Sensitivity analysis of ecosystem services especially food provisioning due to the dynamics of land use change in Bogor Regency, West Java, Indonesia

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Abstract. Land use changes greatly affect the value of ecosystem services. This study aims to analyse the sensitivity of ecosystem services especially food provisioning, affected by land use changes in Bogor Regency. The method used is visual interpretation and manual digitization of Indonesian Topographic Map (RBI) and the SPOT-7 with a resolution of 1.5 meters. The sensitivity assessment of ecosystem services is carried out through analytical hierarchy process (AHP). The results of the study showed that there was a changing in land use of 8.31% in the period 2000 to 2017. Forests area to be the most significant changes contribute 1.86%. Changes in land use are influenced by regional development and population growth, so that conversion of land use occurs massively at some point. Regulatory and supply functions are the most sensitive elements of ecosystem services to land use changes. Conversion of water catchment area causes a decrease in soil infiltration capacity and triggers erosion. This phenomenon leads to land degradation and natural disasters.

Keywords: Bogor Regency, ecoregion, ecosystem services, land use change

1. Introduction
Indonesia is actively promoting the quality of its economy through the development process. The impact of a development process is a decrease in environmental quality due to poor land use planning [1,2,3]. Good land use planning can minimize the negative impacts of a regional development process [4,5,6]. Poor planning can trigger various natural disasters such as floods, landslides and drought. Bogor Regency is one area that is vulnerable to the effects of regional development. That is because Bogor Regency is a satellite city of Jakarta. The need for space that is no longer possible to be met by Jakarta demands the surrounding area including Bogor Regency to provide a place to live and develop. Space needs must be met but in a wise way so that adverse impacts on the environment can be minimized.

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Analysis of ecosystem services is a basis that can be used for evaluating spatial planning and management [7].

Ecosystem services are the benefits that humans derive from an ecosystem [8,9]. Ecosystem service data can provide accurate information on biotic and abiotic components, so that it can be the basis for land management. Assessment of ecosystem services can be done by mapping land use and ecoregions whose stages include field surveys, statistical analysis and interpretation of remote sensing data. Valuation of ecosystem services requires good quality long-term data, so past ecosystem information can be found. It aims to determine trends in increasing or decreasing environmental quality through exploration of land use change. Based on the analysis of land use change data, information on priority areas that must be conserved can be obtained, so that environmental degradation can be controlled.

Furthermore, information about the characteristics of the area is needed in efforts to conserve land. Regional characteristics data can be obtained from ecoregion map data where the map presents information on land units that contain biotic and abiotic components information as well as patterns of human interaction with nature that illustrate the integrity of natural systems and the environment. A comprehensive information on regional characteristics can be obtained from detailed data sources.

This research was conducted in Bogor Regency, West Java, Indonesia. Bogor Regency was chosen as the locus of research because environmental degradation in Bogor Regency continued to decline due to land use changes. Previous research shows that the condition of forests in Bogor Regency is quite alarming, and even tends to be critical [10,11,12]. Furthermore, Bogor Regency has a variety of ecoregions so as to provide an overview of the characteristics of ecosystem services in heterogeneous environments. The purpose of this study is to 1) identify land use changes in the period 2000-2017; 2) analysing ecoregions; and 3) analysing the sensitivity level of ecosystem services especially food provisioning in Bogor Regency.

2. Methodology

The study was conducted in Bogor Regency, West Java Province. Astronomically, Bogor Regency is located between $6^\circ18'0" - 6^\circ47'10"$ S and $106^\circ23'45" - 107^\circ13'30"$ E (figure 1). Bogor Regency has an area of $\pm 300,218.82$ha which is divided into 44 districts.

Temporal land use was analysed using the topographic map of Indonesia (RBI) scale of 1: 25,000 in 2000 and the interpretation of the SPOT 7 2017 images with a resolution of 1.5 meters. The image used has an incidence angle of $\leq 20^\circ$ and cloud cover $\leq 20\%$ so it has geometric and good visual quality. The stages of image preparation are carried out by geometric, radiographic and image sharpening corrections [13,14,15].

