Changes in land use of the land-based leading sectors in West Kotawaringin Regency of Central Kalimantan

[1]Muhtadi G. Sutrisna, [2]Santun R. P. Sitorus, [2]Widiatmaka, [3]Marimin, [4]Nurwajedi

[1] Postgraduate of Environmental and Natural Resources Science, IPB University, Bogor, Indonesia; [2]Department of Soil Science and Land Resource, Faculty of Agriculture, IPB University, Bogor, Indonesia; [3] Department of Industrial System Engineering, Faculty of Agricultural Technology, IPB University, Bogor, Indonesia; [4] Geospatial Education and Training Center of Geospatial Information Agency, Cibinong, Indonesia. Corresponding author: M. G. Sutrisna, muhtadi_gs@yahoo.com

Abstract. Local government has the authority for policy on resource management, but in spatial terms its authority is not absolute, because it must follow the stages of spatial plans. Local government has made considerable efforts to create a safe, comfortable, productive and sustainable regional space by optimizing the performance of leading sectors as the main engine of development. The objectives of this study in West Kotawaringin Regency were: to analyze leading sectors; to analyze land use change for leading sectors; and to build a spatial dynamic model of regional development using land-based leading sectors. Data used in this study are Input-Output (IO) Table, SPOT 5/6/7 imagery and base maps and thematic maps with a scale of 1:50,000. The methods used are input-output analysis, multi-temporal land use spatial data overlays using GIS software, and dynamic spatial modelling which covers Cellular Automata, Markov Chain and Driving Factor. The results show that the leading sectors in the West Kotawaringin Regency are: 1) transportation and communication; 2) trade, hotels and restaurants; 3) agriculture; and 4) processing industry. During the period 2007-2016, significant land use conversion occurs. In the period of 2007-2010 an area of 286,062 ha was converted, and in 2010-2016 an area of 209,839 ha. The majority of the land use change was conversion to plantations, with the main patterns of change being forest-plantation-plantation accounting for 143,299 ha. Based on the simulation of dynamic spatial models using a business as usual scenario, in the year 2027 no further land will be available for conversion into plantations.
Key Words: input-output, land use conversion, plantation, spatial dynamic.

Introduction. Regional development is an effort to accelerate social economic development, to reduce disparities between regions and to preserve the environment (Susilawati 2016). In the Republic of Indonesia, according to Law no. 32 of 2004, regional governments are given autonomous rights to make policies on the management of resources in their territory, but their authority on spatial management is not absolute, because they must follow the rules of spatial planning in stages. The implementation of regional autonomy implies the growing importance of a regional development-based integrated development approach between sectoral, spatial and development actors (Nasoetion et al 2000).

The success of development is inseparable from the performance of sectors in the region that can be seeded as the engine of development. The key to successful regional development lies in the strength of the interaction between sectors within a regional economic system (Sutrisna 2011). The West Kotawaringin Regency was chosen as the study location, as according to Rusmadi (2002) and Pasaribu (2009) it has the following leading sectors of the non-oil and gas industry, transportation and communication, and agriculture. Joko (2002) stated that the construction, transportation, communication and other services sectors are leading sectors. In 2014, the contribution of the West

Kotawaringin Regency to Central Kalimantan's Gross Regional Domestic Product amounted to IDR 9.4 billion. The largest contributions came from the agriculture, forestry and fisheries, manufacturing, trade and transportation sectors, respectively (BPS 2015).

Economic development is closely related to the allotment of land use. Regional development due to rapid economic growth will undoubtedly cause changes in land use. The negative impact of a misdirected development process is deterioration in environmental quality due to poor land use planning (Natalia & Pandjaitan 2018; Hesty et al 2019). Limited land availability is often resolved by shortcuts, namely land conversion. The West Kotawaringin Regency is an area that has quite diverse economic potential, but information regarding the potential of natural resources and the environment in policy making is still limited. In addition, data and spatial information on the potential of the region for exploiting sources of regional revenue have not yet been utilized, resulting in being unable to meet the regional revenue target in 2012-2016. In terms of spatial planning, there has been a massive transformation of land functions, particularly forest and agricultural areas, as well as overlapping land permits (BIG 2018). Information about land use change has not been mapped, so it is not presented comprehensively. Regional Regulation no. 1 of 2018 concerning the West Kotawaringin Regency Spatial Planning is relatively new, so that the lack of information about spatial planning causes obstacles in regulating the balance of sustainable use of space.

Based on these facts and in line with development goals for meeting basic human needs in harmony with land needs, it is necessary to plan for sustainable regional development using land based leading sectors. To overcome problems in terms of regional development planning, which is very complex and dynamic, a solution is needed with a dynamic spatial system approach that is able to predict future land use changes not only in terms of area (magnitude), but also location (spatial) and the time when it will occur (Constanza 1989; Batty et al 1999; Jensen 2000; Odum & Barrett 2005).

The objectives of the study are: 1) to analyze the leading sectors; 2) to analyze the land use change for land-based leading sectors; and 3) to build a dynamic spatial model of regional development using land-based leading sectors in West Kotawaringin.

Material and Method

Data types and tools. The material used consists of primary and secondary data. Primary data in the form of land use maps for the years 2007, 2010 and 2016 were directly interpreted by SPOT 5/6/7 satellite imagery. Secondary data are available in the form of Input-Output (IO) Table and geo-spatial information such as: topographical, regional spatial plan, land suitability, soil type, forest area status maps, and driving factors of land use change. The equipment used included GPS, a camera, Arc-GIS10.2, Global mapper and Python 32 + Mapnik Version 3.0.12. Table 1 summarizes the types of data, analysis methods and outputs for each objective. This research was conducted between May 2019 and February 2020.

Table 1

Data, methods and outputs

No	*Objectives*	*Data*	*Methods*	*Outputs*
1	To analyze the leading sectors	Input-Output table of 2012 of the West Kotawaringin Regency	IO analysis	Leading sectors
2	To analyze the change in land use of the land-based leading sectors	SPOT satellite imagery of 5/6/7, maps with a scale of 1:50,000, which consists of topographic, soil type, land cover, regional spatial plan, land suitability, and forest area status	GIS analysis	Spatial description of the leading sector land use changes
3	To build a dynamic spatial model of regional development using a land-based leading sector	Land use history, driving factors of land use change	Spatial dynamic modelling	Spatial dynamic model of land use change

Data analysis method

1. Determining the leading sectors. The 2012 IO table based on producer prices was used to determine the leading sectors. The IO table is an index that uses two types, namely 9 and 48 business sectors. All sectors are connected through a table of relations between sectors. The linkage mechanism between these sectors is used as a basis for determining leading sectors. The sectors that have the largest total index of linkages are defined as leading sectors (Nurkholis 2003; Hirawan & Nurkholis 2008; Sutrisna 2011; Sutrisna et al 2019). Formulas in determining leading sectors, starting from the arrangement of the IO table in the balanced equation, means that the amount of production is equal to the number of inputs as in equations (1) and (2).

