Spatial Composition and Configuration Changes in the Bangkok Metropolitan Region Landscape

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ABSTRACT

Bangkok and five provinces in the vicinity, called Bangkok Metropolitan Region, BMR, occupies 7,650 Square Kilometers of the most significant delta area and productive agricultural lands of Thailand. According to 2012 database of the Land Development Bureau, Thailand, the BMR has more than 140 types of land-use classifications related to various agricultural usage; paddy fields, crop fields, orchards, perennial plots, horticulture, farming facilities and aquaculture lands. It could be said that BMR's surrounding landscapes, the richness of patches and the diversity of ecology are defined by complex patterns of mixed land-uses. The goal of this study is to understand the overview of BMR's ecological landscape and its changes. By studying landscape ecology, by focusing on agricultural land-use change, and by using the computer software analysis "Fragstats", the changes of landscape metrics reveals that BMR's ecological landscape patterns have previously been more complex. Each selected BMR landscape has changed its pattern and has unique spatial characteristics. It also appears that the loss of landscape diversity is possibly related to the increased dissimilarity of landscape composition. The Ecological landscape metrics were used as research parameters to reveal spatial characteristics of the complexity of ecological landscapes in the Extended Metropolitan Region.

Keywords: *Bangkok Metropolitan Region, Landscape Metrics, Fragstats*

BANGKOK AS AN URBAN REGION OF HETEROGENEOUS LANDSCAPES

From an ecological landscape perspective the urban region is a combination of the metropolitan area of continuous built land and the surrounded urban ring, a green space mosaic with scattered building, villages, towns, and satellite cities. Historically the urban region was studied and planned using these classic models: "Zones of Influence" known as von Thunen bands or Christaller's "Central Place Theory". In Southeast Asia and today's China, McGee's "Desakota" is also being used as a model to develop theories and an understanding of change. The Bangkok Metropolitan Region is an interesting case study where the fast growth of urban sprawl and economic development has created an impact on productive agricultural land and the complex ecology of the delta area. This study of the changes in BMR's land-use is expected to encourage further regional planning in Thailand using the spatial environmental conditions and ecological landscape approach.

According to the official regional organization and administration of Thailand, the Bangkok Metropolitan Region includes the area of Bangkok and its five vicinity provinces- Nakhon Pathom, Pathum Thani, Nonthaburi, Samut Prakan and Samut Sakhon. This Metropolitan Region is also called "Greater Bangkok" or "*Phak Mahanakhon"* (ภาคมหานคร) in Thai. The BMR is considered a national strategic development area because although it is a primate region that occupies only 1.5 % of national land it has reached 22.6 % of the nation's population according to the 2012 census. The average density is also 14 times higher than the national mean. All BMR territories are administratively independent where hundreds of small autonomous governances are assembled. Due to the current decentralization policies, the BMR is experiencing fractal physical development because

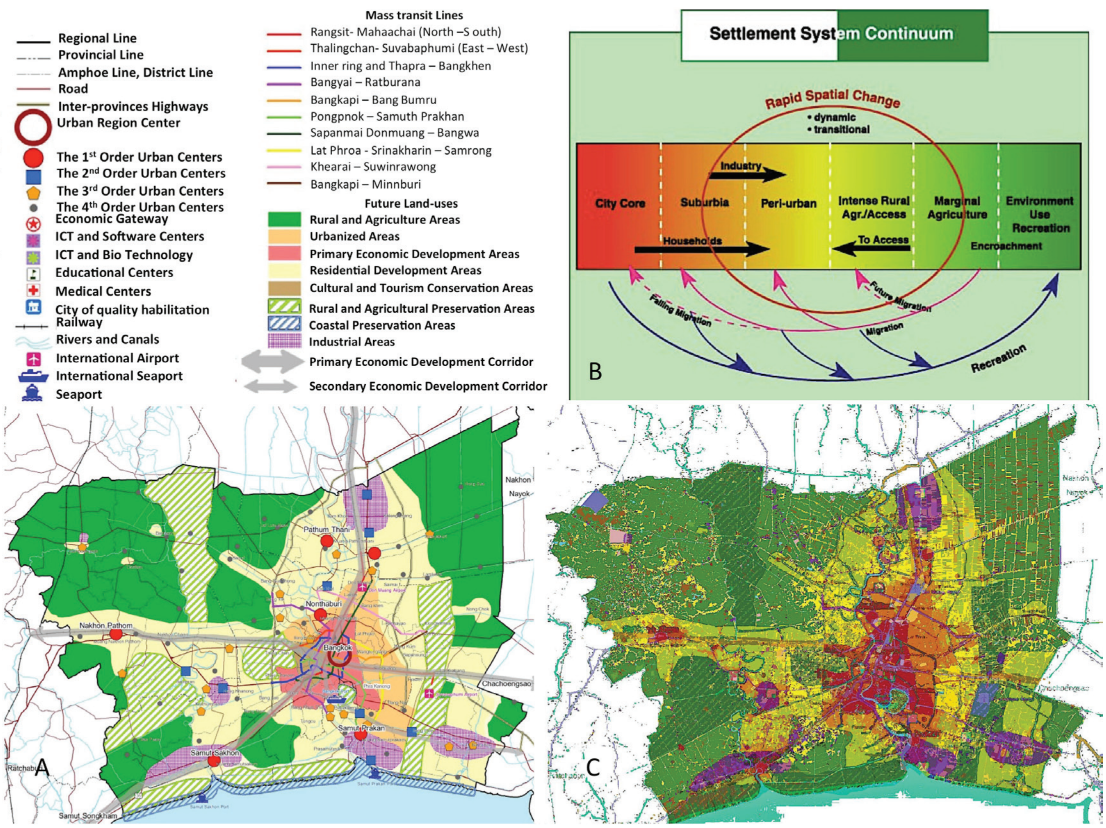

Figure 1:
(A) 2057 BMR development plan by DPT, Thailand, (B) Webster's Urban-rural Continuum in Thailand,
(C) Overlay 2057 BMR development map by DPT on 2012 11-categories land-use map by LDD

the local governments at the township level or *Tambon* have to depend on themselves in preparing their own comprehensive plans. On the other hand, the BMR's administrative system is dominated by the one and only Thai primate local government, the BMA, Bangkok Metropolitan Administration. (Ratanawaraha, 2010)

To respond to the rapid growth of the 1990s, in 2004, the Department of Public Works and Town Planning- the Ministry of Interior, Thailand- (DPT) instituted the 2057 BMR development plan. Expectations is that the 2057 BMR population will reach 12.4 million, thus this policy purposed the conceptual ideas of a compact city surrounded by high quality urban agriculture, sufficiency in economy, and development distribution throughout the region. To balance urban development and conservation, this plan purposed the future structure of the region with the spatial configurations of 4 types of urban development areas; 1) Fully developed areas, 2) Areas under urbanization process, 3) Rural areas under urbanization, and 4) Rural areas. The plan also included four types of urban centers; 1) a National center, 2) Regional centers, 3) Provincial and District centers, and 4) Centers of rural and agricultural lands. According to this plan, the whole metropolitan region will be decentralized with various types of sub-centers and satellite towns. These would be connected by low-density residential zones and road networks, turning the agricultural landscape into smaller pieces. (The Department of Public Works and Town Planning, 2004) It is noted that the registered population of the BMR already reached 10.5 million by 2013 and the population exceeded 14.56 million by the year 2010.

Unlike the perceptions of the political administrative boundary, Webster points out that Bangkok's economics have been extended as an economic dynamic region from Eastern Seaboard (ESB) to the other side of Thai gulf known as Thai Riviera sub-region. (Webster, 2003) (Suwat Wanisabut, 2006) Furthermore, based on McGee's "Desakota" theory,

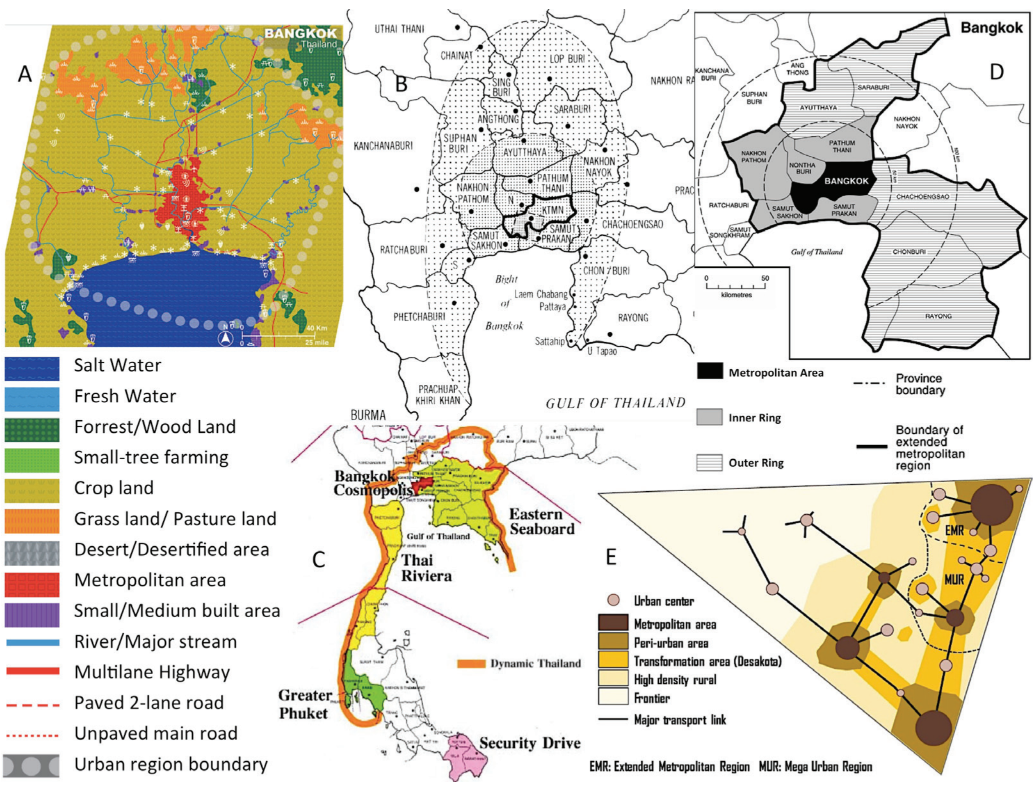

Figure 2:
(A) Forman's Bangkok Urban Region, (B) The Bangkok Mini-megalopolis by in-migration (Sternstein, 1976),
(C) Webster's Thailand Dynamic Region, (D) Gawin's Bangkok Mega-urban region, and
(E) McGee's Desakota Diagram modified by Rodrigue

