A spatial model of sustainable green open space planning in Bandar Lampung City, Lampung Province

[1]Rein S. Hesty, [2]Andi Gunawan, [3]Lilik B. Prasetyo, [2]Aris Munandar

[1] Study Program of Natural Resources and Environmental Management, Graduate School of Bogor Agricultural University (IPB), Bogor, Indonesia; [2] Department of Landscape Architecture, Faculty of Agriculture, Bogor Agriculture University (IPB), Bogor, Indonesia; [3] Department of Forest Resource Conservation and Ecotourism, Faculty of Forestry, Bogor Agriculture University (IPB), Bogor, Indonesia. Corresponding author: R. S. Hesty, reinnaufal_azmi@yahoo.co.id

Abstract. Urban physical development is currently experiencing rapid growth and evolvement; this is marked by an increase in population, with all its activities in the struggle over city space. The impact of this development is a reduction of urban green open space (GOS). This research was conducted in Bandar Lampung City. This study aims to identify changes in land use, analyse the need for green open space, develop a GOS planning model and estimate the need for GOS in the city of Bandar Lampung in the future. The spatial analysis method with guided classification was used. Furthermore, logistic regression statistical analysis and carbon emission analysis were conducted. The highest land use variables consist of slope, village, built space, road and population. The level of CO_2 emission is 87362.702 Gg in Bandar Lampung City. The required GOS area in 2024 is 1503.637 ha. Planning for GOS in the coming years must be able to provide the GOS needs of the citizens of Bandar Lampung City, maintaining the sustainability of GOS through GOS spatial modelling.
Key Words: Bandar Lampung City, carbon emission, green open space, spatial analysis.

Introduction. Urban development has a strong relationship with the physical growth of a city, often clashing with natural resources and the environment. An increase in the number of urban population is one of the causes of urban land shifts. The increase of population will affect other necessities and, therefore, the demand of these needs will concurrently rise. For example, economic activity will increase the need for facilities and services, which will result in the upsurge of housing demands (Hussain & Said 2015). The needs of the city cannot be separated from the urban physical needs of the citizens. The city of Bandar Lampung is the capital of Lampung province, where Bandar Lampung city, Pesawaran district, South Lampung regency, and Metro city act as a core city in the surrounding area. The dynamics of a city life with diverse cultural communities also cause positive and negative access to Bandar Lampung city, in conjunction with environmental problems, city transportation and community welfare. Green open space (GOS) is an important part of a city (Chiesura 2004). GOS is also part of urban open spaces with the presence of plants, plantations and others that directly or indirectly provide benefits such as health, tranquillity, comfort, security and aesthetic values for urban areas (Humaida et al 2016). The development pattern of GOS, especially in Bandar Lampung City, has adapted to its diversity in handling the physical conditions of the area and the community life patterns with regard to consistency in government policies. The issue of GOS is a concern in the city of Bandar Lampung.

Bandar Lampung City has only 5916 Ha of GOS, as mandated by Article 29 Paragraph 3, from Law Number 26 of 2007, which stipulates that the proportion of public GOS in urban areas must be at least 30% of the city area. However, Bandar Lampung City has not currently reached 30%, only reaching up to 20% of the public area. In 2012, the surface was only 2185.59 ha, from which only 289.7 ha was private land. In this regard, it can be seen that in Bandar Lampung City a very significant decrease of GOS has occurred. Therefore, GOS planning must be prioritized.

The reduction of vegetation cover will affect the quality of the environment, as vegetation carries out photosynthesis, in which CO_2 gas from motorized and industrial vehicles will be utilized to produce oxygen and carbohydrates. However, if the reverse occurs, the decrease in vegetation cover will be accompanied by an increase in CO_2, because of land use conversion into residential areas, offices, recreation, industry and other activities. Such a rise contributes to the greenhouse effect, which can ultimately increase the temperature of the earth's surface (Sylvain 2014). GOS can be used as a landmark for a city. The policy development in a city requires a plan that takes into account various aspects of economic, political, social, ecological and sustainability concerns (Maruani & Amit-Cohen 2007). The existence of GOS in Indonesia is also regulated under several regulations, like Law No. 32 of 2009 concerning Environmental Protection and Management and Ministerial Decree of Public Works No. 5 of 2008. These regulations have become guiding points for the regional government to calculate the area of public facilities, including GOS in accordance with the population and service hierarchy. Yet, the calculation in determining the needed amount of GOS that meets the requirements of a 'sustainable' city environment is still quantitative and depends on many determinants. A city, regardless its condition, requires a GOS that meets the requirements of sustainability that offers a management and regulation stability and consistency of law enforcement. The ultimate goal of urban development is the formation of a city that is liveable and sustainable, so that it can realize its city space planning that balances ecological, economic, social, infrastructure, legal and environmental aspects of a spatial model of GOS planning.