Line of IO table (sum of production): $\sum_{j=1}^{n} x_{ij} + f_i = X_i \quad \forall i = 1,\ldots,n$ ....(1)

Column of IO table (sum of input) : $\sum_{i=1}^{n} x_{ij} + v_j + m_j = X_j \quad \forall j = 1,\ldots,n$ ....(2)

where: x_{ij} = value of goods or services flowing from sector i to sector j;
f_i = total of final consumptions;
v_j = added value;
mj = import;
Xi = number of productions;
Xj = number of inputs;
n = number of sectors.

The flow between industries is transformed into the coefficients of inter sectoral linkages and notated as in equation (3):

$$a_{ij} = x_{ij}/X_j \qquad \text{............(3)}$$

In matrix notation, equation (3) can be written as follows:

$$AX + f = X \qquad \text{............(4)}$$

With simple manipulation of equation (4), the following relationship is obtained:

$$(I\text{-}A)^{-1} f = X \qquad \text{............(5)}$$

Matrix $(I\text{-}A)^{-1}$ is an inverse Leontief matrix which contains important information about how an increase in production of one sector causes the development of another sector. To facilitate understanding, the matrix $(I\text{-}A)^{-1}$ of equation (6) is given the notation B, to be:

$$(I - A)^{-1} = B = \begin{pmatrix} b_{11}^{AA} & b_{12}^{AA} & b_{11}^{AB} & b_{12}^{AB} \\ b_{21}^{AA} & b_{22}^{AA} & b_{21}^{AB} & b_{22}^{AB} \\ b_{11}^{BA} & b_{21}^{BA} & b_{11}^{BB} & b_{12}^{BB} \\ b_{21}^{BA} & b_{22}^{BA} & b_{21}^{BB} & b_{22}^{BB} \end{pmatrix} \qquad \text{............(6)}$$

Matrix B is a set of interrelationship coefficients between sectors. There are 2 (two) dependency coefficients across sectors, namely backward linkages which are links to raw materials, and forward linkages which are links to sales of finished goods. The coefficient of linkage equation (3) does not show the series of effects of one sector on another. Analysis of the multiplier effect is used because it is able to trace a series of effects of one sector on other sectors as a whole, both directly, indirectly or in a spillover.

There are three types of multipliers in the analysis with IO, namely output, income and labour. The output multiplier describes a condition if there is a change in the exogenous or shocking variable, the effect of the change can be seen on the increase in output across all sectors. The mechanism of action is to use an input coefficient matrix of a_{ij} coefficients, the effect of changes on final demand. The effect of household income multipliers is often referred to as income effects. The measurement of income multipliers is classified into three types, namely type 1, type 2 and total income multipliers, calculated by equations (7) and (8):

Income multiplier type 1 = $\frac{v(I-A)^{-1}}{v}$ ....(7)

Income multiplier type 2 = $\frac{v(I-A^{*})^{-1}}{v}$ ....(8)

where: v = the value added part of the wage/salary per total output;
$(I\text{-}A)^{-1}$ = Leontief inverse matrix;
$(I\text{-}A^{*})^{-1}$ = new Leontief inverse matrix.

2. Identifying land use change. The data used to analyze land use change are SPOT satellite images 5/6/7 in 2007, 2010 and 2016. The SPOT satellite image data is corrected from geometric, atmospheric and radiometric aspects. The process of sharpening satellite imagery is carried out to produce a clearer visual display so that it is easy and accurate to interpret. Visual interpretation and manual digitization are used because the method has better accuracy compared to digital classification/automation systems (Spruce et al 2018; Kosasih et al 2019). Land cover/land use interpretation is done by using several key interpretations which include hue or colour, size, shape, texture, shadow, pattern and association (Kohl et al 2006; Maulana & Wulan 2015; Purwadhi & Sanjoto 2010).

Land cover classification refers to the classification of the Indonesian land cover map with a scale of 1:50,000. Field checks are carried out for validation of land cover maps produced in 2016. Field checking data were obtained from the results of a field survey of fifty sample points. The use of open source-based satellite imagery is used to further confirm the land cover in the research sites as a complement to the field survey data. Accuracy testing is performed using a confusion matrix. The magnitude of land use classification accuracy is identified by using the producer, user and overall accuracy, and also the Kappa value (Kosasih et al 2019). Redelineation is carried out where land use boundaries are considered inappropriate. The area is calculated using the Equivalent Lambert Cylindrical Equal-Area projection system (Savric & Jenny 2014; Khafid & Artanto 2014). Spatial data analysis in the form of a map of land use change is carried out using the Arc-GIS 10.2.

3. Building a spatial dynamic model. Methods in modelling land use changes are based on Cellular Automata (CA), Markov Chain and Driving Factors. The CA represents changes in land use (where) and time (when). Land use changes with dynamic spatial models, land use change estimates and transition algorithms are determined through a stochastic model (De Almeida et al 2005). Lambin & Meyfroidt (2000) state that dynamic spatial models are better at predicting change and land use change intensity than simultaneous empirical and stochastic models. Markov Chain mathematically explains the stages of land use change. Fifteen driving factors are used grouped into biophysical, socio-economic and policy categories (Table 2).

Table 2

List of driving factors in land use change

Biophysical	*Socio-economic*	*Policy*
1. Distance to arterial road; 2. Distance to footpath (plantations); 3. Distance to a large river; 4. Altitude; 5. Slope; 6. Suitability for rice fields; 7. Land suitability for plantations.	1. Distance to airport; 2. Distance to seaport facilities; 3. Distance to the economic/government centre; 4. Distance to educational facilities; 5. Distance to health facilities.	1. Status of cultivation rights (estate); 2. Freehold and business use rights (services and settlements); 3. Status of forest area.

Important aspects in dynamic spatial modelling are the rasterization, normalization and reclassification of input data. Rasterization is the process of changing the format from vector to raster. This step is done if the driving factor data is not calculated based on distance, but the actual value. If it is based on distance, then the distance is calculated by Euclidian (the distance to the closest source for each cell). Normalization is the equalization of the range of attribute values for all data, bearing in mind that the weight of each data item differs according to the value determined based on the normal distribution, using equation (9):

$$z_i = \frac{x_i - \mu}{\sigma} \quad \text{............(9)}$$

where: z_i = normal distribution;
x_i = pixel raster value to be distributed normally;
μ = mean data;
σ = standard deviation.

