly drainage ability, poorly drainage ability, moderately drainage ability, well drainage ability. That covered area by $2,395.32km^2(23.97\%)$, $83.30km^2(0.83\%)$, $159.97km^2$ (1.60%), 7,353.51 $km^2(73.59\%)$ of the total area respectively. The data of soil drainage abilities were concluded in table 4-12, figure 4-10.

Table 4-12 Soil drainage abilities in Nakhon Si Thammarat province.

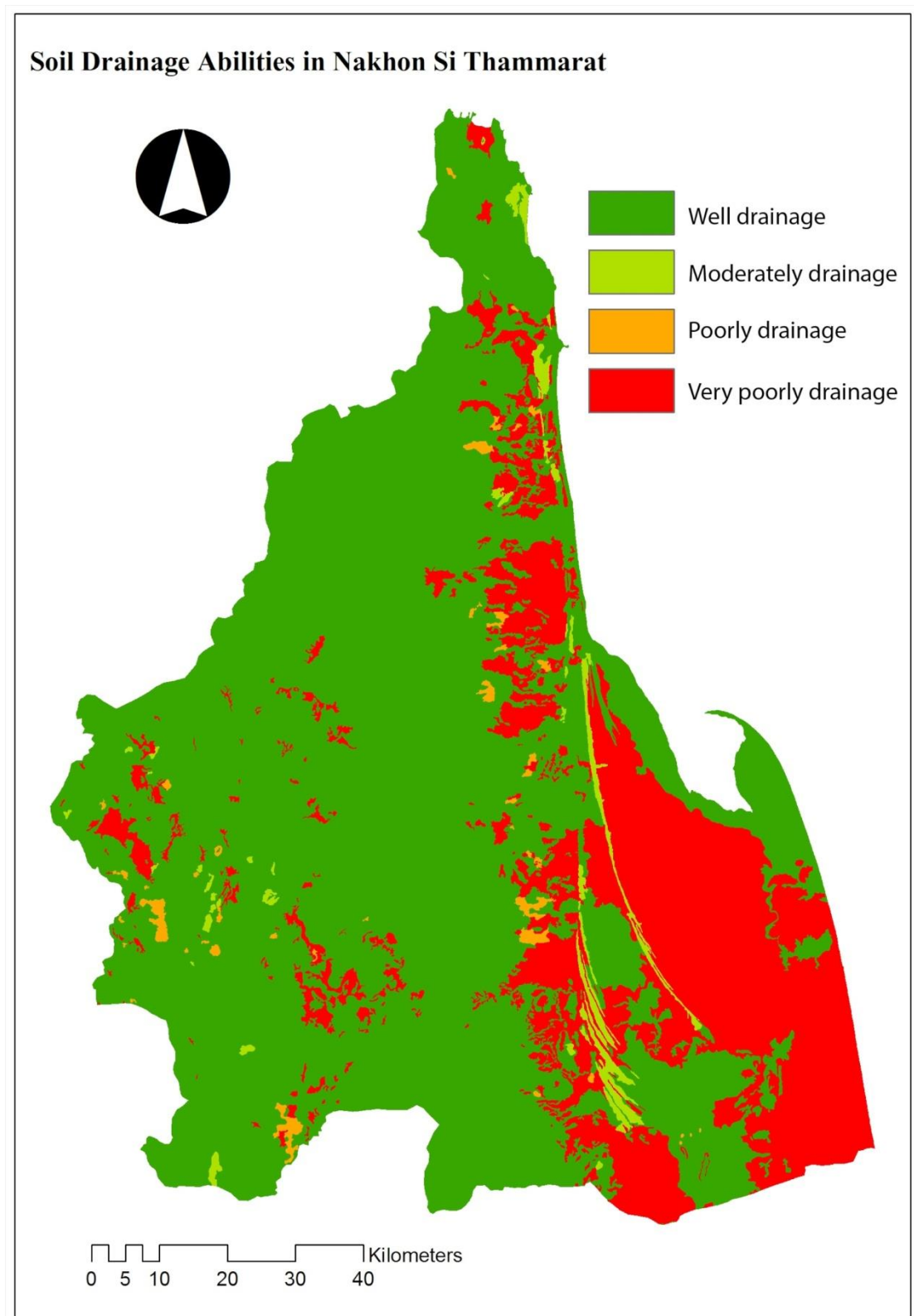| Soil drainage ability	Areas	
	Km²	**(%)**
Very poorly drained ability	2,395.32	23.97
Poorlydrained ability	83.30	0.83
Moderatelydrained ability	159.97	1.60
Well drained ability	7,353.51	73.59
Total	**9,992.10**	**100**

Source: Land Development Department

Figure 4-10 Soil drainage ability in Nakhon Si Thammarat Province.

Source: Calculated

5.) Land Use and Land Cover This factor divided into 4 classes as built-up area, agriculture and aquaculture area, perennial plant, and forest. That covered area by 2,079.04 km^2(20.81%), 3,998.63 km^2(40.02%), 3,166.04km^2 (31.69%), and 748.39 km^2(7.49%) of the total area respectively. The data of land use is concluded in Table 4-13 and Figure 4-11.

Table 4-13 Land useinNakhon Si Thammarat Province in 2011.

