Spatial planning policy evaluation to achieve food security and sustainability in Pandeglang Regency

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Abstract. Pandeglang Regency is designated as the agricultural center of Banten Province. Dedicating a specific area to a protected agricultural area often faces problems of not considering the population growth and food needs. Therefore, this research aims to evaluate the spatial pattern and allocation of the agricultural area based on the comparison between spatial planning policy and land-use model on the current trend in 2031 using CA-Markov model. This research uses remotely sensed data from SPOT satellites in 2006, 2012, and 2018 as the base for the 2031 model. The result shows that the number of paddy fields in Pandeglang fluctuated from 2006 until 2031. In 2031, the paddy field is predicted to increase by around 5%. This increase hasn't been able to keep up with the population growth, as the increase of settlement area exceeds the paddy field at 27%, so that the ratio is around 1:5. The protected agricultural area policy hasn't been implemented thoroughly, leaving most of it at the risk of conversion. Recommendation towards this challenge and the planning policy is headed towards preserving environment and agricultural area by properly allocating and considering the pattern and rate of urban growth to achieve better food security and sustainability.

1. Introduction

Food security is a big issue in Indonesia due to the availability of agricultural land caused by land conversion, especially in Java Island, continually decreasing. Food security is the condition to meet food demand for the state to individuals, as reflected in the availability of sufficient food, both in quantity and quality, safe, diverse, nutritious, equitable, and affordable and does not conflict with religion, belief, and culture of the community, in order to live a healthy life, active life, and productive in a sustainable manner [1]. Availability of agricultural land is one of the things that should be considered to ensure future food security [2].

Agricultural land has a comprehensive function, both economically, socially, and environmentally. However, Indonesia's agricultural land tends to have a lower value than converted agricultural land (into non-agricultural). This can trigger an increase in land-use change from agriculture to non-agriculture [3]. In Java Island, many of agricultural lands were converted to industrial land and or settlement area, that implicates to the government policies which might to be corrected [2].

In addition, the increasing number of residents with a fixed amount of land also causes the current high conversion of agricultural land, resulting in less agricultural land in Indonesia, while the need for...
food is increasing. Therefore, increasing agricultural land conversion needs special attention through comprehensive land-use planning.

One way to plan agricultural land use can be done by developing agricultural food land. Therefore, the government, especially local governments, must make plans and strategies to develop the current use of agricultural land. Land use planning can be defined as planning that regulates the types of land use in an area to be used optimally, giving the highest yield and not damaging land itself and the environment [4]. Therefore, land-use planning must be carried out by understanding the area's potential, regional conditions, and problems in the area to help determine developments in the area.

To tackle the availability and fulfill the needs of food, Indonesia Government has implemented LP2B (Protected agricultural area). The protection for an agricultural area in the local scope (district) is carried out in more detail through agricultural area allocation in spatial planning policy (RTRW). Pandeglang Regency is the largest producer of paddy in Banten Province and its surrounding area; therefore, the availability of paddy fields should be protected and maintained. Pandeglang also experiences significant growth, one of the main reasons is the designation of Tanjung Lesung as a special economic zone (SEZ). The freeway construction between Jakarta – Tanjung Lesung could also be an obstacle in protecting agricultural areas in Pandeglang. Furthermore, the population growth in Pandeglang Regency is also high; from 2010-2017, the population increased by 4.6% or 55,593 persons.

Based on Pandeglang Regency development planning agency (Bappeda) data, land cover in Pandeglang is dominated by the agricultural area around 85,696 ha or 30.92% of the total area. This implies the dominance of the agricultural sector and that it has an enormous potential to be developed even further. However, in 7 years (2010-2017), there is a significant decrease in the agricultural area, from 57,000 ha to 46,304 ha or around 18.76% [5]. Furthermore, based on the spatial policy planning, the protected agricultural area is allocated only around 40,102 ha, which means more than 6,000 ha of the agricultural area is left unprotected from land conversion. Therefore, the development of the agricultural area in Pandeglang is urgently needed because the allocated protected area could not fulfill future needs.