Material and Method. The study was conducted in Bandar Lampung city, Lampung province, in May 2017. Data collection and data processing were conducted with the use of administrative maps, land use maps, Erdas 9.1, ArcGIS 10.3, Google Earth and a digital camera.

The land use of GOS is built based on Landsat data 5, 7, 8 path/row 123/064. The data was processed using Erdas 9.1 for layer stacking, image cutting (subset), supervised classification and assessment accuracy. Supervised classification is a classification that is carried out under supervised analysis. The maximum likelihood algorithm is used for the supervised classification of images. This method takes into account various factors including the probability of a pixel of being classified into certain categories. This is often referred to as prior probability, assessed by calculating the percentage of GOS land use in the image to be classified. Furthermore, the GOS land use classification test was conducted on data from 2017. In addition to field data and Google Earth data, reference data representing each class of GOS land use in the case of non-GOS land use was collected and analysed on 500 randomly determined points, following the field ground check. Afterwards, the comparison of the ground check field data and Google Earth data with the results of the GOS and non-GOS land use classification was statistically analysed and it resulted in the matrix error. The ensuing matrix error was used for statistical analysis. The statistical analysis includes kappa accuracy and overall accuracy (user and producer accuracy).

Analysis of land use changes on GOS and non-GOS. Analysis of land use change is done by calculating the area and percentage of land use change in GOS and non-GOS in each classified image. In addition, the analysis of land use changes in GOS and non-GOS is made by overlapping the two classification images that have been equipped with broad attributes. The focus of this research is land use change in GOS and non-GOS.

GOS spatial model. The model to predict the GOS area is rendered using logistic regression. The response or dependent variable in this study has two values. 0 when there is no change in GOS and 1 is when there is a change in GOS. The independent/free variables used consist of slope, distance from the village, distance from the built land, road and population. Spatial data processing for data validation using statistical methods was done by logistic regression, with the logistic regression equation formulated as follows:

$$Y=[\exp(b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_nX_n)]/[1+\exp(b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_nX_n)]$$

Where: Y - logistic regression; b - regression coefficient; X - factors affecting land change decisions.

Model feasibility test. The feasibility test of sustainable GOS models is conducted based on the Hosmer and Lemeshow tests using the SPSS application to determine changes in GOS (change) and non-GOS (unchanged). The model is declared feasible if the test value has a significance value higher than 0.05 (Hosmer & Lemeshow 2000).

Validation and prediction of GOS spatial models. The logistic regression model equation is built based on the changes in GOS in 2003–2010 by integrating the selected independent variable maps to produce a map of changes in GOS for 2010-2017. The map classification of green space changes is done using the value of y, in which a value of $y<0.5$ is considered as "unchanged" and changes occur if $y>0.5$. Spatial model validation is carried out between the 2010-2017 green space spatial model map to produce overall accuracy, producer accuracy and user accuracy. The same spatial model equation is used to predict changes in green space until 2024 with an independent variable map based on 2017 and with a population size estimated for 2024.

Needs analysis of Green Open Space. The needs of GOS regarding carbon emission is based on the 1996 IPCC methodology, in which the emission source is calculated based on the energy sources (fossil fuel), livestock, agricultural land and population. The formula for calculating the emission source is presented in Table 1.

The determination of the area of green open space based on the function of CO_2 as absorber was made using the following formula:

$$L\ (Ha) = [w\ (tons\ CO_2/year) + x\ (tons\ CO_2/year) + y\ (tons\ CO_2/year) + z\ (tons\ CO_2/year)]/[K\ (tons/year/ha)]$$

Where: L – the green open space; w - total CO_2 emissions from energy; x - total CO_2 emissions from livestock; y - total CO_2 emissions from paddy fields; z - total emissions from humans; K - CO_2 uptake value by forests (trees) of 58.2576 CO_2 (Inverson in Tinambunan 2006).

After obtaining the value of the required GOS area, the additional green space is:

$$L(ha) = A(ha) - B(ha)$$

Where: L - increased area of green open space; A - the need for green open space; B - the area of green open space now.

Predicting the need for green open space in Bandar Lampung City in 2024:

a. The estimation of fuel consumption is obtained through the following calculation:

$$Kt = Ko\ (1 + r)^2$$

Where: Kt - fuel consumption level at the end of the time period t; Ko - fuel consumption level at the beginning of the time period t; r - average percentage increase in the amount of fuel consumption; t - deviation of years.

b. Estimation of livestock population: $Pt = Po\ (1 + r)^2$

Estimation of population: $Pt = Po\ (1 + r)^t$

Where: Pt - livestock population at the end of the t; Po - livestock population at the beginning of the t; r - average percentage increase in population; t - deviation of years.