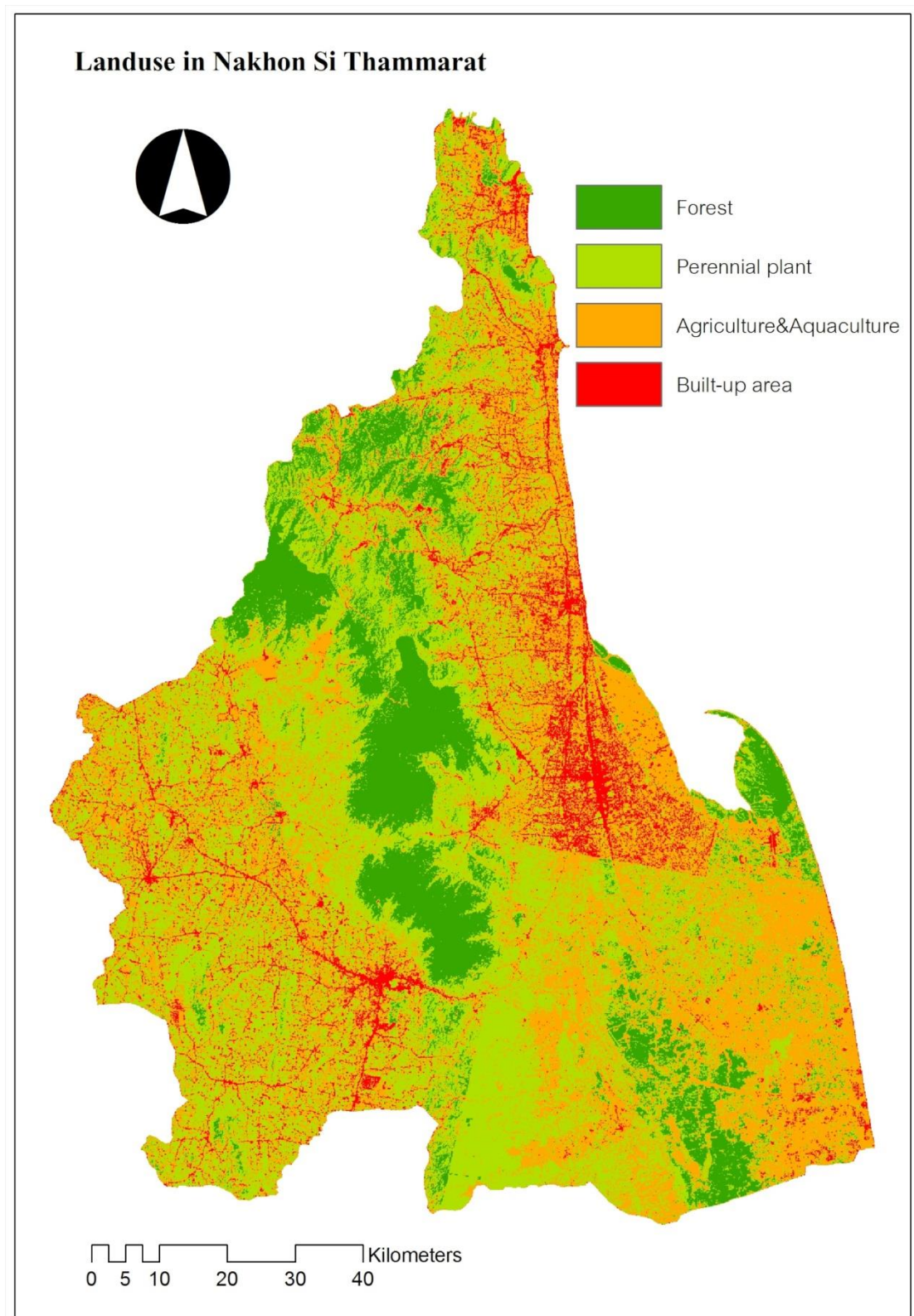| Land Use and Land Cover	Areas	
	Km^2	**(%)**
Built-up area	735.40	7.36
Agriculture and Aquaculture area (Rice Paddy, Field crop, etc.)	3,151.99	31.54
Perennial Plant (Orchard, Para-rubber , etc.)	4,091.60	40.95
Forest (Evergreen, Mangrove, Marsh & Swamp.)	2,013.11	20.15
Total	**9,992.10**	**100**

Source: Satellite image analysis

Figure 4-11 Land use in Nakhon Si Thammaratprovince year 2011.

4.4.2 Weighting and Rating

The details of weighting and rating technique are shown in table 4-14.

Table4-14 Weighting and rating parameters.

Factor	Weighting	Data types	Rating
1. Daily rainfall	5	>100mm.	4
		76-100mm.	3
		61-75mm.	2
		0-60mm.	1
2. Slope	4	0-5%	4
		6-10%	3
		11-15%	2
		>15%	1
3. Elevation	3	0 – 100 M.	4
		101 – 300 M.	3
		301 – 500 M.	2
		> 500 M.	1
4. Soil drainage abilities	2	- Very poorly drainage ability	4
		- Poorly drainage ability	3
		- Moderately drainage ability	2
		- Well drainage ability	1
5. Land-use	1	- Built-up area.	4
		- Agriculture, Aquaculture area	3
		- Perennial Plant (Orchard, Para-rubber , etc.)	2
		- Forest.	1

The result of PSA analysis was dividing into 4 levels of flood risk as follow:

1. High risk areas

2. Moderate risk areas

3. Low risk areas

4. Non risk areas

4.4.3 Flood risk area in 2011

The results of flood risk in normal case (average daily rainfall) was moderate risk area covered 4,261.50 km^2 (42.65%) of the total area. Followed by non risk area, high risk area, low risk area covered areas 2,461.44 km^2 (24.63%), 2,088.89 km^2 (20.91%), 1,180.27 km^2 (11.81%) of the total area, respectively.

In addition to extreme case (maximum daily rainfall) result was found high risk area covered 4,089.97 km^2 (40.93%) of the total area. Followed by low risk area, moderate risk area, non risk area which covered areas 2,672.40 km^2 (26.75%), 2,339.96 km^2 (23.42%), 889.77 km^2 (8.90%) of the total area, respectively. The flood risk map in Nakhon Si Thammarat Province is shown in Table 4-15 and figures 4-12, 4-13.

