USE OF SATELLITE DATA AND POTENTIAL SURFACE ANALYSIS FOR URBAN EXPANSION SA KAEO PROVINCE, THAILAND

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ABSTRACT: In urban planning, the Potential Surface Analysis (PSA) technique is widely used for suitability analysis. This method requires an appropriate ranking technique for weighting the PSA's factors based on the physical data of the studying area. However, PSA is a complex analytical technique and uses a variety of parameters for calculation. Geographic Information System (GIS) plays an important role in analyzing and increasing the accuracy of the weight of parameters in a PSA approach. To create the physical database, the parameters of the urban area were considered. The PSA data are generally collected from the field. Therefore, the process of data collection is time consuming and requires a large number of man power and budget. This research uses a LANDSAT-5 and THEOS satellite data with visual interpretation to identify urban expansion areas and settlement patterns in 3 periods; 1993, 2003 from LANDSAT and 2013-2014 from THAICHOTE. In this research, Sa Kaeo Province was selected as a study area because it is a part of East-West Economic Corridor (EWEC) and Southern Economic Corridors (SEC) which is link from Myanmar to Thailand, Cambodia and Vietnam. Due to a large number of developers currently investing in Sa Kaeo, its environment is subject to change rapidly resulting in urban sprawl. The results of this study show that PSA combining with GIS technology can be applied for urban planning particularly for classifying urban expansion and promoting sustainable urban development. Therefore, this technique is effective for urban management of Sa Kaeo. The results show that the urban areas of Sa Kaeo Province is 222.61 sq.km. in 1993, increasing to 288.22 sq.km in 2003 and 313.47 sq.km.in 2013. The PSA technique exhibits that most of study areas has a moderate potential for urbanization (67.6%). The district of Sa Kaeo Province, which has high potential urbanization, are Aranyaprathet District (23.11 sq.km., 0.339 percent), Mueang Sa Kaeo District (19.87 sq.km., 0.292 percent), and Watthana Nakhon District (5.04 sq.km., 0.074 percent).

1. INTRODUCTION

The rapidfast urban expansion occurs in several provinces in Thailand, such as Phuket, Songkhla, Chonburi, Khonkean, Udorntani and Chiangmai, etc. New infrastructures and expansion of business districts are the results of urbanization. In addition, people from rural areas migrated to work in the cities. This causes many problems including environmental problems; air pollution, housing expansion, traffic jams and insufficient utilities, etc. Lack of regulations or planning are the major causes of these problems. Therefore, it is necessary to to have urban planning and Potential Surface Analysis technique (PSA) is important method to study urban expansion and analyze potential suitable area for urban growth.

Potential Surface Analysis (PSA) is alternative technique for evaluation and analysis of potential areas for residential, industrial, commercial and recreation land uses development. PSA was developed from the overlay mapping technique and that combined with the spatial data and the attribute data in Geographic Information System (GIS). The main function of PSA is weighting factors and this technique providespotential areas from low potential areas to high potential areas.

The concept idea of this study is to use satellite data and PSA analysis technique to study urban expansion of Sa Kaeo Province, Thailand. The data from LANDSAT-5 and THAICHOTE satellite is used for extract urban boundary by visual interpretation in order to identify urban expansion areas and settlement patterns in 3 periods; 1993, 2003 from LANDSAT and 2013 - 2014 from THAICHOTE. The data in 2013-2014 is processed by using PSA technique with GIS to identify for analyzing potential suitable areas of urban growth. We overlay the boundary of urban areas with suitable areas for urban growth. The objective of this research is to identify urban expansion area and settlement patterns in 3 periods and use a PSA technique for analyzing potential suitable areas for urban growth of Sa Kaeo Province, Thailand.

