Community Identification Based on Multispectral Image Classification for Local Electric Power Distribution Systems

TATIYA LUEMONGKOL and THANATCHAI KULWORAWANICHPONG
Power System Research Unit
School of Electrical Engineering
Suranaree University of Technology
111 University Avenue, Nakhon Ratchasima
THAILAND
thanatchai@gmail.com

Abstract: - This paper illustrated an approach of identifying community size in feeding area of local MV power distribution systems by using satellite image processing. Information of community size is essential and can be useful to estimate electric energy used by local customers. Infrared band of satellite images can be used for this purpose. ENVI and GIS ArcView software are both working tools in this paper. Satellite images of LANDSAT 7 covered a test area in Nakhon Ratchasima 2 distribution feeders were employed for test. The results obtained from the satellite image processing based on ISODATA unsupervised classification can be used in associative with GIS information of the power distribution feeder to visualize feeder load allocation in the community point of view.

Key-Words: - Multispectral, Satellite imagery, ISODATA, Unsupervised classification, Minimum square error

1 Introduction

Satellite images have found their several applications in fields of agriculture, geology, forestry, biodiversity conservation, regional planning, education, intelligence, warfare, weather forecast, water resources, electric power system, etc [1-9]. Images can be in visible colors and in other spectra. To interpret and analyze satellite images, some efficient software packages like ERDAS or ENVI are necessary. All satellite images produced by NASA are published by Earth Observatory and are freely available to the public. Several other countries, nowadays, have satellite imaging programs, and a collaborative European effort launched the ERS and Envisat satellites carrying various sensors. There are also private companies that provide commercial satellite imagery.

For decades, electric power distribution systems, particularly in Thailand, were constructed extensively across the country. In recent years, population growth forces community expanding its size. Several villages in local areas have shifted their border and increased their electric demands. One of important work for electric power distribution planning is to manage power feeding systems to gain highest performances in several aspects. Size and site information of all local customers are key. In fact, a local electric distribution company usually bills its consumers. An amount of electric energy consumed by each customer in one month can be easily obtained. What the local utility has not known is how electrical demands are distributed along the feeder line through its distribution transformers. Some may say that this information can be obtained by conducting a direct field survey. However, a large amount of time and efforts is required. Satellite remote sensing, which can easily monitor a large area, could provide effectiveinformation to develop community identification, if it is able to capture the community features in urban areas from satellite images. Multi-spectral characteristics show the difference of reflectance from the materials on the earth surface. Many researchers have already proposed algorithms to classify the features on the earth surface in the fields of natural environment mapping, such as for forests and agricultural lands. In this study, the classification for identifying community in parts of City of Nakhon Ratchasima was attempted using LANSAT 7 satellite images. Satellite images from LANSAT 7 was used in this study. Multi-spectral sensor of LANSAT 7, Thematic Mapper (TM), has eight bands between visible and thermal infrared. Spatial resolution of its image except for the thermal infrared band is 15 – 30 m on ground.

In this paper, Section 2 gave a brief of satellite imaging technique and its processing. Section 3 described the interpretation of satellite images. Section 4 explained the satellite image processing software used in this paper. Section 5 illustrated multi- spectral image classification technique in which ISODATA unsupervised classification is focused on. The next section, Section 6, provided results of the identifying scheme proposed in this paper. Section 7, the last section, concluded the results and discussed further for future work.

2 Satellite Imaging Techniques

As mentioned previously, this paper was based on image analysis. The source of these pictures came from two main sources: i) satellite images from LANDSAT 7 and topographic map based on topographical surveys.

2.1 LANDSAT Imaging

A latest LANDSAT, LANDSAT 7, was launched in April 1999 [10]. It has a unique and essential role in the realm of earth observing satellites in orbit. The earth observing sensors on LANDSAT 7, the enhanced thematic mapper plus (ETM+), replicates the capabilities of the thematic mapper instrument on LANDSAT 4 and 5. The ETM+ also includes new features that make it a more versatile and efficient instrument for global change studies, land cover monitoring and assessment and large area mapping. The primary new features on Landsat 7 are: i) a panchromatic band with 15m spatial resolution, ii) on board, full aperture, 5% absolute radiometric calibration and iii) a thermal IR channel with 60m spatial resolution. Fig. 1 showed a satellite image covering Thailand [11]. As mentioned earlier the dot circle is the area of study in this paper. Fig. 2 gave a close view inside the circle of Fig. 1. It revealed city of Nakhon Ratchasima from the space.

Fig. 1 Satellite image covering Thailand [11]

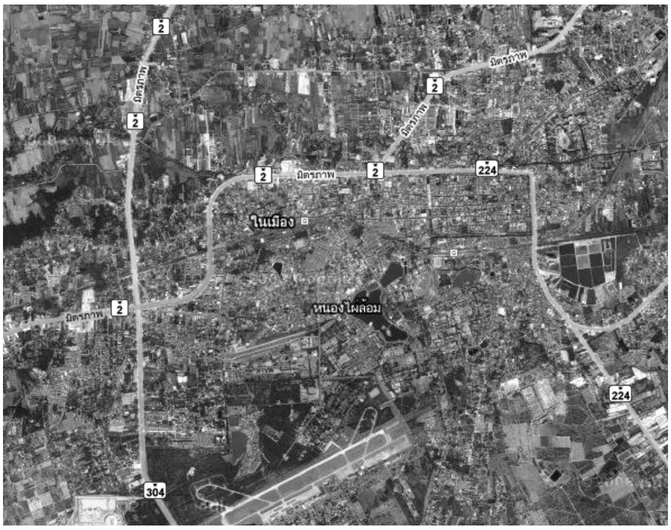


Fig. 2 Satellite image of City of Nakhon Ratchasima [11]

2.2 Topographic Map

A topographic map as shown in Figs 3 – 4 is a typical map characterized by large-scale detail and quantitative representation, usually using contour lines in modern mapping [12]. Traditional definitions require a topographic map to show both natural and man-made features. Topographic maps have found their several applications, for example, any type of geographic planning or large-scale architecture; earth sciences and many other geographic disciplines; mining and other earth-based endeavors; and recreational uses such as hiking.