Webster's study considers the area a "peri-urban" based on the unique and associate character of ASEAN's urban extension definition. With 190 km. extension from Bangkok through ESB, it represents the Thai model of peri-urbanization. (Webster & Muller, 2004)

On the contrary, the size of Thai metropolitan region, based on Richard T.T. Forman's landscape ecological perspective, is larger than 20,000 Km^2 or about 2.6 times bigger than an official size of the BMR. Using Forman's concept the BMR includes the 80-km extended area from Bangkok's city center, the complex system of the delta areas of 4 rivers and dominated cropland. Forman, (2008), indicates that the basic principle of urban regional planning or metropolitan regional planning along with ecological planning is to consider the land-use and land cover of whole region as "Land Mosaic". Forman defines an urban region as a land or territory where the urban area and its surrounding have close interrelationships. Therefore, the boundary of the urban region could be defined with flow or movement from the urban center to vicinities. For the urban region where the population is 250,000 to 10 million, this area could be classified into 4 sections: 1) Major City, 2) Metropolitan Area and Continuous Built Land, 3) Inner and Outer Satellite Cities, and 4) Urban-region Ring with the compounds of land mosaic, green space, villages, distributed constructions, and towns. (Forman, 2008)

Several scholars have explained the BMR spatial conditions in terms of growth, changes, and relationships between spatial elements and socio-economy development. McGee and Greenberg presents the BMR sectors' economics and population growth compared with other ASEAN cities and other Thailand regions. (McGee & Greenberg, 1992) Jones also compared Bangkok with other two ASEAN mega-urban regions, Jakarta and Manila, in terms of population projections, size of spatial expansion, socio-economic conditions, and development of infrastructure to predict the future of these urban regions. (Jones, 2002) Tonmanee and Kuneepong noticed that BMR's environmental problems stem from the change of land-use structures throughout the region. These problems require pollution controls and stakeholders' involvements. (Tonmanee & Kuneepong, 2004) Based on historical review, Jarupongsakul and Kaida illustrated 300 years of Chao Phraya Delta development. This delta compound is the area of 4 rivers and the location of today's BMR. In relation to the direction of national development before 2000, Jarupongsakul and Kaida pictured the 2020 landscape of the BMR as "Satellite Cities". The 2020 BMR became a "Multipolis" connecting the centers through the use of high speed trains and road networks. (Jarupongsakul & Kaida, 2000) Summaniti and et al. mentions spatial structures to the west of BMR that are based on the delta structures of rivers, canals, orchards, floating markets, and modern urbanized areas using data from 1903 - 1913, 1968 – 1975 and 1998 – 2001 analyzed at1:50,000. (Summaniti, Peerapun, & Paksukcharern, 2012) Suwanarit also pointed to the morphology of the east BMR, Rangsit area, based-on historical reviews of the paddy land expansion along manmade irrigation systems and modern urban agglomerations on peri-urban agricultural land. (Suwanarit, 2010)

Bangkok has similarities with Tokyo and Seoul, two mega Asian cities. Yokohari and et al. (2002) denotes that these metropolitan regions have green belt areas. Unlike these two cities and some European cities, the green belt of Bangkok is disconnected and not prepared to control urban growth. Bangkok's green belt is a so called rural and agricultural conservation zone that allows low-density development and urban sprawl to flourish. Referring to McGee's Desakota, and Yokohari the unique characteristic of BMR's green belt is vernacular landscape. This kind of landscape has high resiliency and sustainability for populations on the urban fringe. Yokohari and others also suggests that the environment of the 21st century should control the mixture of urban and rural landscapes. The BMR's green belt could provide multifunctional support for urban requirements such as ecological balance, recreation and healthy environment, and even Sunday farmers' activities. (Yokohari, Takeuchi, Watanabe, & Yokota, 2000)

"Amphibious City" and "Liquid Perception" are Brian McGrath's and Danai Thaitakoo's perception of Bangkok and its vicinities. McGrath and Thaitakoo points out that Bangkok has changed from a water-based city to a land-based city. The landscape of Bangkok and the BMR was a productive arable land because of landscape diversity. Bangkok was connected to the surrounding areas through a complex river, canal, and wetland system. People's lives, agricultural patterns, and eco-system were a symbiosis. For their perception of "Amphibious City", McGrath and Thaitakoo noted that the landscapes of the BMR had positive interactions with natural areas, urbanized areas, and agri-lands. They cited the cases of the orchard-ditch system on the west side of Bangkok and rice paddies in the north and east side of Bangkok as examples of how one kind of infrastructure could serve more than one purpose. In the Bangkok delta, water-based systems served all of the demands that could be gained from modern infrastructures: transportation, irrigation, recreation, utility and consumption. (McGrath & Taitakoo, 2010)

In *"Tasting the Periphery: Bangkok's Agri- and Aquacultural Fringe",* McGrath and Thaitakoo (2005) mentioned the loss of productive food-scapes throughout the BMR due to the modern infrastructures of expressways. They used the emergence of Kanchanaphisek ring road as the case where new modes of transportation lead to new settlements and land-uses occupying the green spaces on the urban fringe. Each part of the road would cause changes to urban agriculture and aquaculture in different degrees. Referring to Steward Pickett's "Ecology Patch Dynamics", McGrath and Thaitakoo indicate that even "the disturbance" was a part of ecological matrix. The natural disturbances, such as big flood or bush fires, help balance the number of species and diversity of the ecosystem. Although this leads to patch dynamics, rapid man-made disturbance could cause the extinction of some species thus leading to the loss of natural balance and resiliency. (McGrath & Thaitakoo, 2005) The BMR is experiencing disturbances from rapidly built-up areas that are emerging due to lack of proper urban development controls and spatial development database.

Based on landscape ecology perspectives, this study aims to investigate spatial structure, landscape composition and configuration of the BMR and to focus on land mosaic, patch, corridor, and landscape matrix. Referring to patch metrics studies, this study manipulates spatial data of the Land Development Department (LDD), the Ministry of Agriculture and Cooperation, Thailand, which is the same database used for present national agricultural zoning projects. For academic purposes, this data was divided into three different data collection time periods - 2000 – 01, 2006 – 07, and 2011 – 12. The data details also include land-use and land cover of the whole BMR and included the third level of data detail classified by LDD. (For example, the third level of agricultural land-use provides details about types of plantation.)

Devoted to a spatial change study at the metropolitan scale, this research selects Fragstats as the analysis tools. 18 land mosaic indicators are selected as the primary metrics to quantify landscape patterns of three study modules on two levels: 1) the whole BMR landscape level and 2) land-use class level (focused on 5 land-use classification- agriculture land, urban villages or gated community area, semiagri-land and village, high and medium urbanization area, and industrial land). All 18 Fragstats metrics would be classified into five simple categories; area and edge metrics, shape metrics, contrast metrics, aggregation metrics, and diversity metrics. The three study modules are classified according to the aims of the study. The first module is the whole BMR landscape as a controlled module. The second module is the set of cropped areas referred to the 2057 BMR development plan, planned and purposed by the DPT. This module contains nine sub-landscapes referring to future land-use zones. The last module is the set of seven selective areas along the second ring road of the BMR to investigate the impact of land-based infrastructure on peri-urban landscapes within the same distance.

FRAGSTATS METRICS AND ECOLOGICAL LANDSCAPE STUDY

The Fragstats program is a well-known freeware computer program for landscape ecology study. Strongly referring to Forman's landscape ecology theory, the second version of the program was developed by Kevin McGarigal, an ecologist and Professor at University of Massachusetts, and Barbara J. Marks, a computer programmer from the University of Oregon. The early version of the software was created and distributed for USA forestry studies, supported by the Department of Agriculture, USA. (McGarigal & Marks, 1995) This program has been developed to be compatible with ArcGIS software. The current software is version 4.2. In reference to 1986 Forman's and Godron's definition of landscape, McGarigal determines that the landscape is an area or territory comprised of a mosaic of patches and other landscape elements. Therefore, the basis of the Fragstats matrix is to consider landscapes in terms of habitat patches. and It was designed to study three aspects of ecological landscapes: 1) landscape ecology structure, 2) functions of landscape elements, 3) changes of Ecological Mosaics. The program was also designed to study not only landscape structure, but also patch and class composition, patch richness, patch evenness, and patch diversity. In addition it investigates quantitative configurations of patches and classes of the landscape. In the program, there are dozens of metrics or indicators to be selected. It is incumbent upon the researcher to understand the purposes and uses of all the different Fragstats metrics and to realize what are the proper levels or proper scales of the metrics. The scales of the metrics are from “cell”, “patch”, “class”, and the whole landscape.