2. DATASET AND METHOLOGY

2.1 Study Area

The selected study area is Sa Kaeo Province; it is in the east of Thailand between 13°14′ - 14°11′ N and 101°51′ - 101°56′ E. Sa Kaeo has the connecting border with Cambodia, 165 kilometers long in the east of Sa Kaeo. Sa Saeo is far from Bangkok, the capital of Thailand, about 236 kilometers. Area of Sa Kaeo is 7,195.138 square kilometers (0.35 percent of Thailand). The border in the north connecting with Buriram and Nakhon Ratchasima Province, the border in the south connecting with Chachoengsao and Chanthaburi Province, in the west, it connect with Prachin Buri Province and in the east connecting with Kingdom of Cambodia.(Figure1.)

Geography of Sa Kaeo has flat plains to high mountains, 74 meters high from mean sea level. Khao Ban Thad Mountain is in the north, it is the location of Pangsida National Park and Taphraya National Park, which are the origin of Bang Pa Kong River. In addition, Khao Ang Runai Wildlife Sanctury is in the south. Central and eastern parts of Sa Kaeo locate in low terrace to high terrace.

Aranyaprathet, one district of Sa Kaeo, is the border trade center between Cambodia and Vietnam. This area is a part of East-West Economic Corridor (EWEC), which is link from Myanmar to Thailand to Cambodia and to Vietnam. The main border has 1 permanent crossing point and 3 Check Points. Trade values of border trade are over 269.23 million dollars in January 2015 and increase from December 2014 more than 8.35 percent)Ministry of Commerce, 2015). Moreover, Ban Nong Ian has a border connecting with Banteay Meanchey Province, which is the location of Poipet O'Neang Special Economic Zone of Cambodia, a twin city of Sa Kaeo Province. All of them are in Aeyawadee-Chaopraya-Mekong Economic Cooperation (ACMECS), which expect tobe areas of bilateral economic cooperation in finance, transport, tourism, industrial and infrastructure development.

Therefore, urban expansion of Sa Kaeo is critical to study. In this research, we used a Potential Surface Analysis (PSA) technique for analyzing potential suitable areas for urban growth. Satellite images are used for extracting boundary of urban areas with visual interpretation in order to identify urban expansion areas and settlement patterns in 3 periods; 1993, 2003 from LANDSAT-5 and 2013-2014 from THAICHOTE. Geographic Information System (GIS) is efficiently applied with PSA for improving boundary analysis. The results of this technique can be used as the guideline for urban planning.

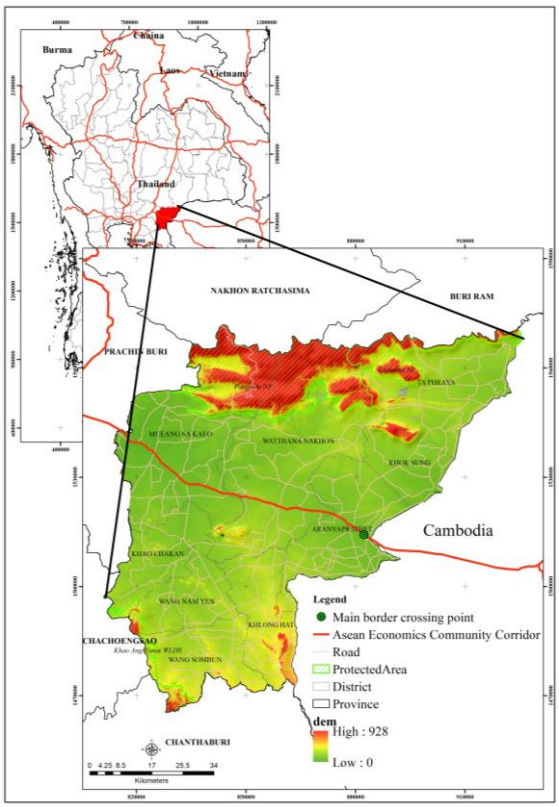


Figure 1. Study Area

2.2 Methodology

This research applied a Potential Surface Analysis (PSA) technique for analyzing potential suitable areas for urban growth based on GIS. Figure 2 shows methodology diagram.

