Spatial modeling of paddy fields in Gorontalo Regency, Indonesia

E L Subandi1,2, Widiatmaka2, M Ardiansyah2
1 Study Program of Regional Planning Science, Graduate School, IPB University, Indonesia
2 Department of Soil Science and Management of Land Resources, IPB University, Indonesia
E-mail: erwinsubandi91@gmail.com

Abstract. Gorontalo Regency has the largest paddy field area in Gorontalo Province. But until now paddy fields in Gorontalo Regency continue to experience conversion. Protection of paddy fields is very important so that the rice needs are still fulfilled so as to realize food sovereignty. The objective of this research is to compile the spatial model of paddy fields in Gorontalo Regency in 2015-2035. The method used is a Weighted Linear Combination (WLC) based on Geographic Information Systems (GIS) and Cellular Automata (CA), and uses thematic accuracy tests for model validation. The results of the validation of the spatial model of paddy fields in Gorontalo Regency have a good level of accuracy, so that the scenarios built can be accepted. Based on scenario 1, paddy fields in 2015-2035 experienced significant conversions despite the increase in paddy fields in other places. The policy intervention built on scenario 2 shows that conversion of paddy fields in 2015-2035 can be slightly suppressed, but the area of paddy fields is still decreasing. The policy intervention built on scenario 3 shows that most of the conversion of paddy fields in 2015-2035 can be reduced so that the area of paddy fields can increase.

Keywords: Cellular automata, Geographic Information Systems, paddy fields, Weighted Linear Combination

1. Introduction
Agricultural land resources provide enormous benefits economically, socially, and environmentally. The loss of agricultural land, which is converted to non-agricultural use, will have a negative impact on various aspects of development [1]. There is a tendency of high demand for land in agricultural areas that have been developed, especially close to the target consumer as the suburbs, land close to access roads and residential areas [2]. On another side, productive land should be used for agriculture, such as paddy field; the current agricultural land began to decrease with the high demand for land to be used as a residential area. The rapid development of various sectors that need more space has an impact on the potential land for agricultural development [3].

The suburban area is an area that experienced high land-use changes [4], especially changes in agricultural land into non-agricultural due to the influence of a nearby town. The rapid growth of Gorontalo City in the sector of trade and services is the cause of the conversion of paddy fields in the

3 To whom any correspondence should be addressed (erwinsubandi91@gmail.com)
suburbs. Based on the analysis of the consistency between the map Gorontalo Regency official land use plan 2012-2032 year with a map of land use in 2015, it was discovered that the land designated as wetland agriculture had undergone conversion to settlements amounting to 143 ha.

The trend of changes in paddy fields that occurred in the past to present has become the basis for making decisions to realize sustainable paddy fields. Changes in paddy fields in the future can be predicted using Cellular Automata-based spatial models that are integrated with Geographic Information Systems (GIS). Geographical information systems are used to investigate information on land-use changes in each district or city [5]. GIS techniques have provided the potential to generate multi-resolution data sets to improve modeling [6]. Cellular Automata (CA) is a spatial modeling framework and a paradigm for thinking about the complexity of spatial-temporal phenomena.

CA is ideally used to simulate and predict the complex geographic phenomena [7]. CA can model the complexity of the event of the spatial-temporal well. The model can allocate the possibility of changes in the transition rules [8,9]. Model CA to consider the physical, social and economic, as well as optimizing the available land resources to support sustainable paddy fields. The spatial model of paddy fields needs to consider the potential of land where paddy fields can be developed [10]. This study aims to compile a spatial model of paddy fields in Gorontalo Regency in 2015-2035.

2. Methods

2.1. Weighted Linear Combination (WLC)

This research was conducted in Gorontalo District, Gorontalo Province, which is located between 0°30' - 0°54' North Latitude, and 122°07' - 123°44' East Longitude. Administratively, the regency is bordered by other regencies: (i) in the north with Regency of North Gorontalo; (ii) in the east with the city of Gorontalo; (iii) in the south with the Gulf of Tomini, and (iv) in the west with Boalemo Regency. Flow stages of research are presented in figure 1.