The method used for land use identification is visual interpretation and manual detection, which has better accuracy than digital classification/automation systems [16,17]. Land use interpretation is done by using several key interpretations which include hue or colour, size, shape, texture, shadow, pattern and its association [18,19]. Classification of land use is determined by its appearance. Land use change was analysed by comparing the RBI data and the results of interpretation of SPOT 7 in 2017 with the overlay method. Field surveys using the stratified random sampling method were conducted to test the accuracy of the maps produced. The test method used is a confusion matrix that compares data from modelling results with data from field surveys [20]. The value of land use classification accuracy is based on producer’s accuracy, user’s accuracy, overall accuracy, and Kappa values [17,21]. Land use area is calculated using the Lambert cylindrical equal-area equivalent projection system to obtain precise results [22,23].
The 1:250,000 scale ecoregion data used was sourced from the Ministry of Forestry and the Environment. On a review scale, ecoregion information presented is genetic criteria, shape, structure, rock association and major processes. Field checks are carried out by purposive sampling at locations where the correctness of attribute information is doubtful by considering affordability access. The reinterpretation phase is carried out to revise the boundary delineation which is not right.

The assessment and weighting of ecosystem services especially food provisioning, is carried out based on expert judgment. Weighting the results of expert assessments is processed using AHP (analytical hierarchy process). The weight of ecosystem services to ecoregions refers to research by the Ministry of Forestry and the Environment (2015) [24]. The calculation of the Food Supply Services Index refers to [7] with the following formula.

\[
FSSI = \frac{\sqrt{EFSSI_{eco} \times EFSSI_{lc}}}{\max(\sqrt{EFSSI_{eco} \times EFSSI_{lc}})}
\]

where:
- **FSSI**: Food supply services index
- \(EFSSI_{eco}\): Ecoregion-based food supply services index
- \(EFSSI_{lc}\): Land use-based food supply services index
- \(\max\): The maximum value of the index synthesis results

The sensitivity assessment is carried out by comparing the Food Supply Services Index in the period 2000 and 2017. Maps of land use in 2000 and 2017 were overlaid to determine the value of the sensitivity of ecosystem services in Bogor Regency. The ecoregion data does not use temporal data because there were no significant changes ecoregion changes in the period 2000-2017. The final results are presented in a map of food service units that have been impaired in the period 2000-2017.

### 3. Result and discussion

#### 3.1. Land use changes period 2000-2017

Temporal land use changing is the basis for regional planning. The interpretation of the satellite SPOT 7 2017 image show that there has been a significant change in land use (figure 2). Land use changing in 2000-2017 reached 24,887.77 Ha or 8.31% of the Bogor Regency area, equivalent to 35,554 football fields. These changes are classified as massive conversion.

Forests are still the most dominant region, although the area continues to decline. In 2000, the forest area reached 27.62% and in 2017 was decreased to 25.76%. The survey results show that forest
conversion occurs mostly in volcanic and structural landscapes which have good soil quality. Forests are converted into plantations and moors. The settlement area increased by 1.05% or equivalent to 3,144 Ha. Most of the conversion of land into housing takes place in the volcanic plains north of Bogor Regency, as a buffer zone of Jakarta development. The northern part of Bogor Regency is a strategic place for community because it has better access to Jakarta, has a flat relief and rarely hit by floods. Decreasing of forest and significant increase of settlements become a potential disruption of local ecosystems that can affect the downstream areas, specifically Depok and Jakarta.

Interestingly, the plantations and paddy fields in Bogor Regency also increased in the period 2000-2017. This can have a positive impact on food supply in Bogor Regency. Plantations area increased from 60,617.26 Ha (in 2000) to 64,167.54 Ha in 2017. Land conversion from shrubs and wasteland to plantations mostly occurred in volcanic and structural landform in the south of Bogor Regency. Paddy fields area increase by 1.67% (4,999 Ha) or equivalent to 294.03 Ha per year. Increasing in paddy fields compensated by decreasing of bare land and fields periodically. Land conversion into paddy fields occurs randomly and is not focused on one landform, indicates that quality of land and water resources is still relatively good. Changes in the area of land use in Bogor Regency in the period 2000-2017 can be seen in table 1.

