Quantification of Land Cover Changes in Sub-urban Areas of Pekanbaru City

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Abstract. Morphologically, land cover, urban and rural areas have different characteristics. It is the same as Pekanbaru City area that has unique characteristics including its surrounding regencies. However, the high level of land demand caused by increasing economic activity, high natural and non-natural population growth, makes the morphology of land cover in urban and rural areas unclear. Empirically this beginning to be considered common in urban areas that have a role as a strategic point or center of economic activity, but one of the concerns is the development of unplanned and dominating areas in a space that later create a more fragile environmental conditions in suburban areas. This study aimed to identify changes in land cover and assess the level of conformity of land use in the suburbs of Pekanbaru City. This study used a description method with two stages, (1). Identifying land cover using temporal images. (2). Analyze the level of conformity of land use. The results showed that there are four patterns of land cover change in the suburbs of Pekanbaru City, especially on the road axis connecting the surrounding area. These developments indicate nonconformity of land use which has an impact on the loss of protected land and productive plantation land in the suburbs of Pekanbaru City.

Keywords: Sub-urban, Land cover, Land conformity, Pekanbaru.

1. Introduction

Economic development and competition certainly affect rural areas greatly and affect the interaction between rural and urban areas [1]. Regional development occurs along with population growth, changes in land use and has an impact on changes in local ecosystem conditions [2]. Changes in spatial use due to urbanization are in line with the increase in built up areas and changes in the biophysical landscape of the region [3]. The transformation process also affects from social patterns marked by the trend of out-of-rural migration along with population expansion in urban areas, to the loss of fertile land in suburban areas [1]. Changes in land use in each region occur due to the complex and dynamic phenomena over time and space [4]. So it can be said that changes in land use in suburban areas are unavoidable, due to various driving factors [5]. It is indicated by an increase in the artificial environment, high population density, changes in energy and nutrient systems [6].

Spatial planning as an instrument that includes planning, utilization and land control, in its implementation aims to create a safe, comfortable, productive, and sustainable area. However, in reality development activities have more impacts in environmental degradation. Fragile environment in suburban areas is the result of very high and dynamic human pressure. It can be seen from low soil fertility, reduced vegetation area, changes in microclimate, land degradation and loss of biodiversity [5].

Good understanding in urban ecology and distinguishing characteristics between urban-rural areas
Deemed as important to address environmental problems and natural resource management in cities and suburbs [2].

The Pekansikawan urban area (Pekanbaru, Siak, Kampar and Pelalawan), which is designated as a strategic economic area of Riau Province, makes Pekanbaru City one of the important urban centers on a national scale. Geographically, Pekanbaru City is located at the intersection of North Sumatera and Southern Sumatera. As a strategic area in the middle of Sumatra Island, it has the opportunity to become a distribution center and regional growth center. Corridor areas as a form of spatial expression of city expansion/spread beyond the administrative juridical boundaries follow the accessibility (transportation) route up to rural areas (hinterland) or other cities [7]. It is hoped that with the spirit of Pekanbaru urban areas development, it can also be assisted by understanding of ecology and the urban environment in the framework of development, as stated in Government Regulation no. 13 of 2017 as Amendments to Government Regulation No. 26 of 2008 concerning National Spatial Planning (RTRWN), as well as Regional Regulation No. 10 of 2018 concerning Provincial Spatial Planning (RTRWP).

Pekanbaru City as an engine of growth for the surrounding urban area, has a major influence in fulfilling the economic and social activities of the community in the suburbs of Pekanbaru City. However, there are indications of land use change and dominance formation, unsuitable land use that is not as planned which lead to non-optimal spatial performance. Spatial activities in sub-urban areas can have a dominant impact on changes, in Nainggolan’s study (2015) that was conducted in the Upper Siak Watershed, there was an association of changes in plantation area by 28.8% and forest by 34.4% which resulted in an increase in the percentage of peak flood discharge every 25 dan 50 year period [8]. Likewise, the conversion of land in protected areas into plantation areas increases the risk of erosion, where the potential value of the ecosystem of Sultan Syarif Hasyim's Tahura has been able to control erosion of 453,674.78 tons/year in areas that still have forest and shrub cover [9].

