Analysis and Prediction of Green GRDP in Indonesia with Ecosystem Service Value Approach

I Gata[1,*] and E Pasaribu[1]

[1] Statistical Computing Department, Politeknik Statistika STIS, Jakarta, Indonesia

*Corresponding author's email: ibnugata.27@gmail.com

Abstract. Gross Regional Domestic Product (GRDP) as a measure of economic output in each region has not reflected sustainability because it overlooks the environmental impacts caused. Green GRDP is an important innovation that integrates environmental aspects into sustainable development. Indonesia has committed through TAP MPR IX/2001, Indonesia Emas 2045, and the SDGs to implement sustainable development. This study analyzes and projects Indonesia's Green GRDP using the Ecosystem Service Value (ESV) approach. Satellite imagery data from MODIS MCD12Q1 and the Cellular Automata–Artificial Neural Network (CA-ANN) method are employed to predict land cover changes, while time series models are applied to forecast GRDP. Variations in provincial ESV are strongly influenced by land cover composition. In 2001, Papua recorded the highest Green GRDP and ESV contribution, whereas by 2020 (projected to 2030), Jakarta leads in Green GRDP but exhibits the lowest ESV contribution percentage. Throughout the period 2001–2030, Papua consistently maintains the highest ESV proportion relative to its Green GRDP. The findings highlight the importance of incorporating ecosystem service values into regional and national economic planning to ensure that economic growth inherently reflects environmental sustainability. This effort should be supported by spatially differentiated development strategies aligned with each region's ecological capacity.
Keyword: CA-ANN, ESV, Green GRDP, MCD12Q1, Sustainability Development

1. Introduction

A country's development is considered successful if it is supported by high output. Generally, this output is measured through Gross Region Domestic Product (GRDP). However, GRDP does not reflect actual income because it does not consider losses due to environmental degradation. The contradiction between economic growth and ecosystem preservation is a major challenge in achieving sustainable development [1]. To overcome this, the concept of Green GRDP was introduced as an innovative solution that incorporates environmental elements into the measurement of sustainable development.

In Indonesia, TAP MPR IX of 2001 provides a strong constitutional basis by emphasizing the sustainable management of natural resources and maintaining environmental carrying capacity for optimal benefits. In line with this, President Prabowo Subianto has put forward a vision of Together Indonesia Advances Towards Indonesia Emas 2045, which is realized through the 8 missions of Asta Cita as the priority agenda for the 2024-2029 development. Asta Cita focuses on inclusive economic growth, sustainable natural resource management, and environmentally based development. As part of its global commitment, Indonesia has also integrated the Sustainable Development Goals (SDGs) into its national development agenda, particularly those related to increasing inclusive and sustainable economic growth to support synergy between economic development and environmental preservation

[2]. Indonesia should implement the concept of Green GRDP because it is rich in natural resources. Through the Green GRDP policy, Indonesia can create a balance between economic progress and environmental preservation with measures such as energy policy reform, sustainable agricultural sector development, and forest ecosystem protection to reduce deforestation [3]. However, Indonesia still faces challenges in implementing Green GRDP. Limited fiscal capacity, lack of environmentally friendly technology, and obstacles in implementing effective policies are often barriers to the transition to a green economy [4]. Therefore, further research is needed to calculate Green GRDP in each region of Indonesia in order to support the implementation of Green GRDP in Indonesia.

Green GRDP with an ecosystem service value approach takes a unique perspective because its main focus is on assessing the positive benefits that nature provides to humans, both consciously and unconsciously, such as the provision of clean water, plant pollination, or climate regulation, which are often not traded in the market and therefore not recorded in GRDP [10]. This approach aims to internalize the non-market values of ecosystems into the economic framework to demonstrate the real contribution of nature to welfare and the economy. This is fundamentally different from Green GRDP, which is obtained by subtracting the depletion and degradation of natural capital from GRDP, where the main focus is to correct or reduce GRDP as a form of cost and loss due to environmental damage caused by economic activities [14]. However, the value of environmental degradation and natural resource depletion is actually also taken into account in Ecosystem Service Value (ESV). ESV is defined as the contribution of ecosystems to the provision of benefits that support economic activities and human well-being [15]. Changes in land cover from types of land cover with high ESV value to types of land cover with lower ESV value result in a reduction in natural value, in other words, environmental degradation and natural resource depletion. Thus, the ESV approach is value adding by recognizing the contribution of nature, while the depletion/degradation approach is reduction value approach to reflect the negative impacts of development [16].