Dedicating a specific area to a protected agricultural area often faces problems of not considering the population growth and food needs. The planning policy often leaves the food security aspects vulnerable. This research aims to evaluate the spatial pattern and allocation of the agricultural area in the Pandeglang Regency. In this research, spatial planning policy is tested with the prediction model obtained from the CA-Markov method using remotely sensed data from 2006-2018. The comparison statistics in each region (sub-district) are then performed to understand better the food security condition, planning, and risk. Then finally, a proper recommendation on the spatial planning policy can be given using the insight obtained from this process.

2. Study Area

Figure 1 shows the location and administrative districts of the study area. Pandeglang Regency is one of eight regencies in Banten Province, located in the west of Java Island (6°21' - 7°10' S, 104°48' - 106°11' E). Administratively Pandeglang Regency is divided into 339 villages and 35 sub-districts.

Pandeglang Regency has a high natural resource potential. Geologically, Pandeglang Regency area is included in the Bogor Zone, which has a hilly path. Meanwhile, the topographical condition of Pandeglang Regency has a height variation between 0 - 1,778 meter above sea level (masl). Most of the Pandeglang Regency topography is lowland, and it is located in the Central and South regions, which covered 85.07% area of the total area of Pandeglang Regency.
3. Methodology
The data used in this research consist of primary and secondary data. The primary data in this study is SPOT satellite imagery years 2006, 2012 and 2018. SPOT satellite imagery was interpreted with visual interpretation and processed by using ArcGIS software version 10.7 to obtained land use map in 2006, 2012 and 2018, and then processed by using Idrisi software with CA-Markov model to obtain the land use prediction data in 2031. Secondary data consists of Indonesia Base map scale 1: 25,000 from Geospatial Information Agency (BIG), Population data from Indonesia Statistic Agency (BPS) year 2018, and spatial planning maps at municipal/city level.

Land use change dynamics are analyzed using overlay method (spatial analyst tools) in ArcGIS. Land use data used in this research is time-series data, from 2006 to 2018, then projected into 2031 using CA-Markov model. This method was also used to evaluate inconsistence of spatial planning policy toward paddy field areas by comparing paddy fields area/land use prediction in 2031 and spatial planning policy map. Furthermore, Conformance Evaluation was used to evaluate Pandeglang Regency Land-Use Planning on Agricultural Land Protection and make some recommendations.

3.1. Land Use Change Analysis
Land use change analysis was carried out in the observed 2006, 2012 and 2018 data. Patterns of change were analyzed for agricultural areas, especially paddy fields and settlement areas using the spatial overlay method in ArcGIS version 10.7. The first step in this analysis is pre-processing consist of radiometric and geometric correction. The next step is visual interpretation to obtain land use patterns. Land use interpretation is done by using several key interpretations aspects, which include color, size, shape, texture, shadow, pattern and its association [6]. Classification of land use is determined by its appearance, and in this study we classified 9 land use classes consisting of bare land, water, forest, mangrove, plantations, settlement, paddy field, shrubs and mix garden. The third step is a ground check to verify and accurately data result of interpretation. The final step analyzed land use change by comparing the land use data from the results of interpretation of SPOT 4, 6 and 7 in 2006, 2012 and 2018 with the overlay method.

3.2. Land Use Prediction Analysis
Land use prediction was carried out using Idrisi software with CA-Markov model. CA-Markov is a combination of Cellular Automata and Markov Chain methods. Cellular automata is a simple model of the spatial distribution process in GIS. Markov Chain is a model based on a random process in determining predictions and optimal control theory [7].
In the CA-Markov model, Markov Chain determines the transition rules in the model to be compiled, while the CA model serves to determine the spatial distribution, neighboring functions, and interactions between cells. CA has the ability to simulate the Spatio-temporal characteristics of a land use system and can be used to simulate behavior in that system that cannot be determined by a single mathematical equation. Meanwhile, Markov Chain has the ability to predict geographical characteristics in two specific time units through a stochastic process. In modeling LUC (Land Use Change), land use is considered as a stochastic process by the Markov Chain and the neighboring system. It works like a chain condition that is interrelated and affects each other [8].