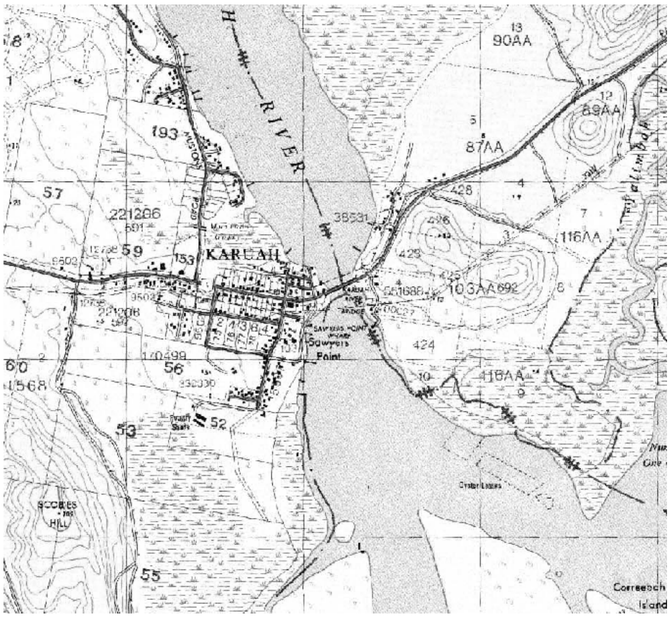


Fig. 3 Example of topographic map [13]

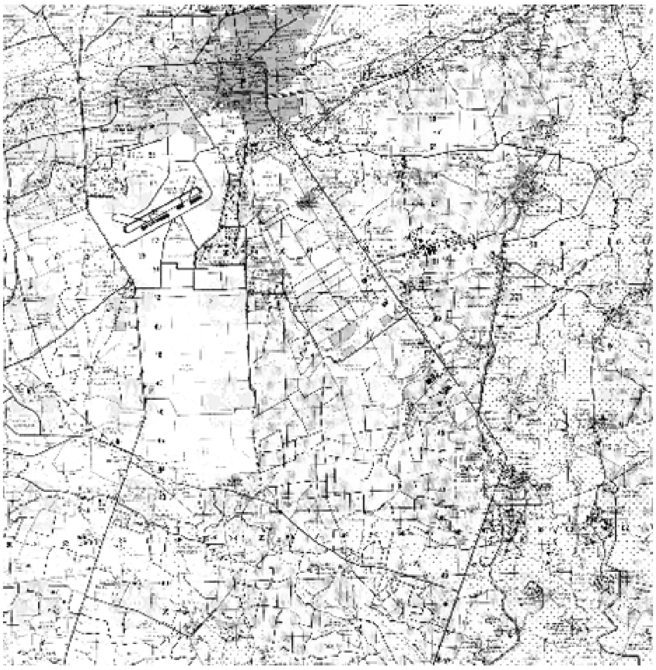


Fig. 4 Topographic map of Nakhon Ratchasima area

In power transmission and distribution system planning, power transmission or distribution lines are located on this kind of maps. Unfortunately, information on this map is out-of-date because the topographical surveys of the country were done for decades. The only one important thing that has never been changed is GPS coordinates [14] of the power lines on the topographic maps. With these coordinates, existing power transmission line routes can be located and then mapped onto a recent version of its satellite image, as shown in Fig. 5. This procedure was described in the next sub-section.

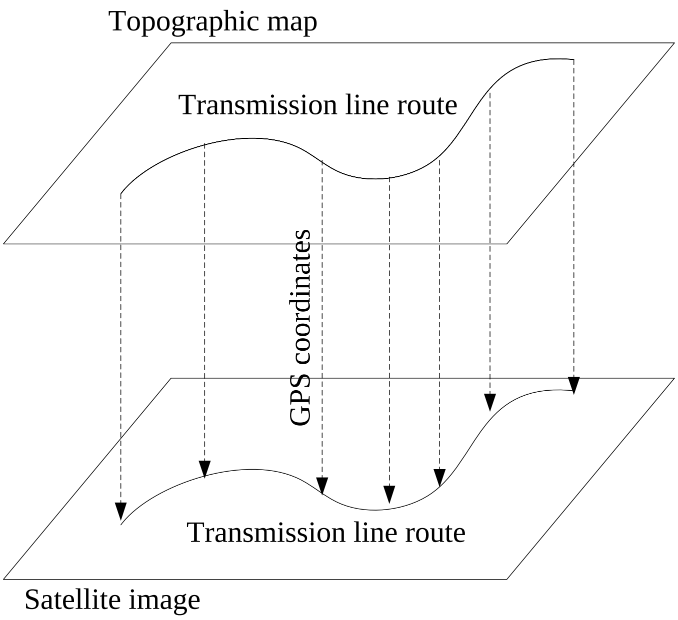


Fig. 5 GPS coordinate mapping

3 Unsupervised Classification

Two methods of classification are commonly used: Unsupervised and Supervised. The logic or steps involved can be briefed from this flow diagram as shown in Fig. 6.