Previous research on Green GRDP conducted by Yu Yuhan et al [1] and Shuanglong Tao [17] in China focused only on assessing the value of environmental services on land because China is mostly landlocked. Meanwhile, the case study in this research is located in Indonesia, which is an archipelagic country. This fundamental difference is important for researching Green GRDP using a land- and water-oriented environmental service value approach. Previous research conducted by Shuanglong Tao calculated Green GRDP on land and in water using a resource depletion and pollution treatment value approach. The study did not use satellite imagery data but used natural resources and environmental series data. The prediction method used in the study was Grey Predictive Analysis. Meanwhile, this study calculates Green GRDP using an environmental service value approach. The prediction method used in this study is Markov Chain. Widayani et al [5] demonstrated that incorporating ESV into regional economic accounting can significantly enhance the measurement of Green GRDP, showing the monetary contribution of ecosystem services, including carbon sequestration, water purification, and climate regulation, to local economies. This highlights the importance of integrating ESV in Green GRDP calculations to more accurately reflect environmental contributions in Indonesia. This study calculates Green GRDP using the ESV approach. However, there is a difference from the previous study, namely the method used, which is CA-ANN, which can consider the driving factors for land cover change. CA-ANN can also model the non-linear relationship of various driving factors with land change. This is different from CA-Markov, which can only model linear relationships based on transition probability matrices [11]. The driving factors used in this study are distance to the provincial capital and distance to national and provincial roads. Provincial GRDP predictions are made using trend analysis. This analysis is considered more flexible and does not require other variables as inputs [9]. This study is conducted in Indonesia, which has an archipelagic geography with diverse regional characteristics, in contrast to China, which is mostly landlocked. Furthermore, research on Green GRDP using the ESV approach in Indonesia is still limited. Most previous studies focus only on calculating ESV and do not integrate it with regional GRDP, leaving a gap in understanding the actual contribution of ecosystem services to regional economic performance.

2. Research Method

The research was conducted using Regional Gross Domestic Product data for all provinces in Indonesia from 2001 to 2020, obtained from a publication by the BPS-Statistics Indonesia [7]. Land cover classification data was obtained from MODIS MCD12Q1, which provides land cover data with a spatial resolution of 500 meters and annual temporal resolution [8]. The area of each type of land cover was calculated based on classification using MODIS MCD12Q1. The land cover classification data are available only up to the year 2020. Therefore, the analysis in this study is limited to 2020. Based on these data, projections of the GRDP values and land cover classifications for subsequent years can be generated. The following is a flowchart of the research depicted in Figure 1.