Table 1

Emission source	*Formula*	*Notes*
Energy	$C = a \times b$ $E = C \times d$ $G = E \times f$ $H = G \times \frac{44}{12}$	C - total fuel consumption based on fuel type (TJ/year); a - fuel consumption based on fuel type (10^3 tonnes/year); b - net calorie value/conversion factor based on fuel type (TJ/10^3 ton); E - carbon content based on fuel type (t C/year); d - carbon emission factor based on fuel type (t C/TJ); G - actual carbon emissions based on fuel type (GgC/year); f - CO_2 fraction, CO_2 fraction for oil is 0.99, while for fuel is 0.995; H - actual CO_2 emissions based on fuel type (Gg CO_2/year).
Livestock	$C = a \times b$ $E = a \times d$ $F = C + E$	C - methane gas emissions from the fermentation process based on the type of livestock (tons/year); a - livestock population by type of livestock (type); b - CH_4 emission factor from fermentation based on livestock type (kg/type/year); E - methane gas emissions from the fertilizer management process based on the type of livestock (tonnes/year); d - CH_4 emission factor from fertilizer management based on livestock type (kg/type/year); F - total methane gas emissions based on livestock type (Gg/year).
Agricultural Fields	$D = a \times b \times c \times d$	D - total methane emissions from agricultural fields (Gg/year); a - area of agricultural fields (m^2); b - measurement value CH_4 emission factor; c - emission factor (18 g/m^2); a - number of harvests per year (year).
Population	$KKp(t) = JPT(t) \times KPt$	KKp(t) - carbon dioxide produced by the population in year t (tonnes CO_2/year); JPT(t) - number of registered population in year t (number of people); KPt - the amount of carbon dioxide produced by humans is 0.96 kg/ CO_2/person/day (0.3456 tons CO_2/person/year).

The prediction of the demand of GOS in year t is obtained from the estimated amount of CO_2 emissions divided by the ability of GOS to absorb CO_2.

L (Ha) = [w (tons CO_2/year) + x (tons CO_2/year) + y (tons CO_2/year) + z (tons CO_2/year)]/[K (tons/year/ha)]

Where: L – The need for green open space; W - Total CO2 emissions from energy; x - Total CO2 emissions from livestock; y - Total CO2 emissions from paddy fields; z - Total emissions from humans; K - CO_2 uptake value by forests (trees) of 58.2576 CO_2 (Inverson in Tinambunan 2006)

The change of GOS area in 2024:

$$MD = \frac{\Sigma |L - \bar{L}|}{N}$$

Where: MD – changes in area; L – area of green open space of time t; N – period of time.

Results and Discussion

Land Use Analysis. This study was conducted based on visual interpretation, field survey and the use of RBI Fine Map data sources to obtain information about land use classes. Land Use Mapping Process presented in Figure 1.