In 1995, Forman discusses how to apply landscape ecology to land-use planning and to study landscape in urban-region ring. In *“Land Mosaic: the Ecology of Landscapes and Regions”*, Forman points out that even though landscape ecology in each area of the world was diversified and complex, it could be simply understood with three simple spatial elements (Forman, 1995):

1) Patch or the piece of land, which is homogenous in a dominant type of land-uses, land covers or ecological systems.

2) Corridor, which is a long piece of land where it is homogenous in a dominant type of land-use, land covers or ecological systems.

3) Matrix, which is the logical coordination and functional systems between patch and patch, patch and corridor, or corridor and corridor as a landscape system or land mosaics.

Forman strongly noted that the researcher needed to be concern about the spatial scale of study area because the different scales of the landscape level be they- global, continental, national, regional, sub-regional, or even one small piece of land,- has its own landscape matrix based on various species and their habitats. Furthermore, to understand regional landscape ecology as a spatial science, the study has to consider that in a region there could be a compound of several smaller-scale landscapes or ecological systems. All of the systems have their own unique spatial arrangements or spatial patterns referencing ecological exchange and complex habitat systems

There are several studies and reports to which the Fragstats landscape metrics are applied. It is used as a significant tool, or used and then compared with other tools to investigate structure, function, and the process of the phenomenon of urban and landscape changes in various scales, sizes, and locations. For future environmental planning, the CORINE program is used to report the environmental conditions based-on LULCC (land-use and land-cover changes) of 11 European Community Countries. The CORINE report used only five simple metrics- PD, ED, NC, SHDI, and IJI- to compare spatial conditions of the EU countries. (European Union, 2000) Uuemaa and et al. gave a general explanation for the whole picture of Estonian landscape. The authors referred to 21 land-cover classifications in 35 sampling sizes, 15 km x 15 km, and analyzed 15 landscape metrics. (Uuemaa, Roosaare, Oja, & Mander, 2011) Focusing on an urban expansion study, Pham and co-authors wanted to evaluate and compare the characteristics of urban composition of four cities: Hanoi, Hartford, Nagoya, and Shanghai. By applying seven landscape metrics as measurement, their discussions were based on the changes of spatial quantity and significant directions of planning and land management legitimating the study areas. They found that all four cities had unique patterns of landscape metrics. (Pham, Yamaguchi, & Bui, 2011) Southworth and et al. aimed to compare classification-based techniques (Discrete Data) with the use of vegetation indices (continuous data) and to examine the patterns of landscape fragmentation and land cover change, focusing on forestry classification. Eight class metrics were applied to compare with NDVI-based analysis. The authors found that both methods were complementary to each other. (Southworth, Munroe, & Nagendra, 2004)

In relation to the principle of “Sustainable Land Planning and its Application”, Leitao and Ahern (2002) made a critical review in reference to many renowned experts’ ideas such as 1985 Fabos’s and 1990 Steinitz’s landscape planning or 1995’s Forman’s and Zonneveld’s landscape ecology. Leito and Ahern’s paper recommended ten critical landscape composition metrics. Each metric is fit to a different theme or phases of planning. (Leitao & Ahern, 2002) Also based on sustainable landscape direction that combines natural capital and socio-economic development, is Blaschke’s paper which highlights elucidate spatial concepts for sustainable landscapes with an emphasis on the role of GIS. The virtue of this research on Fragstats application is to connect a wide range of spatial metrics to particular spatial research questions, to sustainable landscape parameters, and to generate criterion for structural assessment. Almost 20 metrics were introduced. (Blaschke, 2006) Kong and et al. studied green space connectivity with graph theory and gravity model. They chose part of Jinan City, Shandong, China, as their case study and five Fragstats metrics were applied as the primary tool to predict habitat connectivity by investigating landscape structure and patch cohesion patterns of green space. (Kong, Yin, Nakagoshi, & Zong, 2010) This was done by simply quantifying changes in the urban growth patterns, but the results of the study became more complex when these class-based metrics were applied to a future scenario study. Aguilera and et al. compared 2004 spatial data with three simulated future scenarios in 2020 and made interpretations based on four characteristics of urban land-use found in European cities. (Aguilera, Valenzuela, & Botequilha-Leitão, 2011) In 2005, in the early days of LULCC research and Fragstats application, Herold, Couclelis and Clarke used examples from the urban area of Santa Barbara, California, to combine remote sensing and spatial metrics to improve urban modeling: spatial structure and changes. The authors suggested that the studies of urban analysis, urban process required tailored or signature spatial metrics and improvement of remote sensing mapping products. (Herold, Couclelis, & Clarke, 2005)

To detect and compare the variations of urban sprawl trends across the metropolitan, county, and city scales, Ji, Ma, Twibell and Underhill's research studied the correlation between classes of metrics of built-up, forestland, and other vegetational land to study the effect of urban development.. The research also investigated another correlation between distances of built-up areas to the urban core to compare the construction-based indices of land-consumption to conventional population-based indices. (Ji, Ma, Twibell, & Underhill, 2006) Tian, Jianf, Yang and Zhang applied ten simple class metrics to investigate the spatial and temporal dynamic patterns of urban growth of six rapidly urbanized areas of the Yangtze River Delta (YRD) megalopolitan regions in China: Shanghai, Nanjing, Suzhou, Wuxi, and Changzhou. Metric analysis showed that different characteristics of YRD megalopolis expansions and coalescence processes differed in each period of study . (Tian, Jiang, Yang, & Zhang, 2011)

Based on a key concern of landscape ecologist and especially of the forestry landscape fragmentation, Millington and Bradley (2008) matched and correlated three simple class metrics to the phases of land management, settlement, and cultivation 3 three old communities in the Chapare region of Bolivia, in the Amazon Basin, to investigate the impact of infrastructure development (road) and human settlement (farming and urbanization) on forest areas. (Millington & Bradley, 2008) Crew (2008) used a case study in rural area of Thailand to review the successes, limitations, and possibilities of enriching LULCC research. Crew found that the paneled-pattern metric approach, or longitudinal method: following the same subjects over time and detecting the change, provided means for exploring stronger linkages to process and function from patterns. (Crews, 2008) To analyze the landscape fragmentation of the study area, Pechanec and et al. introduced TECI metrics to increase dissimilarity patterns of neighboring patches in the landscape mosaic. (Pechanec, Jelínková, Kilianová, & Machar, 2013)

METHODOLOGY

After several reviews, the study focuses on change and spatial patterns of land-use only in the first and the second levels of data. To correctly compare data from the different periods of time the study chooses only the second level of data as the primary focus of this research. Data from 2001 will be closely analyzed as that is the first year of LDD data collection and processing. The data was classified as two separate areas, that of irrigation supply and none-irrigation supply. Therefore, the study has to aggregate the three levels of land classification into 11 classes or types of land-use: 1) City and Town or High and Medium Density Urbanized Land, 2) Land Occupied by Urban Villages and Gated Community, 3) Agricultural Land Mixed with Rural Villages or Low Density Residences, 4) Agricultural Land, 5) Industrial Land, 6) Land for Transportation and Public Utility Supply, 7) Institutional Land and Government Bureau, 8) Water Bodies, 9) Meadows, Swamp, Rocks, Pits, or Garbage-dump Sites, 10) Public Parks or Recreation Land, and 11) Forrest, Bushes, or Mangroves. In this study, the first five land-uses are the main focus to study and compare quantitative characteristics of the ecological landscape and spatial change patterns. Because in the third level of LDD classification in which some areas are classified as 50% various agricultural land and 50% urban or rural villages on the same land patch, the Agricultural Land Mixed with Rural Villages or Low Density Residences (Agri-Village) is added to the study categories. This type of classification is not included in the second classification is about 5% of the total BMR landscape in 2001 and up to 9% in 2007. The changes in this area represent the transformation from rural settlements to urbanized areas or peri-urbanization. Classification is about 5% of the total BMR landscape in 2001 and up to 9% in 2007. The changes in this area represent the transformation from rural settlement to urbanized area or peri-urbanization.