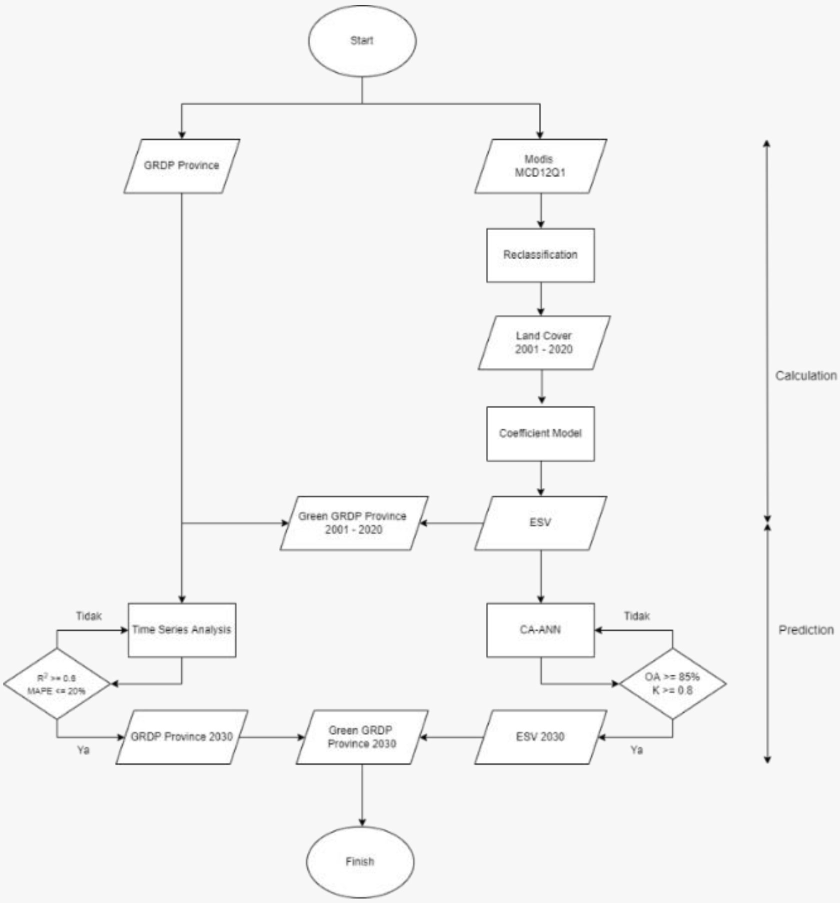

Figure 44. Research Process Diagram

The research began with collecting the necessary data. The next step was to reclassify land cover from MCD12Q1 from the original 17 classes into 6 classes, namely forest, grassland, agriculture, water, built-up land, and undeveloped land. The reclassification aimed to adjust the land cover types to the biomes in the ecosystem service structure described in the study conducted by Coztanza et al in 1997 [10]. After the reclassification was completed, the area for each type of land cover was calculated. The ecosystem service value (ESV) was obtained by multiplying the land area per year by the ecosystem service value coefficient (ESV coefficient), which had been converted into rupiah.

$$ESV = \sum(A_i \times E_i) \quad (1)$$

Ai is the area of each land use function, Ei is the ESV coefficient for each type of land cover that has been adjusted to the biome types identified in the study conducted by Costanza et al. in 1997 [10]. The calculation of the Green GRDP value for each province is performed by summing the GRDP and ESV of each province [5].

To calculate the contribution of ESV to Green GRDP, it can be calculated using the equation,

$$GRDP_G = ESV + GRDP \quad (2)$$

with $GRDP_G$ is Green GRDP, ESV is ecosystem service value, and $GRDP$ is provincial GRDP. The contribution of ESV to PDRB can be calculated using,

$$C_{ESV \to GRDP_G} = \frac{ESV}{GRDP_G} \times 100\% \quad (3)$$

The Green GRDP prediction process begins with simulating land cover changes using the CA-ANN method and forecasting GRDP values using the trend analysis method with time series. CA-ANN is a spatio-temporal model that combines the concepts of Cellular Automata (CA) and Artificial Neural Network (ANN). CA-ANN is often used in geography, environmental science, and regional planning to predict future land cover changes [11]. Cellular Automata (CA) divides an area into grid cells. Each cell represents a spatial unit (e.g., a pixel in a satellite image) and has a specific state (e.g., forest, agricultural land, urban). Changes in the state of a cell are influenced by the state of its neighbouring cells at the previous time, following certain transition rules.

$$\delta i + 1 = f(St, N) \quad (4)$$

δi is a set of cells that are limited and discrete. N is the neighbour cell of the active cell. t indicates iteration. f is the transformation of the local space of the cell. Meanwhile, ANN in land change simulation uses the concept of artificial neural networks with the architecture shown in Figure 2.

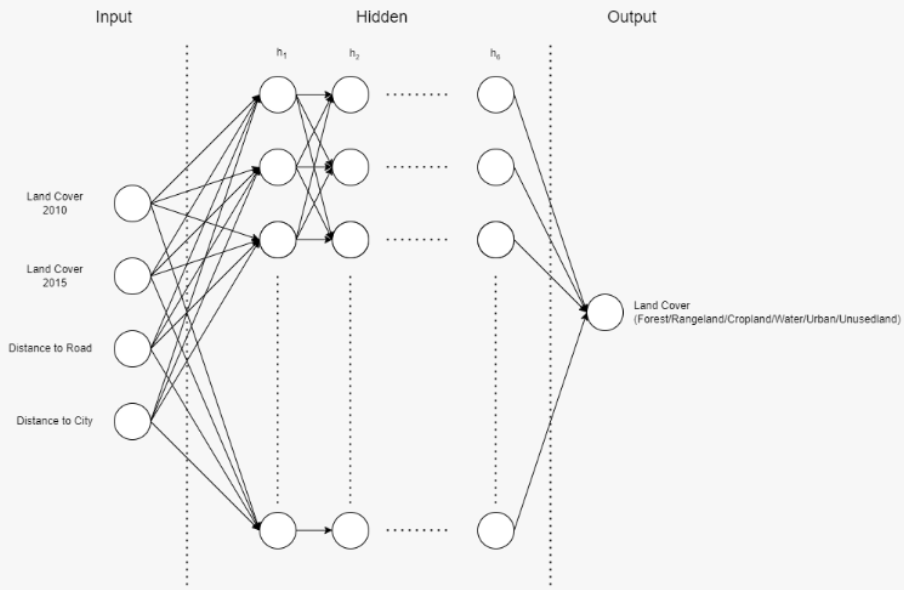

Figure 45. ANN Architecture.