3.3. Conformance Evaluation

Planning effectiveness can be evaluated by assessing the conformance of the outcome with the plan or the performance of the plan itself, which refers to the extent of the plan being used [9,10]. While the performance evaluation also involves the planning and decision-making process, the conformance evaluation is simpler with only assessing the expected outcome and the actual outcome, resulting in the degree of confirmation and deviation between both [11]. Moreover, with how the policy framework in most countries, planning's outcome is more important than its process and implementation [12]. This research will also follow this trend as the outcome of this research is expected to be another input for food security and agricultural land protection policy, with more focuses on agricultural area (as the protection target) and settlement/residential area (as the invasive/conversive land-use).

Conformance evaluation on this research uses an integrated framework offered by the research of Shen et al. 2019 [11], focusing only on the planning content and outcome evaluation (Figure 2). This framework is also in-line spatial planning ministerial regulation no. 6/2017 [13], adding more emphasis on the scoring value (Figure 3).

**Figure 2.** Planning evaluation framework (Shen et al., 2019).

| Code  | Conformance Score (%) | Notes |
|-------|-----------------------|-------|
| D7    | 0-15                  | Very low suitability – Spatial planning needs to be reissued with major revision |
| D6 (P2)| 16-30                | Low suitability – Spatial planning needs to be reissued with medium to minor revision |
| D5    | 31-45                 | Medium suitability – Spatial planning needs an evaluation with minor adjustment |
| D4 (NP)| 46-60                | High suitability – Spatial planning didn't need an evaluation and/or adjustment |
| D3    | 61-75                 | Low suitability – Spatial planning needs to be reissued with major revision |
| D2 (P1)| 75-90                | Medium suitability – Spatial planning needs an evaluation with minor adjustment |
| D1    | 90-100                | High suitability – Spatial planning didn't need an evaluation and/or adjustment |

**Figure 3.** Conformance evaluation scoring (Ministry of Agrarian and Spatial Planning, 2017).
4. Result and Discussion

4.1. Land-use Change

Changes in land use/land cover is one of the major causes of biodiversity loss which is usually caused by human activities such as deforestation, urbanization, agriculture intensification, overgrazing, and subsequent land degradation, natural factors can also contribute to these changes [14,15]. In Indonesia, high population growth is one of the major causes in agricultural land conversion, which needs to be solved [16], where in most case the agricultural land has changed into settlements or built-up areas to fulfill the increasing need for houses. Meanwhile, at the same time, the need for food is also rising, which means that the balance between agricultural area (for food) and settlement area (for housing) must be kept to protect food security. Therefore, an agricultural area protection policy (much like LP2B) must be formulated and implemented in Indonesia.

After an initial assessment of time-series data in 2006, 2012 and 2018 (Figure 4), a change analysis was performed during the period 2006-2012 (Table 1) and 2012-2018 (Table 2). Pandeglang Regency is also experiencing the same problem regarding agricultural lands like the other areas in Indonesia. From 2006 to 2018 there was a change in paddy fields area of 0.8% or around 464.2 ha decrease in total. Even though the decrease might seem small in total, it actually experienced a fluctuation between decrease and increase. The fluctuation starts with a significant decrease in 2006 to 2012 of around 10.31%, followed by an increase of 8.62% in the period of 2012 to 2018 (Table 1 and 2). Based on the result, between 2012 to 2018 forest area was increasing, it might be happened due to the plantation areas that may no longer be productive and neglected due to lack of maintenance so that they were identified as forest or indicated that their land use had changed to forest. The increase of paddy fields happening between 2012 to 2018 was due to the implementation of LP2B policy or government policy that works towards increasing paddy fields by converting unused land (shrub) or mix garden.