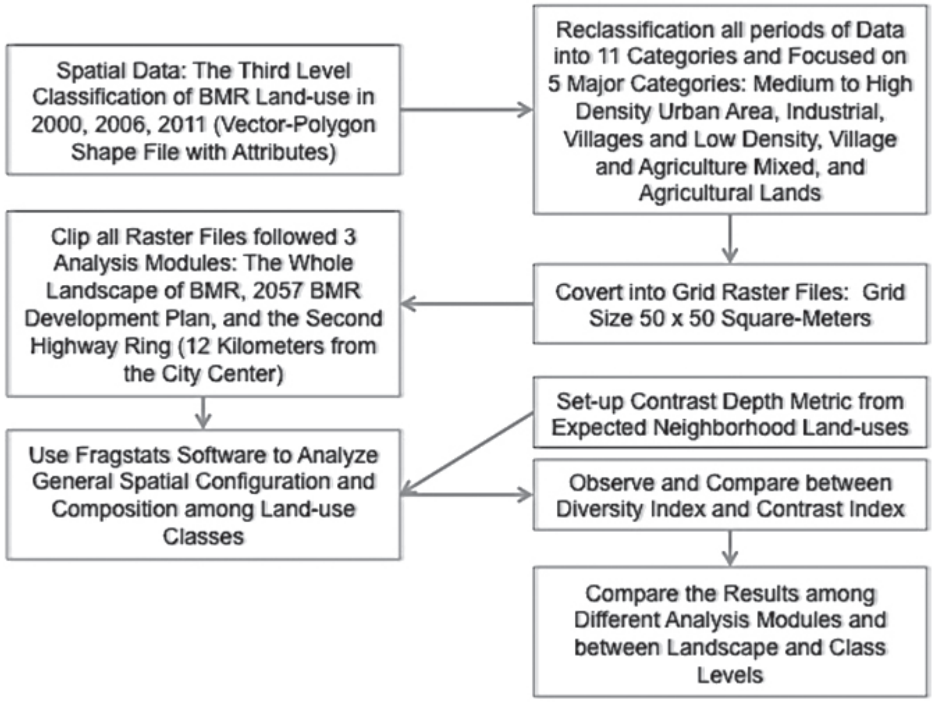

Figure 3:
Research procedure

The LDD data is in the digital format of GIS polygon vector file. To use the Fragstats program properly, all vector files have to be rasterized to the grid files, which are compounds of the mosaic images. The selected raster size for each patch is 50 x 50 square meters, which is proper to 1:4000 to 1:25,000 scale of LDD database. (The smallest detail of LDD database is 40 x40 square meters). At the 2,500 square meters grid scale, the significant details of water bodies and agricultural lands would be maintained. All of the data justifying, reclassifying, rasterizing, or attribute dissolving are operated with ArcGIS computer software version 10.1.

The analysis procedure starts by cropping the whole BMR landscape into modules for analysis. With the exception of the BMR landscape analysis, there are two modules of landscape analysis in this study. They are:

1) The first module of the study uses the classification of the 2057 BMR development plan, which is planned and purposed by DPT. This module refers to nine zones out of 30 selected development zones: 1) Medium-density Urbanized Zone (MD), 2) the East Low-density Residential Zone I (ELD 1), 3) the East Agriculture Zone I (EA 1), 4) the East Industrial Zone I (EI 1), 5) the East Rural and Agricultural Conservation Zone (EAC), 6) the West Low-density Residential Zone I (WLD 1), 7) the West Low-density Residential Zone II (WLD 2), 8) the West Agricultural Zone I (WA 1), and 9) the West Rural and Agricultural Conservation Zone II (WAC 2). The primary research areas are:1) to diversify the area of study following the landscapes which could be separated by the East or West side of BMR or of the Chaophraya River, the main river of the region and 2) to diversify the selection throughout all types of expected land-uses or future regional zoning.

2) The second module is a study of the Kanchanaphisek Ring road, which is the second ring road that cuts through the BMR's suburban and peri-urban. This Kanchanaphisek ring road modules or "K" modules are classified along linear areas buffered five kilometers on two sides of the road. The whole 168-kilometer length of Kanchanaphisek road is divided into eight sections based on important intersections with the major radius road from the city center. Only seven from eight sections are selected as the case studies because they are in the BMR.

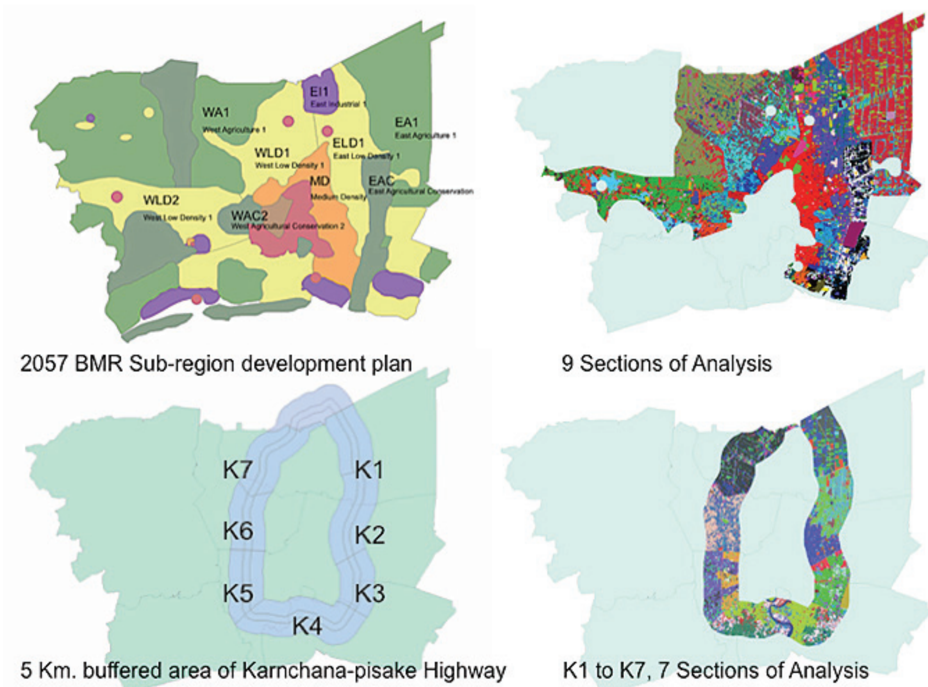

Figure 4:
Analysis modules

To study composition, configuration, and changes of the BMR landscape, the study primarily selects 18 Fragstats metrics as the basic indicators. These 18 metrics are as follows: Total Area (TA), Total (Class) Area (CA), Number of Patch (NP), Percentage of Landscape (PLAND), Patch Density (PD), Large Patch Index (LPI), Edge Density (ED), Landscape Shape Index (LSI), Mean Patch Area (AREA_MN), Perimeter-to Area Ratio (PARA), Perimeter-Area Fractal dimension (PAFRAC), Euclidean Nearest Neighbor Distance (ENN), Contrast-weighted Edge Distribution (CWED), Edge Contrast Index Distribution (ECON), Total Edge Contrast Index (TECI), Contagion Index (CONTAG), Interspersion & Juxtaposition Index (IJI), and Shannon's Diversity Index (SHDI). Some of the metrics could be both landscape and class metrics. Therefore, all of the metrics are selected and tested for their capability with the purposes of the study. For the analysis focusing on composition and configuration of some classes, the study had to select the metrics that are applicable to class level analysis.

All of the metrics could be classified into two basic groups of index variables. The first is patch area and the second is patch parameter. These two simple attributes of each patch could make several forms of the equation for understanding class or landscape composition. Because dozens of metrics and equations could be selected, the study selected more than one index per one metric type to compare the results and to consider what the most applicable index that could be used for each metrics in this research. For example, LSI, PARA, and PAFRAC are chosen for the same purpose, to understand shape complexity, as shape metrics. This study also tried to select the indicators with different representation such as percentage, length, size of area, and ratio between two variables. One of special indices is ENN, which is an aggregation metrics. This index measures the distance between the same-class patches. Therefore, it could be applicable in wide range of metrics from patch level to landscape level. Moreover, to apply to higher levels of the metric, this kind of metrics has to be simple statistic functions such as mean, median, or standard deviation to demonstrate the complexity of patch metrics at class and landscape level. Sometimes, the result could not be interpreted because the number of sample patches is too low.

Table 1: Contrast weight matrix or dissimilarity

	Agri-	Forest	Ranges	City	Village	Institutes	Trans-	Indust-	Recreate	Agri- Vil-	Water
Agri-	0	0	0	0.75	0.5	0.5	0.25	1	0	0.25	0
Forest	0	0	0	1	0.75	0.75	0.5	1	0.1	0.1	0
Ranges	0	0	0	0.25	0.1	0.1	0.1	0.25	0	0	0
City	0.75	1	0.25	0	0.25	0	0	0.5	0	0.5	0
Village	0.5	0.75	0.1	0.25	0	0	0	0.75	0	0	0
Institutes	0.5	0.75	0.1	0	0	0	0	0.5	0	0	0
Trans-	0.25	0.5	0.1	0	0	0	0	0	0.1	0	0
Indust-	1	1	0.25	0.5	0.75	0.5	0.1	0	1	0.75	0
Recreate-	0	0.1	0	0	0	0	0	1	0	0	0
Agri- Vil-	0.25	0.1	0	0.5	0	0	0	0.75	0	0	0
Water	0	0	0	0	0	0	0	0	0	0	0

Furthermore, because all indices could not be applied to every range of study (some could support only patch metrics, some could be used for both landscape and class metrics), several indices are then chosen to make an analysis that can be applied to all types of data. For example, between aggregation metrics and diversity metrics, there are some variables and index characteristics which could be a good correlation. They could be both positive and negative correlations, but normally, the indices of diverse metrics are only landscape level metrics. Some of aggregation metrics that could be applied to both landscape and class metric have to be selected as a surrogate index or as corresponding metrics. One type of metrics requires an escalation factor to complete the equation and it is contrasting metrics. This type of metrics requires edge contrast weight or a dissimilarity model to dissimilate the relationship among different patch types into unequal numbers. The dissimilarity model or edge contrast weight metrics also requires a separate study or set up before running contrast metric models in Fragstats.

Edge Contrast Weight or Dissimilarity Model

To study edge contrast metrics or dissimilarity, the contrast weight file is required and specified. Contrast weight 'matrix' (table 1) is a set of numbers from 0 to 1 scale measuring different magnitudes to reflect similarities or differences between any two patches which share the same edge but differ in ecological attributes or physical conditions based on a primary classification. The weight equals to "1" when the two patches or classes of each patch have a high contrast or, with some logics, they should not be adjacent or share their edges together. The weight becomes "0" when two shared-edge patches are classified as the same or there is no contrast value shown between the two classes.