ANN consists of three main layers, namely the input layer, hidden layer, and output layer [6]. The input layer receives several features or input variables which are then forwarded to one or more hidden layers. The hidden layer functions to process and extract complex patterns from data through neurons that are interconnected with specific weights. After processing in the hidden layer, the results are passed to the output layer, which generates predictions or network outputs according to the modelling objectives. Each connection between neurons has a weight that is optimized during the training process using the backpropagation algorithm to minimize errors prediction [12]. Simulation of land cover change using CA-ANN was carried out by adding a factor driving land change in the form of distance to the provincial capital and distance to national roads. The distance was determined using the Euclidean Distance method.

$$Predicted\ Year = Final\ Year + Year\ Range \quad (5)$$

Therefore, to create land cover in 2020 as the data used for testing is first iteration. Meanwhile, for land cover in 2030, iteration 3rd is performed. The ESV prediction is calculated based on the area of each type of land cover in 2030 and the ESV coefficient as in equation (1) for the ESV of each province in 2030. Meanwhile, GRDP forecasting will produce the GRDP value in 2030. Based on the ESV and GRDP prediction results, the Green GRDP and the contribution of ESV to it in 2030 can be calculated for each province in Indonesia. For provincial GRDP predictions, prediction modelling is carried out using the trend analysis time series method. There are three types of trend analysis: linear, quadratic, and exponential. The linear trend model is used when the data is assumed to experience changes or growth that tend to be constant in amount from one period to the next. This pattern is described as a straight line, either ascending or descending [9]. The linear trend model can be formulated as follows,

$$\widehat{Y_t} = \beta_0 + \beta_1 t \quad (6)$$

Y_t is the predicted GRDP value at time t, where t is the year. β_0 is the constant value and β_1 is the trend coefficient, which is the average change in GRDP value for each year. The quadratic trend model is more flexible than the linear model and is used when the data trend pattern shows a tendency for a single curve or curve [9]. This means that the data does not increase or decrease at a constant rate but can experience acceleration or deceleration. The quadratic trend model can be formulated as follows,

$$\widehat{Y_t} = \beta_0 + \beta_1 t + \beta_2 t^2 \quad (7)$$

Y_t is the predicted GRDP value at time t, where t is the year. β_0 is the constant value, β_1 is the slope coefficient of the curve, and β_2 is the curvature coefficient of the curve, which is positive if the parabola is open upward, and if negative, the opposite. The exponential trend model is used when the data tends to change exponentially over time [9]. The exponential trend model can be formulated as follows,

$$\widehat{Y_t} = \beta_0 \exp^{\beta_1 t} \quad (8)$$

Y_t is the predicted GRDP value at time t, where t is the year. β_0 is the constant value and β_1 is the annual growth or decline rate of GRDP. Based on these three models, the best model was selected to be used to calculate the predicted GRDP of the province.

3. Result and Discussion

3.1. Land Cover Reclassification

Land cover classification still needs to be adjusted for ESV calculations related to the relationship between land cover types and the ecosystem services provided by nature. Reclassification was carried out to adjust to these requirements by changing the data specifications from the initial classes, which were more heterogeneous (large), to more homogeneous (small) ones. A smaller number of classes by combining attributes with similar tendencies can also improve data accuracy. Reclassification was carried out on the MCD12Q1 dataset to simplify the classes in the dataset and adjust them to the types of land cover for which the ESV coefficients of each type of land cover were calculated. Forest land cover (Forest) includes five types of forests, namely Evergreen Needleleaf Forest, Evergreen Broadleaf Forest, Deciduous Needleleaf Forest, Deciduous Broadleaf Forest, and Mixed Forest, which represent various types of forest cover based on leaf type and life cycle. Rangeland land cover consists of various forms of natural vegetation, such as Closed Shrublands, Open Shrublands, Woody Savannas, Savannas, and Grasslands. Cropland land cover includes intensive agricultural land and a mosaic of natural vegetation and agriculture, namely Cropland and Natural Vegetation Mosaic. Meanwhile, water land cover combines water areas and permanent wetlands, namely Permanent Wetland and Water Bodies. Built-up land cover (Urban) consists only of the Urban class, which indicates built-up areas. Finally, unused land cover (Unused) includes areas that are not directly utilized, such as Permanent Snow and Ice and Barren Land

Table 20. Validation Test for Dataset

	Validation Test	MCD12Q1 Documentation
Overall Accuracy	0.75	0.73

Based on Table 1, the MCD12Q1 dataset for Indonesia has a higher overall accuracy than the global with overall accuracy of 75%. In general, the overall accuracy value indicates that the land cover data can be used for research.