| Table 1. Land use change in Pandeglang regency (2006-2012). |
|---------------------------------------------|
| Land-use Class | 2006 | 2012 | Land change (%) |
|----------------|------|------|-----------------|
| Water          | 1,480.41 | 1,541.76 | 61.35 | 3.98 |
| Mangrove       | 766.14  | 664.87  | -101.27 | -15.23 |
| Forest         | 74,493.64 | 67,115.73 | -7,377.91 | -10.99 |
| Plantations    | 118,751.8 | 90,692.76 | -28,059.00 | -30.94 |
| Settlement     | 10,123.91 | 11,080.93 | 957.02 | 8.64 |
| Bare land      | 880.02  | 281.18  | -598.84 | -212.98 |
| Paddy fields   | 58,321.99 | 52,869.56 | -5,452.43 | -10.31 |
| Shrubs         | 5,446.98  | 32,929.53 | 27,482.55 | 83.46 |
| Mix garden     | 5,391   | 18,479.57 | 13,088.57 | 70.83 |

| Table 2. Land use change in Pandeglang regency (2012-2018). |
|---------------------------------------------|
| Land-use Class | 2012 | 2018 | Land change (%) |
|----------------|------|------|-----------------|
| Water          | 1,541.76 | 1,581.67 | 39.90 | 2.52 |
| Mangrove       | 664.87  | 80.17  | -584.71 | -729.36 |
| Forest         | 67,115.73 | 77,078.86 | 9,963.13 | 12.93 |
| Plantations    | 90,692.76 | 122,055.32 | 31,362.56 | 25.70 |
| Settlement     | 11,080.93 | 11,521.52 | 440.60 | 3.82 |
| Bare land      | 281.18  | 175.74  | -105.43 | -59.99 |
| Paddy fields   | 52,869.56 | 57,857.77 | 4,988.21 | 8.62 |
| Shrubs         | 32,929.53 | 80.50  | -32,849.03 | -40,806.42 |
| Mix garden     | 18,479.57 | 5,224.62 | -13,254.95 | -253.70 |
On the contrary with the decrease in paddy fields, settlement areas in Pandeglang Regency always experienced an increase from 2006-2018, even though the percentage of growth in 2012 to 2018 period (3.82%) is lower than 2006-2012 period (8.64%). The expansion trend of the settlement occurs at one of the highest paddy-producing areas in Pandeglang Regency that is Mandalawangi sub-district. Furthermore, there was a significant decline in bare land area in the period of 2006-2012 and 2012-2018, 212.98% and 59.99%, respectively. The forests and plantations were increasing in the period of 2012-2018 even though there were decreases in 2006-2012 (Table 1 and 2). As seen in figure 4, in the period 2006-2012 there was a significant change in plantations area to bare land and mix garden. This also happened in paddy field areas, mostly it changed to settlement and shrubs areas.

![Figure 4. Pandeglang Regency land use map (2006, 2012, 2018).](image)

### 4.2. Land Use Prediction in Pandeglang Regency

#### 4.2.1. Model Accuracy.

The VALIDATE module technique available in IDRISI was employed in this study to validate the predicted outputs and to assess the quality of the predicted land use map [17]. Table 3 presents the summary of statistics of validation obtained from VALIDATE module for the reference LULC 2018 and comparison LULC 2018. This validation method gives an idea about the level of agreement/disagreement between predicted and actual LULC maps. This informs about the number of cells in each class and the level of agreement of a pair of maps regarding the location of the cells in each class [18].

Table 3 displays that an overall agreement between the actual and predicted LULC of 2018 is 0.9382, while the total disagreement is 0.0598. The results in Table 3 indicate that the future LULC changes prediction capability of Markov's chain-based model is very high. Disagreement Grid Cell and Disagreement Quantity component is essential to understand the model predicted outcomes [19]. Table
3 depicts that the Disagreement Grid Cell and Disagreement Quantity are at 0.0032 and 0.0566, respectively. The Kappa variation technique was used in the validation procedure, where the land use 2018 prediction received an overall Kappa score of 0.92. This confirmed that the prediction methodology and results met the analysis requirements. The results indicate that the CA-Markov model was successful in predicting the land use in 2031. This indicates that the model can be reliably used to predict future land use change in the area given the assumption of stable rates of change.