Developing a weight scheme between classes is generated from a theoretical guideline of land-use interaction and ecological dissimilarity. In this study, the weight magnitude is also considered from 3 different aspects: 1) the differentiation between land-cover characteristics of each use,- natural and ecological characteristics, 2) aspects related to conforming and nonconforming uses conducted according to the 2013 BMA comprehensive plan, and 3) the research direction to differentiate agricultural land-use, change, and pattern from other uses. Therefore, a high degree of contrast is given to the edge between agricultural land and industrial land or park and recreation land and industrial land. On the contrary, the edges between and among green spaces, farmland, forest, and natural infrastructures such as water bodies are considered as coherent ecology in which the contrast weight is considered low. In this study, it could be said that the differentiation between "Brown" and "Green" is a major concern. Expended urban villages and gated community estates are another concern of weight contrast definition. Unlike general low-density expansion in the urbanized areas, urban village expansion into agricultural lands in Thailand expresses urban sprawling and potential ecological spoliation. Changing from major water-based to road-based utilization causes changes in infrastructures, utility services, and economic activities. In this case of contradiction, even though open-space ratio and floor area ratio of urban villages are considered low, emerging gated community estates could cause concern as a minor threat to the socio-ecology of rural farmland, which could lead to major and long term change in ecological conditions in the area.

RESULT AND DISCUSSION[1]

Comparison of the data from different periods shows that the 2001 data structure is incompatible with other years. (Table 2) Based on the data characteristics, the 2001 data was collected in a different way from t others means of collection. Therefore, the data could represent a tendency of data projection and comparison in the same year rather than comparing across periods of time. From 2007 to 2012, the landscape of the BMR has gradually changed into a more complex system. The increased number of the many metrics, such as PD, ED, PARA, shows that the whole BMR landscape has been become more complex in terms of the numbers of patches and patch shape complexities. Subsequently, the decreased number of LPI shows that the dominated patch has been broken down into a smaller size.
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At the class level (Table 3), the study concerns only spatial configuration and composition in some types of land-use for the whole BMR. This study focuses on five major types of land-use; Agriculture, Agriculture and Village, Urban Village and Gates Community, City and High Density Urban Area, and Industry, and in 14 spatial indices. Agri- land is the dominated landscape of the BMR. It occupies more than 50 % of the whole BMR landscape and contains the largest patch in the area. For the shape complexity measured by the ratio between patch parameter and size of the land, urban village land or gated communities have significantly high numbers in LSI and PARA_MN. For the edge contrast metrics, there are two different aspects to considered. Based on CWED, agricultural land could have the highest edge contrast but based on TECI and ECON, which is the ratio between edge contrast and total edge length,

Table 2: 2001, 2007, and 2012 landscape metrics comparison

	NP	PD	LPI	ED	LSI	PARA_MN	PARA_SD	PAFRAC
2001	3,204	0.42	20.67	21.23	48.22	183.40	138.94	1.43
2007	40,344	5.24	10.35	47.85	106.65	554.81	232.41	1.38
2012	52,427	6.81	10.03	55.77	124.17	566.98	228.19	1.39

Table 3: 2001, 2007, and 2012 landscape metrics comparison

	LID	CA	PLAND	NP	PD	LPI	LSI	PARA_MN	PARA_SD	PAFRAC	CWED	TECI	ECON_MN	ECON_SD	IJI
2007	Agriculture	420,569.00	54.65	2489.00	0.32	10.35	91.66	319.45	197.98	1.37	7.04	22.78	27.52	18.60	78.71
2012	Agriculture	410,873.00	53.36	3321.00	0.43	10.03	104.14	327.73	193.28	1.38	10.57	30.47	37.21	19.18	74.64
	& of Change	-2.36	-2.42	25.05	25.02	-3.25	11.99	2.53		0.94	33.38	25.25	26.05		-5.45
2007	Agri- Village	69,123.25	8.98	3950.00	0.51	0.38	103.28	431.91	201.04	1.47	1.91	13.53	14.65	5.65	56.72
2012	Agri- Village	10,265.75	1.33	1142.00	0.15	0.04	58.15	413.07	193.24	1.47	0.46	15.03	15.09	6.30	56.81
	& of Change	-573.34	-573.73	-245.88	-246.12	-913.53	-77.60	-4.56		0.25	-314.58	9.96	2.90		0.17
2007	Village	66,614.75	8.66	4254.00	0.55	0.65	87.13	458.83	216.82	1.39	3.53	30.17	34.30	13.25	65.07
2012	Village	115,439.25	14.99	8323.00	1.08	1.11	140.68	483.74	201.54	1.47	8.18	32.92	36.61	11.99	59.80
	& of Change	42.29	42.26	48.89	48.86	41.25	38.06	5.15		5.48	56.87	8.36	6.31		-8.82
2007	City and Town	63,884.75	8.30	57.00	0.01	5.10	25.10	276.27	280.73	1.42	0.75	22.81	41.09	25.86	82.85
2012	City and Town	73,945.00	9.60	136.00	0.02	6.02	41.19	389.72	272.56	1.44	1.13	19.41	32.54	21.33	84.21
	& of Change	13.61	13.56	58.09	58.19	15.34	39.06	29.11		1.91	33.34	-17.53	-26.27		1.61
2007	Industrial	18,564.50	2.41	1553.00	0.20	0.16	49.75	323.67	159.77	1.32	2.22	62.89	65.58	24.82	76.23
2012	Industrial	18,564.50	2.41	1553.00	0.20	0.16	49.75	323.67	159.77	1.32	2.22	62.89	65.58	24.82	76.23
	& of Change	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00		0.00

[1] In-text Abbreviation list.

Landscape Indices
TA =Total Area, CA = Total (Class) Area, NP = Number of Patch, PLAND = Percentage of Landscape, PD = Patch Density, LPI = Large Patch Index, ED = Edge Density, LSI = Landscape Shape Index, AREA_MN = Mean Patch Area, PARA = Perimeter-to Area Ratio, PAFRAC = Perimeter-Area Fractal dimension, ENN = Euclidean Nearest Neighbor Distance, CWE = Contrast-weighted Edge Distribution, ECON = Edge Contrast Index Distribution, TCEI = Total Edge Contrast Index, CONTAG = Contagion Index, IJI = Interspersion & Juxtaposition Index, and SHDI = Shannon's Diversity Index

Classified planning zones in 2057 BMR plan
MD = Medium-density Urbanized Zone, ELD 1 = the East Low-density Residential Zone I, EA 1 = the East Agriculture Zone I, EI 1 = the East Industrial Zone I, EAC = the East Rural and Agricultural Conservation Zone, WLD 1 = the West Low-density Residential Zone I, WLD 2 = the West Low-density Residential Zone II, WA 1 = the West Agricultural Zone I, WAC 2 = the West Rural and Agricultural Conservation Zone II

industrial land has significantly the highest score in edge-contrast number. For the diversity metric, medium density urbanized landscape or City and Town is the area where the IJI is the highest.

Referring to the study of landscape change between 2007 and 2012, the agricultural village land, or the area with a close mix of rural villages and agricultural land-use, had a pattern that significantly declined. From 8 in 14 metrics, the BMR Agri-villages declined in many of the class metrics: CA, PLAND, NP, PD, LPI, LSI, PARA, and CWED. Especially for PLAND, this metrics had been decreased to 574%. In contrast, urban villages or gated communities and medium density urbanized area expanded to 49% and 58%. For the BMR agricultural land, all contrast metrics are increased 25.25 % to 33.38% but IJI is decreased only 5.45%. The same as the agricultural land, the score of contrast metrics of urban village is also increased but decreased in diversity metric. After several revisions of the raw data, no metric of industrial land has changed between 2007 and 2012, It means that there is not only no change in size of the class, but also no change in terms of relationships between industrial land-use and other land-use classes.

The whole BMR landscape has not changed equally. Each zone has its own landscape characteristics. (Figure 5) All nine study areas derived from the 2057 BMR development zones have unique spatial composition characteristics. On the east side of the region, the LPI score of EA1 changed the least and is lower than the regional average (10.03). This area is quite small in terms of single patch domination and quite average in patch and edge density. On the other hand, compared with EAC, spatial composition of EA1 is different in terms of PD and ED. These are significant factors of study to determine differentiation. The ecological landscape of EA1 is simpler than EAC. At the same time, WA1 also has its own spatial character. This WA1 area has a very high number in LPI. It means that some large agricultural patches dominate this area. However, WAC2 has a unique character in the high number of ED and PD but low in LSI and LPI. Based on the quantity of spatial composition, there is no particular area that shares the same spatial characteristics with others

Not only does spatial composition represent the characteristics of each landscape, the changed patterns of composition also reflect the unique characters of each landscape in a particular period of time. (Figure 6) For an overall picture of the whole BMR landscape, patch density is increased about 23 percent but the AREA_MN and LPI decreased. Referring to the changed percentage of all landscape composition metrics, LPI is the metrics that could indicate which landscape generated a significant change among the different zones. The LPI also dramatically decreased in WA1 but it significantly increased in ELD1. The AREA_MN is dramatically decreased in MD. Even though there is no significant change in terms of landscape shape complexity, the areas like MD and WA1 show recognizable changes in many metrics. These affect the significant changes in landscape configuration.