![Flow steps of research](image-url)

GIS-based Weighted Linear Combination (WLC) is one of the multi-criteria evaluation models that are widely used for land suitability analysis, land use analysis, priority land selection, and others through the process of standardizing values, weighting, and overlays [11]. GIS-based WLC can provide explanations and considerations for several criteria in selecting locations that are suitable to be developed for certain activities. According to [12], WLC is a concept that combines maps by applying standardized values to each parameter class and factor weights for the parameters themselves. WLC can
be used with GIS applications as described by [13] in equation 1. In this study, WLC can be operated using ArcGIS 10.5 software, because it has excellent ability in analyzing, converting vector to raster/raster to vector and overlay capabilities. GIS-based WLC procedures in this study include: (i) identification of a set of criteria; (ii) standardizing attribute values; (iii) weighting; (iv) scenario; and (v) overlay.

\[ V(X_i) = (\sum w_j r_{ij})(\prod r_{ik}^*) \]  

where:
- \( w_j \): Normal weight
- \( V(X_i) \): Function value attribute to \( j. \ X_i = (x_{i1}, x_{i2}, \ldots, x_{in}) \)
- \( r_{ij} \): Attributes are converted to comparable scales
- \( r_{ik}^* \): The value given to cell-i to the obstacle map

This study considers the value of land rent, previous studies related, and patterns of changes in land use/land cover over the past ten years. Parameters collected consist of 2 (two) factors, namely the driving factor and constraint factor in land use/land cover change (table 1). The standardization of attribute values used is 0 to 1. The closer to the value of 1, the stronger it is to encourage changes in land use/land cover. Conversely, the closer to 0 then the weaker or less feasible in contributing to changes in land use/land cover. In other words, a value close to 0, has a considerable limit. The standardized approach to attribute values is based on the assumption of strong linearity [14].

Weighting attributes by using binary logistic regression is used to obtain parameters that affect changes in land use/land cover. The relationship between changes in land use/land cover with driving factors can be evaluated using binary logistic regression analysis [15]. Regression analysis is applied to examine the relationship between land-use change and driving factors based on historical data [5,6]. The spatial model of paddy fields is carried out based on the scenario being constructed. Scenarios indicate the role of local government through policy interventions on the status and sustainability of paddy fields in Gorontalo Regency. It is essential to know because paddy fields are one of the primary food sources producing rice. The model scenario constructed in this study consisted of scenario 1, scenario 2, and scenario 3 (table 1). Overlay on WLC is multiplying each attribute of the drivers of standardized land use/land cover changes with attribute weights. Then add up all the attributes of the driving factors and increase them by inhibiting the changes in land use/land cover.

### Table 1. Scenario.

| Scenario | Information | Policy Intervention |
|----------|-------------|---------------------|
| Scenario 1 | The model simulation is built on the assumption that there is no prohibition on the conversion of paddy fields by the local government. | **Business as usual** |
| Scenario 2 | The model simulation is built on the assumption that there are policy restrictions on the conversion of paddy fields by the local government. | Paddy fields that are not maintained are:  
- Paddy fields located 100 m from the main road (arteries and collectors)  
- Paddy fields that are 2 km from the city center (Capital of the Regency and the City of Gorontalo). |
The model simulation is built on the assumption that there is a policy prohibiting the conversion of paddy fields by the local government based on Law Number 41 of 2009 concerning to sustainable food agriculture land and Gorontalo Regency official land-use plan.

Gorontalo Regency official land-use plan for 2012-2032:
- Existing paddy fields in wetland farming areas are maintained.
- Existing paddy fields outside the wetland farming area are not maintained.
- Paddy fields planned in the wetland farming area are maintained for the future development of paddy fields.

2.2. Simulation model
The spatial model is constructed using computational techniques based on the output destination 1 and 2, by utilizing LanduseSim software version 2.3.1. According to LanduseSim is a software and spatial modeling using a cell-based grid or raster data as a land-use spatial attribute. LanduseSim designed and developed for the needs of planning where the planner can determine the factors that are used to predict the future in spatial orientation. Implementation of models and simulations on LanduseSim software using cellular automaton method.