The reduced area of non-built areas can lead to greater runoff and increase the risk of flooding in lower areas. BPBD Riau Province from their the report identified the flood hazard in Pekanbaru City with high hazard category, Siak Regency in medium hazard category, Kampar Regency in medium hazard category, and Pelalawan Regency in medium hazard category. For this reason, the disruption of the urban environment is a challenge that must be faced by the community as well as stakeholders, along with the increase in urban economic activity.

This study aimed to identify changes in land cover and assessed the spatial conformity of land use in the sub-urban areas of Pekanbaru City. This research is expected to be able to contribute in studying the condition of land use development in sub-urban areas of Pekanbaru City, which focuses on changes and conformity of spatial use in Urban Area of Pekanbaru.

2. Data and Methods

This study used a description method with two stages, (1). Identifying land cover by using temporal images, (2). analyzing the spatial conformity of land use. The first stage was started with composite analysis to determine the sub-urban area of Pekanbaru City. The initial approach used the administrative boundaries of sub-districts (kecamatan) in Pekanbaru City including the sub-district that is directly next to the border of Pekanbaru City, then three criteria were used including the physical environment, social population, and strategic value area [10–12] (0). After identifying sub-urban areas, the next step was multitemporal land cover analysis using Landsat data in 1999, 2010, land use in 2014 and Pleides in 2019. Observing spatial changes in land is one of the approaches to identify the phenomenon of urban activities development. To identify comparative spatial-temporal developments that occurs in suburban areas of Pekanbaru City, this research used a 30 meter fishnet grid approach, with a total cell in the research area of 1,048,575 cells. The second stage, to analyze the conformity level of land use, there are some requirements to be met namely; data on spatial planning documents, land ownership status, land cover map data and chronology of land use. The analytical methods carried out at this stage including map overlay, land use conformity assessment, and field verification.
3. Results and Discussion

3.1 The Profile of Sub-urban areas of Pekanbaru City

Basically the boundaries of urban areas are still unclear (McIntyre et al. 2000) in Gianotti et al. [2], the physical formation of a city is the result of the articulation of the inhabitation process which always has its own characteristics [13]. Therefore, some experts argue that justification is needed to measure the boundaries of urban areas and could also distinguish the characteristics of urban, sub-urban, and rural areas, moreover quantification is needed to determine the urban-rural gradient [2]. Judging from the speed of regional development that differs between locations, according to Rahardjo (1982) in [14] there are 6 factors that influence the development of cities, namely; 1) social population, 2) strategic location, 3) urban area function, 4) complete facilities and infrastructure, 5) land conformity, and 6) technological advancement factors. Referring to Ernest Burgess (1924) and Hoyt (1939), who are known as the concentric and sectoral models, they are the pioneer that provides an explanation of the composition of space based on social groups of urban society. Along with the development of the transportation system, advancement in information technology, economic transactions, social status encourage the transformation of a more dynamic zone form.

Physical changes in an area certainly cannot be separated from the socio-cultural dynamics that occur, including Pekanbaru Urban Area. Geostrategic and geopolitical advantages of Pekanbaru City have driven the growth of residents in Pekanbaru City even trigger further physical expansion to its surrounding areas. Increased access to infrastructure services and capital accumulation also increases due to concentration and agglomeration [14], so physical expansion of the area cannot be avoided. Pekanbaru City has the advantage to be among areas that have great natural resource potentials including Siak Regency, Kampar Regency, Pelalawan Regency. Based on the population of Pekanbaru in 2019, it was recorded that the growth reached 1.1 million people and has a tendency to continue to grow with a growth rate of 2.86% per year so that it can be categorized as metropolitan. The centralization of activities has an impact on increasing the number of residents in sub-districts outside Pekanbaru city, Tampan sub-district being the district with the largest population compared to other sub-districts, while the population > 100,000 people are grouped around Tampan and Tenayan raya District (Pekanbaru City) including Tapung sub-district, Siak Hulu sub-district, and Tualang sub-district (Error! Reference source not found.).