Table4-15 Flood risk area in Nakhon Si Thammarat Province in 2011

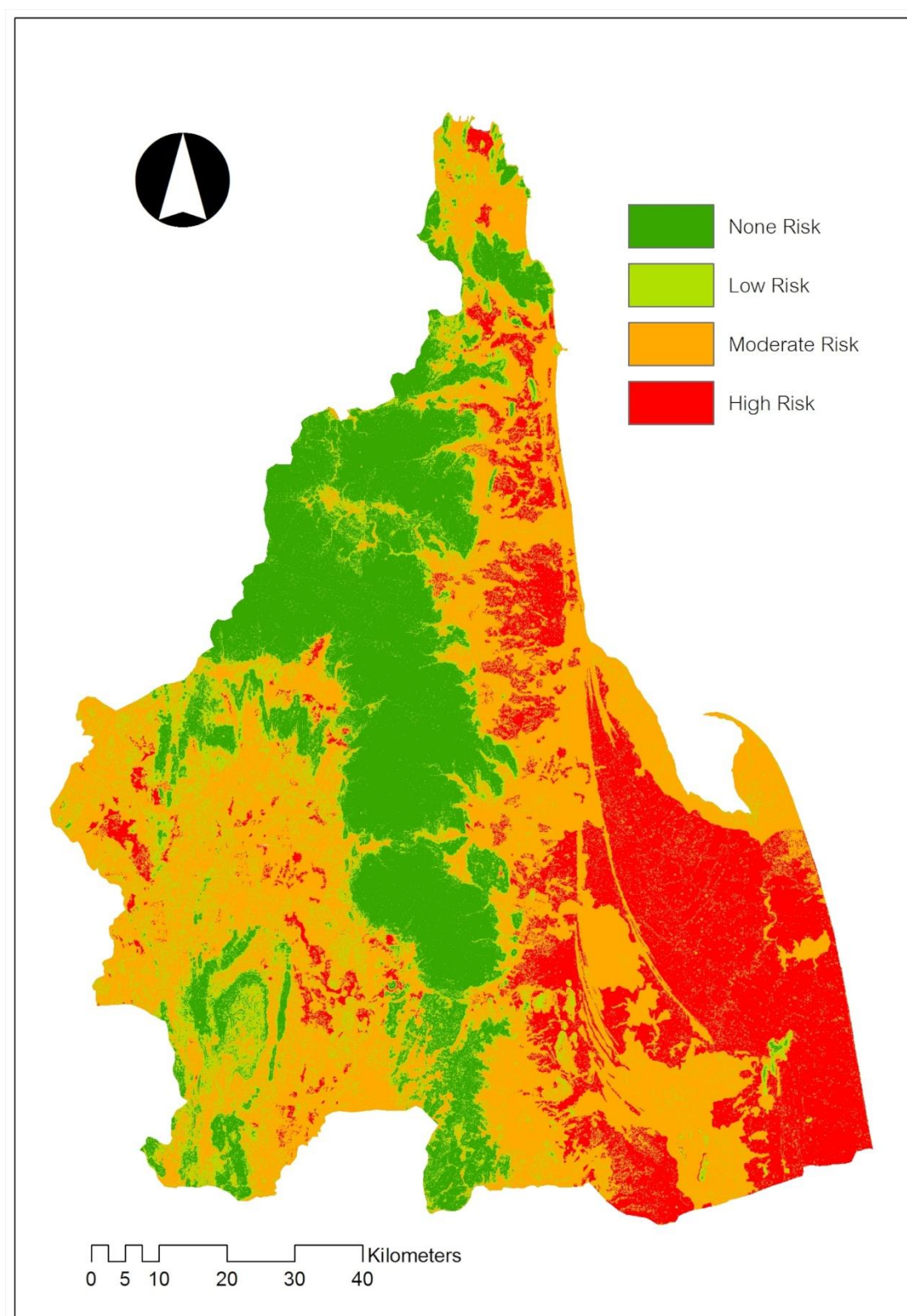| Level	Normal Case		Extreme Event	
	Km^2	**(%)**	**Km^2**	**(%)**
Non risk areas	2,461.44	24.63	889.77	8.90
Low risk areas	1,180.27	11.81	2,672.40	26.75
Moderate risk areas	4,261.50	42.65	2,339.96	23.42
High risk areas	2,088.89	20.91	4,089.97	40.93
Total	**9,992.10**	**100**	**9,992.10**	**100**

Figure 4-12 Flood risk area in Nakhon Si Thammarat Province in 2011.
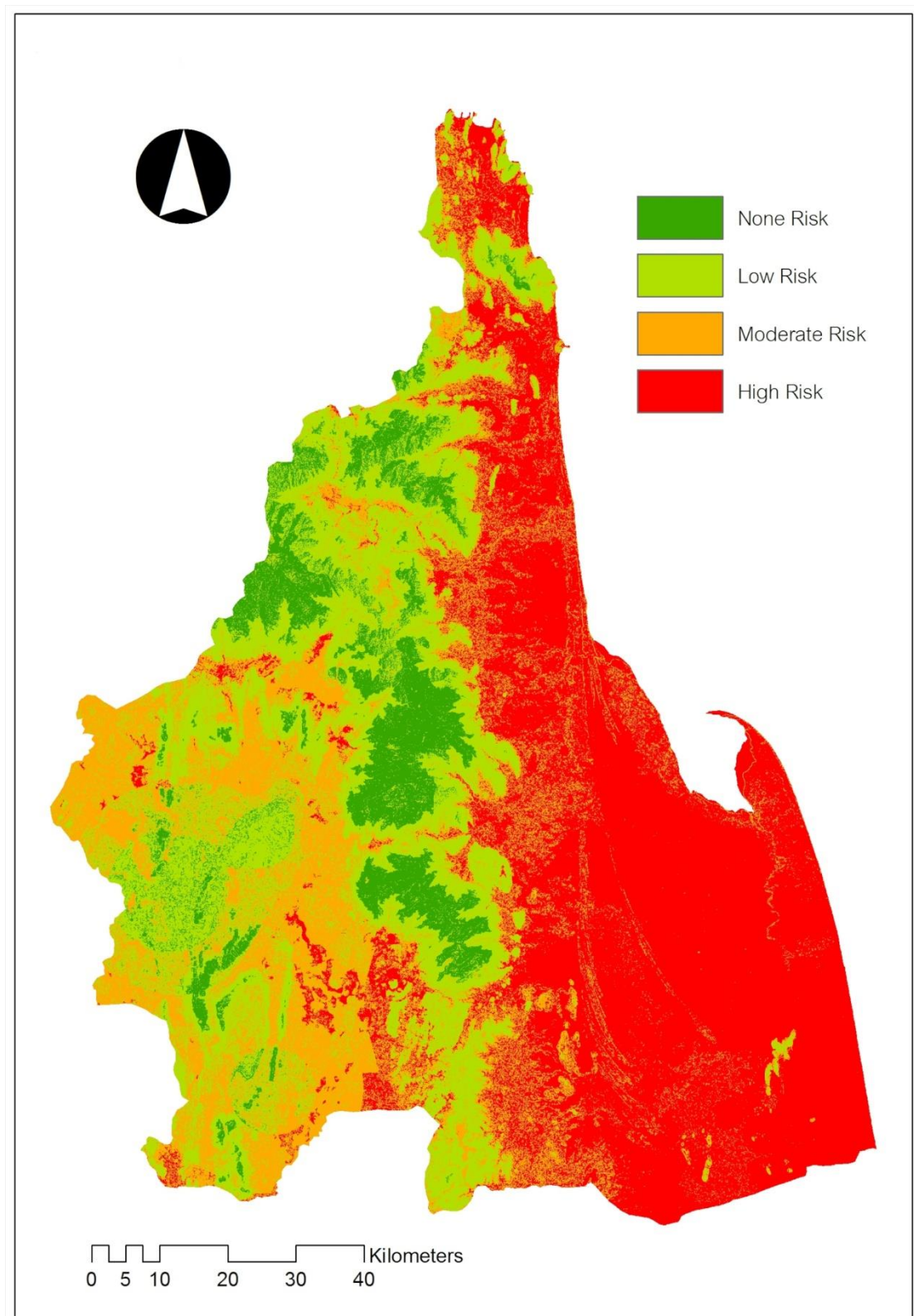
Source: Calculated