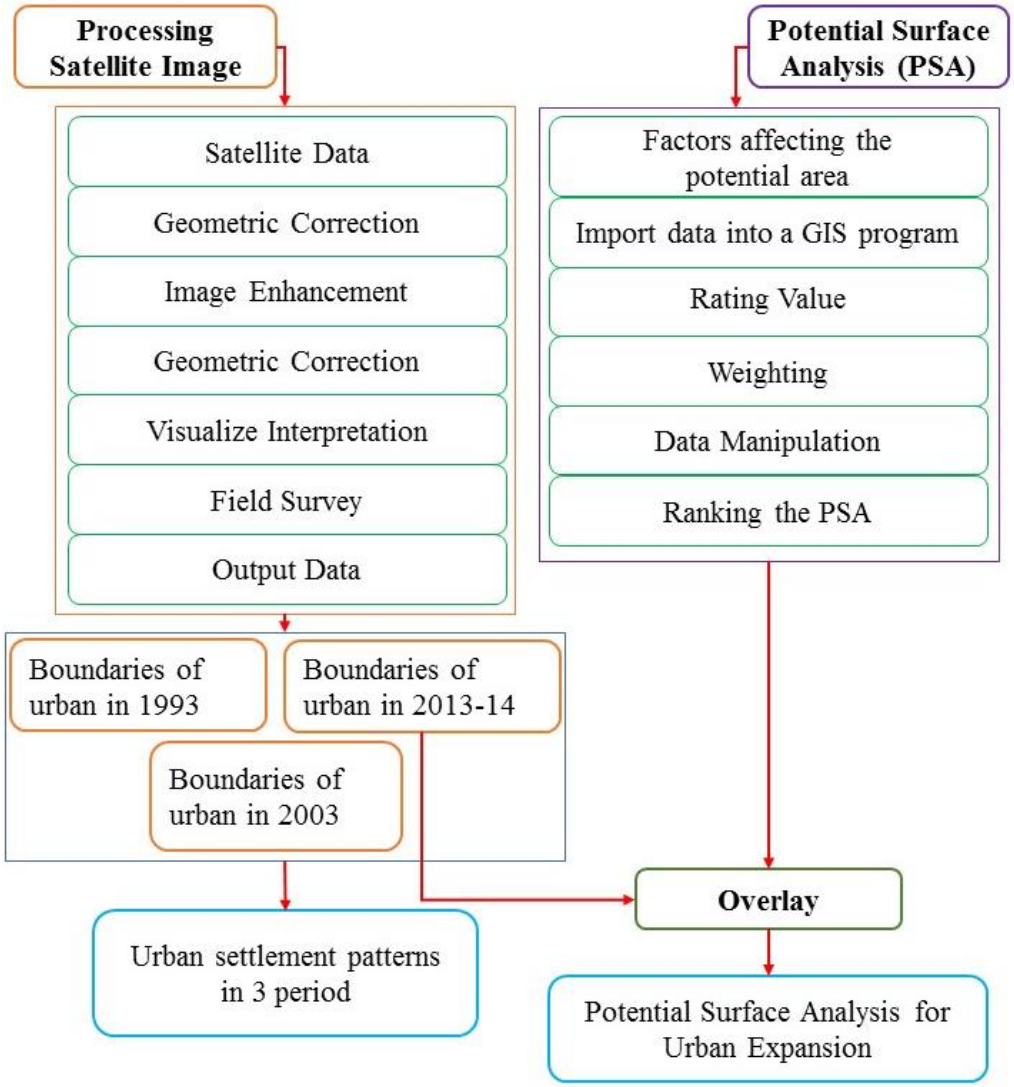


Figure 2. Flow diagrams of methodology

2.2.1) Primary data collection

Satellite images were used for analyzing urban settlement patterns in 3 periods; LANDSAT-5 on Dec.18th were used in 1993; LANDSAT-5 on Dec.30th were used in 2003; and THAICHOTE on Dec.14th, 2013 and THAICHOTE on Jan.24th, 2014 were used in 2013.

The 12 factors for PSA were generated to vector data and were divided into three groups: physical, environmental, and social support factors. The ranking and rating scores of each factor were obtained from various agencies. The importance criteria ranking factors determines the rate score between 5and 15. The important factors are flood areas from 2000-2013 and AEC Road; the second important factors are road, railway, factory and tourist attractions, these factors are important factors for the study of urban expansion. All factors are processed in GIS based on PSA method. The factors are listed in Table 1.