Table 21. Evaluation Matrix for Each Class

	Forest	Rangeland	Cropland	Water	Urban	Unusedland
Precission	0.75	0.43	0.88	0.95	0.93	1.00
Recall	1.00	0.71	0.69	0.9	0.88	0.34
F1-Score	0.86	0.54	0.78	0.92	0.90	0.51

Based on Table 2, the evaluation results show that the model performance varies significantly among the land cover classes analysed. This model excels in identifying classes with clear visual characteristics, such as Water, which achieved the highest F1-Score. Therefore, it can be said that the best class resulting from the modelling is Water land cover. Land area calculations were performed on Google Earth Engine based on MCD12Q1 data, which uses a sinusoidal grid projection system that can maintain the actual area values on the earth's surface projected onto a sphere [13]. With this projection system, land area calculations can be more accurate. The calculations produced area data for each land type for the period 2001 to 2020.

Recent land use changes show an increase in grassland area by 16.7 million hectares, suggesting either an expansion of grasslands or a shift from previously degraded land toward open land. Similarly, built-up urban areas have expanded by 141.3 thousand hectares, reflecting ongoing urban growth and infrastructure development. On the contrary, several land types have declined notably: forested land decreased by 7.7 million hectares, a worrying trend given forests' crucial roles in ecosystem balance, biodiversity, and climate regulation. Cropland area shrank by 5 million hectares, potentially threatening food production and national food security. Water bodies also reduced by 4.1 million hectares, which could impact water resources and aquatic ecosystems. Additionally, unused land diminished slightly by 29 thousand hectares. These patterns reveal increasing pressures on both natural and productive lands driven by urbanization and land use shifts, highlighting the urgent need for sustainable land management to protect essential ecosystem functions while supporting development. Based on the data, in 2001, the province with the largest forest cover was Papua, with an area of 34.2 million hectares. The province with the largest area of rangeland was South Sumatra with an area of 3.7 million hectares. The province with the largest area of cropland was East Java with an area of 2.9 million hectares. The province with the largest area of water was Papua with an area of 4.1 million hectares. The province with the largest built-up land cover is West Java with an area of 286.2 thousand hectares. The province with the largest unused land cover is East Java with an area of 8.8 thousand hectares. Meanwhile, in 2020, the province with the largest forest land cover is Papua with an area of 26.3 million hectares. The province with the largest area of rangeland is West Kalimantan with an area of 5.6 million hectares. The province with the largest area of cropland is East Java with an area of 2.6 million hectares. The province with the largest area of water is Papua with an area of 2 million hectares. The province with the largest built-up land cover is West Java with an area of 322,600 hectares. The province with the largest unused land cover is East Java with an area of 3,300 hectares.

3.2. Calculation of Provincial Green GRDP for 2001-2020

After the area of each type of land cover is known, the ESV is calculated using the formula described earlier, which uses the land area input for each type of land and the ESV coefficient value. The ESV value coefficient is in accordance with the ESV algorithm proposed by Costanza et al [10].

Table 22. Coefficient ESV Index

Land Cover Type	Biome	ESV Coefficient ($US)	ESV Coefficient (Rupiah)
Forest	Tropical Forest	2,007	18,044,937
Rangeland	Rangeland	232	2,085,912
Cropland	Cropland	92	827,172
Water	Water	14,785	132,931,935
Urban	Urban	0	0

Unused	Ice/Rock	0	0

Based on Table 3, the ESV coefficient with the highest value is water, with a value of Rp. 132,931,935. This explains how valuable water resources are for the needs of humans and other creatures that support human life. Meanwhile, urban and undeveloped land cover types have a coefficient of 0. This means that developed and undeveloped land does not provide any natural benefits to humans. The ESV coefficient for other land cover types is Rp. 2,085,912 for grassland and Rp. 827,172 for agricultural land.