Figure 4-13 Flood risk area in Nakhon Si Thammarat Provicne in 2011
(extreme event).
Source: Calculated

4.4.4 Flood risk area in 2017

The results of flood risk in normal case (average daily rainfall) was found Moderate risk area covered 4,359.56 km^2 (43.63%) of the total area. Followed by High risk area, Non risk area, Low risk area covered areas 2,378.31km^2 (23.80%), 2122.79 km^2 (21.24%), and 1,131.44 km^2 (11.33%) of the total area, respectively.

In addition to extreme event (maximum daily rainfall) result was found High risk area covered 4,202.15 km^2 (42.05%) of the total area. Followed by Low risk area, Moderate risk area, Non risk area which covered areas 2,727.47 km^2 (27.30%), 2,358.53 km^2 (23.60%), 703.95 km^2 (7.05%), of the total area, respectively. The flood risk map in Nakhon Si Thammarat Province is shown in Table 4-16 and Figures 4-14, 4-15.

Table4-16 Flood risk area in Nakhon Si Thammarat Province in 2017

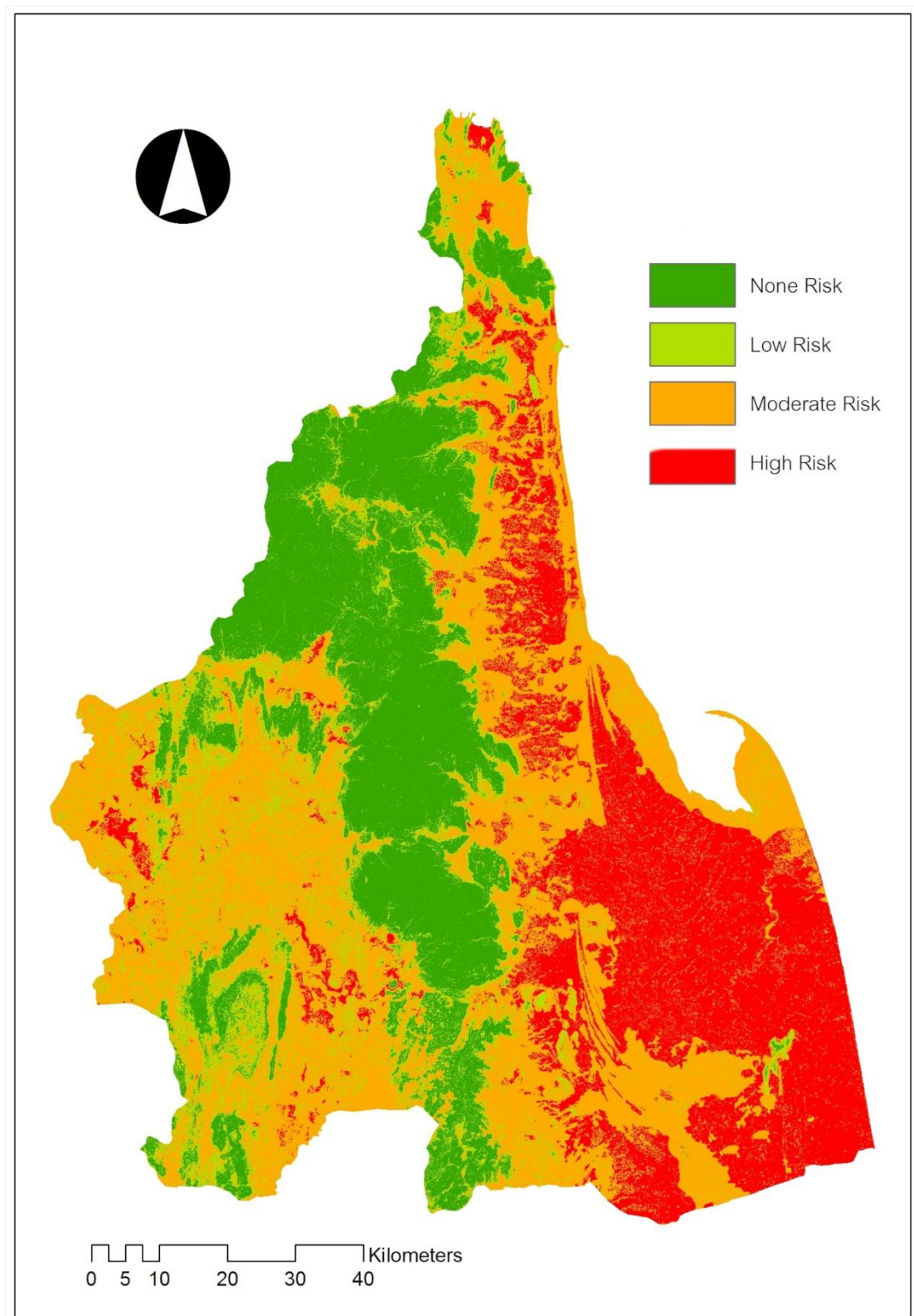| Level	Normal Case		Extreme Event	
	Km^2	(%)	Km^2	(%)
Non risk areas	2122.79	21.24	703.95	7.05
Low risk areas	1,131.44	11.33	2,727.47	27.30
Moderate risk areas	4,359.56	43.63	2,358.53	23.60
High risk areas	2,378.31	23.80	4,202.15	42.05
Total	**9,992.10**	**100**	**9,992.10**	**100**