Table 1. Land use change in Bogor Regency.

| Nr | Land Use                  | Area (ha)      | Difference | %   | Explanation |
|----|---------------------------|----------------|------------|-----|-------------|
|    |                           | 2000           | 2017       |     |             |
| 1  | Forest                    | 82,929.23      | 77,334.08  | 5,595.15 | 1.86        | Reduced     |
| 2  | Plantation                | 60,617.26      | 64,167.54  | 3,550.28 | 1.18        | Increase    |
| 3  | Settlement                | 47,889.88      | 51,033.54  | 3,143.66 | 1.05        | Increase    |
| 4  | Paddy Field               | 61,572.75      | 66,571.39  | 4,998.64 | 1.67        | Increase    |
| 5  | Scrub                      | 11,304.29      | 8,982.98   | 2,321.31 | 0.77        | Reduced     |
| 6  | Wasteland                 | 4,603.05       | 2,858.02   | 1,745.05 | 0.58        | Reduced     |
| 7  | Moor                      | 28,212.48      | 25,411.03  | 2,801.45 | 0.93        | Reduced     |
| 8  | Water Bodies              | 2,303.38       | 2,291.18   | 12.20   | 0.004       | Reduced     |
| 9  | Others Vegetation Classification | 787.87  | 1,570.43   | 782.58  | 0.26        | Increase    |
|    | Total                     | 300,220.19     | 300,220.19 | 24,950.28 | 8.30        |             |

Land use maps resulting from visual interpretation have a total accuracy of 94.81% with a kappa index of 0.93. The quality of interpretation is high because it meets the minimum accuracy requirements of > 85% and kappa value > 0.8 [25]. The commission error is dominated by misclassification between moors and shrubs. The same hue, texture, colour and size of moors and shrubs cause misinterpretation of both. The presence of dike in the imagery also indicates that the area is a moor, but when checking in the field, moor is no longer used and becomes a shrub. Omission error is dominated by plantations and forests. The error occurred because the existing plantation crops have the same physical appearance...
as forest plants so that the boundaries of both of them look vague. Redelineation of land use maps after accuracy testing is carried out to produce of a better maps quality.

3.2. Ecoregion of Bogor Regency

Bogor Regency is composed of four land forms namely volcanic, structural, karstic and fluvial. Bogor Regency is dominated by volcanic origin from the formation of material sourced from Salak and Pangrango Volcano. Based on the ecoregion map, Salak and Pangrango are located in the volcanic mountains of the Karang - Merapi - Raung volcano line. Pangrangostrato-shaped volcanic and has a caldera. This shows that there has been a terrible eruption in the past even though the history of the Pangrango eruption has not been recorded until now. Even though the valley of the stamped Ancient Pangrango eruption leads to Sukabumi, the impact is also very much felt in the area of Bogor Regency. The reality is proven by the discovery of the basalt lava from the catapult to the direction of Caringin - Cigombong even though the amount is only a few.

Salak Volcano is a volcanic cone of the valley composed by volcanic deposits that typically have great geological and geothermal potential [26]. Salak eruption was first recorded on January 5, 1699 and last occurred in 1938, a phreatic eruption that occurred in the Cikuluwung Putri Crater [27]. Salak Peak has two craters, one open to the northeast and one to the southwest. In general, Salak is composed of andesitis lava, lahari breccias, lapilli tuffs, rocky tuffs, stretched tuffs, and tuff pumicete strings, with different land facilities from very high levels [28].

The existence of Salak and Pangrango makes the landscape in Bogor Regency fertile. A good level of soil fertility is a big resource that can be used to increase the index of food service provision. Volcanic origin material in the form of pyroclastic material experiences weathering due to geomorphic processes and develops into volcanic soil. Volcanic soils are known to have high fertility, so they have the potential to be developed as forestry, agriculture and plantation areas. This is verified by the abundant production of food crops and plantations in the southern part of Cijeruk Bogor Regency, such as Cisarua, Megamendung, Ciawi, Caringin, and Cibungbulang. Fertile surface soil layers are transported through erosion to the downstream area and are deposited, fertilize the downstream area. The process of land transportation occurs in fluvial landforms located along rivers that are tipped in Salak and Pangrango. On a review scale, fluvial landform units in Bogor Regency appear to be very small and overlap with other landforms.

Karst landforms in Bogor Regency are composed of Miocene-aged limestone. Based on ecoregion data, karst in Bogor Regency dominates Klapanunggal District. On a more detailed scale, karst is also found in several other locations such as in Ciampea, Gunung Putri, Ciseeng and Rumpin [29, 30, 31, 32]. The Klapanunggal karst formation is composed of coral limestone, sandy limestone inserts, napol, glauconitan quartz sandstones, green sandstones. The Bojongmanik karst formation, including Rubin to Ciampea, consists of limestone material containing limestone lenses containing molluscs. Karst formation is potential for a raw material of cement industries. This can push the local economy, but utilization of karts must be controlled to prevent negative impacts on the environment.