### Table 3. Statistic of validation.

| Agreement/Disagreement       | Value |
|------------------------------|-------|
| Agreement Chance             | 0.1250|
| Agreement Quantity           | 0.1432|
| Agreement Grid Cell          | 0.6720|
| Disagreement Grid Cell       | 0.0032|
| Disagreement Quantity        | 0.0566|
| Kno                          | 0.9316|
| Klocation                    | 0.9952|
| Kstandard                    | 0.9183|

#### 4.2.2. Land use prediction.

Land use prediction for the year 2031 (Table 4) under Business as Usual (BAU) condition shows that the projected change will experience a similar pattern with the past years. Settlements are projected to increase by 27%, while plantations and mix garden will continue to experience an area of 7.78% and 20.15% decline, respectively (Table 4). As seen in Figure 5, the trend in settlement is projected to experience an increase, similar to the past year trends. Expansion of built-up areas is expected to continue to grow, considering the high populations growth and the ongoing construction of the Jakarta-Panimbang ring road in Pandeglang Regency. Prediction in settlement and paddy field land uses are expected to come at an increase, where the increase of settlement area is around 4,218.55 ha, while the increase of paddy field is only 3,086 ha. Both increases are still disproportional, as in the long run it will impact the rice productivity; and ultimately, food security [20].

### Table 4. Comparison of the land-use change in the past years and the land-use prediction.

| Land-use class | 2006 | 2012 | 2018 | 2031 | % Land change (2018-2031) |
|----------------|------|------|------|------|--------------------------|
| Water          | 1,480.41 | 1,541.76 | 1,581.67 | 1,836.25 | 13.86                    |
| Mangrove       | 766.14  | 664.87 | 80.17 | 104.08 | 22.97                    |
| Forest         | 74,493.64 | 67,115.73 | 77,078.86 | 79,128.09 | 2.59                     |
| Plantations    | 118,751.8 | 90,692.76 | 122,055.32 | 113,243 | -7.78                    |
| Settlement     | 10,123.91 | 11,080.93 | 11,521.52 | 15,740.08 | 26.80                    |
| Bare land      | 880.02  | 281.18 | 175.74 | 215.11 | 18.30                    |
| Paddy fields   | 58,321.99 | 52,869.56 | 57,857.77 | 60,944.06 | 5.06                     |
| Shrub          | 5,446.98 | 32,929.53 | 80.50 | 97.14 | 17.13                    |
| Mix garden     | 5,391  | 18,479.57 | 5,224.62 | 4,348.54 | -20.15                   |
4.3. Conformance Evaluation and Planning Recommendation

As predicted in the CA-Markov model for 2031, both paddy field and settlement area are predicted to have an increase in its total area. However, some of the prediction results will often not be in line with the current land use planning in the region due to the changing trend and dynamic in planning period (in which in this research was around 13 years, 2018-2031). Conformance analysis are then used as the measurement in whether the planning will have to be revised and/or replaced before its due date to better direct the land use dynamics.

This research uses the predicted 2031 land use (paddy field and settlement) and overlays with the land use planning. The result shows that on average, the consistency between two of the most dynamic land uses in Pandeglang Regency are around 65-67% (Table 5), meaning that the spatial planning is unable to direct the land use dynamics for around 30%. As per the regulation in spatial planning evaluation and revision by Ministry of Agrarian and Spatial Planning (2017) conformance level of 65-67% was placed in D3 category, meaning that the spatial planning has a medium suitability level in which the spatial planning needs an evaluation with minor adjustment. Indonesian planning policy does have a high standard to follows, being that the conformance level needs to be above 75% for it to be considered as a "proper" planning policy. That was done due to the state of rapid urbanization and land use change that happens in most of the urban area and its adjacent area.