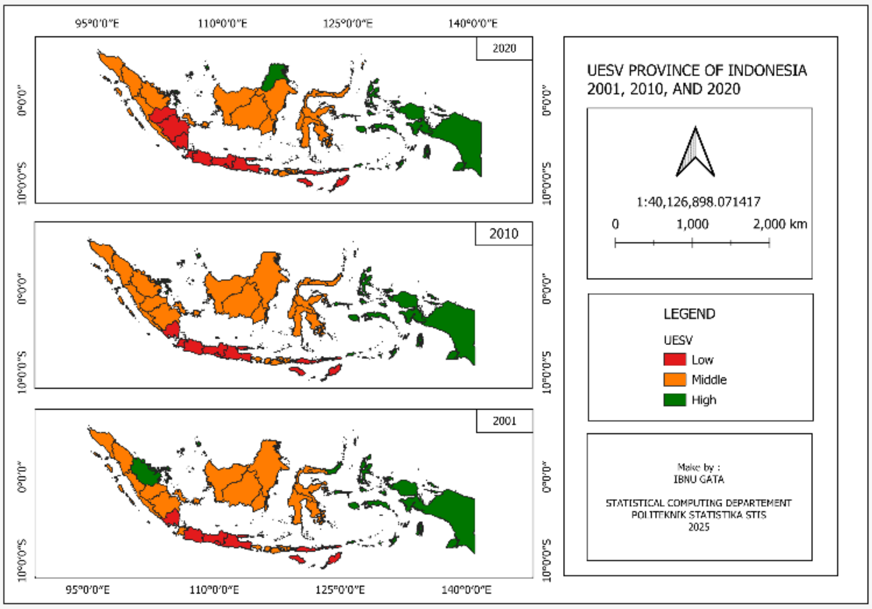

Figure 46. Provincial UESV level in Indonesia 2001 - 2020

ESV is the monetary value of environmental services provided by ecosystems in Indonesia. Figure 3 shows the Unit Ecosystem Service Value (UESV), which is the ESV per unit area (hectare). UESV is more useful for comparing ESV values for classification purposes because it does not depend on the area of a province. This is because provinces with larger areas have the potential for higher ESV values regardless of the land cover structure within them. The Fixed Class method ensures consistency in comparing regions because the ESV value ranges are established using predetermined minimum and maximum values from the dataset. This allows each region to be directly categorized into Low, Middle, or High classes. With this consistent classification, comparisons between provinces or regions can be made in the same way from year to year, facilitating both temporal analysis and spatial comparison. In addition, the use of fixed classes simplifies the spatial visualization of ESV values in maps or statistical analyses. Since the class boundaries remain constant, ESV maps from different years can be directly compared to observe whether the ESV values have developed, declined, or remained stable over time.

In 2001, the provinces with high UESV values were Riau, North Sulawesi, North Maluku, Maluku, West Papua, and Papua. In the same year, there were four provinces that did not have ESV values, namely Riau Islands, West Papua, West Sulawesi, and North Kalimantan. This was because these four provinces were still part of other provinces or had not yet been separated from their parent provinces. In 2010, Riau's category changed to a province with a medium UESV level. Meanwhile, the Riau Islands, which were separated from Riau province, had a high UESV category. Other provinces that experienced a decline were.

North Sulawesi has changed from a high UESV category to a moderate one, and Banten has changed from a moderate category to a low one. The Papua region, which has undergone expansion, remains in the high category. Similarly, the province resulting from the expansion, West Papua, is also in the high category. Meanwhile, in 2020, all provinces studied have become independent provinces because of the expansion of their parent provinces. North Kalimantan Province is in the high UESV category, while East Kalimantan remains in the moderate category. This shows that North Kalimantan has a relatively pristine ecosystem. This year, several provinces on the islands of Sumatra and Bali also showed a decline in UESV values from moderate to low. This may reflect high development pressure, urbanization, and land conversion, which have led to ecosystem degradation and a reduction in environmental services. Provinces in eastern Indonesia, such as Papua and Maluku, consistently show high UESV values throughout the period from 2001 to 2020. This indicates that ecosystems in these regions are still relatively well preserved and provide significant environmental services, such as clean water supply and habitats for biodiversity

Table 23. GRDP Province 2001 - 2020

	2001		2010		2020	
	Value (Billion)	Province	Value (Billion)	Province	Value (Billion)	Province
Highest GRDP	648,596.02	Jakarta	1,075,183.48	Jakarta	1,792,291.09	Jakarta
Average GRDP	143,898.46		208.004,03		318,751.20	
Lowest GRDP	8,248.29	Gorontalo	14,983.91	Maluku Utara	28,031.44	Maluku Utara

Based on Table 4, in 2001, the average GRDP of provinces in Indonesia was 143,898.46 billion rupiah. This average value continued to increase until 2020 with a value of 318,751.20 billion rupiah. Meanwhile, Jakarta became the province with the highest GRDP from 2001 to 2020. Meanwhile, the province with the lowest GRDP in 2001 was Gorontalo with a value of 8,248.29 billion rupiah. In the following period, the lowest ranking for provincial GRDP was North Maluku, which had a GRDP of 14,983.91 rupiah in 2010 and 28,031.44 billion rupiah in 2020. Even so, the GRDP in each province showed a positive trend. This indicates the success of economic development in all provinces in Indonesia.