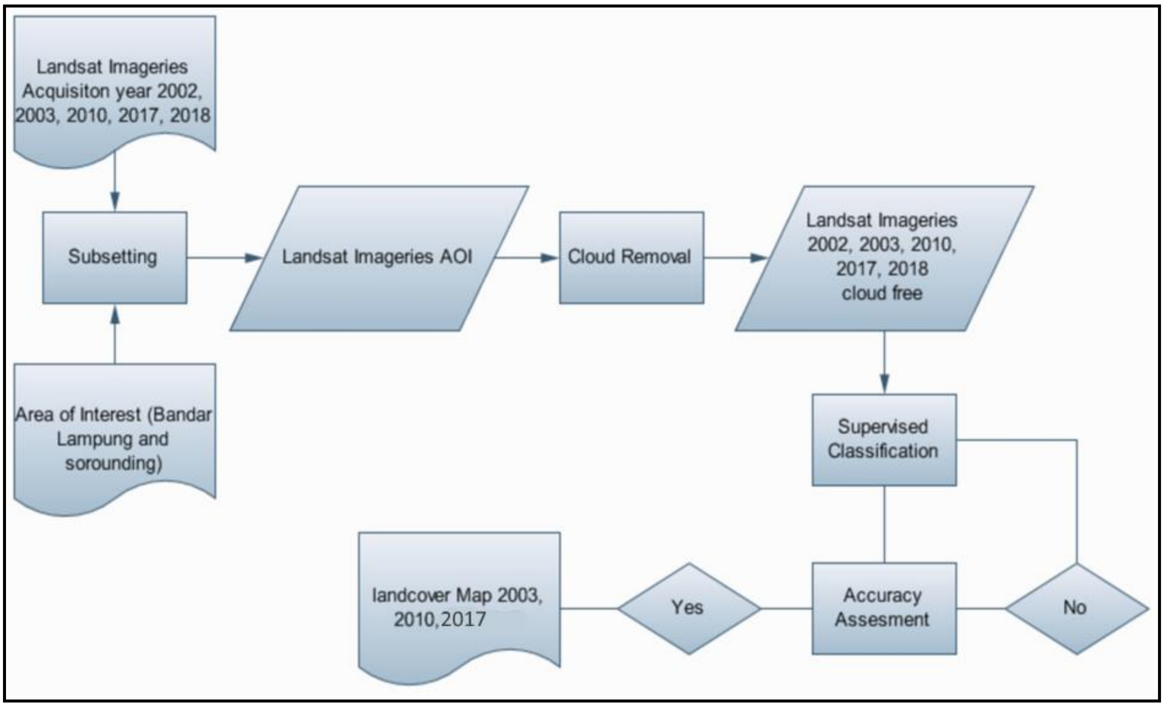

Figure 1. Land use mapping process.

Figure 2 presents land use in 2003 and Figure 3 presents land use in 2010. There were 13 sub-districts with land use dominated by agricultural land totalling 10477.01 ha in 2003. In 2010 the number of sub-districts increased to 20. The green open space at that time amounted to 13313 ha, while the built area was 5181 ha. The data analysis used vector data, namely the road point and centre point in 2003 and 2010. There seemed to be an expansion from 2003 to 2010, which can be seen in Figure 4.

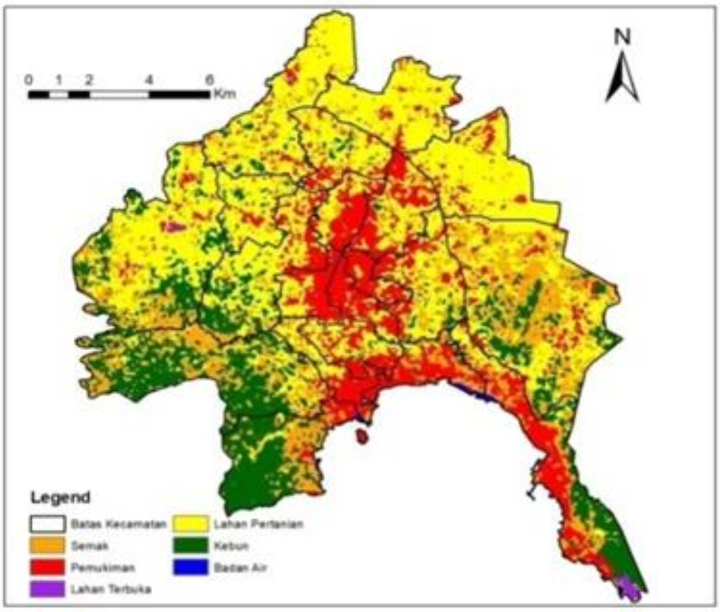

Figure 2. Land Use in 2003.

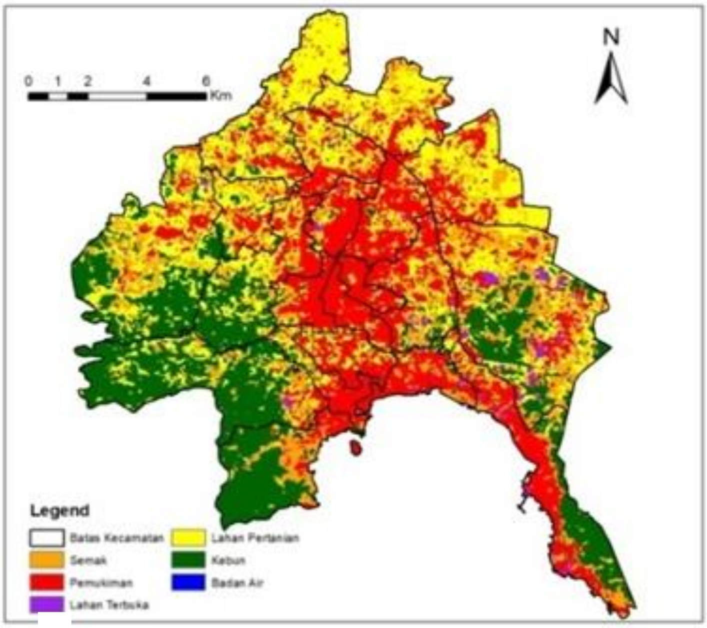

Figure 3. Land Use in 2010.