Cellular Automata (CA) is one of the dynamic models with local interaction that reflects the evolution of the whole system, in which space and time are considered as discrete units. CA has been widely used among planners in performing such geographic modeling to predict changes in land use/land cover, urban development planners, and others. Model CA can generate different spatial patterns based on transition rules defined locally. Cellular Automata consists of 5 elements consisting of Cell, State, Neighborhood, Transition Rule, and Time-Step. The CA elements used in this study include Cells (30 x 30 meters), State (LULC in 2010), Neighborhood (Moore, 3 x 3), Transition Rule (IF, THEN), and Time Step (2015, 2020, 2025, 2030, 2035).

The land-use change model is usually carried out by testing accuracy by comparing two map datasets simultaneously to reproduce known historical changes. Accuracy assessment reflects the real differences between the use/land cover simulation results with the use/land cover reference. Accuracy assessment is described in the error matrix (Error Matrix). The error matrix is the arrangement of squares of the numbers specified in rows and columns, which state the number of sample units for a particular category. The values in the cells contained along the diagonal are the correct classification results.

Accuracy assessment methods used in this study are thematic accuracy assessments, which include overall accuracy, user accuracy (user’s accuracy), and producer’s accuracy. The error matrix is a comparison between the area of land use/cover in 2015 simulation results with actual land use/cover in 2015 in Gorontalo Regency. The level of acceptable overall accuracy was 85% as the limit of acceptable results and unacceptable.

3. Results and discussion

3.1. Weighted Linear Combination (WLC)
The results of the overlapping analysis of the driving factors and inhibiting factors for land use/land cover changes produce a map of opportunity changes in land use/suitability based on scenario 1, scenario 2 and scenario 3. Land suitability map scenario 1, scenario 2, and scenario 3 are shown in figure 2, figure 3, and figure 4. The difference between land suitability maps in each scenario is policy intervention. Policy interventions are poured into spatial growth/land cover growth factors. The opportunity map for changes in land use/land cover indicated by green shades is an area that has high land priority. The opportunity map for changes in land use/land cover shown by yellow gradation is an area that has moderate land priority. The opportunity map for changes in land use/land cover indicated by red
gradations is an area that has low land priority. Low land priorities have significant limits based on physical, social, economic conditions and policy interventions.

**Figure 2.** Map of opportunity for land use/land cover changes scenario 1.

**Figure 3.** Map of opportunity for land use/land cover changes scenario 2.

**Figure 4.** Map of opportunity for land use/land cover changes scenario 3.
3.2. Simulation model

The model is validated using a thematic accuracy assessment, taking into account the overall accuracy (AK) obtained from equation 2. Data that were compared in this model is a comprehensive validation of land use/land cover in 2015 with an area of actual land use/land cover prediction in 2015 in scenario 1. Based on the results of the model validation scenario between land use/land cover in 2015 with the actual land use/land cover prediction in 2015 resulted in an overall accuracy value (AK) amounted to 87.81%. The total accuracy value (AK) is higher than 85%; then, the scenario model can be accepted for accuracy. The results of scenario 1 are built on the Cellular Automata (CA) model with the assumption that there is no prohibition on the conversion of paddy fields by the Gorontalo government (Business as usual) local government can be seen in figure 5.

![Figure 5. Prediction of changes in land use/land cover scenario 1.](image)

Prediction of changes in paddy field scenario 1 in 2015 has an area of 11,826 ha, entering the 2020 paddy field area has decreased to become 11,038 ha. In 2025 the area of paddy fields again reduced to become 10,342 ha, and in 2030 the same conditions occurred where the area of paddy fields was reduced to become 9,623 ha. At the peak of the prediction, which is in 2035, the paddy field area has again contracted to become 8,882 ha.

From 2015 through 2020, paddy fields have a conversion of 1,054 ha. Paddy fields in that period changed the function to plantations by 648 ha, to settlements by 229 ha, and sugar cane by 178 ha. From 2020 to 2025, paddy fields has again experienced a conversion of 920 ha. Paddy fields that change function into plantations are 566 ha, into settlements are 173 ha, and paddy fields that change the function to become sugar cane are 181 ha.