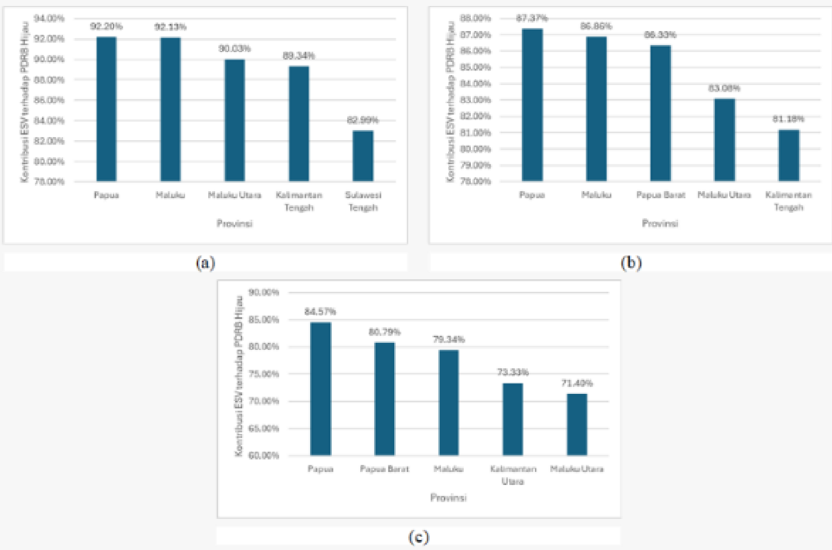

Figure 47. Five Provinces with the Highest ESV Contribution to Green GRDP (a) 2001, (b) 2010, and (c) 2020

Based on Figure 4, Papua Province also had the highest ESV contribution to Green GRDP among other provinces from 2001 to 2020. At least four provinces were among the five provinces with the highest ESV contribution to Green GRDP during the 2001–2010 and 2010–2020 periods. Papua, Maluku, and North Maluku are the three provinces that have consistently been among the provinces with the highest ESV contribution to Green GRDP in each period. Meanwhile, West Papua, which was split off from Papua Province, also falls into this category in the period after the split. This means that the eastern region of Indonesia, which includes the islands of Papua and Maluku, has a well-preserved natural ecosystem.

3.3. Green GRP Forecast for Provinces in 2030

After understanding the conditions and changes in ESV values in various provinces in Indonesia from 2001 to 2020, the next step is to predict future Green GRDP values. This prediction is important to anticipate trends in land cover change and its impact on ecosystem service values and sustainable economic growth. By using land cover change simulation methods and GRDP prediction models, we can obtain a clearer picture of the potential for green economic development in each province. This will provide a strong basis for formulating more environmentally friendly and sustainable development policies

Table 24. Hyperparameter for ANN

Sampel	Neighbourhood	Hidden Layer	Iteration	Learning Rate	Momentum	Kappa
2,500	4	6	1,000	0.005	0.05	0.84
3,000	4	4	1,000	0.001	0.05	0.73
3,000	4	6	1,500	0.005	0.06	0.56
7,500	4	6	1,000	0.001	0.05	0.86
10,000	4	6	1,000	0.001	0.05	0.80

Based on Table 5, it is known that the combination of hyperparameters to produce the best ANN modelling is with 7,500 samples, a neighbourhood of 4, 6 hidden layers, and a minimum iteration of 1,000 iterations, learning rate 0.001, and momentum 0.05. This combination produced the best Kappa value of 0.85, which means it falls within the Almost Perfect Agreement criteria. The processing time ranged from 2 to 3 hours using a computer with the following specifications: 8th generation Intel Core i5 processor, 16 GB RAM, 512 GB SSD, and NVIDIA GeForce MX230 graphics card. The processing time also depended on the combination of hyperparameters specified. The more samples, neighbourhoods, hidden layers, and iterations, the longer the processing time required. The simulation data used is the land cover classification for 2010 and 2015. The validity of the model was then tested by comparing the 2020 land cover classification from MCD12Q1 with the land cover classification results generated from the 1st iteration of the CA-ANN simulation. The simulation results using the CA-ANN method showed good performance with an Overall Accuracy value of 93.25%, which indicates that 93.25% of the data was classified correctly. In addition, the Overall Kappa value of 0.87 indicates a strong level of agreement between the classification results and the actual data, so that this model can be considered valid and reliable for use in further analysis. After the model was validated, the 2030 land cover classification was generated from the 3rd simulation iteration, which then calculated the area of each type of land cover. Based on the result of simulation, the land cover area in various provinces in Indonesia shows significant differences and reflects diverse land use characteristics. Papua ranks first with a forest cover area of approximately 26.6 million hectares, indicating that there are still many preserved natural forest areas there. For rangeland or grassland, West Kalimantan is the province with the largest area, approximately 5 million hectares. In terms of agricultural land, East Java leads with an area of 2.55 million hectares. Papua also dominates water coverage with an area of approximately 1.7 million hectares. For built-up areas, West Java has the largest urban land coverage, approximately 277 thousand hectares. This is likely due to West Java's extensive industrial complex. Finally, for undeveloped land, East Java has the largest area. Overall, this data illustrates how natural conditions and human activities shape different land use patterns in each province.