Because BMR landscape is more than 50% dominated by agricultural land (Agri-land), revealing the landscape composition of urban agriculture lands is a significant purpose of the study. (Table 4) In 2007, the highest PLAND of agri- land is 78.88% in WA1 and WA1 also has the highest LPI, 77.15%. The second highest PLAND is 71.78% in EA1 but LPI of

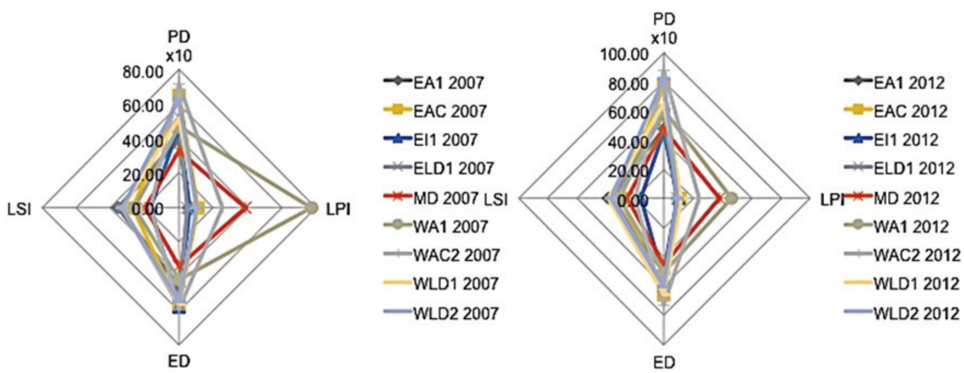

Figure 5:
2007 and 2012 landscape metrics of 9 BMR 2057 development zones

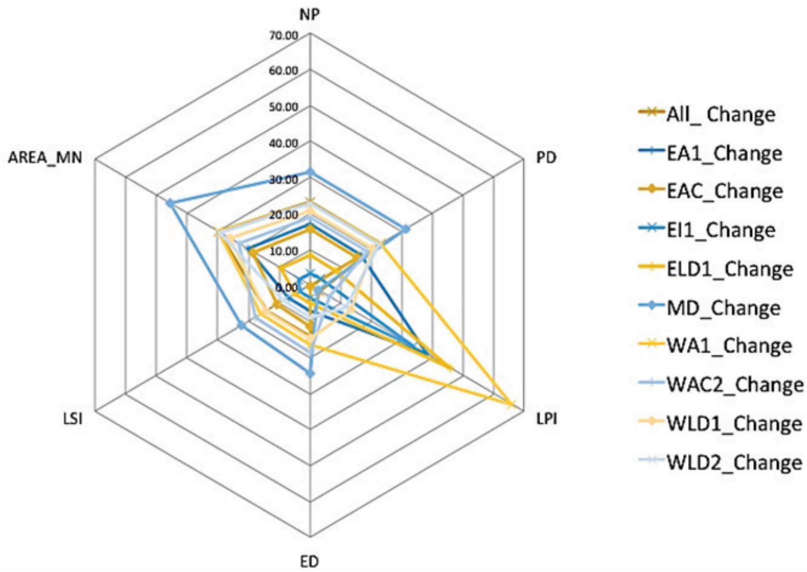

Figure 6:
Percentage of landscape-metric change between 2007 and 2012 in 9 study areas

Table 4: Class metrics of Agricultural Lands in BMR and 9 study areas (2057-BMR development zones)

LID	CA	PLAND	NP	PD	LPI	LSI	AREA_MN	AREA_SD	PARA_MN	PARA_SD	PAFRAC	ENN_MN	ENN_SD	CWED	TECI	ECON_MN	ECON_SD	IJI
2007	420569.00	54.65	2489.00	0.32	10.35	91.66	168.97	2312.03	319.45	197.98	1.37	163.47	153.41	7.04	22.78	27.52	18.60	78.71
2012	410873.00	53.36	3321.00	0.43	10.03	104.14	123.72	1952.57	327.73	193.28	1.38	160.23	148.23	10.57	30.47	37.21	19.18	74.64
EA1_2007	60912.25	71.78	263.00	0.31	5.74	30.37	231.61	694.37	306.47	220.68	1.34	126.58	66.22	6.29	17.80	16.78	13.38	72.19
EA1_2012	60258.25	70.97	288.00	0.34	9.31	32.65	209.23	728.59	307.32	222.16	1.35	123.15	53.34	9.74	25.79	26.26	16.36	65.51
EAC_2007	12118.75	41.07	300.00	1.02	10.28	25.38	40.40	225.97	329.36	205.75	1.36	160.00	197.42	10.17	26.81	29.10	17.30	76.33
EAC_2012	12024.50	40.75	352.00	1.19	9.34	28.28	34.16	186.98	329.89	190.23	1.38	152.79	110.60	15.20	36.13	37.23	16.15	56.24
EI1_2007	2622.50	23.29	98.00	0.87	6.43	15.13	26.76	77.04	292.71	181.85	1.33	167.21	143.13	6.63	24.06	23.96	15.64	73.59
EI1_2012	3067.00	27.23	90.00	0.80	6.62	15.59	34.08	87.15	280.83	185.47	1.36	164.11	145.14	9.93	32.29	29.79	19.44	77.39
ELD1_2007	15300.75	31.91	451.00	0.94	2.45	28.99	33.93	100.88	261.47	162.01	1.29	173.51	161.03	7.35	24.55	26.57	16.00	75.62
ELD1_2012	14927.25	31.13	482.00	1.01	3.61	29.85	30.97	116.52	278.10	168.69	1.30	169.58	143.18	10.36	34.04	36.58	17.41	70.99
MD_2007	4976.00	11.78	155.00	0.37	2.07	17.99	32.10	102.83	316.39	189.13	1.33	283.95	425.39	3.68	30.54	28.24	19.38	79.30
MD_2012	4572.50	10.82	232.00	0.55	1.07	23.46	19.71	55.60	321.65	176.18	1.37	256.64	284.55	6.81	45.29	47.03	17.17	65.52
WA1_2007	40795.00	78.88	63.00	0.12	77.15	23.23	647.54	4985.41	433.35	268.98	1.41	125.28	40.07	8.05	22.17	22.77	16.68	80.70
WA1_2012	39512.75	76.53	113.00	0.22	46.45	27.83	349.67	2597.17	427.43	259.83	1.40	132.69	69.16	13.93	32.48	32.86	19.73	80.56
WAC2_2007	2057.25	19.98	238.00	2.31	2.28	20.66	8.64	23.74	384.19	185.53	1.34	154.61	102.56	11.62	31.81	31.11	14.49	60.85
WAC2_2012	1973.25	19.17	254.00	2.47	1.71	21.85	7.77	17.63	384.60	179.87	1.36	163.52	113.26	14.48	38.33	39.10	16.45	57.89
WLD1_2007	18061.25	36.03	214.00	0.43	10.44	28.77	84.40	405.80	296.23	205.53	1.38	179.06	208.93	8.31	26.92	28.17	17.50	76.21
WLD1_2012	18419.75	36.78	360.00	0.72	12.14	35.64	51.17	343.49	306.73	188.70	1.41	161.90	131.99	15.01	38.86	41.87	17.74	69.31
WLD2_2007	25949.00	50.68	297.00	0.58	10.32	29.14	87.37	462.96	346.54	199.52	1.40	177.10	140.22	10.25	27.92	30.10	19.93	85.04
WLD2_2012	24474.00	47.80	350.00	0.68	9.23	31.23	69.93	385.23	358.88	207.29	1.39	174.17	137.56	13.45	35.23	38.30	18.22	74.89

EA1 is significantly low, only 5.74%. In term of shape complexity, no study module has a noticeably high or low score in any shape complex metrics, LSI and PAFRAC. At the same time, WAC has a significantly high percentage of agricultural patch density.

From 2007 to 2012, the overall picture of agri- land is deceased to 2.42 %. The most recognizably deceasing rate of agri-land is 8.82 % in MD. (See: figure 7) Most of agri-land in each study zone is decreased, such as 6.02% in WLD2 or even 4.23% in WAC2 (Agricultural conservation area). Only the agri-land in EI1 is increased 14.48% despite small percentage of agri-land in EI1, only 23.29% in 2007. Therefore, the changing pattern of agri-land EI1 is noticeably different from other zones. The changes of NP and PD have a noticeably positive correlation. NP and PD of agri-lands in all study zones have increased except in EI1. It is possible to say that agri-land in EI1 has increased in terms of big pieces of land. In EI1, the agricultural patches in 2012 are bigger than those in 2007 (this is related to AREA_MN score). The change of ENN_MN is hard to recognize. According to ENN_MN figures, only from 125 to 280 meters, agriculture patches in the BMR are close to one another,- thus meaning less isolation or less openness. More ENN_MN is more ENN_SD. High ENN_MN score could be unreliable in terms of equal distribution, such as the distance among agri-patches in MD. The same as in the

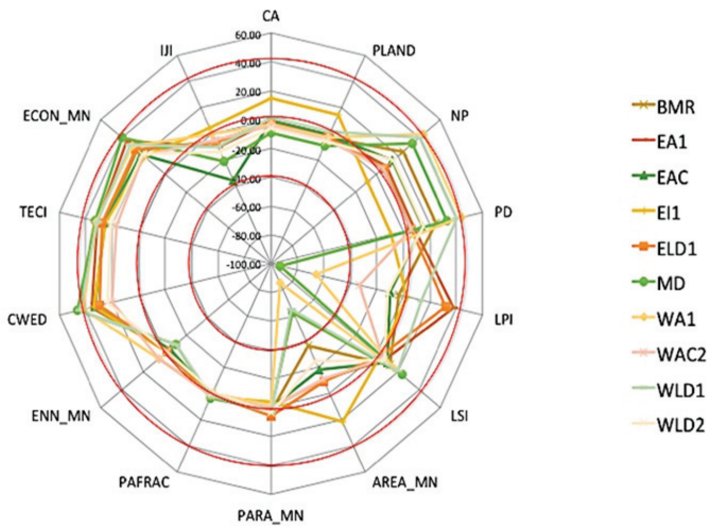

Figure 7:
Percentage of class-metric change between 2007 and 2012 in BMR and 9 study areas

landscape metrics, the change pattern of LPI in class metrics simply signifies the groups of landscape because the LPI change displays how the landscape or classes are transformed into a unified pattern with a dominant patch or modified into a patchier pattern. Observing the largest patch in the landscape, LPI change becomes the most recognizable indicator.