Figure 4-14 Flood risk area in Nakhon Si Thammarat2017.
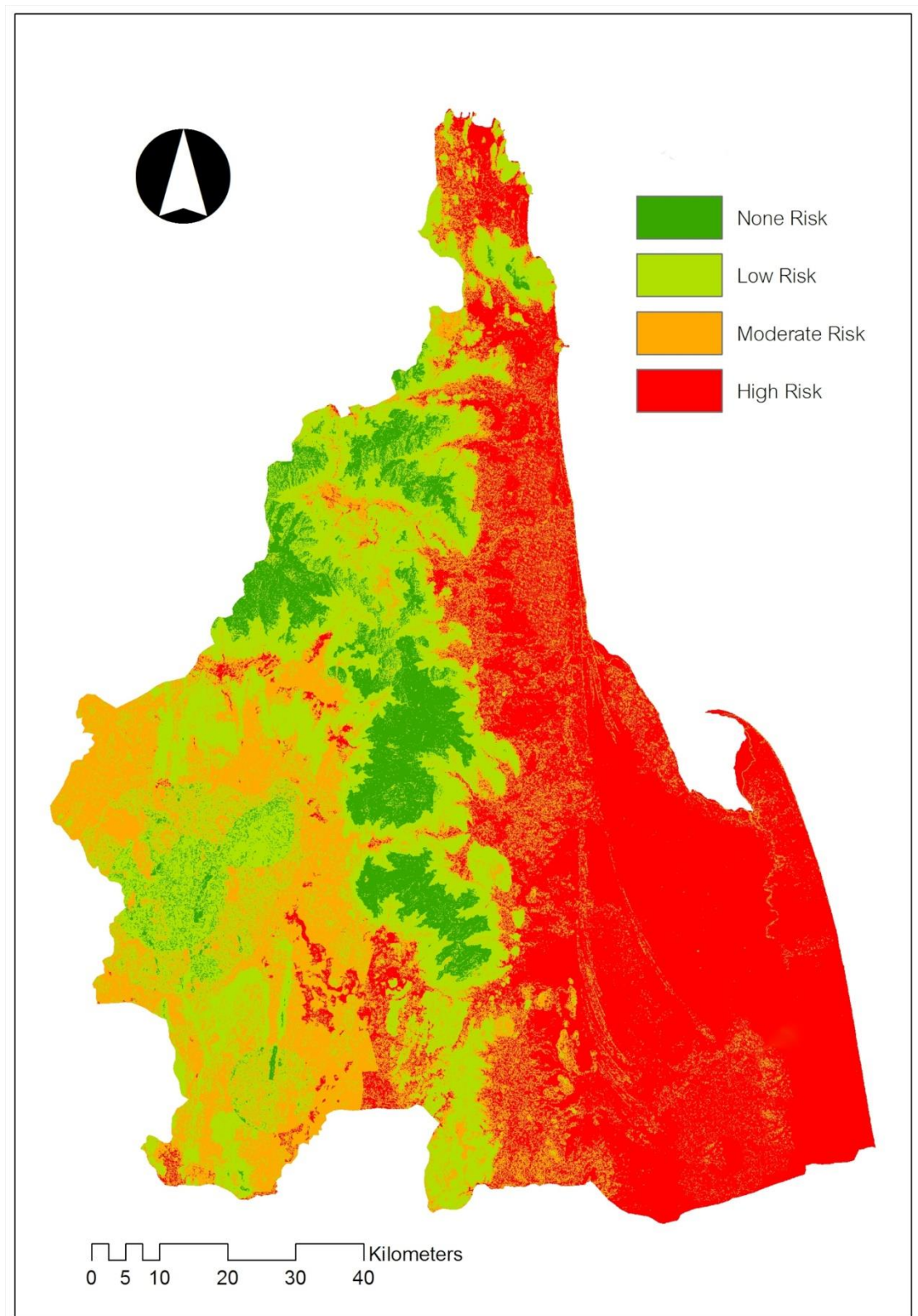
Source: Calculated

Figure 4-15 Flood risk area in Nakhon Si Thammart Province in 2017 (Extreme event).
Source: Calculated