Between 2025 and 2030, paddy fields have been converted by 891 ha. Paddy fields that change function into plantations are 543 ha, into settlements are 166 ha, and paddy fields that change function into sugar cane are 182 ha. From 2030 through 2035, paddy fields have undergone a conversion of 841 ha. Paddy fields that change function into plantations amounting to 511 ha, into settlements covering 145 ha and paddy fields that change to become to sugar cane are 185 ha.

The conversion of paddy fields in scenario 1 from 2015 to 2035 is 3,706 ha. During this period, paddy fields that were converted into plantations and settlements tended to decrease in area. Meanwhile, paddy fields that are converted into sugar cane tend to increase in area. The area of paddy field conversion scenario 1 is presented in table 2.
Table 2. Area conversion of paddy fields scenario 1.

| Period of year | Conversion of paddy fields (ha) | Total  |
|----------------|---------------------------------|--------|
|                | Plantations | Settlement | Sugar cane |        |
| 2015-2020      | 648         | 229        | 178        | 1,054 |
| 2020-2025      | 566         | 173        | 181        | 920   |
| 2025-2030      | 543         | 166        | 182        | 891   |
| 2030-2035      | 511         | 145        | 185        | 841   |
| Total          | 2,268       | 713        | 726        | 3,706 |

In the same condition, scenario 1 under wetland experienced growth or increase in area. But the phenomenon of conversion and extension of paddy fields tends to be disproportionate. The conversion of paddy fields is higher than its growth.

From 2015 to 2020, paddy fields grew by 267 ha. Paddy fields which experienced growth in scenario 2 in 2015-2035 amounted to 753 ha originating from forest of 6 ha, from shrubs of 126 ha, and moor of 139 ha. From 2020 through 2025, paddy fields have experienced a growth of 224 ha. Paddy fields growth from forest 2 ha, from shrubs 100 ha, and from moor 122 ha.

Between 2025 and 2030, paddy fields have grown by 172 ha. Paddy fields experience growth from the forest 1 ha, from shrubs 84 ha, and from moor 87 ha. From 2030 to 2035, paddy fields has grown by 101 ha. Paddy fields experience growth from forest 1 ha, from shrubs 50 ha, and from moor 50 ha.

The growth of paddy fields in scenario 1 of 2015-2035 was 764 ha, where paddy fields grew in forests by 5 ha, from bushes 361 ha, and moor 398 ha. During this period, the type of forest, shrubs, and moor that turned into paddy fields tended to decrease in area. The growth area of paddy field in scenario 1 is presented in table 3.

Table 3. Extensive growth of paddy fields scenario 1.

| Period of year | Growth of paddy fields (ha) | Total  |
|----------------|-----------------------------|--------|
|                | Forest | Shrubs | Moor |        |
| 2015-2020      | 1      | 126    | 139  | 267   |
| 2020-2025      | 2      | 100    | 122  | 224   |
| 2025-2030      | 1      | 84     | 87   | 172   |
| 2030-2035      | 1      | 50     | 50   | 101   |
| Total          | 5      | 361    | 398  | 764   |

The results of scenario 2 are built into the Cellular Automata (CA) model with the assumption that there is no limit to the conversion policy of paddy fields by the Gorontalo Regency government, as shown in figure 6.

Prediction of changes in paddy fields in scenario 2 in 2015 has an area of 12,292 ha; in 2020, paddy fields are predicted to decrease to 12,150 ha. In 2025 the area of paddy fields again predicted to reduce to 12,016 ha, and in 2030 the same conditions occurred where the area of paddy fields was reduced to become 11,853 ha. Meanwhile, the paddy fields area in 2035 also experienced to become 11,679 ha.

From 2015 to 2020, paddy fields experienced a conversion of 407 ha. Paddy fields in that period changed a function to plantations by 139 ha, to settlements as much as 129 ha, and paddy fields that transformed to become sugar cane are 138 ha. Between 2020 and 2025, paddy fields have again experienced a conversion of 355 ha. Paddy fields that changed to become plantations are 121 ha, to become settlements are 107 ha, and paddy fields that are turned to sugarcane are 127 ha.
a. 2015  

b. 2020  

c. 2025  

d. 2030  

e. 2035

**Figure 6.** Prediction of changes in land use/land cover scenario 2.

In the year 2025-2030, paddy fields have undergone a conversion of 330 ha. Paddy fields that change function as plantations are 103 ha, as settlements are 111 ha, and paddy fields that are converted to sugar cane are 115 ha. From 2030 to 2035, paddy fields have a conversion of 270 ha. Paddy fields that change function into plantations amounting to 77 ha, into settlements covering 97 ha and paddy fields that change function into sugar cane are 97 ha.