Population dominance in these sub-districts was identified in 2010, and has a tendency to increase every year. Maulida [15] stated that the high level of urbanization of the population that occurs is influenced by the minimum wage set in Pekanbaru City. The dynamics of regional development that is happening cannot be separated from the change of land use as well as social conceptions. Likewise, the
opinion of Medha and Ariastita [16] stated social phenomena that occur in urban areas encourage the gentrification of local people who choose to move to find cheaper housing and more comfortable conditions. Luckily, the percentage of poverty in Pekanbaru City for the past 5 years has a downward trend, urbanists who have skills can compete with other immigrants, so there is no transfer of poverty from rural to urban areas. This urbanist domination makes the characteristics of Pekanbaru people to have the main activity of non-agricultural economic activity.

Table 1. Residents Distribution in Sub-urban areas in Pekanbaru City based on Sub-districts

| Country town | Subdistrict | Village | Population (person) |
|--------------|-------------|---------|---------------------|
|              |             |         | 2010    | 2015    | 2016    | 2017    | 2018    | 2019    |
| Kampar       | Tapung Hilir| 16      | 52.122  | 60.106  | 61.603  | 63.096  | 64.788  | 75.439  |
|              | Perhentian Raja | 5 | 15.404  | 16.624  | 16.779  | 17.159  | 17.277  | 17.890  |
|              | Tambang      | 17      | 52.634  | 61.027  | 62.640  | 64.266  | 65.958  | 67.650  |
|              | Siak Hulu    | 12      | 85.881  | 100.253 | 103.099 | 106.007 | 107.699 | 110.327 |
|              | Tapung       | 25      | 82.249  | 95.476  | 98.031  | 100.613 | 102.305 | 105.287 |
| Siak         | Tualang      | 9       | 50.519  | 121.609 | 124.894 | 126.329 | 128.202 | 131.464 |
|              | Minas        | 5       | 12.716  | 30.386  | 31.236  | 31.667  | 32.098  | 32.953  |
| Pelalawan    | Bandar Sei Kijang | 5 | 17.469  | 30.272  | 33.599  | 37.233  | 41.484  | 45.490  |

The agricultural, forestry and fisheries sectors are potential sectors that can be developed in contribution to regional income, different trade sectors, industrial sectors as well as other non-agricultural sectors have a rapid growth [18]. This typology of economic sector development places Pekanbaru City as the center of economic distribution from the hinterland region which places agricultural products as the leading sector and has good development.

Based on the results of spatial data analysis, the dominance of land cover in Pekanbaru is in the form of built-up land with plantations in the surrounding area (Table 2). The dominance of residential land cover is found in eight sub-sub-districts, including Bukit Raya, Limapuluh, Marpoyan Damai, Pekanbaru City, Sail, Senapelan, Sukajadi, and Tampan sub-district. All of these sub-distribs are included in administration of Pekanbaru City, in contrast to the other 12 sub-districts, plantation land cover types still dominate (0). The road network system to the area around Pekanbaru City allows residents to move permanently or just temporarily. The pattern of relationships between accessibility, job opportunities, and land availability encourages the formation of sub-urban areas characterized by new urban areas (urban fringe).