Based on Landscape diversity of the BMR, observing on the change of diversity metrics is a significant approach of the study. This study chose to compare diversity index (SHDI) and edge conflict Metrics (TECI and CWED) to study the patterns of correlation. The Figure 8 shows all correlations between two diversity indices (SHDI X 50), aggregation index (IJI), and between two contrast metrics (or dissimilarity, TECI and CWED). The first three graphs on the left show landscape metrics comparing the whole picture of the BMR landscape in 2001, 2007, and 2012 and nine areas of study based on the 2057 BMR development plans of 2007 and 2012. The study selects IJI for studying the diversity pattern of spatial configuration for both landscape and class levels because even SHDI is a well-known indicator for landscape diversity, but SHDI is not designed to measure the diversity at class level. The first three graphs in figure 8 illustrate positive correlations between SHDI and IJI. Moreover, the graphs also illustrate positive correlations between TECI and CWED at the landscape level. The correlation between TECI and CWED in the class metrics is not in positive proportion. Because CWED is calculated based on a ratio between edge length and the whole area of one landscape, the areas in the case study do not indicate the size of all landscapes to be equal. Therefore, the study chose TECI as a major metrics for contrast-edge variation to compare with IJI for both landscapes and class levels.

The study choose only five major land-use classes,- agriculture, agriculture and village, village, city and town, and industry, to investigate the correlation between diversity and edge contrast. Unlike data presented in the figure 8, the correlation between TECI and IJI, figure 9 illustrates details focusing on the last three numbers of TECI and IJI. Based on the three last highest number of TECI (the first highest edge contrast numbers), 7 out of 14 cases show that the relationship between TECI and IJI has a negative correlation. In all cases one of the lowest IJI scores is always associated with the highest TECI score. Furthermore, this negative correlation is obviously displayed in other modules of study. The figure 9 also illustrates that of 13 cases in 14, the lowest score of IJI is always related to the highest score of TECI. It is highly possible when TECI scores become significantly high or the highest, the IJI score could be decreased to the lowest point. The negative correlation between TECI and IJI also appears strongly in the study of K module. (Figure 10) In 9 out of 10 area cases, the highest TECI score obviously correlates to the lowest IJI score. In six of the cases, IJI scores are dramatically decreased when TECI value rises to the top three. Therefore, it could also indicate that when TECI score becomes the highest or significantly high, there is more opportunity to have the lowest score of IJI.

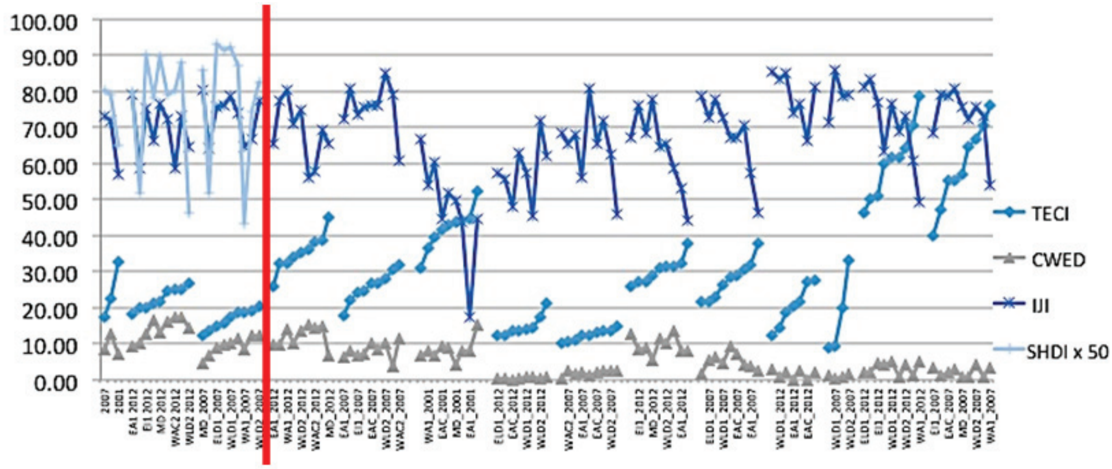

Figure 8:
Correlation between TECI and CWED, between IJI and SHDI x 50 at landscape level in the whole BMR (the first three graphs on the left of the red line) and 9 study areas (graphs on the right of the red line)

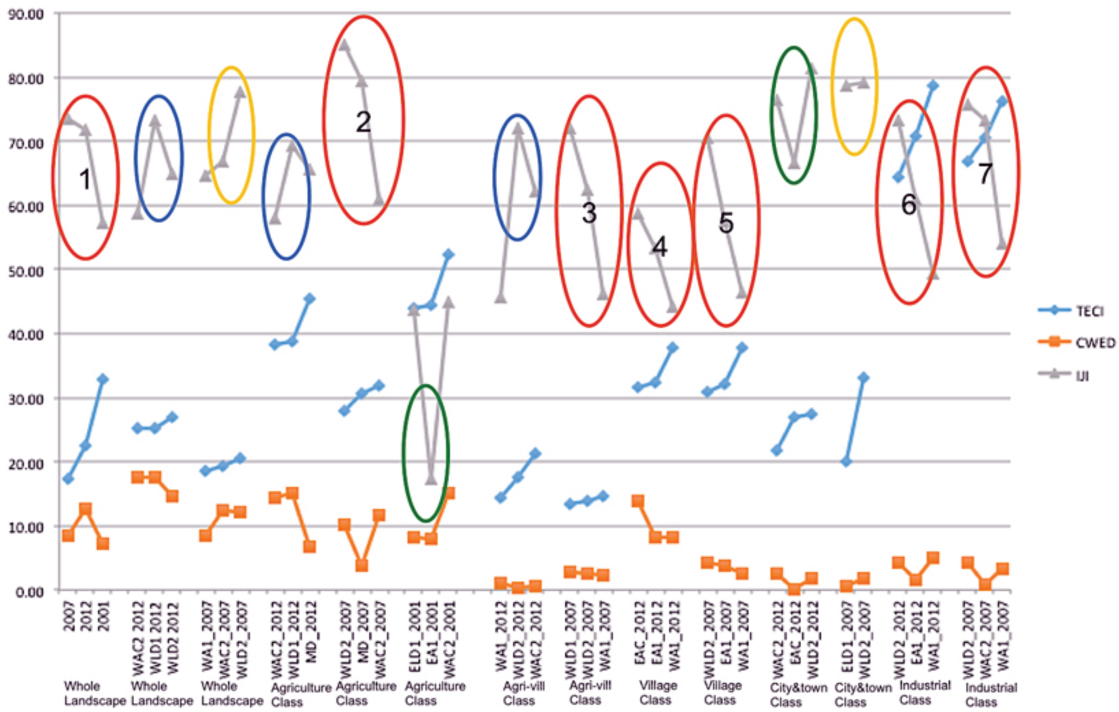

Figure 9:
IJI, CWED, and TECI of the whole BMR and 5 land-use classes (Extruded the last three numbers from the graphs in figure 8)

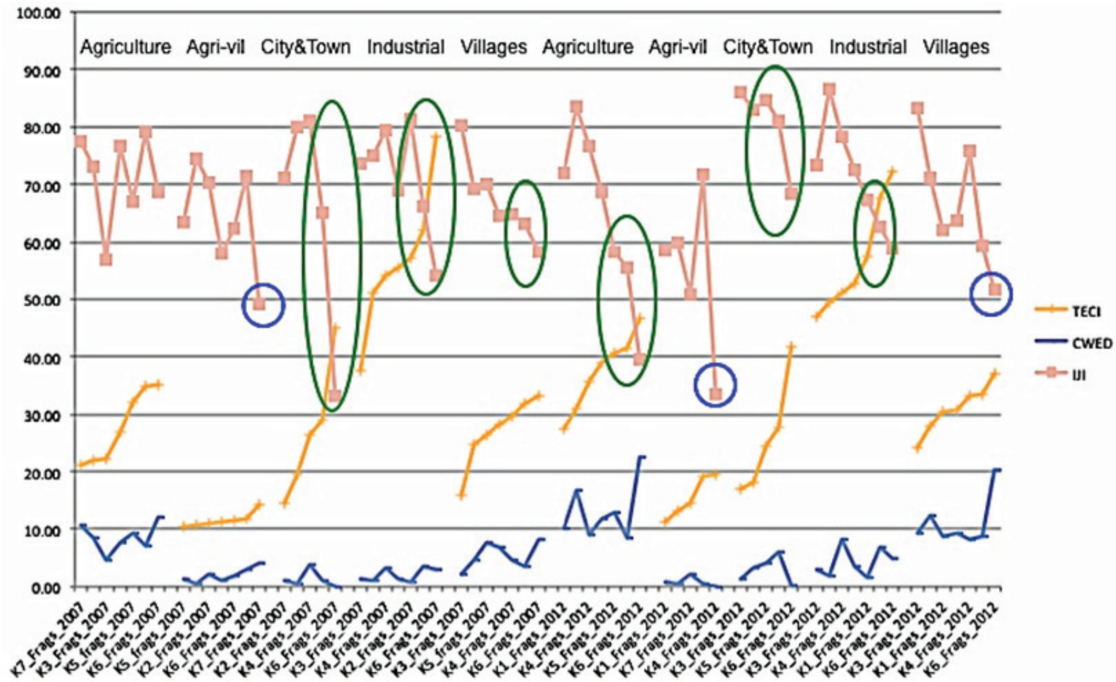

Figure 10:
IJI, CWED, and TECI of agricultural land-use in 7 areas on Karnchanaphisake ring road (K-module)