Secondary data including research, papers and other documents were also used in this study and transformed to attribute data in GIS. The other data related the physical characteristics from the biological, economic and social agencies were applied to understand the study area and use of the data analysis.

Table 1: Factors used in the Potential Surface Analysis. (Unit in meter)

GROUP	FACTOR	WEIGHTING	RATTING (Potential)			
			High (4)	Relatively High (3)	Moderate (2)	Low (1)
Physical Factors	Road	10	0-500	500-1,000	1,000-1,500	>1,500
	Railway	10	0-500	500-1,000	1,000-1,500	>1,500
	AEC Road	15	0-500	500-1,000	1,000-1,500	>1,500
Environmental Factors	Flooded (Time in 9 years)	15	0	1	2	>3
	Out of Forest cover area	5	5	-	-	-
	Factory	10	0-500	500-1,000	1,000-1,500	>1,500
	Tourist attraction	10	0-500	500-1,000	1,000-1,500	>1,500
Social Well Being Factors	Urban	5	0-500	500-1,000	1,000-1,500	>1,500
	School	5	1,500	-	-	>1,500
	Police Station	5	1,500	-	-	>1,500
	Hospital	5	15,000	-	-	>15,000
	Health Office	5	1,500	-	-	>1,500
Total		**100**				

2.2.2) Image processing

Preprocessing process, geometric correction and image enhancement, were applied to LANDSAT-5 and THAICHOTE images. Then, urban boundaries were extracted from satellite images by visual interpretation to identify urban expansion area and settlement patterns in 3 periods; 1993, 2003 from LANDSAT and 2013 - 2014 from THAICHOTE. Accuracy assessment were implemented by field survey.

2.2.3) Potential Surface Analysis (PSA) with GIS

Potential Surface Analysis (PSA) is alternative technique for evaluation and analysis of potential areas for residential, industrial, commercial and recreation land uses. PSA was developed from the overlay mapping technique and combined with the spatial data and the attribute data in Geographic Information System (GIS). The main function of PSA is weighting factors and this technique provides potential areas from low potential areas to high potential areas. This technique is prevalently used in various fields of studies in the past decade such as geography, environmental science, landscape architecture and urban planning.

Ranking and rating process in PSA technique were applied to spatial factors, which influence on urban development to identify suitable urban areas. The spatial data were obtained from several organizations in Thailand and were processed in an ArcGIS program. Weighting and rating scores of each factor range from 5 to 15 according to the importance of factor in urban areas; Road, Railway, AEC Road, Flooded (in 9 years), Factory, Tourist attractions, Urban, Schools, Police Stations, Hospital and Health Offices.

3. RESULTS AND DISCUSSION

3.1 Urban expansion areas and settlement patterns in 3 periods

The results shows that the urban areas of Sa Kaeo Province are 222.61 square kilometers in 1993, and increase to 288.22 square kilometers in 2003 and 313.47 square kilometers in 2013. The details are illustrated in Table 2 and Figure 3.

The pattern of urban areas in 1993 were clustered in downtown of Sa Kaeo, especially in the areas of comprehensive plan, which were 33 and 3,462 of the cross road highway in Mueang Sa Kaeo District and

Aranyaprathet District of the crossing point next to Cambodia, respectively. Scattered settlements were found in Mueang Sa Kaeo District, Wang Nam Yen District, Khao Chakan District and Ta Phraya District, which are the areas around the city. In addition, linear settlements along the 317 roads were found in Mueang Sa Kaeo District to Chanthaburi Province (Figure 4).

Inner city areas in 2003, in the old downtown and in comprehensive plan, were extended to surrounding areas. Urban sprawl were found in the same areas in 1993 (Figure 5).

Urbanization in 2013 was expanded out of city along the 317 highway in Wang Nam Yen District. Urbanization continued to expand to surrounding areas, except the downtown (Figrue 6).