Table 2. Land Cover Distribution of Sub-urban Areas of Pekanbaru City

| Classification     | Pekanbaru City | Sub-urban Area |
|--------------------|----------------|----------------|
|                    | Ha  | %   | Ha   | %   |
| Rivers             | 508.78 | 0.81 | 1,523.29 | 0.90 |
| Lakes              | 105.72 | 0.17 | 121.63 | 0.07 |
| Fishponds          | 117.44 | 0.19 | 169.45 | 0.10 |
| Forest             | 912.22 | 1.46 | 3,686.43 | 2.17 |
| Swamp              | 49.96 | 0.08 | 421.77 | 0.25 |
| Plantations        | 39,299.80 | 62.85 | 138,920.37 | 81.83 |
| Field moor         | 5,066.61 | 8.10 | 7,390.34 | 4.35 |
| Rice fields        | 41.16 | 0.07 | -    | -    |
| Settlements        | 12,553.07 | 20.07 | 4,748.60 | 2.80 |
| Runways/airports   | 24.88 | 0.04 | -    | -    |
| Industrial buildings| 5.64 | 0.01 | 5.18  | 0.00 |
| Shrub              | 3,333.59 | 5.33 | 11,676.43 | 6.88 |
| Grasslands         | 17.63 | 0.03 | 106.04 | 0.06 |
| Mines              | 3.84 | 0.01 | 159.61 | 0.09 |
| Empty lot          | 491.47 | 0.79 | 847.16 | 0.50 |
| Total              | 62,531.81 | 100.00 | 169,776.30 | 100.00 |
3.2 The Development of Land Utilization in Sub-urban areas of Pekanbaru City

The unique condition of suburbs development of Pekanbaru City is that the increase is not only from the development of residential areas, but the change is also strongly influenced by the development of plantation areas opening, especially oil palm commodities. According to the Plantation Office of Riau Province, the area of plantations in general increases every year (0). Chalid [19] added in his research, that the development of oil palm plantation area began in 1982 in Indragiri Hulu regency with an area of 7,000 Ha, it is known that the growth of plantation area opening in Riau province in the period 1984 – 2009 was 14.20%, with an average production growth rate for the period 1984 - 2009 was 27.59% per year.

As a comparison, the area around Pekanbaru City experienced an increase in plantation area in the 2014-2018 period, which was 9.01% or 326 ha/year. The commodity of oil palm plantations dominates, where most of the plantation areas have increased by an average of 2.99% or 84 ha/year. However, it is an irony that the agricultural, plantation, fishery and forestry sectors are categorized as not developing, in contrast to the service sector and the processing industry which is growing rapidly, especially in Pekanbaru City [18].

In addition to the development of new settlements, there is also a significant development of plantation areas in the sub-urban area of Pekanbaru City. This is based on the results of observations of land cover changes in 1999 and 2019 which show the dominance and distribution of the use of settlements and plantations almost in all around Pekanbaru City (0 and 0). The plantation type dominated the land cover, with a fairly consistent kappa index value of 78%, in contrast to forest functions which had the lowest consistency value. The biggest change in land cover is into plantations and fields, while the most vulnerable location is Tahura SSH (Sultan Syarif Hasyim) area. Based on the information from the Riau Provincial Forestry Service, at that location there are still frequent encroachments carried out by individuals or groups or companies, the orientation is to create plantation or residences area. The high expansion of plantation land at this location occurred before the issuance of the Riau Province RTRW Regional Regulation which was set in 2018.

These urban activities are growing rapidly on the main roads, including Jalan Arterial Pekanbaru, Bangkinang and Jalan Kaharudin Nasution which connect areas outside Pekanbaru City, forming a built-up area outside the city limits (spillover). To form a new growth center which is characterized by planned settlement is not only occupying "vacant areas" or agricultural land, but often occupying part of "traditional" settlements which is characterized by unplanned settlement that have been built previously [13]. The physical development of Pekanbaru City is the increase of land use including corridors of Jalan Kaharudin Nasution, Jalan Raya Pekan, Jalan Garuda Sakti. Increasing activity of land use can be
affected by location, price of the lot/land [20], infrastructure service level, and the high level of urbanization which also affect urban development [7]. Local policy and land ownership aspect also influence the development of built-up land quite massively, one of which is towards the northeast of the suburbs of Pekanbaru City which seems to form a leap-frog type of urban sprawl formed by the agglomeration of plantation activities and the paper industry (0).