The result of flood risk area is consistent with redundant flood area(Figure 4-16). It was found that the most of flood risk area located at The East of NakhonSi Thammarat mountain range that the land form is the coastal plains next to high mountain range. This area transformed to the large basin and the land use has been changed to urban, transportation and agriculture area continuously. These are the barrier for drain to sea and may occur the flood because of the heavy prolong rain.
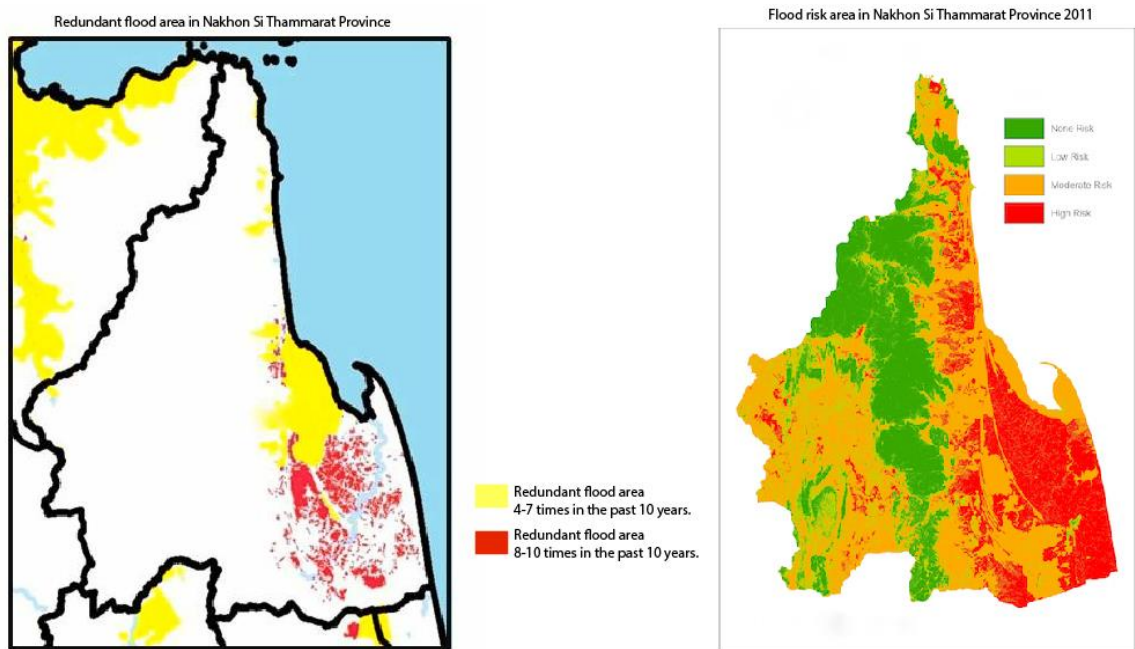
Figure 4-16 Flood risk area and Redundant flood area in Nakhon Si Thammarat Province

Source : Land Development Department, Department of Disasters Prevention and Mitigation

4.5. Landslide hazard area studies

This study was applied Geographic Information System (GIS) integrated with Potential Surface Analysis (PSA) in order to study landslide hazard in Nakhon Si Thammarat Province. The results of landslide area are as follows:

4.5.1 Landslide factor

This Landslide study use factor like flood risk studyand geology. The details of landslide factors are as follows:

Geology This study divided geology into 4 classes as (Granite), (Shale, Limestone), (Sandstone), (Deposite). That covered area by $1,575.51 km^2$ (15.77%), $1,117.72$ km^2 (11.19%), 729.91 km^2 (7.30%), and $6,568.96$ km^2 (65.74%) of the total area respectively. The data of Geology were concluded in Table 4-17and Figure 4-17.

Table 4-17 Geology in Nakhon Si Thammarat province.

Geology	Areas	
	km^2	(%)
Granite	1,575.51	15.77
Shale, Limestone	1,117.72	11.19
Sandstone	729.91	7.30
Deposite	6,568.96	65.74
Total	**9,992.10**	**100.00**