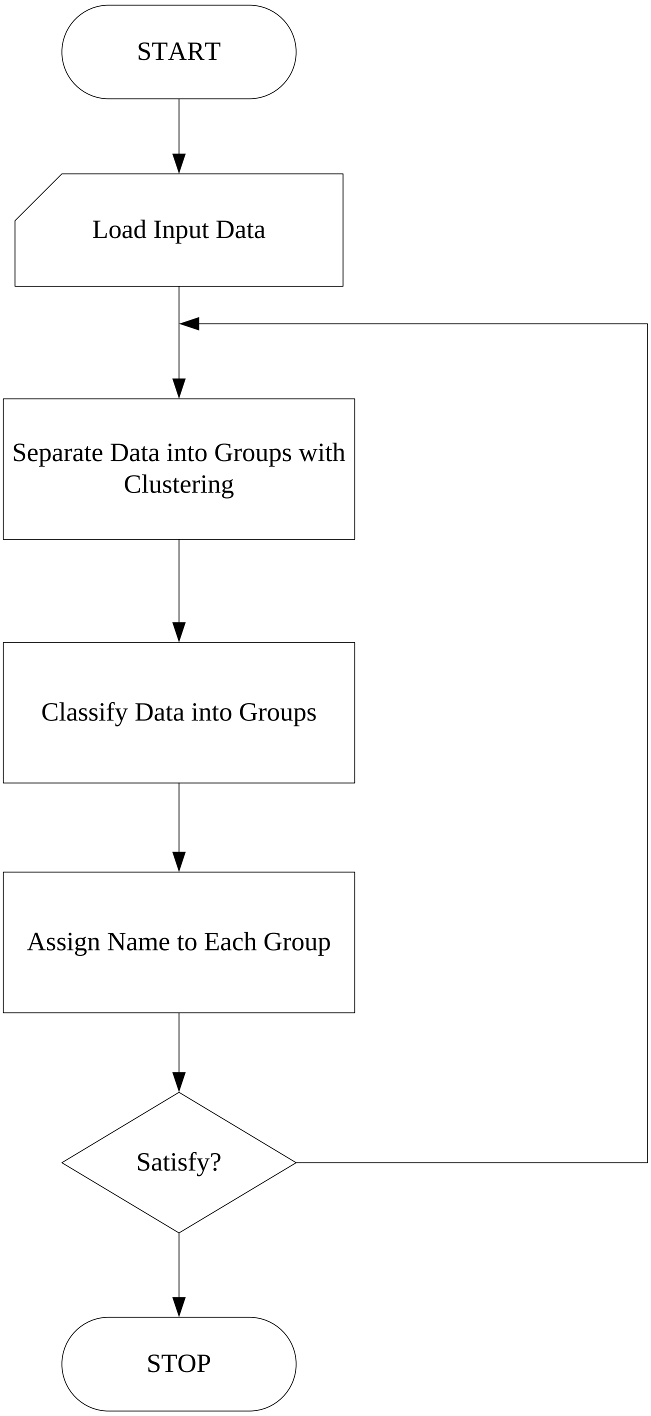


Fig. 6 Unsupervised classification

In contrast to the supervised classification, unsupervised classification requires very few inputs into the classification processes [15]. The computer selects natural groupings of pixels based on their spectral properties. However, an unsupervised classification algorithm still requires user interaction, however these occur after the classification has been performed. In unsupervised classification, the user attempts to assign information classes to the spectral classes the computer has created. Several potential problems exist. The first is that some of the classes may be meaningless as they represent a mix of different surface covers. In other instances, a single informational class may be split among two spectral classes. As with selection of training sites, it takes careful consideration and considerable knowledge to correctly label these spectral classes.

To date, several different unsupervised classification algorithms are commonly used in remote sensing [16]. The two most frequently used algorithms are the K-mean and the ISODATA clustering algorithm. Both of these algorithms are iterative procedures. In general, both of them assign first an arbitrary initial cluster vector. The second step classifies each pixel to the closest cluster. In the third step the new cluster mean vectors are calculated based on all the pixels in one cluster. The second and third steps are repeated until the change between the iteration is small. The change can be defined in several different ways, either by measuring the distances the mean cluster vector have changed from one iteration to another or by the percentage of pixels that have changed between iterations. The isodata algorithm has some further refinements by splitting and merging of clusters. Clusters are merged if either the number of members (pixel) in a cluster is less than a certain threshold or if the centers of two clusters are closer than a certain threshold. Clusters are split into two different clusters if the cluster standard deviation exceeds a predefined value and the number of members (pixels) is twice the threshold for the minimum number of members. The isodata algorithm is similar to the k-means algorithm with the distinct difference that the ISODATA algorithm allows for different number of clusters while the k-means assumes that the number of clusters is known a priori. The objective of the k-means algorithm is to minimize the within cluster variability. The objective function (which is to be minimized) is the sums of squares distances (errors) between each pixel and its assigned cluster center. Isodata, probably the most common unsupervised classification scheme, is the Iterative Self-Organizing Data Analysis Technique (ISODATA). ISODATA is an iterative unsupervised classification scheme. It has been developed with empirical knowledge gained through experimentation and requires relatively little in the way of human interaction. While implementations of ISODATA vary there is often some nominal inputs that need to be specified by the users.

4 Results and Discussion

In this paper, electric power distribution feeders of Nakhon Ratchasima area were used for evaluation of the unsupervised classification. Fig. 7 shows a topographic map of the test area.