Reclassification is a step to reclassify data resulting from the normal distribution of driving factors so that the class becomes homogeneous with the class of land expansion. The sampling window is the stage of taking the land expansion type layer. In line with objective number 1, settlement/service and plantation lands are calculated for similarity values with several image sizes. In dynamic spatial modelling, the two types of expansion are called the sampling window, which is mathematically calculated by equation (10):

$$f_w = \frac{\sum_{s=1}^{t_w}\left[1 - \frac{\sum_{i=1}^{p}|a_{1i} - a_{2i}|}{2_{w^2}}\right]}{t_w} \quad \text{............(10)}$$

where: f_w = the similarity value (f) of the window size/sampling window size (w);
w = the size of the image for which you want to see similarity (window size);
a_i = number of categories (i) in image size (k) in the sampling window size;
p = the number of different categories or classes in the picture;
t_w = number of image cuts (t) calculated in sampling windows (w).

The weight calculation which is the average similarity value of various sizes according to the goodness of fit model is calculated by equation (11):

$$f_t = \frac{\sum_{s=1}^{t_w} f_w\, e^{-k(w-1)}}{\sum_{w=1}^{n} e^{-k(w-1)}} \quad \text{............(11)}$$

where: f_t = the average similarity of the results of the sampling window, and is assumed to be the weight of the driving factor;
k = the similarity value constant. k=0 means all the similarity values of the sampling window are considered important, and k=1 means that only the first or the smallest sampling window is considered important, and the rest are not.

Spatial validation is done to test the results of the model by calculating the overall accuracy (Jensen 1995). The range of overall accuracy values is 0 to 100 and expressed in units of percent (%) and can be calculated by equation (12):

$$\textbf{Overall Accuracy} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} [\![(x]\!]_{i+}\, \mathbf{x}\, x_{+i})}{N\sum_{w=1}^{n} e^{-k(w-1)}} \quad \text{............(12)}$$

Until now, the category of overall accuracy value in spatial modelling has not been determined as an agreement. The overall accuracy value in the model validation in this study was set at > 70% and then used in the calculation of spatial simulation.

Land attractiveness is determined by three models, namely CA, Markov Chain and Driving Factor. Based on the 2016 land use data the process of calculating changes in use is carried out using priority transition rules determined based on cost factors. The analysis used in the CA model is the nearest neighbour factor using equation (13):

$$p_{ij} = \frac{p_{ij}^{0} - p_{ij}^{r}}{r_{ij}^{n} + max.r_{ij}^{n}} \quad \text{............(13)}$$

where: p_{ij} = interesting land from the nearest neighbour at coordinates (i, j);
p^0 = cost priority of the type of land to be converted;
p^r = cost priority of the type of land that will be converted;

r^n = the distance in coordinates (i,j) to the class of land that will convert to n data that has been normally distributed.

The nearest neighbour factor is sorted by land type and priority order of cost. Open land has the lowest cost value, while settlements have the most expensive cost value. Based on these calculations, the cost priority table based on the nearest neighbours shows that: if open land has the same distance from the rice fields, then for the benefit of settlements there is a tendency to choose open land to be converted rather than rice fields. Likewise other types of land can also be explained using the same analogy.

The Markov model represents a model of land attractiveness based on historical land use data. For this purpose, land use data must be available for at least two time periods. From the two time periods the land use change can show the change of function and the percentage of the change. Calculation of land attractiveness based on historical land use change data using equation (14):

$$h_{ij} = \frac{a_1^1 - a_n^0 / a_1^1}{r_{ij}^1 + max.\, r_{ij}^1} \quad \text{.............(14)}$$

where: h_{ij} = the pull of the land use from the probability value in coordinates (i, j);
a^1 = area of a type of land use that converts previous land use;
a^0 = size of the initial land use type converted to new land use;
n = type or class of land use being converted;
1 = types or classes of land use undergoing expansion;
r_1 = distance to land use expansion that converts other land use (n) where the distance data is normally distributed.

The role of the driving factor model is as a determinant of costs and benefits in calculating land use attractiveness and can be calculated by Constanza as equation (15):

$$d_{ij} = \frac{\left(1 + \sum_m w_m . b_{ij}^m\right) + max\left(1 + \sum_m w_m . b_{ij}^m\right)}{\left(1 + \sum_n w_n . c_{ij}^n\right) + max\left(1 + \sum_n w_n . c_{ij}^n\right)} \quad \text{.............(15)}$$

where: d_{ij} = land use attractiveness at coordinates (i, j);
b_{ij} = benefits of driving factors that are normally distributed at coordinates b (i,j);
c_{ij} = benefits of driving factors that are normally distributed at coordinates c (i, j);
w_m = weight of cost determinant m;
w_n = weight of cost determinant n;
m = type or class of land use that suitable for conversion;
n = type or class of land use being converted.

The three determinants of land use attractiveness are calculated in a ratio of 1:1:1 in determining the location of the most attractive to unattractive land use. Then the land use attractiveness for the growing class is calculated using equation (16):

$$a_{ij}^n = d_{ij}^n \ x \ p_{ij}^n \ x \ \boldsymbol{h}_{ij}^n \quad \text{.............(16)}$$

where: a_{ij} = attractiveness of land use for classes that are growing or converting land use;
n = the class or type of land use included in the spatial model.

Results and Discussion

Leading sectors and inter sectoral linkages. Based on the IO table, the overall relationship (direct or indirect linkages) between sectors is calculated. The result is a leading sector, often called a catalyst, because if there is a shock to the sector, it will have a significant impact on the economic system, and vice versa.

Direct forward linkage illustrates the effect of one sector on another that uses a part of the output per unit of total demand directly. Direct backward linkage is the direct influence of one sector in providing intermediate inputs for the needs of the sector per unit of total demand. According to Sutrisna (2011), the sector that has the largest total both direct Forward Linkage Index (FLI) and Backward Linkage Index (BLI) is defined as the leading sector. Table 3 shows direct FLI and BLI and its total for the 9 sector grouping category.

Table 3

Index of direct linkage in 9 sector groups

No	Sector name	Direct linkage index		Total	Ranking
		FLI	*BLI*		
1	Agriculture	0.34	1.16	1.50	3
2	Mining and quarrying	0.05	1.01	1.06	9
3	Processing industry	0.33	1.10	1.43	4
4	Electricity and clean water	0.15	1.04	1.19	6
5	Buildings	0.07	1.03	1.10	7
6	Trade, hotels and restaurants	0.50	1.24	1.74	2
7	Transportation and communication	0.67	1.33	2.00	1
8	Financial institutions and rent	0.27	1.07	1.34	5
9	Other services	0.04	1.02	1.06	8

By looking at the total values of FLI and BLI, it can be seen that the leading sectors in the West Kotawaringin Regency are: 1) Transportation and communication (2.00); 2) Trade, hotels and restaurants (1.74); 3) Agriculture (1.50); and 4) Processing industry (1.43). Rusmadi (2002) stated that the leading sectors in the West Kotawaringin Regency are manufacture, transportation and communication industries, and agriculture. Nurhayati (2016) stated that the leading sectors of the West Kotawaringin Regency are agriculture, forestry and fisheries; processing industry; and trade, restaurants and hotels. BPS (2012) confirms that growth is influenced by the agricultural sector (oil palm); processing industry; trade, restaurants and hotels; and transportation. The agricultural sector contributes 41%, of which oil palm has a 24.69% output share. The processing industry contributed 24.25%; trade, restaurants and hotels accounted for 11.91%; and transportation 7.46%. Leading sectors of this study are aligned but slightly different from the results of Nurhayati's research (2016) and supported by BPS data (2012).