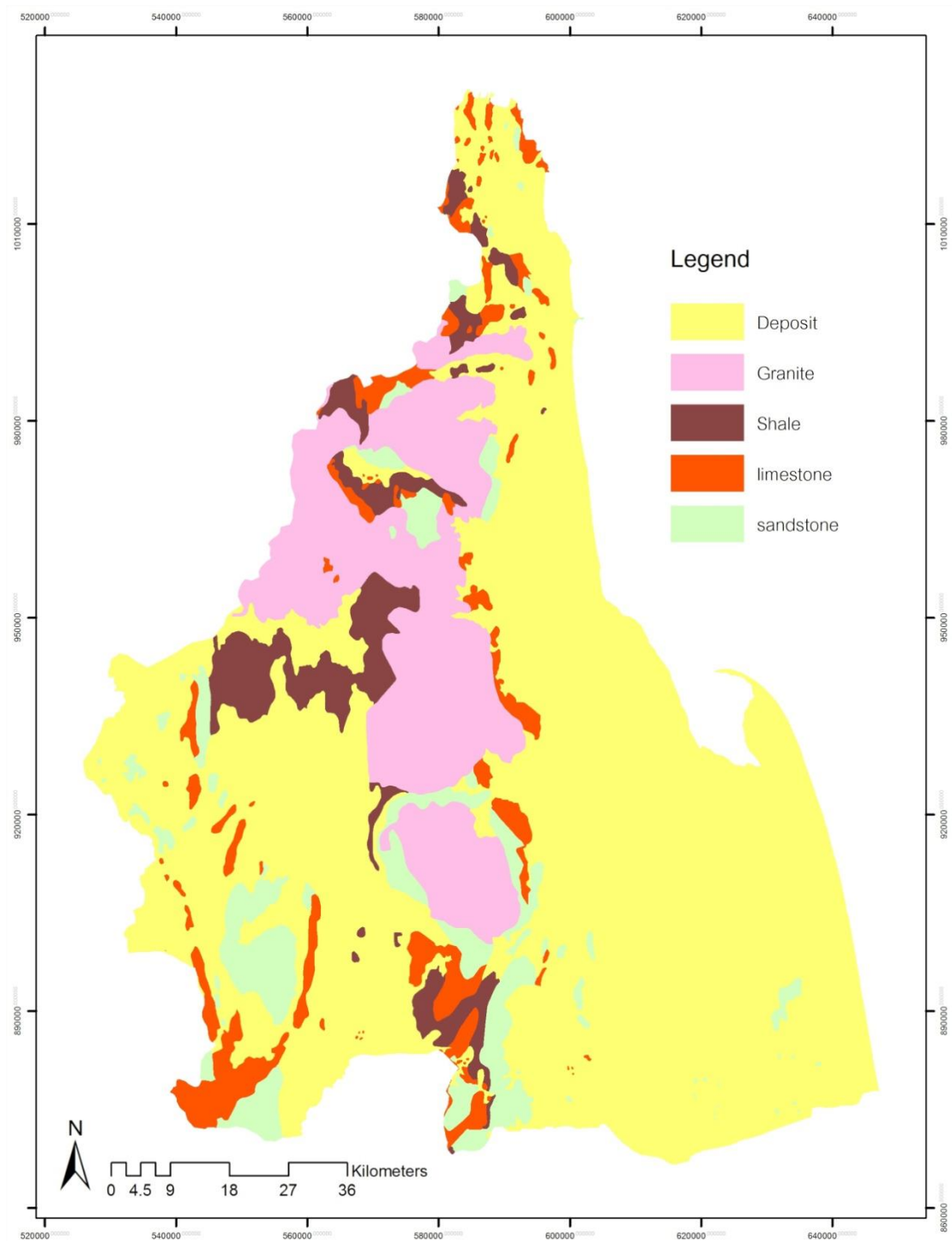Source: Royal Thai Survey Department

Figure 4-17 Geology in Nakhon Si Thammarat Province.

Source: Calculated

4.5.2 Weighting and rating of landslide hazard area

The details of weighting and rating technique are shown in Table 4-18

Table 4-18 Parameter of weighting and rating technique.

Factor	Weighting	Data types	Rating
1. Geology	5	Granite	4
		Shale, Limestone	3
		Sandstone	2
		Deposit	1
2. Slope	4	>60	4
		41-60	3
		21-40	2
		0-20	1
3. Daily rainfall	3	>100mm.	4
		76-100mm.	3
		61-75mm.	2
		0-60mm.	1
4. Soil drainage abilities	2	- Very poorly drainage ability	4
		- Poorly drainage ability	3
		- Moderately drainage ability	2
		- Well drainage ability	1
5. Land-use	1	- Built-up area.	4
		- Agriculture, Aquaculture area	3
		- Perennial Plant (Orchard, Para-rubber , etc.)	2
		- Forest.	1

The result of landslide hazard analysis was divided into 4 levels as follow:

1. High risk areas

2. Moderate risk areas

3. Low risk areas

4. Non risk areas

4.5.3 Landslide hazard area

The results of landslide hazard in normal case (average daily rainfall) was found none risk area covered 5699.82 km^2 (57.04%) of the total area. Followed by low risk area, moderate risk area, high risk area covered areas 2,533.49 km^2 (25.35%), 1,705.28 km^2 (17.07%), 53.51km^2 (0.54%) of the total area, respectively.

In addition to extreme event (maximum daily rainfall) result was found low risk area covered 5419.41km^2 (54.24%) of the total area. Followed by none risk area, moderate risk area, high risk area which covered areas 2,142.35 km^2 (21.44%), 1,625.2 km^2 (16.26%), 805.14 km^2 (8.06%), of the total area, respectively.

The result of landslide hazard area was found that the most of landslide area located at Nakhon Si Thammarat Province mountain range that the land form is high steep areas. And the land use of this area has been changed, from forest to Para-ruber and orchard .This area may occur the landslide, when has prolong rain. The landslide hazard map shown in Table 4-19 and figures 4-16, 4-17.

Table4-19 Landslide hazard area inNakhon Si Thammarat Province in 2011

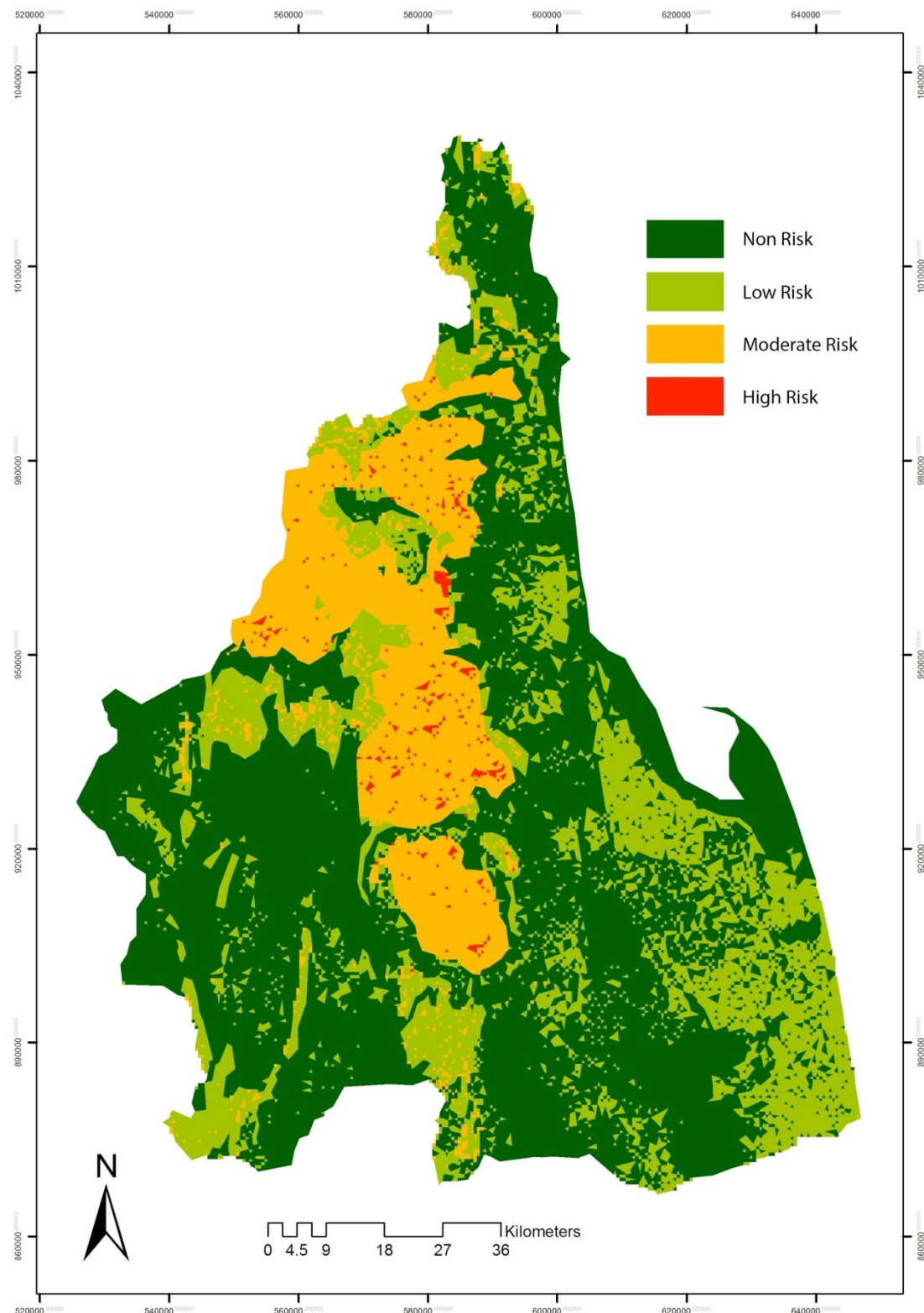| Level	Normal Case		Extreme Event	
	Km^2	**(%)**	**Km^2**	**(%)**
Non risk areas	5699.82	57.04	2142.35	21.44
Low risk areas	2533.49	25.35	5419.41	54.24
Moderate risk areas	1705.28	17.07	1625.2	16.26
High risk areas	53.51	0.54	805.14	8.06
Total	**9,992.10**	**100**	**9,992.10**	**100**