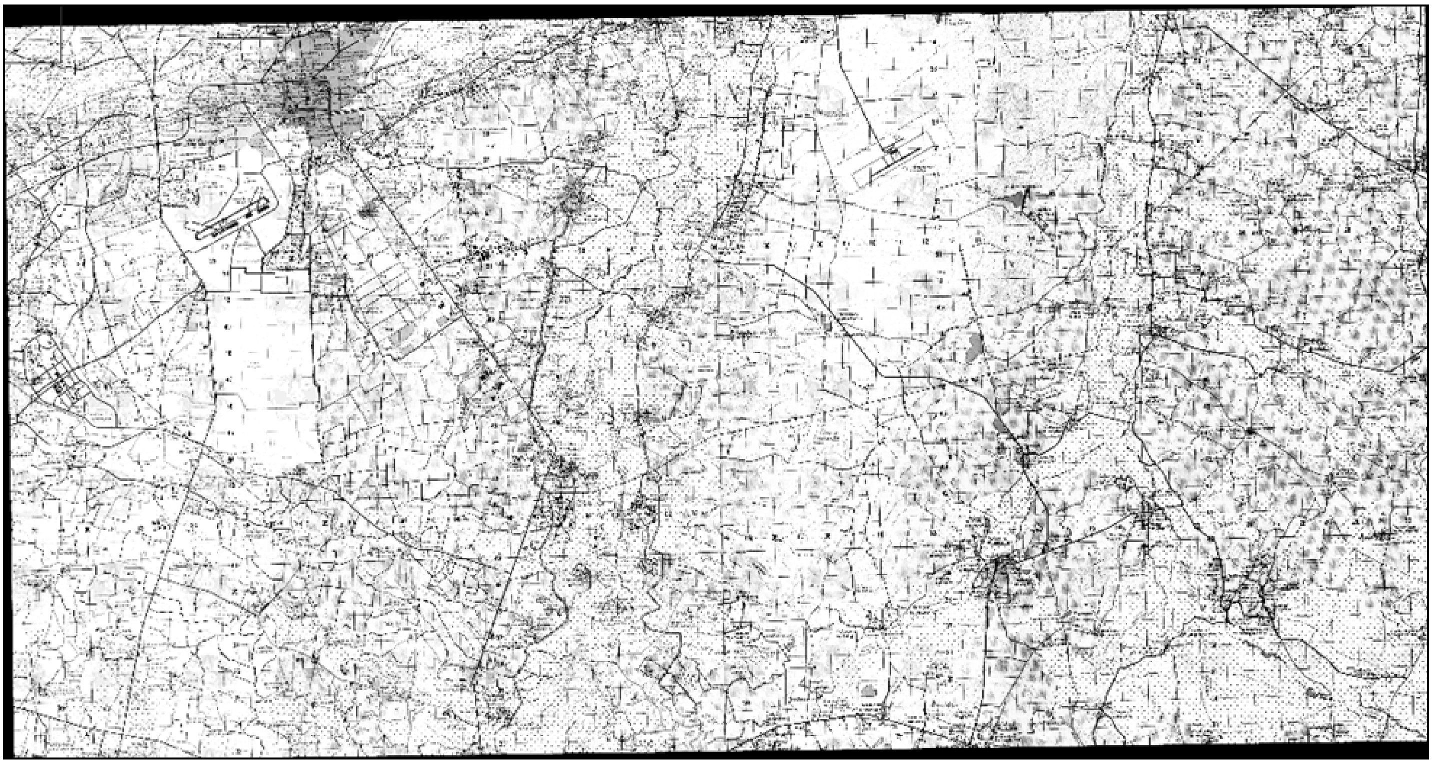


Fig. 7 Topographic map of the test area

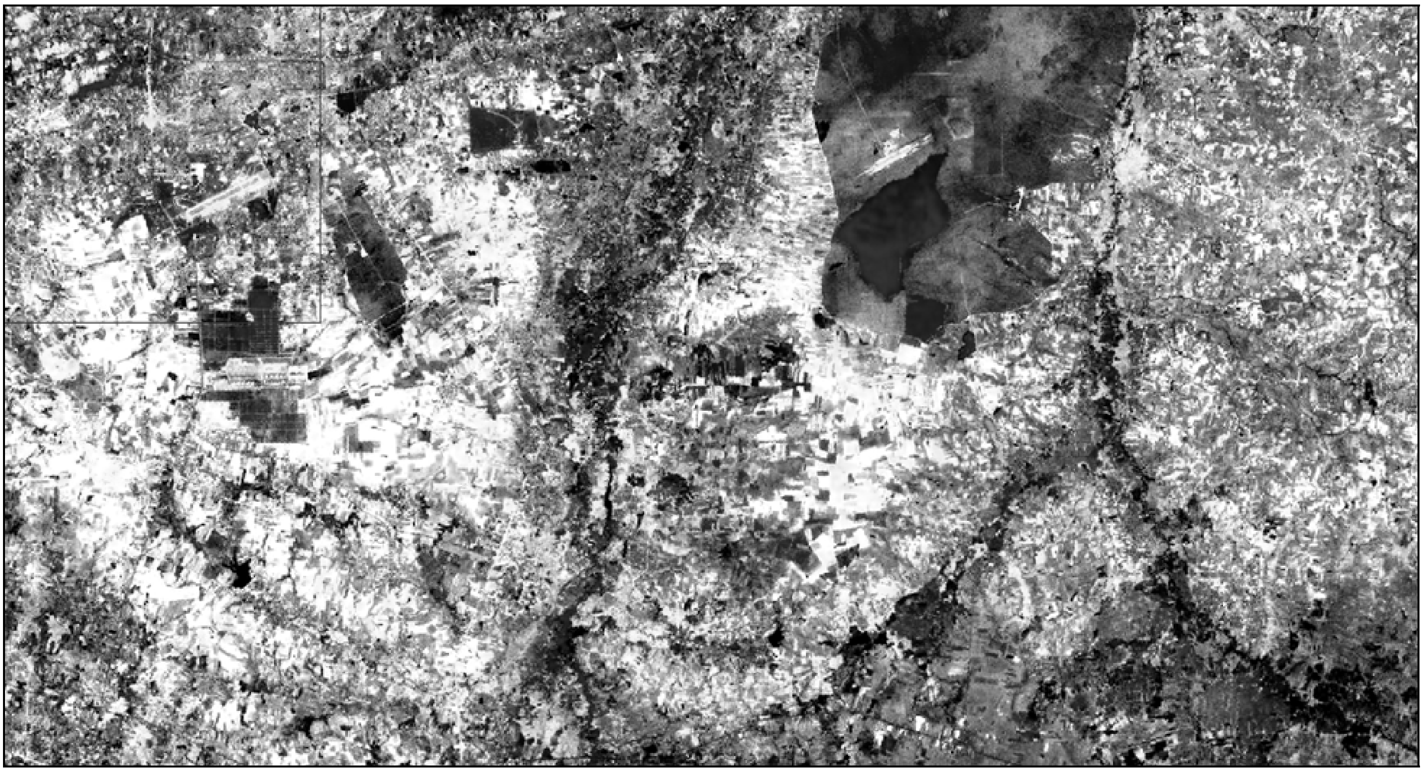


Fig. 8 Multispectral image of the test area (band4, 3, 2)

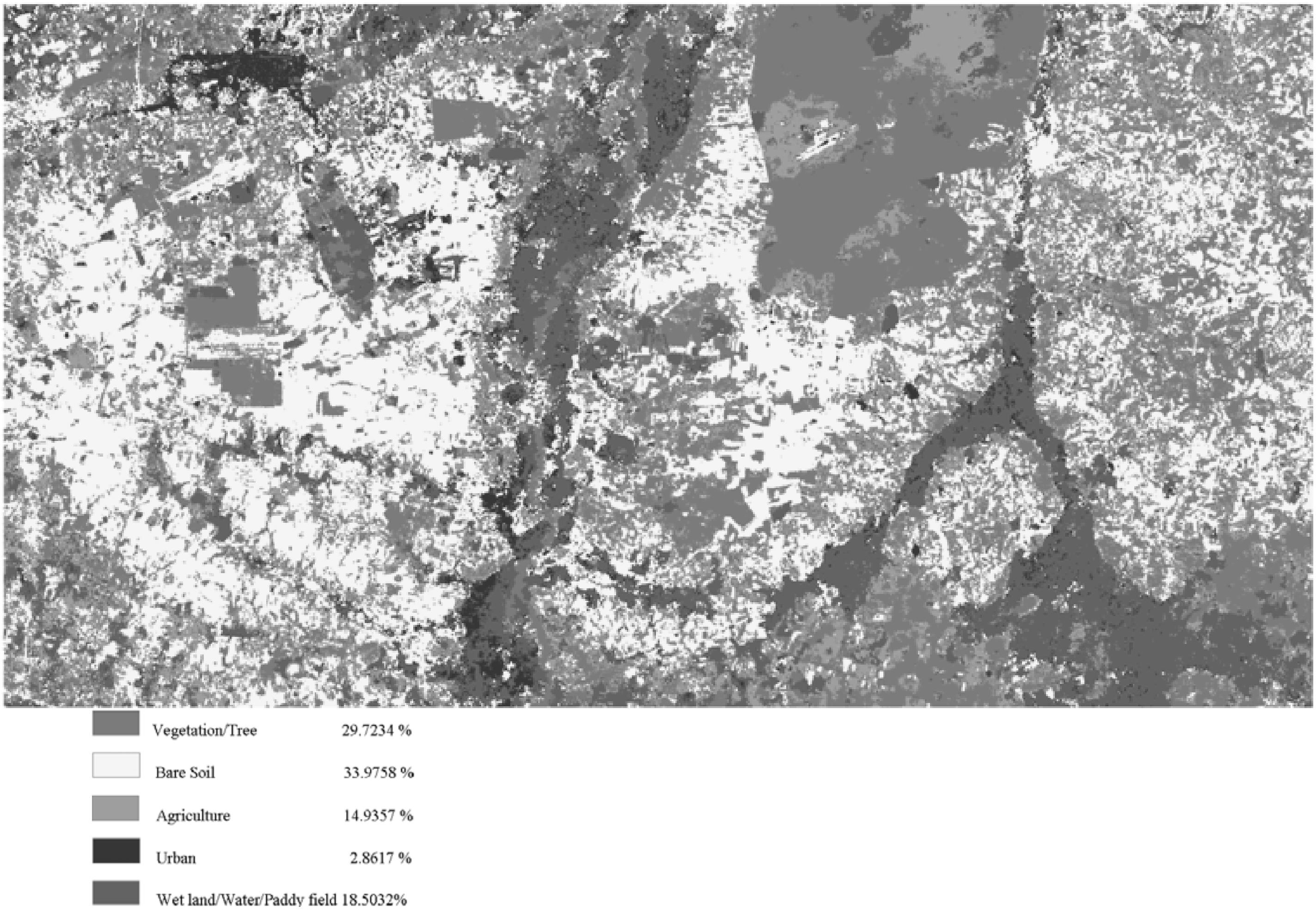


Fig. 9 Multispectral image after classification

By using ISODATA unsupervised classification, it can be partitioned areas into 5 zones: i) vegetation and tree, ii) bare soil, iii) agriculture, iv) wet/water/paddy fields, and v) urban as shown in Fig. 8. The result of ISODATA classification according to the five provided zones can be shown in Fig. 9. It consists of