Table 2: The visualize interpretation of urban boundaries in 3 period

Year	Image Satellite Data	Class (sq.km.)		Percent (%)	
		Urban Area	Other Areas	Urban Area	Other Areas
1993	LANDSAT-5 18 December 1993	222.61	6,582.68	3.27	96.73
2003	LANDSAT-5 30 December 2003	288.22	6,517.07	4.24	95.76
2013	THAICHOTE 14 December 2013 and 24 January 2014	313.47	6,491.82	4.61	95.39

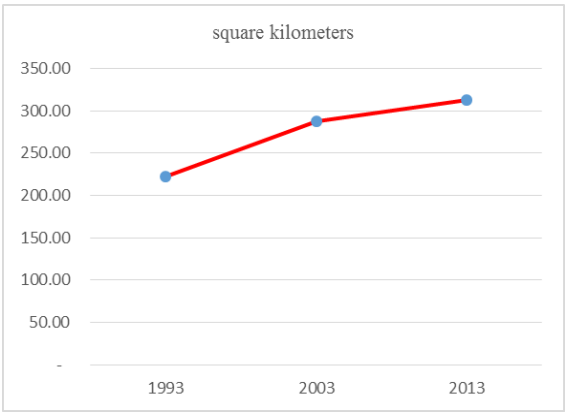


Figure 3. Trend of Urban boundaries

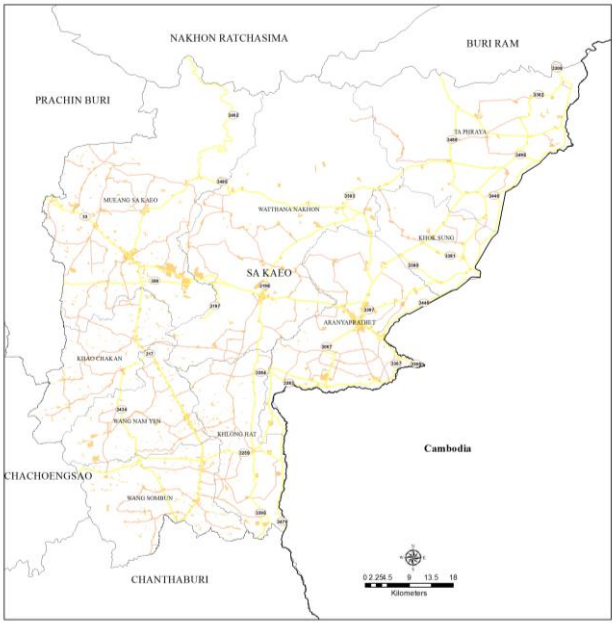


Figure 4. Urban boundaries 1993

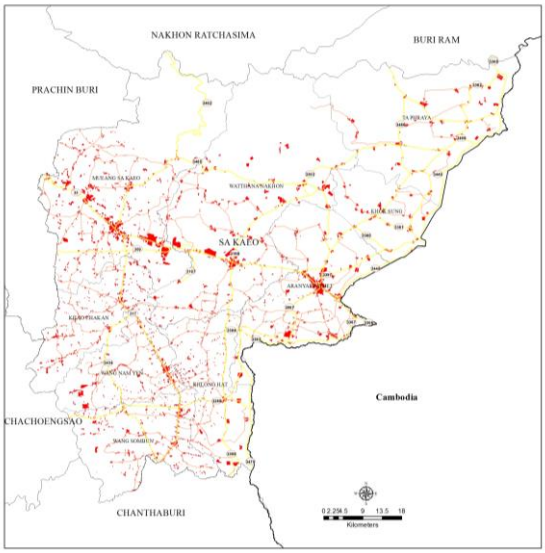


Figure 5. Urban boundaries 2003

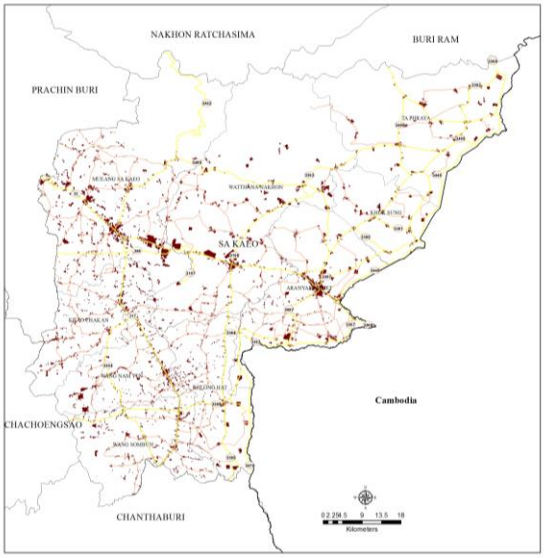
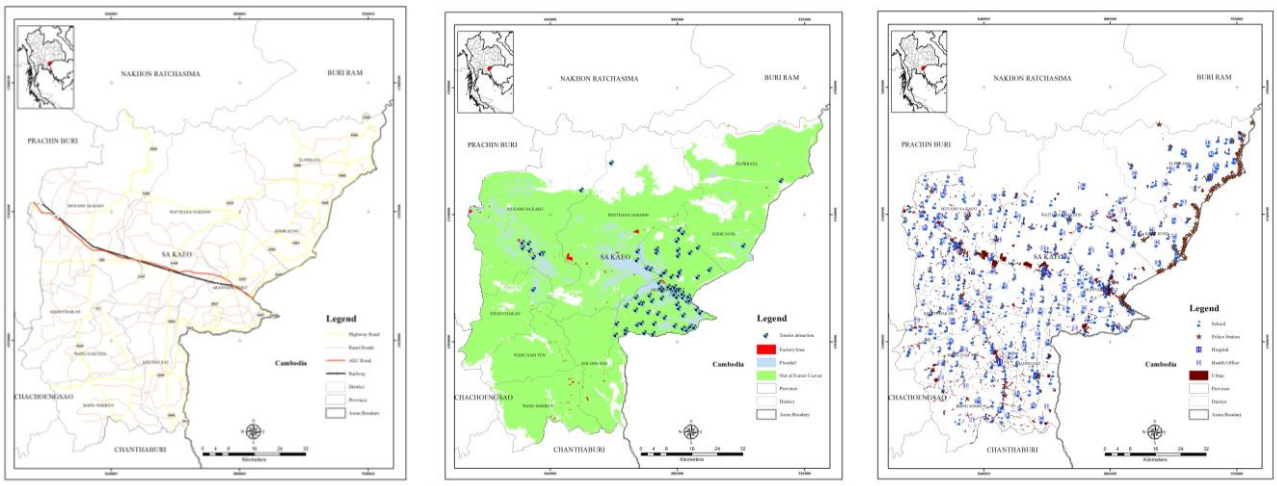


Figure 6. Urban boundaries 2013

3.2 Potential Surface Analysis (PSA) with GIS.



A B C

Figure 7. Factors used in PSA (A: Physical Factor, B: Environmental Factor and C: Social support factors).

The urban growth areas from PSA techique are shown in Table3 and Figure 8. The results exhibits 3 categories as follows; the low potential class for urban areas is approximately 131.35 sq.km. (1.93 percent), the moderate potential class is 4,601.55 sq.km. (67.60 percent), the relatively high potential class is 767.89 sq.km. (11.28 percent) andthe high potential class is 48.02 sq.km. (0.70 percent), respectively. The areas out of urban potential areas are waterbody covering 109.75 sq.km. (1.61 percent) and the protected areas, where are National Park and Wildlife Sanctuary covering 1,148.74 sq.km. (16.88 percent).