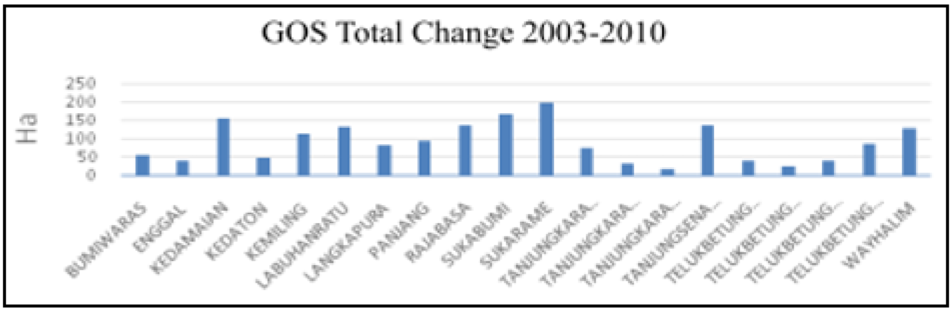

Figure 4. Land Change in 2003-2010.

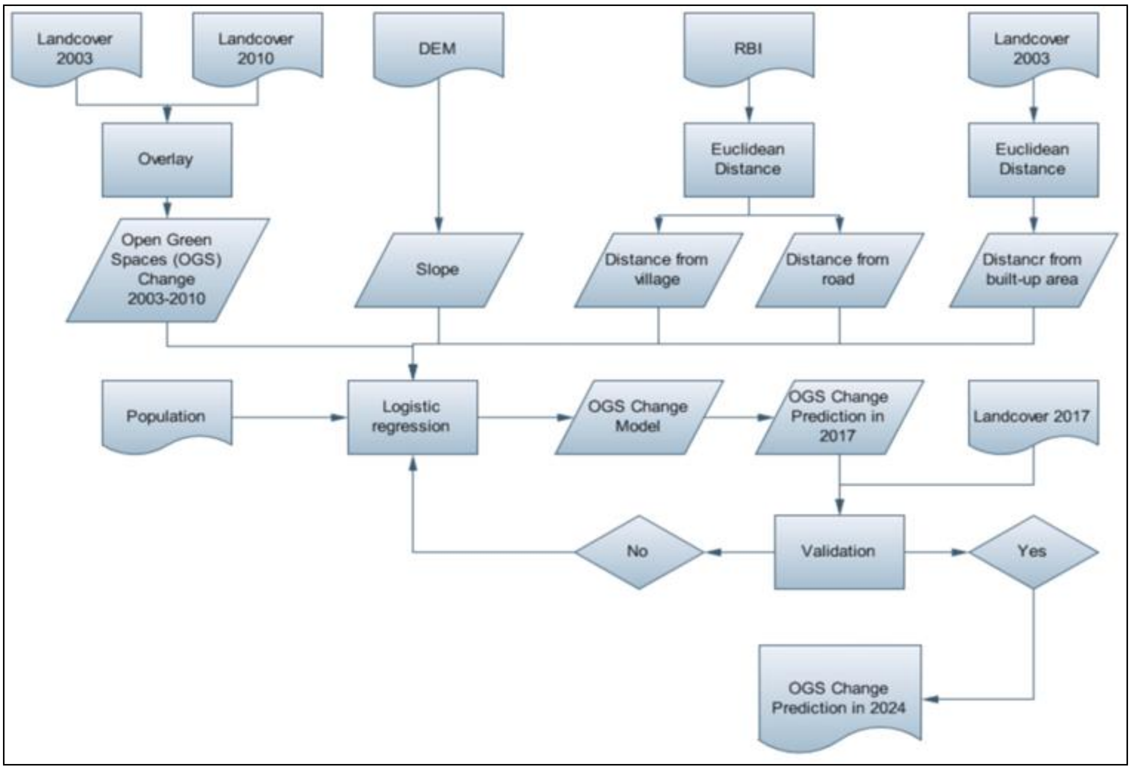

Figure 5. Green open space prediction in 2024 diagram.

Data validation. The results of land use mapping in 2003, 2010 and 2017 were used to build the Sustainable Green Open Space Spatial Model of Bandar Lampung City, which was then used for predictions in 2024, as presented in Figure 5. A map of Bandar Lampung City land use in 2017 is presented in Figure 6. Changes in GOS 2010-2017 are presented in the Figure 7.