The dominant business fields in the agricultural sector are oil palm, wood and rubber. The increase in oil palm production is in line with the increase in plantation area. In the transportation sector, the sea transportation business field contributed Rp 317 billion. There is a difference with the results of this study because the land transportation business field does not enter the leading sector category. The trade, hotel and restaurant sector consist of two business fields and what stands out is trade with a contribution of Rp 1.02 trillion. In the manufacturing industry sector, the building timber industry business field ranks first, followed by the sawn and processing industry (BPS 2012).

Direct and indirect linkages in the future describe the magnitude of the influence of a sector directly and indirectly on other sectors that use the output of that sector. Direct and indirect backward linkages are the rate of change due to an increase in the unit demand for the end product of one sector that provides a sector input to another sector. Table 4 shows direct and indirect FLI and BLI and its total for the 9 sectors grouping category.

Table 4

Index of direct and direct linkages in 9 sector groups

No	Sector name	Direct and indirect linkages index		Total	Ranking
		FLI	*BLI*		
1	Agriculture	1.09	0.99	2.08	4
2	Mining and quarrying	0.77	0.89	1.66	9
3	Processing industry	1.04	1.10	2.14	3
4	Electricity and clean water	0.86	0.97	1.83	6
5	Buildings	0.80	1.08	1.88	7
6	Trade, hotels and restaurants	1.26	0.98	2.24	2
7	Transportation and communication	1.44	1.11	2.55	1
8	Financial institutions and rent	0.97	1.01	1.98	5
9	Other services	0.77	0.99	1.76	8

Table 4 shows the output as a total index for the Transportation and communication sector (2.55); Trade, hotels and restaurants (2.24), Processing industry (2.14) and Agriculture (2.08). Other sectors using the most output from the transportation and communication sectors are trade, hotels and restaurants (11.04%) and agriculture (1.70%). The significant role of the transportation sector is sea transportation, river-lake-crossing transportation, and air transportation. The output of the trade, hotel and restaurant sector is mostly used for the agriculture sector 8.99%, the transportation and communication sector 5.73% and the manufacturing industry sector 2.73%. The hotel and restaurant business sector has more dominant role compared to the trade sector (1.34). The agricultural sector is used for transportation and communication (3.98%), the trade, hotel and restaurant sector (3.54%), and the manufacturing sector (3.24%). The types of agricultural sector commodities are rubber (1.44) and wood and palm oil (1.26). Output of the manufacturing sector is used for agricultural purposes (11.41%), trade, hotels and restaurants (4.90%), and transportation and communication (4.78%).

The multiplier effect is the total impact of exogenous effects on economic activity, the magnitude of which depends on the extent/intense interaction between sectors (Basri 2008). From the results, the output multiplier of the trade, hotel and restaurant sector is the highest in using the demand for goods/services in meeting its sector production inputs (78.08%). The leading sectors supported are agriculture (8.99%) and transportation and communication (5.73%). The manufacturing industry sector fulfilled 74.08% of production and consumption inputs, and its output was able to support the transportation and communication sector (3.98%), trade, hotels and restaurants (3.54%), and agriculture (3.24%). The agricultural sector, and the transportation and communication sector are actually in 6th and 8th positions. Therefore, it can be said that the agriculture and transportation and communication sectors have not been able to boost output.

Land use change. Land use change was quite rapid in the West Kotawaringin Regency during 2007-2016. BPS (2015) shows an increase in plantation area and a significant decrease in forest area. The 2007 topographic map shows forests still dominate with an area of 633,538 ha (greater than 78,607 ha of plantations) in 2007. After 2007 plantations began to develop into the Sub Districts of North Arut, Pangkalan Banteng and Pangkalan Lada, because the land was suitable for oil palm and rubber. The increase in population and yield of plantations expand to the Sub Districts of Kotawaringin Lama and South Arut. In 2010, more than 80% of the land in Sub Districts Pangkalan Lada and Pangkalan Banteng was used for oil palm and rubber. Geographically, plantation expansion in 2010 occurred in the central and northern regions. Figure 1 shows the land cover of the West Kotawaringin Regency in: a) 2007, b) 2010 and c) 2016.

The expansion of the plantation area in 2016 was not as fast as in the previous period being 6,500 ha year^{-1}, whereas the growth of plantation land changes in the 2007-2010 period was 46,000 ha year^{-1}. The conversion of forests to plantations was significant. For the period of 2007-2010, the forests that were converted for use reached 85,570 ha. During 2010-2016, the forest area was reduced by 104,830 ha. The trend of land use change from 2007 to 2010 is located in the middle and to the west, namely in the Sub Districts of Pangkalan Lada, Pangkalan Banteng, South Arut and Kotawaringin Lama.

An extreme condition is shown in the Sub District of Pangkalan Lada, where more than 50% of land use has changed. The most dominant land use changes are shrubs, forests and dry fields. Conversion of forest areas to plantations covers an area of 4,093 ha, and dry fields to plantations covers an area of 3,623 ha. The Sub District of Kotawaringin Lama also underwent major changes, from forests to plantations covering an area of 36,398 ha. Converting from shrubs occurred on 8,307 ha. Settlements in the Sub District of Kotawaringin Lama are advancing more slowly than in the Sub District of Pangkalan Lada where settlement reaches 256 ha.