Paddy field conversion in scenario 2 in 2015-2035 is 1,362 ha. During this period, paddy fields that were converted into plantations and sugar cane tended to experience a decrease in the area, whereas paddy fields that are converted into moor tend to increase. Meanwhile, paddy fields that were converted into settlements experienced fluctuations. From 2020 to 2025, paddy fields that changed into settlements have decreased. Entering the period of 2025-2030, the conversion of paddy fields into a settlement and other human activity increased, and between 2030 and 2035 again, they are declined. The conversion of the paddy field in scenario 2 is presented in table 4.

**Table 4.** Area conversion of paddy fields scenario 2.

| Period of year | Conversion of paddy fields (ha) | Plantations | Settlement and other human activity | Sugar cane | Total |
|----------------|---------------------------------|-------------|-------------------------------------|------------|-------|
| 2015-2020      |                                 | 139         | 129                                 | 138        | 407   |
| 2020-2025      |                                 | 121         | 107                                 | 127        | 355   |
| 2025-2030      |                                 | 103         | 111                                 | 115        | 330   |
| 2030-2035      |                                 | 77          | 97                                  | 97         | 270   |
| **Total**      |                                 | **441**     | **444**                             | **478**    | **1,362** |

From 2015 to 2020, paddy fields grew by 265 ha. Paddy fields experienced growth in the forest of 1 ha, from shrubs of 126 ha, and from moor of 138 ha. Between 2020 and 2025, the period in paddy fields has experienced a growth of 221 ha. Paddy fields experience growth in the forest of 2 ha, shrubs of 100 ha, and moor of 119 ha.

The period of 2025-2030 paddy fields has grown by 168 ha. Paddy fields experienced growth in the type of forest of 2 ha, shrubs as much as 83 ha, and moor of 83 ha. From 2030 through 2035, paddy fields have grown by 100 ha. Paddy fields experience growth from the forest of 1 ha, from shrubs of 50 ha, and from moor of 49 ha.
The growth of paddy fields in scenario 2 of 2015-2035 was 753 ha, where paddy fields grew in forests by 6 ha, from shrubs of 359 ha, and moor of 389 ha. During this period, the type of shrubs and moor that turned into paddy fields tended to decrease. The growth of wetland area originating from paddy fields in scenario 2 of 2015-2035 amounted to 753 ha arising from the forest of 6 ha, which is increased in the period 2020-2025 and 2025-2030, and declined again in the period 2030-2035. The area of wetland growth in scenario 2 is presented in table 5.

| Period of year | Growth of paddy fields (ha) | Total |
|----------------|-----------------------------|-------|
|                | Forest | Shrubs | Moor |       |
| 2015-2020      | 1      | 126    | 138  | 265   |
| 2020-2025      | 2      | 100    | 119  | 221   |
| 2025-2030      | 2      | 83     | 83   | 168   |
| 2030-2035      | 1      | 50     | 49   | 100   |
| Total          | 6      | 359    | 389  | 753   |

The results of scenario 3, which is built on the Cellular Automata (CA) model with the assumption that there is a prohibition on conversion of paddy fields by the Gorontalo District government based on official land use plan regarding the direction of wetland agricultural areas can be seen in figure 7.

Prediction of changes in paddy fields scenario 3 in 2015 has an area of 12,521 ha, entering 2020 paddy fields have increased to 12,606 ha. In 2025 the area of paddy fields will rise to 12,667 ha until 2030; the area of paddy fields will increase to 12,728 ha. In 2035 the area of paddy fields again increased to 12,740 ha.

The period of the 2015-2020 paddy fields has been converted by 179 ha. Paddy fields in that period changed function into plantations by 85 ha, settlements for 24 ha, and paddy fields that changed function to sugar cane by 71 ha. The 2020-2025 period of paddy fields has again experienced a conversion of 160 ha. Paddy fields that change function into plantations are 76 ha, settlements are 27 ha, and paddy fields are converted into sugar cane by 57 ha.