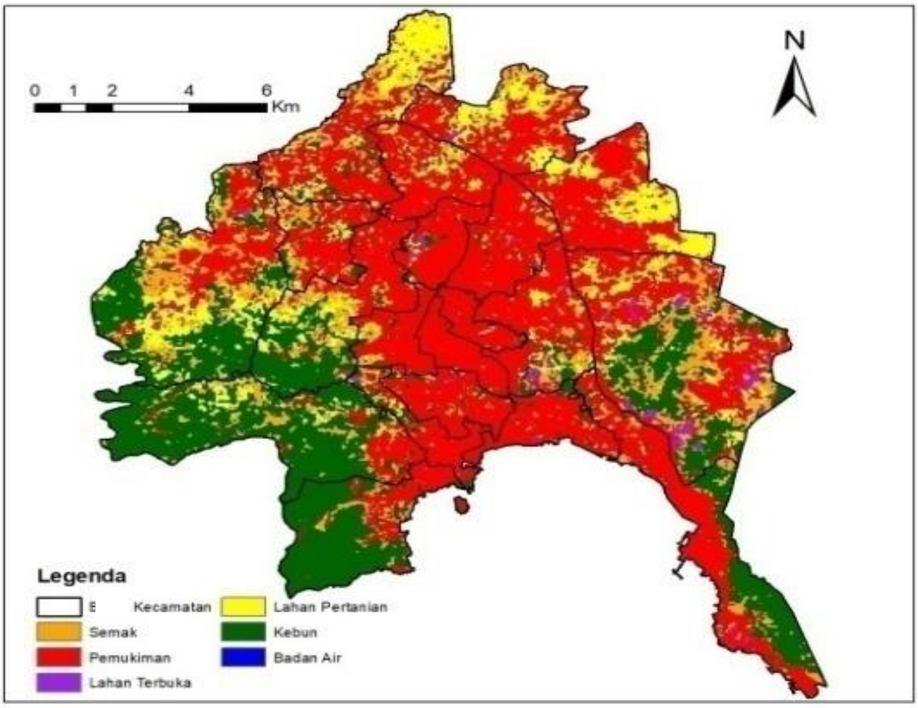

Figure 6. Land use in 2017.

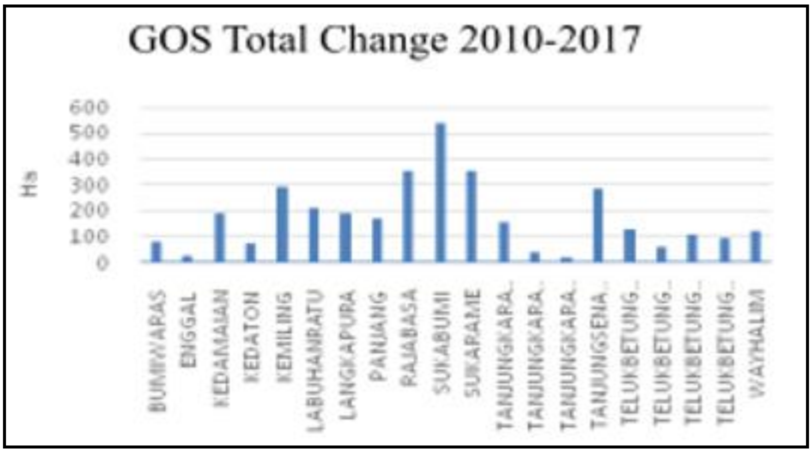

Figure 7. Changes in GOS 2010-2017.

The GOS area is 9812 ha and non-GOS is 8682 ha. During the spatial data validation processing, parameters consisting of elevation, slope, village, built on land and population are mapped out. The results of the mapping carried out in 2003 and 2017 focus only on elevation, while for 2010 and 2017 stripping is also carried out. Afterwards, selections are made based on changes and what remains unchanged in the data validation. Out of the 10-parameter variables that were previously carried out during the data validation, only five parameter variables can be used: slope, road, village distance, land built and population. Afterwards, random data retrieval was carried out in 500 points for validation, which is then extracted with its group so that it can continue with logistic regression analysis with 0 as the value of change and 1 as unchange and the results can be shown in Table 2.

Table 2

Regression logistics results for 2010-2017

Observed	*Green Open Space*		*Percentage Correct*
	Change	Unchange	
Step 1 GOS			
Change	212	38	84.8
Unchange	78	172	68.8
Overall percentage			76.8

Based on the actual conditions of the obtained percentage results, which showed an accuracy value of 76.8%, the results of spatial processing in 2003 and 2010 are at 76.6%. This means that the values are close and therefore it can be concluded that the model can be accepted statistically as suitable, if the significance shown in the results of the Hosmer and Lemeshow test is above 0.05 with a 95% confidence level and is used for prediction in 2024.