The consistency of paddy field area in Pandeglang Regency is around 67.77%, with inconsistency level of 32.23%, which almost half of it was due to the inconsistency from other agricultural activities. This level of inconsistency happens due to the policy from Pandeglang's Department of Agriculture that wants to diversify the agricultural product to increase the regency's local product competitiveness. Other major inconsistencies also came from the protected area zoning, where in reality, those area is also used in agricultural practices by local residents. There is also inconsistency from settlement area, where the predicted paddy field growth is planned as settlement area (mainly a rural settlement setting). The pattern of inconsistency spread across the southern part of Pandeglang Regency, with the major one in Munjul, Cikeusik, Cigeulis, Panimbang, and Cibitung sub-district (Figure 6).
The consistency of Settlement area in Pandeglang Regency is around 65.78%, with an inconsistency level of 34.16%, in which almost all of it comes from the inconsistency with other agricultural activities. This type of inconsistency was due to the invasive/conversive nature of settlement land use over agricultural-type land use. The inconsistency pattern of settlement area in Pandeglang Regency covers two major patterns, which is along Pandeglang's west coast due to Labuan urban area's expansion; the other came in along the Jakarta-Panimbang ring road corridor. Those two patterns end in Panimbang sub-district, where Tanjung Lesung special economic zone is located, which is predicted to stimulate growth over the southern part of Pandeglang Regency (Figure 7).

### Table 5. Conformance evaluation result

| Conformance Evaluation | Paddy Field (%) | Settlement (%) |
|-------------------------|-----------------|----------------|
|                         | Percentage      | Total Area (Ha) | Percentage | Total Area (Ha) |
| Consistent              | 67.77           | 41296.8         | 65.78      | 10350.8         |
| Inconsistent            | 32.23           | 19682.5         | 34.16      | 5475.8          |
|                         | Protected Area  | 9.65            | 5880.4     | 4.68            | 736.6          |
|                         | Other           | 13.96           | 8504.2     | 25.72           | 4047.8         |
|                         | Agriculture     | 5.84            | 3558.8     | -               | -              |
|                         | Settlements     | 2.78            | 1694.0     | 3.76            | 591.4          |

A common criticism of planning is that governments expend a great deal of energy making plans, only to have them 'sit on the shelf for years without being used and without accountability for results' [21]. Conformance analysis suggests that Pandeglang Regency spatial planning needs an evaluation and minor adjustments. Recommendation on Pandeglang Regency spatial planning was more towards the designation of areas to concentrate growth (growth pole) of settlement area, which could be based on the land availability and suitability; distance, relationship, and interaction with the other growth pole; and/or as designated by the higher planning authority, followed by proper limitation and regulation for further expansion. The same could also be applied to agricultural areas, where a stricter zoning regulation must be implemented in the entire regency and implementation of agricultural area incentives and protection. Strategic areas for agricultural activities must also be designated in order to promote better agricultural activities. The development of Pandeglang's specialized product also could be developed as an enclave area for agroindustry.

![Figure 6. Inconsistency of paddy field land-use](image6.png)

![Figure 7. Inconsistency of settlement land-uses](image7.png)
5. Conclusion
The dynamics of land-use change over the last 13 years in Pandeglang Regency are dominated by the increase of plantations and settlement areas. The other land uses experienced fluctuating change, such as paddy field areas, shrubs, mix garden and bare land. Projected land use in 2031 reached a good level of accuracy with the kappa index of 0.92. Land-use prediction using a CA-Markov method finds out that under BAU condition, settlement areas will continue to increase until the year 2031, as well as the paddy field areas. The increase of paddy field areas is happening due to the implementation of LP2B policy, even though the increase of paddy field areas is not equal to the increase of settlement areas. Both the high population growth and the ongoing construction of the Jakarta-Panimbang ring road in Pandeglang regency are the problems that will trigger an increase in the conversion of agricultural land to settlement. Therefore, due to those problems, paddy fields should be specially protected by the government to minimize conversion rates of agricultural lands.

Conformance analysis between the predicted model of paddy field and settlement area is classified as D3 and that the spatial planning needs and evaluation with minor adjustments. The inconsistency of paddy fields comes mostly from other agricultural activities, protected areas, and settlement areas, which is due to the inability of spatial planning to predict and direct the needed growth of paddy fields. On the other hand, the inconsistency of settlement area comes from the other agricultural activities due to its invasive/conversive nature over agricultural area. Following this result, there are some recommendations. The settlement area needs to have a designated growth pole to concentrate the force of growth and expansion, as well as the zoning regulation to limit those expansions. At the same time, agricultural area also needs a stricter zoning regulation that makes it harder for land use change to occur, especially in the designated agricultural strategic area.

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