The structural landforms in Bogor Regency are scattered in Jasinga, Cigudeg, Tanjungsari, Cariu, Jonggol, Sukamakmur, Citeureup and Babakanmadang. Globally, it can be grouped into structural forms of the western and eastern parts of Bogor. The western structural shape is characterized by corrugated to wavy relief, while in the east it is characterized by corrugated to mountainous relief. The western part has rougher relief with blunted V-shaped valleys. This has implications for the type of local land use, which is often found in forests and plantations. Rough relief also counts the number of intermittent rivers. In contrast, eastern part of Bogor is more used for settlements and paddy fields because the relief is smoother. The process of erosion and water reservoir is relatively easier to be maintained, so it is precisely designated as a residential and paddy field area.

3.3. Ecosystem Services Sensitivity in Bogor Regency

Each element weight of land use towards the food services provision has changed between 2000-2017.
Expert judgements place paddy fields as the most dominant element in the food service index. This is relevant with the consumption patterns of Indonesian people who make rice as a major food commodity. Paddy weights also increased from 0.136 (in 2000) to 0.416 (in 2017), consistent with the increasing of paddy fields by 4,999 Ha within 17 years. The lowest weight is settlements as shown in figure 3.

![Figure 3. Value of the temporal land use coefficient for food services provision based on AHP calculation.](image)

The ecoregion weight for calculating food service provision refers to the research of Riqqi et al [7]. Java Fluvial Plain has the highest ecoregion value with a weight of 1. The fluvial plain in Bogor Regency is indeed an area suitable for paddy farming because of fertile soil, good water sources and not prone to flooding. Volcanic Plain of Mount Karang - Merapi - Raung have weight of 0.48, since the volcanic soil erupted by Salak and Pangrango volcanoes has good soil quality. The lowest weight value occurs in the Structural Hills of Bogor - Kendeng - Rembang Path with a coefficient value of 0.13. This relates to the parent material in the form of solid rock and fairly steep slope.

The comparison of the whole study area shows impressively a change in the value of food supply services in 2000-2017, which is controlled by land use change factors (figure 4). The ecoregion factor does not have a big effect because the geomorphic process that occurs in Bogor Regency runs slowly. The most significant change is due to an increase in paddy fields and plantations where both land uses are sources of food supply services. Potential sources of declining food supply are moors. The results of the interpretation show that some moorings turned into settlements and some others were left uncultivated. Furthermore, the growth of settlements in the north also influenced the fluctuation of food service provision. Moreover, the northern area is a volcanic plain that has fertile soil and a good water supply. The area should have great potential to be developed as a source of food supply, but the economic value of the settlement is higher so that landowners prefer to use land as a settlement rather than paddy fields.
Figure 4. Aggregate ecosystem service “food provision” in the year 2000 (left) and 2017 (right) of Bogor Regency.

Sensitivity, in the sense of decreasing the index value of food service provision occurs evenly in the Bogor Regency (figure 5). Some of these decreases are major and minor. Examples of major decreases are plantations that become moor with a weight loss of 0.000245. Major changes occurred in the paddy fields which became settlements with a decrease in weight of 0.069528. Other examples are plantations that have turned into scrub or wasteland, as has happened in Tenjo, Parungpanjang, Sukamakmur and Jonggol. Overall, the area in Bogor Regency that has a high sensitivity to food service provision is 2,230.24 Ha. Some locations can be restored, such as scrub or wasteland that can be refunctioned into paddy fields or plantations. It depends on the land owner and the government regulations.

Figure 5. Food supply sensitivity due to land use changes in the period 2000-2017.

4. Conclusion
Assessment conducted in this study shows that 24,887.77 (8.31%) of land use in Bogor Regency has been changed in 2000-2017 period. Land use map has a total accuracy of 94.81% with a kappa index of 0.93. The ecoregion is dominated by volcanic and structural landform with a small area of karst and fluvial, indicates that Bogor Regency has good soil quality for food supply service. Analysis of temporal ecosystem services shows that there has been a change in the index value of food service provision in 2000-2017. The changing in food supply services are affected by changing in land use. The highest sensitivity to food supply service occurs in paddy fields that are converted into settlements. The results of this study can be used by policy makers as a consideration in land management arrangements in Bogor Regency.
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