Logistic regression equations. For the unchange variable, the slope, as a parameter, affects the land use change. From the data processing results, the biggest influential land change parameter is the parameter of the built land:

$Y_{per\ GOS\ -\ non\ GOS}$ = [exp (1.110 x slope + 1.456 x village distance + 6.479 x distance of built land – 0.87 x distance from road – 0.48 x number of population)]/[1 + exp (1.11 x slope + 1.456 x village distance + 6.479 x distance of built land – 0.87 x distance from road – 0.48 x number of population)]

From the equation, the most influential variable towards the GOS changes is the built on land with an exponent value of 853213. The next variables are the village, slope, road and population. Subsequently, the results of the formulations that have been validated can be used in making the 2017 spatial model.

Prediction for 2024. Based on the spatial model obtained and from the results of logistic regression calculations, the mapping is laid out for the changes in GOS. The change in GOS based on the 2017 model that has changed between changing green open space and unchanged green open space in Bandar Lampung City can be seen in Figure 8a and GOS predictions for 2017 can be seen in Figure 8b.

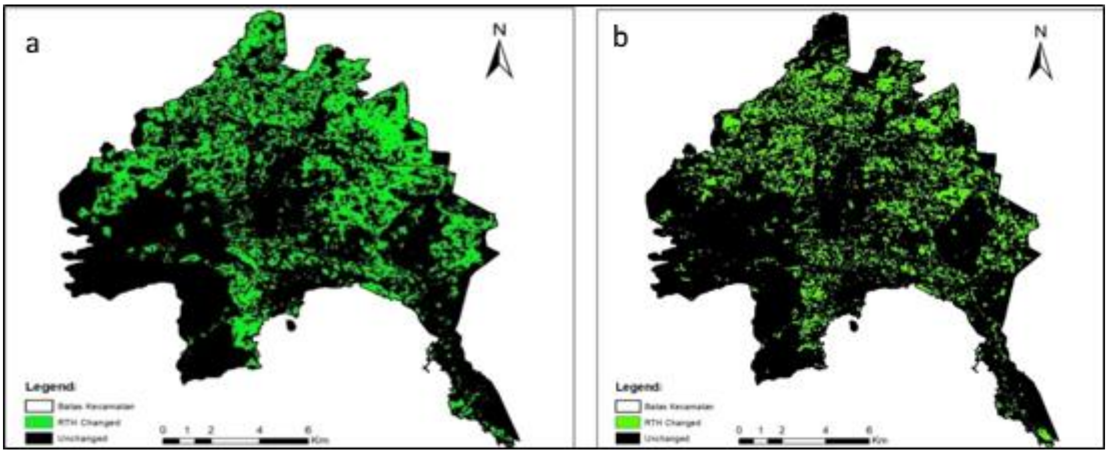

Figure 8. a – green open space map for 2017; b – green open space predictions that have been made for 2017.

The next process is to carry out predictions in 2024. This is known as the Green Open Space Spatial Model in Bandar Lampung City. To be able to anticipate the conditions from the changes that will occur of the GOS, it is necessary to strategize and manage the urban space, especially in conjunction with GOS, by stipulating strict consequences that are controllable and accountable so that the utilization of urban space in Bandar Lampung City in its development can be carried out optimally.

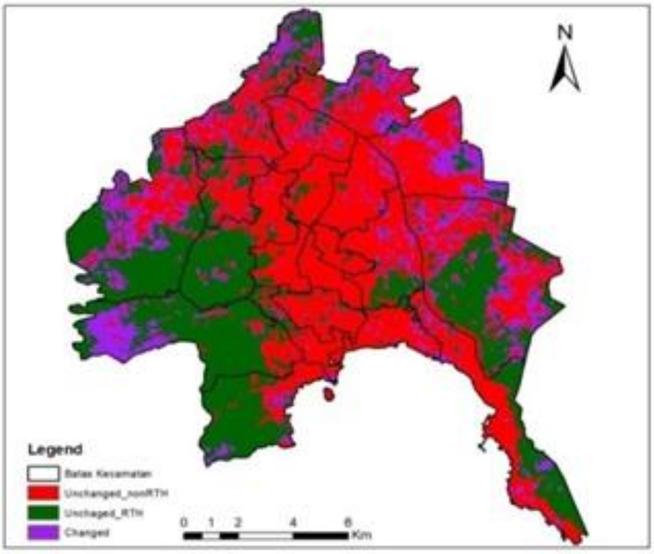

Figure 9. Spatial model of green open space.

Figure 9 shows the spatial model of Bandar Lampung City's GOS that has changed and that not changed. The largest predicted change in GOS in 2024 is in the Sukabumi sub-district, with a changed area of 585 ha. The green space conditions are still met, but as an urban space that continues to develop in line with the needs of urban residents, the GOS will continue to experience a decrease in area, which will ultimately affect the sustainability of the city of Bandar Lampung itself.