Figure 4-16 Land slide hazard area in Nakhon Si Thammarat Province
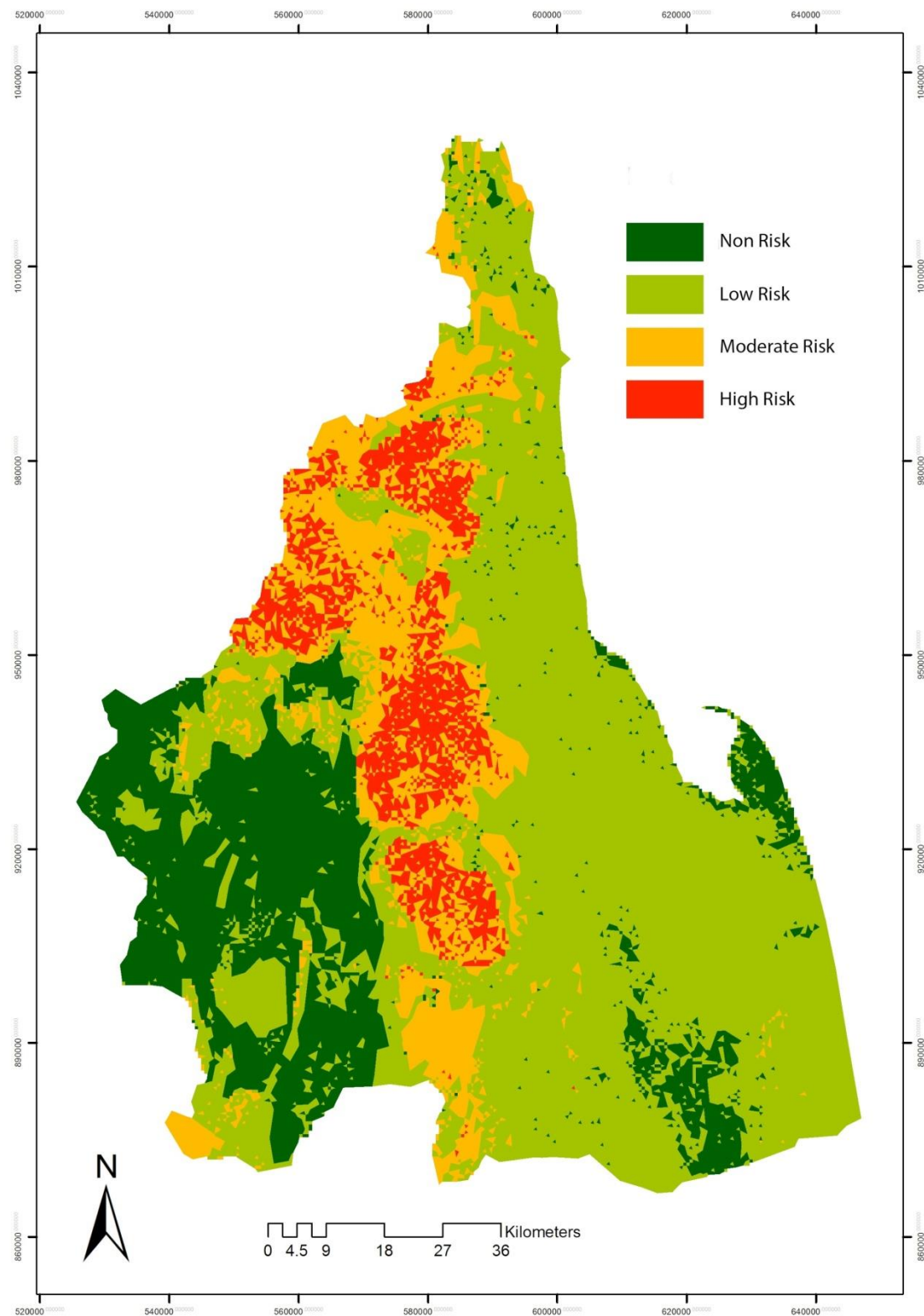
Source: Calculated

Figure 4-17 Extreme event landslide hazard area in Nakhon Si Thammarat Province

Source: Calculated