Zone 1: Vegetation/tree	29.7%
Zone 2: Bare soil	34.0%
Zone 3: Agriculture	14.9%
Zone 4: Wet/water/paddy fields	18.5%
Zone 5: Urban (community)	2.9%

To achieve the goal of identifying the community, Zone 1 – 4 in the image must be separated. By keeping Zone 5 as the community zone, the two-color image rendering can be used to visualize zones of residences representing customer locations as shown in Fig. 10. The black color is the non-community while the lighter color showed the community areas. In this area, there are a number of medium voltage feeders to energize electric power to loads that are represented by community zones as shown in Figs 11-13.

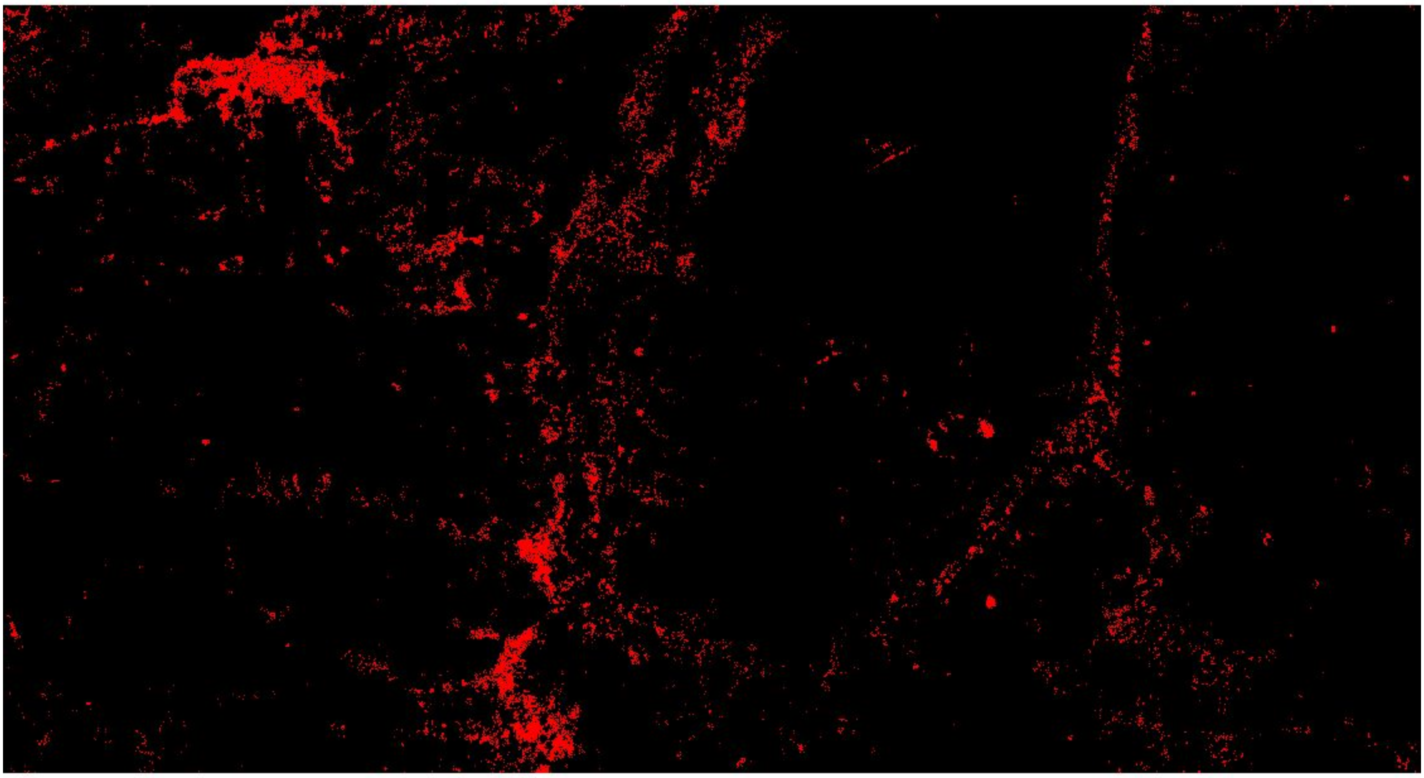


Fig. 10 Classification for community and non-community

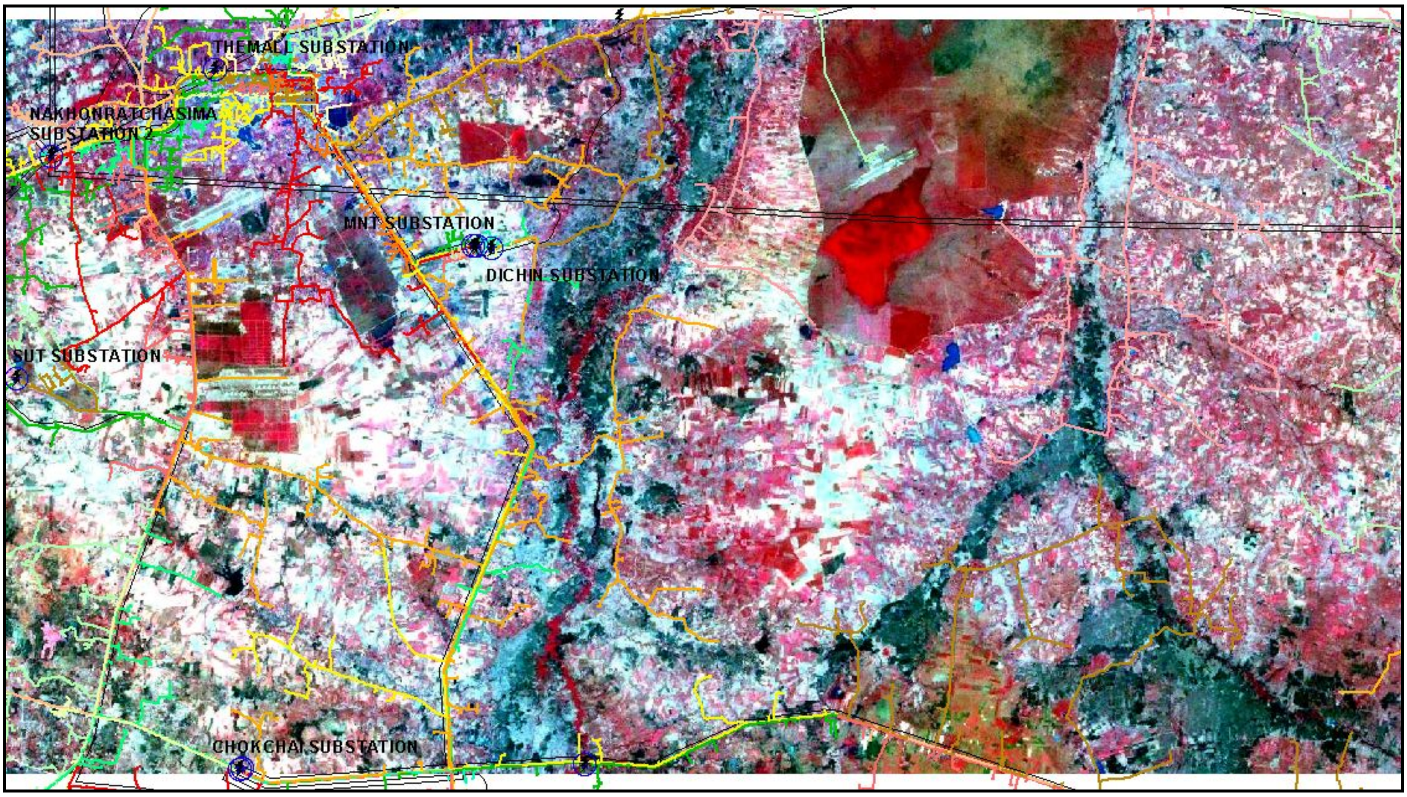


Fig. 11 MV feeders overlaying on the LANSAT 7 image of the target area

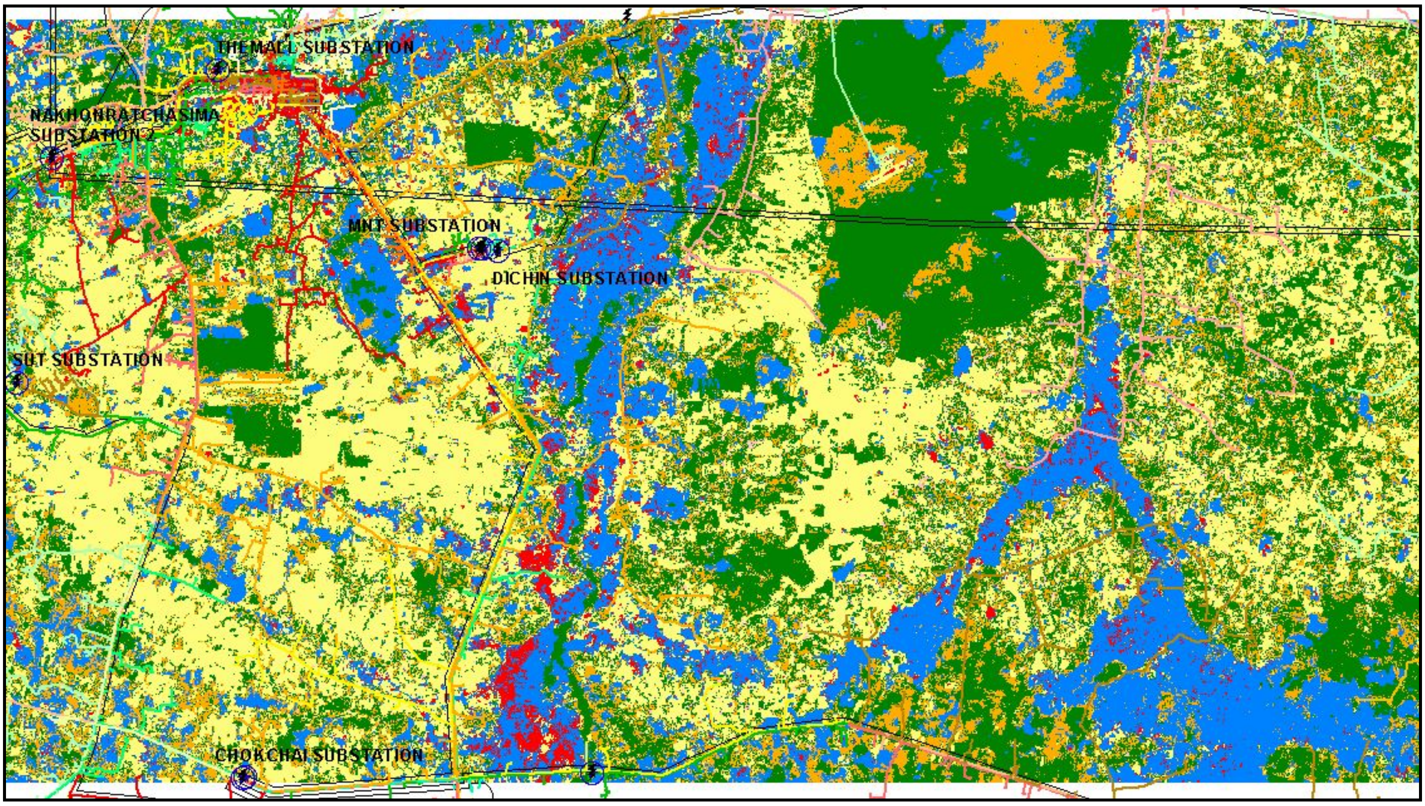


Fig. 12 MV feeders overlaying on the land use of the LANSAT 7 image of the target area