Table 3. Land Cover Change Matrix in 1999 and 2019

| Land cover | Land cover (1999) | Land cover (2019) |
|------------|-------------------|-------------------|
|            | Water body | Forest | Plantations | Settlements | Open Ground | Total |
| River      | 7,080      | -      | -           | -           | -           | 7,080 |
| Lakes      | 1,291      | -      | -           | -           | -           | 1,291 |
| Fishponds  | 778        | -      | -           | -           | -           | 778   |
| Forest     | 1,251      | 10,785 | -           | -           | -           | 12,036|
| Swamp      | 133        | 1,075  | 174         | -           | -           | 1,382 |
| Plantations| 6,796      | 274,655| 430,186     | -           | 29,030      | 740,667|
| Field moor | 709        | 23,655 | 44,575      | -           | 2,641       | 71,580|
| Rice fields| -          | 523    | 899         | -           | -           | 1,422 |
| Settlements| 1,484      | 13,229 | 93,268      | 17,396      | 9,755       | 135,132|
| Runways/ airports | 3 | - | 189 | 23 | 232 | 447 |
| Industrial buildings | - | - | 54 | 55 | - | 109 |
| Shrub      | 544        | 32,960 | 31,656     | -           | 416         | 65,576|
| Grasslands | 234        | 529    | 933         | -           | 17          | 1,713 |
| Mines      | -          | -      | 4           | -           | -           | 4     |
| Empty lot  | 30         | 1,891  | 6,117       | -           | 1,320       | 9,358 |
| Total      | 20,333     | 359,302| 608,055     | 17,474      | 43,411      | 1,048,575|

Kappa Index (level of land cover consistency)  
45% 3% 78% 100% 4%

The activity density of an area can also be seen from the characteristics of the built-up environment of the area. Activity density is one of the keys of attractive factors and can be interpreted in the form of area and capacity, intensification of built-up land, and development tendency [21]. Characteristics of land changes that occur in the Sub-urban area of Pekanbaru City occur vertically and horizontally, the physical expansion with urban characteristics is identified in almost all road axis of Pekanbaru City, including Garuda Sakti Street, Pekanbaru-Sungai Pagar Street, Kubang Raya Street, Sukarno-Hatta Street, Kaharudin Nasution street, Pasir Putih street, including the Sumatra National Road (Arterial). Vertical land changes are found at the boundaries of Pekanbaru City, namely in Tampan District, Marpoyan Damai District, Bukit Raya District, and Tenayan Raya District. As Rizki and Asteriani [22] in his research on the Sukarno-Hatta Road, he found an increase in the land function for economic activities by 19.56% in the period 2008-2018, in line with the reduction in the residential space function.
Figure 3. Land Cover Distribution in 1999, 2010, and 2019

Based on the Chi-Square test in 1999 – 2010, it showed a significant p-value of 0.000040 (> 0.05), this indicates a change in land cover that was not massive during that period, but different from the period of 2010 – 2019 which showed a significant p-value 0.097115 (> 0.05). This indicates a massive land cover changes in that period. The result of Cohen's Kappa coefficient from the two periods shows a low level of agreement (< 0.20). It means that there is a change in cover land from 100 sample points.

Figure 4. The Development of Built-up Area based on Land Cover in sub-urban areas of Pekanbaru City
set around the city/district administrative transition area. From changes in land cover that occurred in the transition area (sub-urban) of Pekanbaru City, a certain patterns in the period of observation were identified. The changes in land cover occurred include forest functions turned into plantations or empty lot/barren land, then turned back into moor, shrubs and settlements/built up. The change in land cover occurred horizontally, based on spatial-temporal observations for the period 1999–2010–2019, a pattern of land use change in the Pekanbaru City sub-urban area was formed, including Pattern 1: no change in land use, Pattern 2: changes in forest function to plantations, Pattern 3: have the potential to change into built-up land, Pattern 4: experience changes to settlements or built-up land (0).