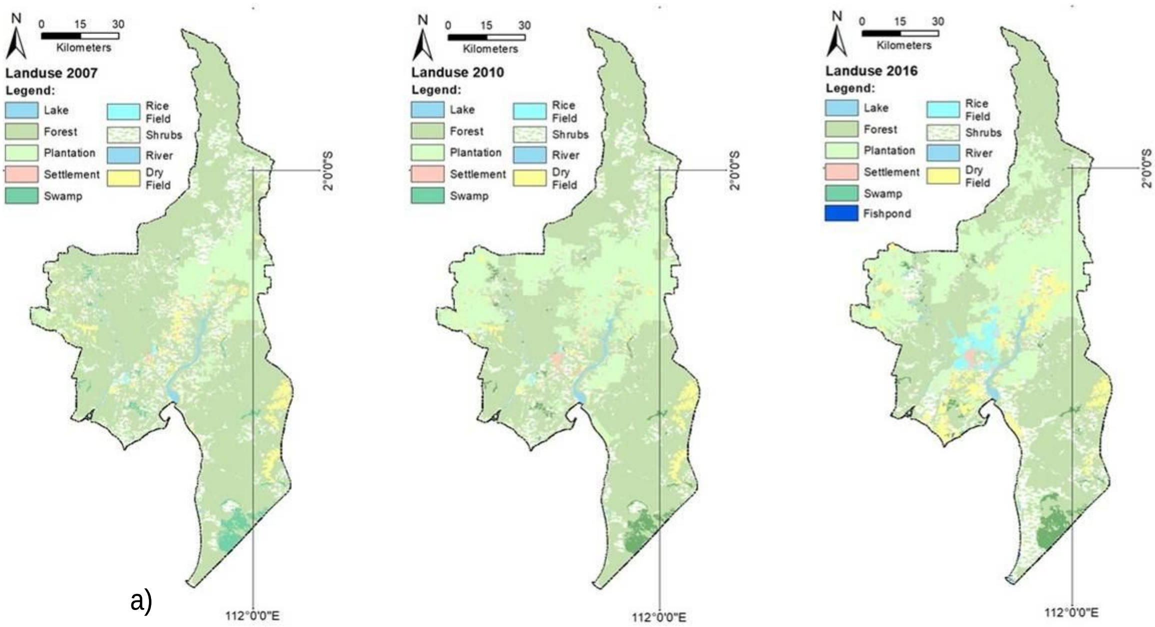

Figure 1. Land cover of the West Kotawaringin Regency in: a) 2007, b) 2010, c) 2016.

Changes in land use for the period of 2010-2016 are more evenly distributed. Plantation growth is highest in the Sub District of North Arut and South Arut. The conversion of forests into gardens in the Sub District Arut Utara reached 23,514 ha. This result is in accordance with the research of Tacconi et al (2008), Hansen et al (2009), Moore et al (2013), Margono et al (2014), and Gaveau et al (2016).

The conversion of land into plantations benefits from the economic aspect because there is a large river. Transportation costs can be reduced because the oil palm and rubber products are transported by river. The agricultural sector plays a role in the economy, foreign exchange earnings, provision of food and industrial materials, poverty, employment, and increasing income. Every year there is a fluctuation in labour in the plantation sector even though the area of plantations is always increasing. The trade, hotel and restaurant sector can be spatially observed based on the development of the extent of land use for settlement designation. During 2007-2016, the area of residential land use continued to increase from 4,757 ha to 9,519 ha. The land use change during 2007-2016 can be seen in Table 5.

Table 5

Land use change in 2007, 2010 and 2016

No	*Land use*	*Area (ha)*			*Percentage (%)*		
		2007	*2010*	*2016*	*2007*	*2010*	*2016*
1	Lake/situ	284	284	1,210	2007	2010	2016
2	Forest	633,538	547,968	443,138	0.3	0.3	0.1
3	Plantation	78,607	219,247	258,497	66.5	57.5	46.5
4	Settlement/place of activity	4,757	7,011	9,519	8.3	23.0	27.1
5	Swamp	19,391	19,528	21,386	0.5	0.7	1.0
6	Rice fields	1,413	1,129	17,663	2.0	2.1	2.2
7	Shrubs	173,021	121,520	141,142	0.2	0.1	1.9
8	River	9,664	9,664	9,574	18.2	12.8	14.8
9	Pond	0	0	398	1.0	1.0	1.0
10	Dry field	32,555	26,879	50,703	0	0	0
	Total	953,230	953,230	953,230	3.4	2.8	5.3
					100.00	100.00	100.00

In the pattern of land use change in 2007-2016, forest-plantation-plantation ranks first with a total area of 143,299 ha, followed by forest-shrubs-shrubs with a total area of 77,137 ha. The shrubs-plantation-plantation pattern rans 3rd with a total area of 68,606 ha. Whilst dry field-plantation-plantation occupies the 4th position with a total area of 5,638 ha. Overall the pattern of major land use changes are forest-plantation-plantation, shrubs-plantation-plantation and dry field-plantation-plantation with a total area of 217,543 ha. More detail can be seen in Table 6.

Table 6

Patterns of land use change in 2007-2016

Year			*Total area (ha)*
2007	*2010*	*2016*	
Forest	Plantation	Plantation	143,299
Shrubs	Plantation	Plantation	68,606
Dry field	Plantation	Plantation	5,638
Forest	Shrubs	Shrubs	77,137
Shrubs	Forest	Forest	35,697
Dry field	Settlement	Settlement	1,420
Others	Others	Others	115,200

An accuracy test of the results of land cover classification was carried out through a field survey at 50 sample points. The results of the calculation of overall accuracy = 94.43 and Kappa's index = 0.93.

Dynamic spatial model of land use change. Historically, in the 2007-2016 period there were significant changes in land use in the West Kotawaringin Regency. In the 2007-2010 period, land use changed on 286,063 ha (30%), and in the 2010-2016 period it changed on 209,839 ha or 22%, equivalent to the area of the West Kotawaringin Regency. The largest land use conversion was in the 2007-2010 period on plantation land which reached 140,640 ha in three years. The biggest conversion of forest land to other land uses in the period 2010-2016 is 104,830 ha or equal to 11% of the area of West Kotawaringin. The main patterns of land use change during the period of 2007-2016 are forest-plantation-plantation covering 143,299 ha, shrubs-plantation-plantation covering 68,606 ha, and dry field-plantation-plantation covering 5,638 ha.

The results from the analysis of land use change and land use patterns are an important part of modelling related to the prediction of future land use expansion. Driving factors are categorized into biophysical, socio-economic and policy. Some driving factors have more than one category of variables because their functions are related to land use change. Types of land use change in urban areas differ from rural areas, but in modelling it is likened because the parameters of the rules are contained in commensurate rules. For example: land use permits use spatial licensing, while the difference is at the scale of detail, the city spatial plan uses a scale of 1: 25,000, and the district spatial plan uses a scale of 1: 50,000.

Driving factors data must have the same format and scale of data. Data in various formats is made uniform through the process of data conversion. Then the weighting of the driving factors is carried out. The rasterization process is carried out for all types of data in vector format (point, line and polygon). Normalization is done by equation (9) and reclassification. The results of the three processes are as in Table 7. The index presented in Table 7 shows the minimum (Min.) and maximum (Max.) figures.