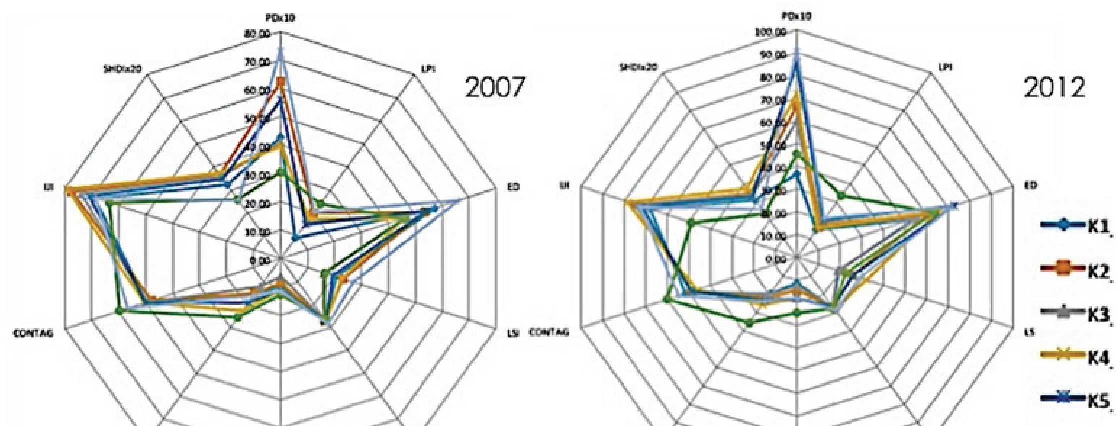

Figure 11:
2007 and 2012 landscape metrics of K-module 7 areas

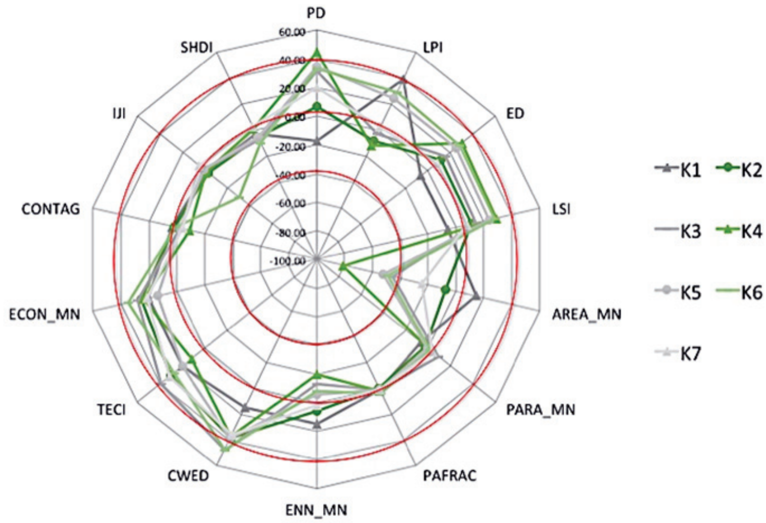

Figure 12:
Percentage of landscape-metric change of the areas in K study module

According to the comparative graphs between 2007 and 2012, whole groups of sub-landscapes, from K1 to K7, have almost the same pattern of landscape composition and configuration except for the area K6. Figure 11 illustrates that K6 has a unique pattern. It has highest figures in many indicators- CONTAG, TECI, CWED, and LPI- but lowest in both IJI and SHDI. This pattern is obviously unique in 2012.

Even 6 out of 7 landscape modules on Karnchanphisek ring road have identical patterns of composition and configuration and they seem to have the same pattern of landscape change. According to change percentage analysis (Figure 12), each studied area has a unique pattern in percentage of change in specific indices. Obviously, IJI changed dramatically only in the K6 area. K4 has significantly increased in PD score but has greatly decreased percentages in AREA_MN. At the same time, K1 has a high percentage of change in LPI and is significantly low in PD, ED, LPI. Most of the studied areas have identical percentage of change between two metrics, ED and LPI. Except for K1, most of areas have significantly increased in CWED and are quite stable in diversity and shape metrics: CONTAG, SHDI, PAFRAC, and PARA_MN.

FINDINGS AND CONCLUSION

This study is not the first research that applies Fragstats metrics to study the change of the BMR. In 2011, based on the same LDD database, Nagasawa and others discussed the changes that were made during 1994, 2000 and 2009 with seven landscape metrics; NP, PD, PROX (Proximity Index), ENN, CONNECT (Connect Index), CONTAG (Contagion Index), and SHDI They compared only three classifications; - built-up, vegetation, and water bodies. The study focused on the details of 2009 land-use and made observations based on the administration boundaries of Bangkok city and five vicinities. Their conclusion was that the Bangkok landscape was significantly different from the vicinities. (Nagasawa, Durina, & Patanakanog, 2011) Different from the approach of Nagasawa and et al., this research considers Bangkok and vicinities as one piece of landscape with complex diversity in land-use and land-cover. The research considers Fragstats as a powerful application that could reveal and quantify spatial patterns and significant changes in landscape composition and configuration. This study realizes the BMR in term of landscape ecology in 3-dimensions:

Not only the BMA, the whole landscape of BMR in 2012 is more complex than in 2007.

According to the increased number of NP, PD, and LSI and the decreased LPI during 2007 and 2012, it could be noted that the whole landscape of BMR in 2012 is more complex than in 2007. But the complexity of the landscape based on the area metrics and shape metrics could not represent aggregation patterns and diversity. The declined ENN score of the same-class patches, which could be observed from the decreased ENN_MN of agri-land class, reveals that the same class patch is aggregated. The tendency of the BMR landscape is complex, but with less diversity, because the aggregation patterns lead the same land-use class to the same area and at the same time, thus the shape complexity and the number of patches are increased.

For the detail of landscape composition, each land-use class in the whole BMR landscape indicated changes in usage. The transition land-use class as “Agricultural Land Mixed with Rural Villages or Low Density Residences” was dramatically decreased. Therefore, during 2007 and 2012, compared with the whole BMR landscape, the urban village or gated community area significantly increased in all metrics except IJI.

For the change of ecological landscape influenced by infrastructure, the study of the Kanchanaphisek ring road illustrates that there are two critical areas where spatial composition and configuration change significantly. These areas are K6 and K1. These two areas are not in BMA but in the city expansion area, the peri-urban. K6 is now the target area of low-density gated community settlement. Whereas, K1 was the target area of low-density gated community settlement it has now become a more aggregated patch.

Higher dissimilarity is illustrated when the diversity is lost.

Even though the whole landscape of BMR in 2012 is comparatively more complex than in 2007, the number of aggregation metrics and diversity metrics such as IJI and SHDI are slightly decreased. It appears to be a positive relationship between landscape diversity metrics (SHDI) and negative class-aggregation metrics (IJI).

On the other hand, analysis on the landscape and class levels illustrates that there are more opportunities to find the highest TECI score when the lowest IJI is found. It is obvious that the TECI of 7 out of 14 agri-lands from the nine zones is the highest when the IJI is the lowest and 9 out of 10 landscape cases on the Karnchanaphisek road (K modules) also have the same pattern. Therefore, it could be said that when the landscape loses its diversity in significant degrees, it is possible to gain more dissimilarity and lead to future land-use conflict. The most critical contrast areas are the west agriculture land 1 (WA1) and the west rural and agricultural conservation zone (WAC).

Fragstats metrics work together to reveal BMR LULCC.

Comparisons among nine zones classified following 2057 BMR development plan, with only 4 basic metrics PD, ED, LPI, and LSI, indicates that there is less difference in the LSI. However, the changes of LPI, PD and ED indicate the different characteristics among the nine zones. The west agricultural zone I (WA1) has the most significant change in LPI, and the medium density urban zone (MD) has the significant changes of shape and area metrics. The change patterns of all nine zones show that there is no correlation in the changing pattern expected among similar development zones and the regional locations. The west agricultural zones have different patterns of landscape, and are not similar to the changes of all zones in the east. At the same time, the industrial zone may have a similar landscape pattern of changes to that of the agricultural zone. These unpredictable patterns could be due to these three factors: 1) improper zoning boundary defining, 2) different background of landscape caused by the various adaptation pattern, and 3) limited data to observe the change pattern.

For the change and spatial patterns of the BMR agricultural land-use, even though it occupies more than 50% of BMR, the PLAND of agri-land has obviously declined in general, except for one, the east industrial zone. According to the highest percentage of agri-land, it dominated the change of the whole BMR landscape and that of many zones. Similar to what happened at the landscape level of nine zones, the LPI of agri-land presents itself as a significant change indicator. The declined LPI could be the cause of change in class structure- indicated with NP and PD.

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