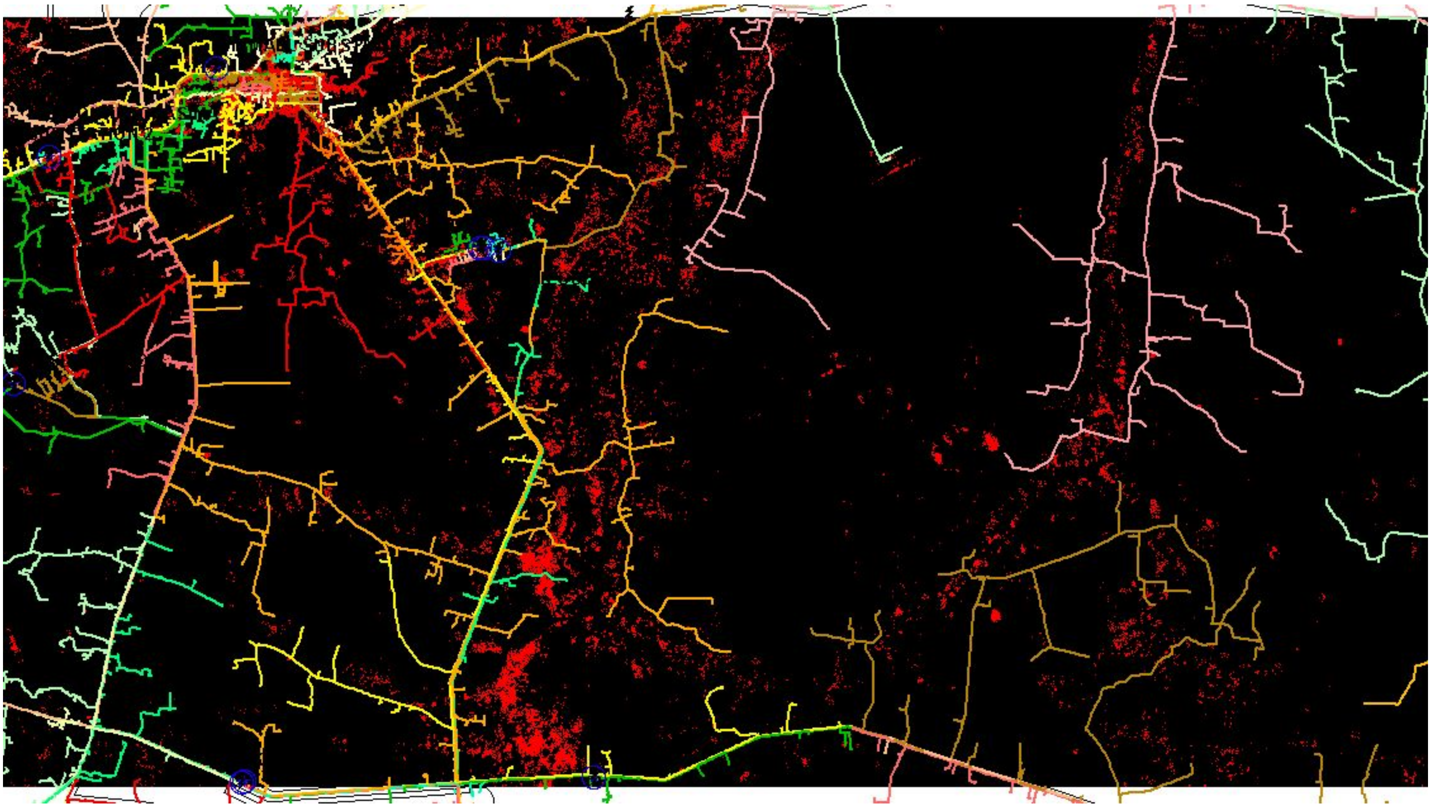


Fig. 13 MV feeders with communities

The ideal of using multispectral image classification is to distinguish community zones. The community identification can represent a densely populated area of customers that consumes a considerable amount of electric energy from the power supply grid.

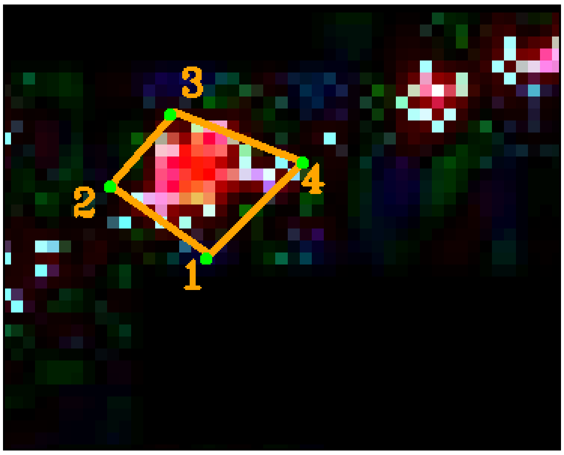
- **Verification of the classification results**

Verification of the classification results requires information of already known GIS areas. Matching between areas classified by the proposed method and land use information obtained by the topographic map was described according to the comparisons between two target areas, i) Nakhon Ratchasima 2 Power substation and ii) Bueng Tale area.

8.1 Nakhon Ratchasima 2 Power Substation

Table 1 GIS information for Nakhon Ratchasima 2 Power substation area

Point	GIS coordinate	
	Longitudes	Latitudes
1	190299.72E	1654555.64N
2	189245.72E	1655725.64N
3	189939.72E	1656175.64N
4	190839.72E	1654765.64N



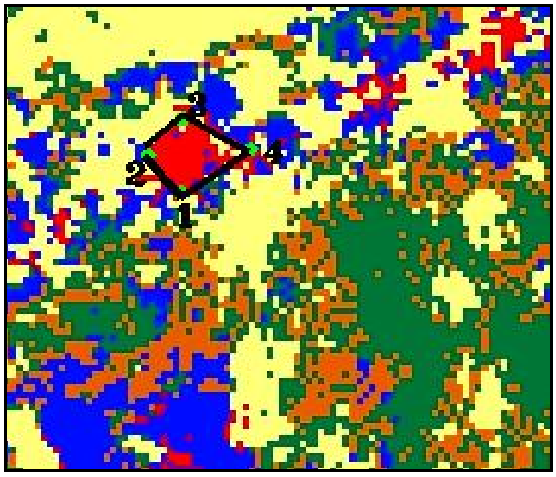


Fig. 15 Satellite image of Nakhon Ratchasima area

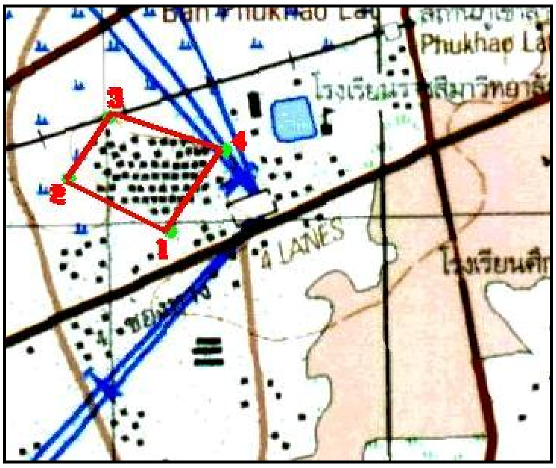


Fig. 16 Topographic map of Nakhon Ratchasima area

As shown in Figs 15-16, the target area was the square 1-2-3-4. The GIS coordinate of the square can be found in Table 1. This represented a community according to the result from the classification. It was confirmed by the square in the topographic map as shown in Fig. 16.