The period of the year 2025-2030 of paddy fields has been converted by 106 ha. Paddy fields that change function into plantations are 48 ha, settlements are 19 ha, and paddy fields are converted into sugar cane by 38 ha. The period of 2030-2035 paddy fields has a conversion of 137 ha. Paddy fields that
change function into plantations are 45 ha, settlements are 15 ha, and paddy fields are converted into sugar cane by 31 ha.

Paddy fields conversion in scenario 3 in 2015-2035 is 536 ha. During this period paddy fields that were converted into plantations, and sugar cane tended to experience a decrease in area. Whereas paddy fields that have been converted into settlements for the period 2020-2025 have increased. Entering the period of 2025-2030, 2030-2035, the conversion of paddy fields into settlements has decreased. The area of paddy field conversion scenario 3 is presented in table 6.

Table 6. Area conversion of paddy fields scenario 3.

| Period of year | Conversion of paddy fields (ha) | Total |
|----------------|---------------------------------|-------|
|                | Plantations Settlement and sugar cane of activity |       |
| 2015-2020      | 85                              | 24    | 71    | 179  |
| 2020-2025      | 76                              | 27    | 57    | 160  |
| 2025-2030      | 48                              | 19    | 38    | 106  |
| 2030-2035      | 45                              | 15    | 31    | 90   |
| Total          | 254                             | 85    | 197   | 536  |

From 2015 to 2020, paddy fields experienced a growth of 265 ha. Paddy fields experienced growth in the forest by 1 ha, from shrubs by 126 ha, and from moor by 138 ha. In the year 2020-2025, paddy fields returned to growth of 221 ha. Paddy fields experienced growth in the forest of 2 ha, from shrubs of 103 ha, and from moor of 117 ha.

From 2025 through 2030, paddy fields experienced growth of 169 ha. Paddy fields experienced growth in the forest by 2 ha, from shrubs by 85 ha, and from moor by 82 ha. From 2030 to 2035, paddy fields experienced growth of 106 ha. Paddy fields experienced growth in the forest by 1 ha, from shrubs by 54 ha, and from moor by 51 ha.

The growth of paddy fields in scenario 3 of 2015-2035 was 761 ha coming from forests of 6 ha, from shrubs by 368 ha, and from moor by 387 ha. During this period, shrubs and fields that turned into paddy fields tended to decrease. The growth of paddy fields originating from forests experienced an increase in the period of 2020-2025 and 2025-2030, and again declined between 2030 and 2035. The area of paddy field growth in scenario 3 is presented in table 7.

Table 7. Extensive growth of paddy fields scenario 3.

| Period of year | Growth of paddy fields (ha) | Total |
|----------------|-----------------------------|-------|
|                | Forest Shrubs Moor          |       |
| 2015-2020      | 1 126 138                   | 265   |
| 2020-2025      | 2 103 117                   | 221   |
| 2025-2030      | 2 85 82                     | 169   |
| 2030-2035      | 1 54 51                     | 106   |
| Total          | 6 368 387                   | 761   |

4. Conclusion
Simulation of paddy field models in this research results in a good level of accuracy that is 87.81%. The scenarios built can be used as a basis for decision making in maintaining paddy fields in Gorontalo Regency. In scenario 1, paddy fields experienced a very significant decrease in the area (3 706 ha) despite the growth of paddy fields (764 ha), so that the land in 2035 became 8 882 ha. The policy intervention built on scenario 2 can reduce the conversion of paddy fields in Gorontalo Regency in 2015-2035 by 2 344 ha, but the area of paddy fields is still decreasing (1 362 ha) so that the paddy field in
2035 becomes 11 679 ha. Policy interventions built on scenario 3, can reduce the conversion of paddy fields in Gorontalo Regency in 2015 by 3 170 ha, and there is an increase in the growth of paddy fields to become 12 740 ha.