Analysis of green open space needs in Bandar Lampung. Based on the results obtained in Table 3, the calculation was carried out by dividing the total emissions with the ability of GOS in absorbing carbon (equal to 58.2576 CO_2). It is presumed that the green open space in 2024 will amount to 1503 ha. The method of calculating carbon emissions is a comprehensive method because it considers four aspects in its approach: population, livestock, fuel and agricultural area. The need for carbon emissions in 2024 in Bandar Lampung City is still sufficient with 6476 ha of available land. There is, however, a need to maintain stable and sustainable environmental conditions. Therefore, efforts should be made to suppress energy-emitted CO_2 by establishing governmental policies focusing on restricting energy usage in Bandar Lampung City. The efficient use of public transportation is needed to expand municipal services to the community; as such, it will reduce the use of private vehicles. In addition to saving energy, the community needs to put in some efforts to reduce CO_2 emissions through the application of environmentally-friendly activities, such as tree planting, continue in maintaining the existence of environmental ecosystems and conserving fuel usage and equipment that reduce CO_2 emissions.

Table 3

Predictions of carbon emission

Source of carbon emission	*Carbon emissions (Gg CO_2/year)*
Cattle	2.973
Rice fields	0.495
Energy	85445.778
Population	1913.456
Total	87362.702

Conclusions. In 2024, the green open space of Bandar Lampung City will probably amount to 6476 ha, with a level of CO_2 emission of 87.362 Gg, while the required green open space in 2024 would be 1503 ha. The presence of green open space in the city of Bandar Lampung will be even better enhanced by the ecological substance and equitable distribution of green open space for environmental sustainability and quality of comfort to create ideal city conditions and meet the city's sustainability standards.

References

Chiesura A., 2004 The role of urban parks for the sustainable city. Landscape and Urban Planning 68:129-138.

Hosmer D. W., Lemeshow S., 2000 Applied Logistic Regression Second. John Wiley and Sons Inc., New York, 397 p.

Humaida N., Prasetyo L. B., Rushayati S. B., 2016 Priority Assessment Method of Green Open Space (Case Study: Banjarbaru City). Procedia Environmental Sciences. 33:354-364.

Hussain S. Y. S., Said I., 2015 Knowledge Integration between Planning and Landscape Architecture in Contributing to a Better Open Space. Procedia – Social and Behavioral Sciences 170:545-556.

Maruani T., Amit-Cohen I., 2007 Open space planning models: A review of approaches and methods. Landscape and Urban Planning 81(1):1-13.

Sylvain T., Stefan B., Jens B., Sam B., Filip N., Quanlin Z., 2014 Using Pressure and Volumetric Approaches to Estimate CO_2 Storage Capacity in Deep Saline Aquifers. Energy Procedia 63:5295-5303.

***IPCC (Intergovernmental Panel on Climate Change), 1996 [Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories Workbook]. [in Indonesian].

***MENLH, 2009 [Law Number 32 of 2009 concerning Environmental Protection and Management]. [in Indonesian].

***MENPU (Minister of Public Works), 2007 [Republic of Indonesia Law No. 26 of 2007 concerning Spatial Planning]. [in Indonesian].

***MENPU (Minister of Public Works), 2008 [Government Regulation No. 5 of 2008]. [in Indonesian].

Received: 26 January 2019. Accepted: 12 June 2019. Published online: 20 December 2019.
Authors:
Rein Susinda Hesty, Study Program of Natural Resources and Environmental Management, Graduate School of Bogor Agricultural University (IPB), Jl. Raya Dramaga Kampus, Dramaga, 16680 Bogor, West Java, Indonesia, e-mail: reinnaufal_azmi@yahoo.co.id
Andi Gunawan, Department of Landscape Architecture, Faculty of Agriculture, Bogor Agricultural University (IPB), Jl. Raya Dramaga Kampus, Dramaga, 16680 Bogor, West Java, Indonesia, e-mail: andigunawan.arlipb@yahoo.co.id
Aris Munandar, Department of Landscape Architecture, Faculty of Agriculture, Bogor Agricultural University (IPB), Jl. Raya Dramaga Kampus, Dramaga, 16680 Bogor, West Java, Indonesia, e-mail: amunandaripb@gmail.com
Lilik Budi Prasetyo, Department of Forest Resource Conservation and Ecotourism, Faculty of Forestry, Bogor Agricultural University (IPB), Jl. Raya Dramaga Kampus, Dramaga, 16680 Bogor, West Java, Indonesia, e-mail: lbprastdp@apps.ipb.ac.id

How to cite this article:
Hesty R. S., Gunawan A., Munandar A., Prasetyo L. B., 2019 A spatial model of sustainable green open space planning in Bandar Lampung City, Lampung Province. AES Bioflux 11(3):216-226.