Table 7

The results of rasterization, normalization and reclassification

Driving factor	*Rasterization*		*Normalization*		*Reclassification*	
	Min.	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*
DF_01 Altitude	-13.00000	1.528000	-1.000000	26.000000	0.000000	255.000000
DF_02 Distance to the main road network	0.001797	0.438308	-0.947474	3.368424	0.000000	255.000000
DF_03 Slope	0	83.317850	-0.732579	12.505240	0.000000	255.000000
DF_04 Distance to the airport	0.001797	1.220796	-1.799629	3.393158	0.000000	255.000000
DF_05 Distance to seaport	0.001797	1.145639	-1.712226	3.562405	0.000000	255.000000
DF_06 Distance to major rivers	0.001797	0.199822	-1.364724	3.991463	0.000000	255.000000
DF_07 Distance to education	0.001797	0.633976	-1.254952	2.999959	0.000000	255.000000
DF_08 Distance to health facilities	0.001797	0.925758	-1.548858	3.490685	0.000000	255.000000
DF_09 Distance to the economic centre	0.001797	0.791827	-1.366409	3.444849	0.000000	255.000000
DF_10 Distance to plantation paths	0.001797	0.567761	-0.752885	4.101421	0.000000	255.000000
DF_11 Conformity of oil palm plantations	0.000000	1.000000	0.000000	1.000000	0.000000	128.000000
DF_12 Suitability for rice fields	0.000000	1.000000	0.000000	1.000000	0.000000	128.000000
DF_13 Property rights and building rights	0.000000	1.000000	0.000000	1.000000	0.000000	128.000000
DF_14 Cultivation rights	0.000000	1.000000	0.000000	1.000000	0.000000	128.000000
DF_15 Forest area status	0.000000	1.000000	0.000000	1.000000	0.000000	128.000000

The next step is to take the average driving factor weight towards the expansion of residential and plantation land. Weight calculation is based on the similarity pattern between driving factors and the spatial pattern of changes in land use types. The magnitude of the similarity value is 0.01 (not similar) to 0.99 (very similar).

As seen in Table 8, there is no real difference in the weight of the driving factor on land expansion of both settlements and plantations. The weighting range of the driving factor to the expansion of the smallest residential area is 0.8500 for DF_12 and the largest is 0.9339 for DF_02, while the smallest expansion of plantation land is 0.8500 for DF_12 and the largest is 0.9518 for DF_10. In other words, the expansion of residential land mostly has a similar pattern to the proximity of the main road. This is linear with conditions in most other regions. DF_06 has the second largest average weight of 0.9219, meaning that in the initial period, rivers functioned for transportation, but based on the calculation of spatial weights in 2007-2016, the road factor became more important to the trend of expansion of residential land compared to large rivers.

Furthermore, based on the calculation of the spatial weighting in the 2007-2016 period, the tendency for expansion of residential land/services to major roads (collectors/arteries) is higher than that of expansions related to large rivers. Likewise, regarding the expansion of plantation land, the effect of expansion based on spatial analysis in 2007-2016 shows that the areas that have suitability for oil palm plantations show the greatest effect. The high weight of the two driving factors on the pattern of plantation and settlement land expansion leads to the assumption that the spatial data for land suitability from the Ministry of Agriculture had already been used by the government, the community, and the parties to the plantation business as initial planning for regional development.

Land attractiveness is considered only for two land use classes, namely residential areas and plantation areas. These two classes were chosen based on historical data, and the dynamics of time series land use in 2007-2016 showed the most dominant changes with positive and consistent trends. The process of compiling spatial information on land attractiveness is the final stage of spatial dynamics modelling before simulating land use projections. The last stage is excluding the spatial data of land attractiveness with existing data on residential and plantation areas. In this step, spatial data is cut to reduce model errors and ensure that future projections of changes in settlements and commercial areas grow in areas outside existing residential areas and plantation areas.

Table 8

The driving factor and the average weight for land expansion

Driving factor	*Weight for land expansion*	
	Settlement	*Plantation*
DF_01 Altitude	0.8510	0.8580
DF_02 Distance to the main road network	0.9339	0.9079
DF_03 Slope	0.8865	0.8882
DF_04 Distance to the airport	0.8881	0.8643
DF_05 Distance to seaport	0.8933	0.8670
DF_06 Distance to major rivers	0.9219	0.8886
DF_07 Distance to education	0.9211	0.8827
DF_08 Distance to health facilities	0.9109	0.8741
DF_09 Distance to the economic centre	0.9139	0.8782
DF_10 Distance to plantation paths	0.9067	0.9518
DF_11 Conformity of oil palm plantations	0.8508	0.8507
DF_12 Suitability for rice fields	0.8500	0.8500
DF_13 Property rights and building rights	0.8833	0.8833
DF_14 Cultivation rights	0.8753	0.8753
DF_15 Forest area status	0.8154	0.8154

Validation of dynamic spatial models is calculated using the overall accuracy method by performing a simple calculation between the appropriate number of pixels from the reference use map (in this case the results of the interpretation of land cover in 2016) with land use maps of the 2016 model results. The process of calculating overall accuracy is performed on land use data that has been converted to raster format. The results of the overall accuracy calculation show that the spatial dynamics model has a level of accuracy of 71.3%. Improving the accuracy of the model can be done in several ways such as carrying out the process of reinterpreting land use with field data or other references, and re-running the model with higher pixel unit determination.

The simulation results show that since 2017 the change in settlement land is stagnant, with only relatively small changes (10,322 ha to 15,632 ha), shrubs continue to decrease from 137,464 ha to 103,224 ha, forests reduced from 428,224 ha to 219,924 ha, the remaining land became plantations. From 2027 there is no more available land for the expansion of plantations. If there is still forest remaining, it cannot be converted because it is a national park area. It can be seen in Table 9 (note: the unit of area is one thousand hectares).

The land use change resulting from spatial simulation of the business as usual scenario in spatial forms can be seen in Figure 2: (a) 2020, (b) 2025, (c) 2030, (d) 2037.

Table 9

Land use projection simulating a business as usual scenario

Land cover	*Year of*											
	2016	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*	*2025*	*2026*	*2027*
Lake/situ	1	1	1	1	1	1	1	1	1	1	1	1
Forest	447	428	406	384	362	340	318	298	279	259	239	220
Plantation	261	280	300	320	340	360	380	400	420	440	460	480
Settlement	10	10	11	11	12	12	13	14	14	15	15	16
Swamp	22	22	22	22	22	22	23	23	23	23	24	24
Rice fields	18	20	21	23	25	27	29	30	32	34	36	37
Shrubs	142	137	135	133	131	129	127	122	117	112	108	103
River	10	10	10	10	10	10	10	10	10	10	10	10
Pond	0	0	0	1	1	1	1	1	1	1	1	1
Dry field	51	52	54	55	57	59	60	62	63	65	68	70
Total area	961	961	961	961	961	961	961	961	961	961	961	961