The provincial GRDP forecast for 2030 uses the time series trend analysis method. The method used is quadratic trend analysis with an average of R^2 = 0.97 and $MAPE$ = 2.01%. The Mean Absolute Percentage Error (MAPE) was calculated based on the difference between actual and predicted GRDP values using the time series data. No separate testing data group was used, as the model utilized continuous annual GRDP data. The MAPE was first calculated individually for each province and then averaged to obtain the overall MAPE value. Based on this model, the GRDP value for each province in 2030 is produced. Provinces on the island of Java dominate the five provinces with the highest GRDP in 2030. There are four provinces on the island of Java that are included in the five provinces with the highest GRDP, namely Jakarta, East Java, West Java, and Central Java. Jakarta remains the province with the highest GRDP since 2001, with an increase of around 659,663.05 billion rupiah from 2020 to 2030. Meanwhile, North Sumatra ranks 5th in terms of GRDP, despite being quite far behind Central Java, which ranks 4th.

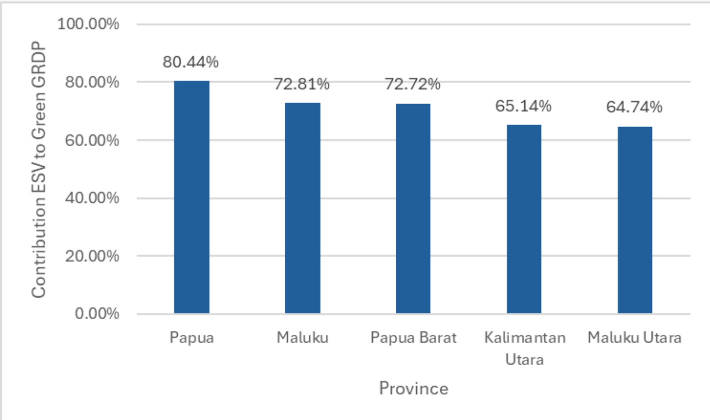

Figure 48. Five Province with Highest Contribution of ESV 2030

Referring to Figure 5, there was no change in the ranking of the five provinces with the highest ESV contribution to Green GRDP. Papua, Maluku, West Papua, North Kalimantan, and North Maluku consistently ranked. The provinces with the highest ESV contribution to Green GRDP, even though all provinces experienced a decline in percentage terms. Based on the results described above, it can be said that the uniform implementation of sustainable development policies throughout Indonesia has proven to be ineffective because each province has fundamentally different economic characteristics and ecological dependencies. These differences can be comprehensively analysed through two main indicators, namely the percentage of GRDP to Green GRDP and the percentage of ESV to Green GRDP. When a province shows a much higher ratio of GRDP to Green GRDP, this reflects a strong economic dependence on environmentally damaging activities, such as extractive industries, resulting in high environmental damage costs. In this context, ecosystem services play a minor role in the regional economic structure. Therefore, the government needs to implement policies that emphasize environmental restoration, strengthening industrial regulations, and diversifying economic sources. Conversely, provinces with a high percentage ratio of ESV to Green GRDP indicate that their economic structure tends to be environmentally friendly and highly dependent on natural capital, such as the tourism and sustainable agriculture sectors. For provinces like this, the government needs to prioritize the protection of conservation areas, the development of ecotourism, and environmental service payment schemes. The clear contrast between these two types of provinces reinforces the argument that a general policy approach cannot address the complexity of existing environmental economic issues. Therefore, policymakers must design interventions tailored to the specific data and conditions of each region so that sustainable development can be achieved effectively and on target

4. Conclusion

The Green GRDP values of Indonesian provinces have generally increased alongside their overall GRDP growth. However, the contribution of Ecosystem Service Values (ESV) to Green GRDP tends to decrease as the provincial Green GRDP rises. Papua consistently exhibits both high Green GRDP and ESV contribution, reflecting abundant natural resources, while Jakarta, despite having the highest Green GRDP, shows the lowest ESV contribution, driven largely by non-ecosystem-based sectors. Provinces such as Papua, West Papua, Maluku, North Maluku, North Kalimantan, and the Riau Islands are projected to remain top contributors to national ESV by 2030. These projections suggest that resource-rich provinces will remain key providers of ecosystem services, highlighting the need for targeted conservation and sustainable management to maintain ecological balance and support long-term national development. The study highlights the importance of integrating Green GRDP into official regional development metrics and using ESV economic values to justify funding for conservation initiatives, promoting sustainable economic growth in harmony with nature preservation.

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