Table 3: The results of potential urban areas in different categories

Urban Area Weight	Area (sq.km.)	Percent (%)
Protected Area	1,148.74	16.88
Waterbody	109.75	1.61
PSA Level : 1 (Low Potential)	131.35	1.93
PSA Level : 2 (Moderate Potential)	4,601.55	67.60
PSA Level : 3 (Relatively High Potential)	767.89	11.28
PSA Level : 4 (High Potential)	48.02	0.70
Total area	**6,807.30**	**100**

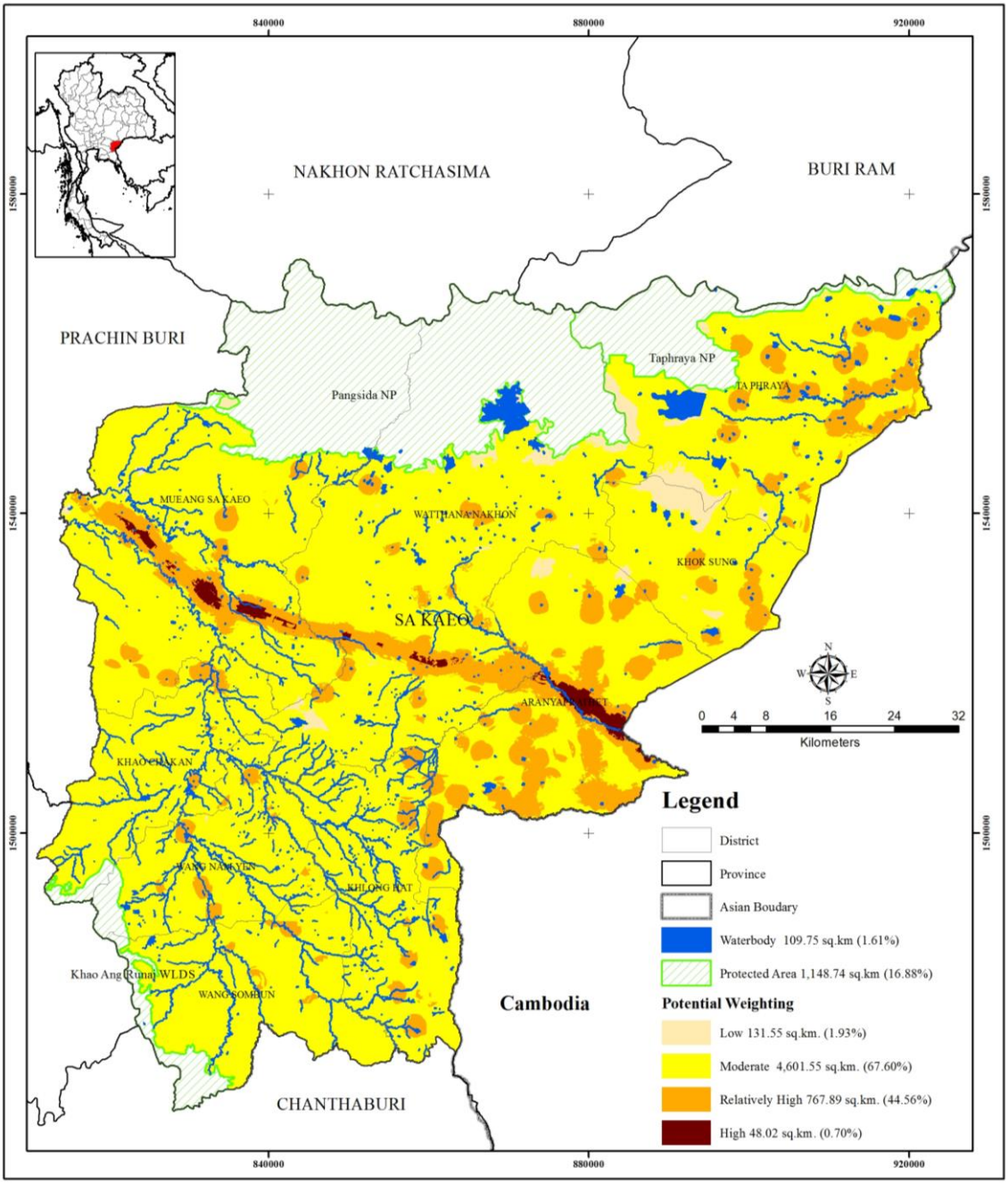


Figure 8. Map of potential suitable areas for urban growth.