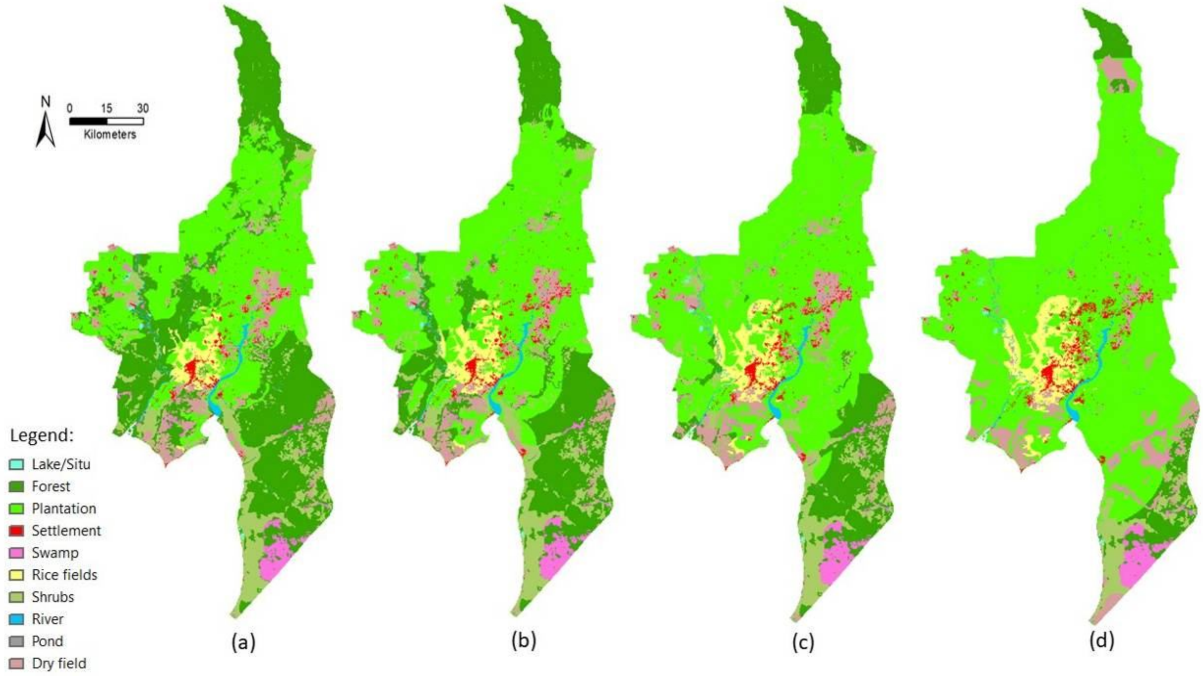

Figure 2. Land use change on: (a) 2020, (b) 2025, (c) 2030, (d) 2037.

An interesting point regarding the projections of swamp land use during the 2017-2037 period is that it will continue to increase though not significantly at a rate of 76.6 ha/year. The existence of swamps in other regions in Indonesia often occurs in marginal areas and often changes functions to other uses that have more economic value, as in most coastal cities in Indonesia, swamp areas are modified in such a way as to be forced into land use that is more productive. The analysis results of land use interpretation in the 2007-2010-2016 period indicate this fact. In West Kotawaringin there is a protected area, namely Tanjung Puting National Park which is an area that must be conserved. Based on the study, this area is dominated by peat ecosystems with mangrove vegetation. Such areas have a unique typology in relation to the process of interpreting remote sensing satellite images. These ecosystems are more recognized as swamps for land cover classification. Outside of the Tanjung Puting National Park area, most of the swamp area is distributed in the river meander area.

Upland land use also increases quite considerably by almost 20,000 ha for the projection for the next 20 years. In the land transition process, the field occupies the middle level, meaning the land use object has a semi-natural process, where economic activities such as primary product harvesting in these areas are still taking place although on a minor scale. Rice land use is also found in the study area, the results of multi-time interpretation analysis indicate an increase in rice area, so that it is normal for the land use projection process in the spatial dynamics model to develop as well. The value of rice field expansion is linearly significant, in 2016 the area of rice fields was recorded as 17,848 ha and in 2037 it becomes 53,608 ha.

The three dominant types of land use are forest, plantations and shrubs, which are the main concerns in the spatial dynamics analysis. Based on the analysis of land use projections up to 2037, forest land use experiences the most significant reduction in area of 388,764 ha over the next 20 years or an area reduction rate of 19,438 ha/year. The dynamics of shrub land use has the same pattern relative to forest land use, only the value of changes in the area is not as great as for forest. The use of shrub land is projected to experience an area decrease of 102,856 ha up to 2037 or a change of function from shrubs to other uses of 142.8 ha/year. The area for residential land use, both in terms of historical analysis and future projections will continue to increase. This is logical because of population dynamics that also continue to grow. The West Kotawaringin Regency statistics show a relatively large population growth. Based on statistics from the West Kotawaringin Regency, the population in 2007 was 223,432 people, in 2010 there were 244,900 people and in 2017 there were 304,302 people. The average population growth rate in 2007-2010 was 3.02%, and for 2010-2017 it was 3.50%.

Conclusions. The leading sectors of the West Kotawaringin Regency are transportation and communication; trade, hotel and restaurant; agriculture; and processing industry. The fields of business in the transportation and communication sector are sea, river-lake-crossing, and air transportation; in the trade, hotel and restaurant sector the leading sector is trade; in the agriculture sector the leading sectors are oil palm, wood and rubber; and in the manufacturing sector they are the building, sawn timber and processing industries. There are significant levels of land use conversion. In the period of 2007-2010 land conversion affected an area of 286,062 ha (30.01%), and in 2010-2016 an area of 209,839 ha. Overall the pattern of major land use changes is forest-plantation-plantation, shrub-plantation-plantation and dry field-plantation-plantation with a total area of 217,543 ha. Based on the results of the simulation model, from 2027 there will no longer be any conversion of land to plantations because there will be no land available.

Acknowledgements. Special thanks to the Postgraduate Program of Environmental and Resources Management, IPB University. Thanks to Habib Subagio, Edwin Maulana, Daning Panularsih and Ali Nurmoko from the Geospatial Information Agency who have played an active role in giving advice and input in this research.

References

Basri C., 2008 [Formulation and analysis of the Jakarta IO table]. UI, Indonesia, pp. 40-60. [in Indonesian]

Batty M., Xie Y., Sun Z., 1999 Modeling urban dynamics through geographic information system based CA. Computers, Environment and Urban Systems 23:205-233.

BIG (Badan Informasi Geospasial/Geospatial Information Agency), 2018 [Implementation of one map policy acceleration program]. Cibinong, Indonesia, pp. 60-66. [in Indonesian]

BPS (Badan Pusat Statistik/Central Bureau of Statistics), 2012 [West Kotawaringin IO table]. Catalog No. 9208.6201, West Kotawaringin, Indonesia. [in Indonesian]

BPS (Badan Pusat Statistik/Central Bureau of Statistics), 2015 [West Kotawaringin in numbers]. Catalog No. 1102001.6201, Kotawaringin Barat, Indonesia. [in Indonesian]

Constanza R., 1989 Model goodness of fit: a multiple resolution procedure. Ecological Modelling 47(3-4):199-215.

De Almeida C. M., Monteiro A. M., Camara G., et al, 2005 Geographic information system and remote sensing as tools for the simulation of urban land-use change. International Journal of Remote Sensing 26(4):759-774.

Gaveau D. L. A., Sheil D., Salim M. A., et al, 2016 Rapid conversions and avoided deforestation: examining four decades of industrial plantation expansion in Borneo. Scientific Reports 6:32017.