**Figure 5.** The Pattern of Land Cover Change in Sub-urban areas of Pekanbaru City

Development policy factors that encourage spatial utilization licensing activities in some areas of the city support the centralization of spatial use in these areas. It triggers high population mobilization from the area around the city into the city for work purpose, then the population who decide to settle causes the need for housing to increase in this area, in this case the Tampan district, Marpoyan Damai district and Bukit Raya district to the outer limits of the city. The occurrence of land transformation in Pekanbaru suburb is also influenced by declining plantation harvests, low land value, and population growth, as well as the access of mobility for commuters. it was also expressed by Putri and Pramono [23] that the relationship between the transportation system and land use in Pekanbaru City has an increasingly linear trend, which this relationship was still in the poor category in 2002, the medium category in 2007 and better in 2012 and 2017.

### 3.3 Land Utilization Development Conformity in Sub-urban areas of Pekanbaru City

The land cover transformation that occurred in the sub-urban area of Pekanbaru City shows that structural and pattern changes are more complex than those identified. The development of warehouse industry and settlements areas is quite significant as a driving force for changes in the landscape of sub-urban areas. Based on the spatial analysis (overlay), it was identified that there was an unsuitable land use between the utilization of the existing sub-urban area of Pekanbaru City with the spatial pattern plan of Riau Province, as well as the spatial pattern plan of Pekanbaru city with 420 location points with an area of 5,064.53 Ha (0).

a. The land use in the forest park area and built-up natural tourism park has 1 location point and plantation type has 7 location points.

b. Built-up land located in green open space area has 1 location point.

c. Built-up land located in agricultural and plantation areas has 409 location points.

d. Built-up land located in production forest areas that can be converted to 3 location points.
In order to help the identification process of the unconformity of land utilization, it is then categorized into two categories. First: activities/buildings had existed before the spatial planning policy was legalized, second: activities/buildings existed after the spatial planning policy had been legalized. Through this categorization, it can be identified that the activities that develop in the sub-urban areas of Pekanbaru City are considered as planned or unplanned activities. For the first category, it can be identified that there are 402 location points equivalent to 4,973 Ha, while the second category indicated 18 location points equivalent to 90.8 Ha.

This condition illustrates that most land utilization activities in the sub-urban areas of Pekanbaru City have developed far before the spatial planning policy, this gives an overview of land utilization activities developing faster than the formulation of land utilization policies. The continuation of this unconformity in land use has a consequence of increasing risk of flooding in Pekanbaru City, also having an impact on reducing the productivity of agricultural land and plantations. In ‘business as usual’ conditions, environmental management and community capacity building do not have special attention [24]. Along with increasing industrial activity and service business activity in Pekanbaru City, overflow of residential activities occurs to the sub-urban area of the city. Spatial-temporal changes in uneven built-up land use encourage segregation of rural communities [23].

4. Conclusion

This study investigates the spatial-temporal land cover change in the sub-urban area of Pekanbaru City. Based on the results of the analysis, the main conclusions can be drawn as follows:

First, the Sub-urban area of Pekanbaru City experienced a fairly massive land cover change, especially in the 2010-2019 period. The increase in population is clearly a major trigger for changes in built-up land, but uncontrolled plantation activities cause the level of environmental critical condition to increase, especially during the dry season.

Second, the development of industrial areas, warehousing and settlements is a significant drive in changing the landscape of sub-urban areas. 0.35% (420 Ha) of built-up land which was identified as unconformity in spatial use, but only 90.8 Ha were indicated that the activities/buildings were built after...
the spatial planning policy had been legalized. For this reason, land utilization policies are expected to become non-structural instruments in anticipating spatial developments, especially in urban transition areas.

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