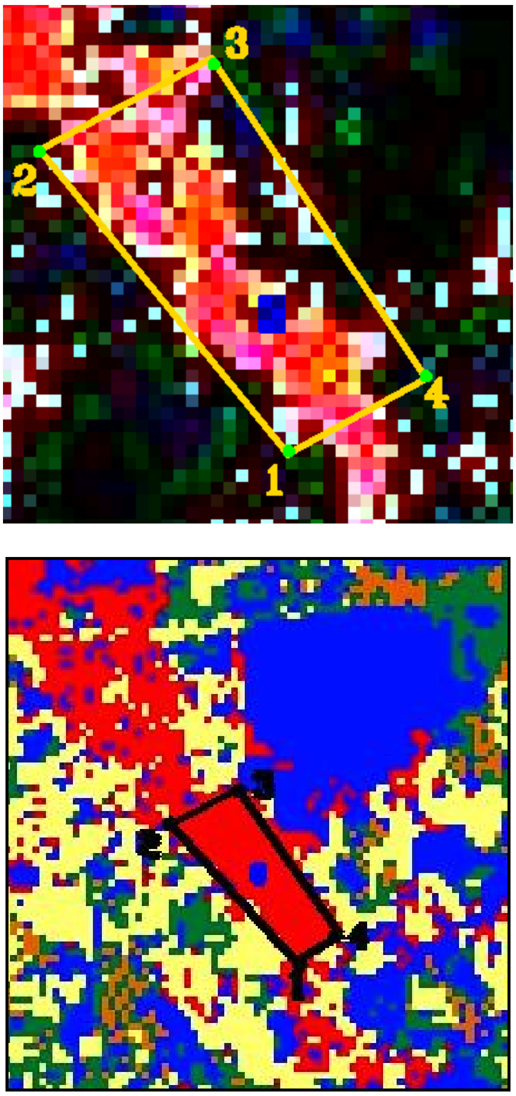


Fig. 17 Satellite image of Nakhon Ratchasima area

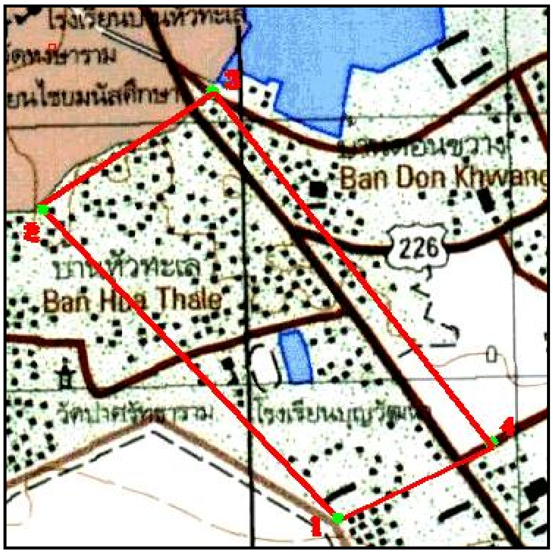


Fig. 18 Topographic map of Nakhon Ratchasima area

8.2 Bueng Thale Area

Table 2 GIS information for Bueng Tale area

Point	GIS coordinate	
	Longitudes	Latitudes
1	179259.72E	1654885.64N
2	178899.72E	1655005.64N
3	179079.72E	1655185.64N
4	179499.72E	1655095.64N

As shown in Figs 17-18, the target area was the square 1-2-3-4. The GIS coordinate of the square can be found in Table 2. This represented a community according to the result from the classification. It was also confirmed by the square in the topographic map as shown in Fig. 18.

8 Conclusion

In this paper, topographic maps and satellite images were exploited in order to extract some key information describing power distribution systems, located on the maps. The application demonstrated here was the identifying community that can be used to estimate groups of customers along the power distribution feeders. A 22-kV power distribution system in province of Nakhon Ratchasima was used as a case study. As a result, exploitation of satellite image processing was very helpful. Power distribution engineers can visualize locations of their local customers without doing field surveys that are time-consuming and very expensive.

As satellite imaging is a powerful tool, our research could be extended to employ satellite image processing techniques in various fields. Power distribution planning is one of applications that can gain this work results.

References:

[1] W. Elshorbagy and A. Elhakeem, Risk assessment maps of oil spill for major desalination plants in the United Arab Emirates, *Desalination*, Volume 228, Issues 1-3, pp. 200-216, 2008

[2] X. Jin and C. H. Davis, An integrated system for automatic road mapping from high-resolution multi-spectral satellite imagery by information fusion, *Information Fusion*, Volume 6, Issue 4, pp. 257-273, 2005

[3] G. Finnveden and A. Moberg, Environmental systems analysis tools – an overview, *Journal of Cleaner Production*, Volume 13, Issue 12, pp. 1165-1173, 2005

[4] Y. Nishigami, H. Sano and T. Kojima,Estimation of forest area near deserts — production of Global Bio-Methanol from solar energy, *Applied Energy*, Volume 67, Issue 4, pp. 383-393, 2000

[5] G.P. Patil, W.L. Myers, Z. Luo, G.D. Johnson and C. Taillie, Multiscale assessment of landscapes and watersheds with synoptic multivariate spatial data in environmental and ecological statistics, *Mathematical and Computer Modelling*, Volume 32, Issues 1-2, pp. 257-272, 2000

[6] T. Luemongkol, A. Wannakomol and T. Kulworawanichpong, Rerouting electric power transmission lines by using satellite imagery, *WSEAS Trans. Environment and Development*, Issue 2, Volume 5, pp. 189 – 198, 2009

[7] H. Roosta, R. Farhudi and M.E. Afifi, Comparison between sub-pixel classifications of MODIS images: linear mixture model and neural network model, *WSEAS Trans. Environment and Development*, Issue 2, Volume 4, pp. 161 – 168, 2009

[8] V. Barrile, G. Armocida and F. Di Capua, Advanced thermatic mapping: GIS/neureal networks application for tracking isoseismic lines, *WSEAS Trans. Environment and Development*, Issue 6, Volume 9, pp. 435 – 444, 2009

[9] K. Norsangsri and T. Kulworawanichpong, Application of satellite image processing to earth resistivity map, *The 9th WSEAS International Conferences on Power Systems*, 3-5 September 2009, Budapest, Hungary, pp. 137 – 141

[10] C. Elachi and J.V. Zyl, *Introduction to the physics and techniques of remote sensing*, Wiley-Interscience, 2006

[11] http://maps.google.com/

[12] I. Kim, D. Jung and R. Park, Document image binarization based on topographic analysis using a water flow model, *Pattern Recognition*, Volume 35, Issue 1, pp. 265-277, 2002

[13] http://www.lyovic.com/

[14] E. Mok, A fast GPS-based system for survey check of road alignments, *Advances in Building Technology*, pp. 1637-1643, 2002

[15] Tutorials the environment for visualizing images, ENVI version 3.2, July, 1999

[16] Yanfei Zhong, Liangpei Zhang, Bo Huang and Pingxiang Li, An unsupervised artificial immune classifier for multi/hyperspectral remote sensing imagery, *Geoscience and Remote Sensing*, *IEEE Transactions,* Volume 44, Issue 2, pp. 420- 431, Feb. 2006