Hansen M. C., Stehman S., Potapov P., et al, 2009 Quantifying changes in the rates of forest clearing in Indonesia from 1990 to 2005 using remotely sensed data sets. Environmental Research Letters 4(3):034001.

Hesty R. S., Gunawan A., Prasetyo L. B., Munandar A., 2019 [Comparison of various techniques for estimating green open space in Bandar Lampung City]. Journal of Soil and Climate 43(1):59-70. [in Indonesian]

Hirawan S. B., Nurkholis, 2008 [Development of inter sectoral and inter-regional relations in the Indonesian economy: analysis of inter regional input-output in 1995-2000]. Journal of Indonesian Economy and Development 8(2):35-61. [in Indonesian]

Jensen J. R., 1995 Introductory digital image processing: a remote sensing perspective. 2^{nd} edition. Prentice Hall, New Jersey, USA, 316 pp.

Jensen J. R., 2000 Remote sensing of the environment: an earth resource perspective. Prentice Hall, New Jersey, USA, 544 pp.
Joko T., 2002 [Development direction, shape and physical structure of Pangkalan Bun-Kumai City, West Kotawaringin]. MSc Thesis, Diponegoro University, Semarang, Indonesia, 144 pp. [in Indonesian]
Khafid, Artanto E., 2014 [Method of calculation of the area of the unitary state of the Republic of Indonesia]. Centre for Boundary Mapping of the BIG: 50-67: [in Indonesian]
Kohl M., Magnussen S., Marchetti M., 2006 Sampling methods, remote sensing and GIS multiresource forest inventory. Springer-Verlag, Berlin, Germany, 373 pp.
Kosasih D., Saleh M., Prasetyo L., 2019 [Visual and digital interpretation of land cover classification in Kuningan District, West Java]. Indonesian Journal of Agricultural Sciences 24(2):101-108. [in Indonesian]
Lambin E. F., Meyfroidt P., 2011 Global land use change, economic globalization, and the looming land scarcity. Proceedings of the National Academy of Sciences 108(9):3465-3472.
Margono B. A., Potapov P., Turubanova S., et al, 2014 Primary forest cover loss in Indonesia over 2000-2012. Nature Climate Change 4:730-735.
Maulana E., Wulan T. R., 2015 [Identification of Barcan distribution in the Parangtritis sand dune core zone using unmanned aerial vehicle data]. National Symposium on Geoinformation Science IV, Jakarta, Indonesia: 15-35. [in Indonesian]
Moore S., Evans C., Page S., et al, 2013 Deep instability of deforested tropical peatlands revealed by fluvial organic carbon fluxes. Nature 493:660-663.
Nasoetion I. L., Rustiadi E., Saefulhakim S., 2000 [Use of IO analysis for selecting regional development priorities]. Proceedings of Seminar on Regional Autonomy, Jakarta, Indonesia, 11 pp. [in Indonesian]
Natalia G., Pandjaitan N. H., 2018 [Analysis of water storage capacity in Cibinong, Bogor]. Journal of Civil and Environmental Engineering 2(3):133-142. [in Indonesian]
Nurhayati N., 2016 [Determination of food crop commodity based on production value in West Kotawaringin]. Scientific Journal of Agriculture 3(2):81-89. [in Indonesian]
Nurkholis, Brojonegoro B. P. S., 2003 [The impact of fiscal decentralization on inter-regional economies: analysis of the IRIO model]. Journal of Indonesian Economy and Development 3(2):51-70. [in Indonesian]
Odum E. P., Barrett G. W., 2005 Fundamentals of ecology. 5th edition, Brooks Cole, USA, 598 pp.
Pasaribu E., 2009 [Regional economic performance review: empirical study of the province of central Kalimantan 2003-2007]. Palangkaraya, Indonesia. [in Indonesian]
Purwadhi S. H. F., Sanjoto T. B., 2010 [Introduction to remote sensing image interpretation]. LAPAN and State University of Semarang, Indonesia:50-57. [in Indonesian]
Rusmadi, 2002 [Analysis of leading agricultural and other sectors in the province of central Kalimantan]. Management UGM, Yogyakarta, Indonesia: 5 pp. [in Indonesian]
Savric B., Jenny B., 2014 A new pseudocylindrical equal-area projection for adaptive composite map projections. International Journal of Geographical Information Science 28(12):2373-2389.
Spruce J., Bolten J., Srinivasan R., Lakshmi V., 2018 Developing land use and land cover maps for the lower Mekong basin to aid hydrologic modeling and basin planning. Remote Sensing 10(12):1910.
Susilawati I. D., 2016 [Determination of main commodities in the food crops sector in Bone regency, South Sulawesi]. Proceedings of the Scientific Meeting IPLBI, pp. 23-30. [in Indonesian]
Sutrisna M. G., 2011 [The impact of infrastructure development in the master plan for the acceleration and expansion of Indonesia's economic development on the Indonesian economy]. Journal of Economic Policy 1(6):89-114. [in Indonesian]

Sutrisna M. G., Sitorus S. R. P., Widiatmaka, Marimin, Nurwajedi, 2019 Leading sector analysis in West Kotawaringin regency, Central Kalimantan Province, Indonesia. IOP Conference Series: Earth and Environment Science 399:012068.
Tacconi L., Jotzo F., Grafton R. Q., 2008 Local causes, regional cooperation and global financing for environmental problems: the case of Southeast Asian haze pollution. International Environment Agreements 8(1):1-16.

Received: 26 June 2020. Accepted: 27 July 2020. Published online: 30 August 2020.
Authors:
Muhtadi Ganda Sutrisna, Postgraduate of Environmental and Natural Science, IPB University, Pajajaran Street No. 1, Bogor (16127), West Java, Indonesia, e-mail: muhtadi_gs@yahoo.com
Santun R. P. Sitorus, Department of Soil Science and Land Resource Faculty of Agriculture, IPB University, Dramaga Street, Babakan, Bogor (16680), West Java, Indonesia. e-mail: santun_rps@yahoo.com
Widiatmaka, Department of Soil Science and Land Resource Faculty of Agriculture, IPB University, Dramaga Street, Babakan, Bogor (16680), West Java, Indonesia. e-mail: widi.widiatmaka@yahoo.com
Marimin, Department of Industrial System Engineering, Faculty of Agricultural Technology, IPB University. Dramaga Street, Babakan, Bogor (16680), West Java, Indonesia. e-mail: marimin_07@yahoo.com
Nurwajedi, Geospatial Education and Training Center of Geospatial Information Agency. Jakarta-Bogor Street Km. 46, Cibinong, Bogor Regency (16911), West Java, Indonesia. e-mail: nurwadjedi.big.go.id.

How to cite this article:
Sutrisna M. G., Sitorus S. R. P., Widiatmaka, Marimin, Nurwajedi, 2020 Changes in land use of the land-based leading sectors in West Kotawaringin Regency of Central Kalimantan. AES Bioflux 12(2):178-193.