5. References
[1] Irawan B 2005 Konversi Lahan Sawah: Potensi Dampak, Pola Pemanfaatannya dan Faktor Determinan Agro Economic Research Forum. 23(1) 1–18
[2] Pasandaran E 2006 Alternatif Kebijakan Pengendalian Konversi Lahan Sawa Beririgasi di Indonesia J of Agricultural Research and Development. 25(4) 123–129
[3] Djaenudin D 2008 Perkembangan Penelitian Sumber Daya Lahan dan Kontribusinya Untuk Mengatasi Kebutuhan Lahan Pertanian Di Indonesia J of Agricultural Research and Development. 27(4) 137–145
[4] Rahayu S 2009 Kajian Konversi Lahan Pertanian di Daerah Pinggiran Kota Yogyakarta Bagian Selatan Studi Kasus Dibagian Daerah Kecamatan Umbulharjo Journal of Regional and City Development. 5(3) 365–372
[5] Wu Q, Li H, Wang R, Paulussen J, He Y, Wang M, Wang B and Wang Z 2006 Monitoring and Predicting Land Use Change in Beijing Using Remote Sensing and GIS. Landscape and Urban Planning. 78 322–333
[6] Hu Z and Lo C P 2007 Modeling Urban in Atlanta Using Logistic Regression Computers, Environment and Urban System. 31 667–668
[7] Liu X, Li X, Liu L, He J and Ai B 2008 A bottom-up Approach to Discover Transition Rules Of Cellular Automata Using Ant Intelligence International Journal of Geographical Information Science. 22(11-12) 1247–1269
[8] Moreno N, Wang F and Marceau D J 2009 Implementation of A Dinamic Neigborhood in A Land-Use Vector Based Cellular Automata Model. Computer, Environment and Urban System. 33 44–54
[9] Arsanjani J J, Helbich M, Kainz W and Boloorani A D 2013 nteration of Logistic Regression, Markov Chain and Cellular Automata Models to Simulate Urban Expantion International Journal of Applied Earth Observation and Geoinformation. 21 265–275
[10] Widiatmaka, Ambarwulan W and Sudarsono 2016 Remote Sensing and Land Suitability Analysis to Establish Local Specific Inputs for Paddy Fields in Subang, West Java Agrivita Journal of Agricultural Science. 38(2) 110-115
[11] Malczewski J 2004 GIS-Based Land-Use Suitability Analysis: A Critical Overview Progress in Planning.g 62 3 – 65
[12] Yalcin A 2008 GIS Based Landslide Susceptibility Mapping Using Analytical Hierarchy Process and Bivariate Statistic in Adresen (Turkey): Comparisons of Result and Confirmations CATENA. 72(1) 1–12
[13] Eastman J R, Jin W, Kym P A K and Toledano J 1995 Raster Procedures For Multicriteria/Multi-objective Photogrammetric Engineering and Remote Sensing. 61 539–47
[14] Malczewski J and Rinner 2015 Multicriteria Decision Analysis in Geographic Information Science (New York, US: Springer Science)
[15] Verburg P H, Veldkamp W S E, Espaldon R L V, and Matsura S S A 2002 Modelling the Spatial Dynamics of Regional Land Use: The Clue-S Model Environment Management. 30(3) 391–405
[16] Pratomoatmojo N A 2014 LanduseSim Sebagai Aplikasi Pemodelan dan Simulasi Spasial Perubahan Penggunaan Lahan Sistem Informasi Geografis Dalam Konteks Perencanaan Wilayah dan Kota National cities seminar Indonesia. 6 69–79 ISBN: 978-602-71612-07
[17] Zhou C H, Sun Z H, Xie Y 1999 Geographic Cellular Automata Study (Beijing, CN: Science Press)
[18] Liu Y 2009 Modelling Urban Development with Geographical Information Systems and Cellular Automata (Boca Raton, EN: CRC Press)
[19] Vilet J V, Bregt A K and Zanker A H 2011 Revisiting Kappa to Account for Change the Accuracy Assesment of Land-Use Change Model Ecological Modelling. 222 1367–1375
[20] Congalton R G and Green K 2009 Assessing the Accuracy of Remotely Sensed Data (Boca Raton, EN: CRC Press)
[21] Bogoliubova A and Tymkow P 2014 Accuracy Assesment of Automatic Image Processing For Land Cover Classification of ST. Petersburg Protected Area. Geodesia et Descriptio Terrarum. 13(1-2) 5–22