The results of the potential suitable areas for urban growth found that the high potential class are in Aranyaprathet District (23.11 sq.km., 0.339 percent), Mueang Sa Kaeo District (19.87 sq.km., 0.292 percent) and Watthana Nakhon District (5.04 sq.km., 0.074 percent). This is because these areas are in East-West Economic Corridor (EWEC) and Aranyaprathet has permanent crossing point connecting to Kingdom of Cambodia. The results of potential areas are shown in Table 4 and Table 5. Most of relatively high potential class areas are in Aranyaprathet District (242.02 sq.km., 3.555 percent), Watthana Nakhon District (138.00 sq.km., 2.027 percent), Ta Phraya District (134.48 sq.km., 1.976 percent), and Mueang Sa Kaeo District (124.70 sq.km., 1.832 percent).

Most of moderate potential class areas are in Watthana Nakhon District (919.12 sq.km., 13.502 percent), Mueang Sa Kaeo District (791.81 sq.km., 11.632 percent), Ta Phraya District (546.81 sq.km., 8.033 percent) and Aranyaprathet District (459.32 sq.km., 6.747 percent).

Table 4: The potential suitable areas for urban growth divided by the district of Sa Kaeo Province: Unit: square kilometers.

District	Protected Area	Waterbody	Potential Class (sq.km)				
			1	2	3	4	Total
Aranyaprathet	0	4.74	7.84	459.32	242.02	23.11	**737.03**
Khao Chakan	16.61	8.19	1.05	386.38	16.27	0	**428.50**
Khlong Hat	0	10.54	0.18	437.40	38.67	0	**486.79**
Khok Sung	0	3.06	31.61	269.26	38.13	0	**342.06**
Mueang Sa Kaeo	413.11	12.06	9.28	791.81	124.70	19.87	**1,370.83**
Ta Phraya	219.08	24.09	41.26	546.81	134.48	0	**965.72**
Wang Nam Yen	25.55	7.96	0.36	356.95	23.45	0	**414.27**
Wang Sombun	61.64	6.53	0.20	434.50	12.16	0	**515.03**
Watthana Nakhon	412.76	32.57	39.58	919.12	138.00	5.04	**1,547.07**
Grand Total	**1,148.75**	**109.74**	**131.36**	**4,601.55**	**767.88**	**48.02**	**6,807.30**

Table 5: The percent of the potential suitable areas for urban growth divided by the district of Sa Kaeo Province

District	Protected Area	Waterbody	Potential Class (Percent)				
			1	2	3	4	Total
Aranyaprathet	-	0.070	0.115	6.747	3.555	0.339	**10.826**
Khao Chakan	0.244	0.120	0.016	5.676	0.239	-	**6.295**
Khlong Hat	-	0.155	0.003	6.426	0.568	-	**7.152**
Khok Sung	-	0.045	0.464	3.955	0.560	-	**5.024**
Mueang Sa Kaeo	6.069	0.177	0.136	11.632	1.832	0.292	**20.138**
Ta Phraya	3.218	0.354	0.606	8.033	1.976	-	**14.187**
Wang Nam Yen	0.375	0.117	0.005	5.244	0.345	-	**6.086**
Wang Sombun	0.905	0.096	0.003	6.383	0.179	-	**7.566**
Watthana Nakhon	6.064	0.478	0.581	13.502	2.027	0.074	**22.726**
Grand Total	**16.87500**	**1.61200**	**1.92900**	**67.59800**	**11.28100**	**0.70500**	**100.000**

4. Conclusion

The integration of satellite data and PSA allows us to understand the pattern of urban expansion of Sa Kaeo province. In addition, PSA in GIS increases efficiency of urban analysis. This method improved the accuracy of geographic coordinate and reduced processing time. However, we should consider the limitation of using satellite images, for example, data resolution, temporal inquisition, and cloud cover, etc.

In addition, using PSA technique depends on the objective of the study. More factors may be required in some cases. For example, water supplies, communication routes and poison garbage management are important for industrial area analysis.

This study demonstrates the technique for identify the potential urban areas and the results is very useful for urban planning and urban development and can be applied to other urban areas.

ACKNOWLEDGEMENTS

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