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Spatial Analysis of Landscape Change in the Puncak Bogor Cianjur Tourism Area 2013-2023

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ABSTRACT

This research analyzes the dynamics of land cover change in the Puncak Area over the last 10-year period (2013-2023). Using the Random Forest Classification method on Landsat 8 and 9 image data, this study evaluates the contribution of tourism to the economy of the Puncak Region and reveals facts related to land use change. The Puncak area, known as a mountain tourism destination in West Java, is experiencing rapid economic growth, but tourism activities and infrastructure development have the potential to negatively impact local ecosystems. The research used BIG administrative data, Landsat imagery, and landform systems for analysis. Through Google Earth Engine (GEE), data processing was performed, including cloud masking, mosaic, clip, and pan-sharpening. The Random Forest classification method was used to determine land cover in 2013 and 2023 with kappa accuracy tests reaching 85.81% and 88.42% respectively. The results show an increase in built-up land area of 4,632.68 hectares with a decrease in agricultural and forest land. Obstacles in the interpretation of low-resolution Landsat imagery became one of the challenges in this study. The Urban Expansion Intensity Index (UEII) calculation results show a moderate increase in built-up land area over the past 10 years. The phenomenon of urbanization and the drive of economy and tourism are the main factors of land change from vegetation cover to built-up land. This study provides important insights for the regulation and monitoring of the Puncak Area to maintain a balance between economic growth and environmental sustainability.

***Keywords**: Spatial Analysis, Random Forest, Landsat Imagery*

1. INTRODUCTION

The definition of landscape continues to evolve along with the human ability to understand phenomena that occur in the physical environment (Miklos, 2018). Anthrop (2013) explains that the beginning of the study of landscape has existed since the 13th century, starting from paintings about the landscape. Then it developed towards garden design or architectural landscape.

In the 19th century, the perspective on landscape has entered the realm of ideology, where landscape is used as a reference for urban development plans. Geography plays an important role in understanding the landscape holistically as a geosystem (Miklos, 2018). Landscape must be understood broadly, not only physically, but as human activities, the natural environment, and the result of interactions between humans and the environment. (Blache, 1922).

Thus, the landscape is formed as a result of the interaction between humans and the environment that occurs continuously in a space (Naveh, 1990). Indonesia is located between the confluence of four major plates, namely Eurasia, Indo-Australia, the Philippines, and the Pacific (Hamilton, 1979). The meeting of the continental plates gave birth to a series of volcanoes, ranging from Sumatra, Java, Bali, Nusa Tenggara, Sulawesi, and Maluku, so Indonesia is often called the ring of fire (Blair, 1988).

Mountainous areas present unique and interesting landscapes, plus the cool climate that characterizes them (Sonjaya, 2005). It is no wonder that mountainous areas attract tourists to visit and sightsee. One of the most famous mountain tourist destinations in West Java is the Puncak area (Syurawati, 2021). Geographically, the Puncak area is located in the valley between Mount Gede-Pangrango and the Jonggol Mountains complex (Mangunsong, 2017).

In West Java Regional Regulation No. 15 of 2015 concerning the West Java Provincial Tourism Development Master Plan, the Puncak Natural Ecotourism Area and its surroundings are designated as a Provincial Tourism Strategic Area covering Bogor Regency and Ciajur Regency. Initially the Puncak area was a tea and coffee plantation area (Soedirgo, 2023). The Puncak area is used as a tourist destination inseparable from the influence of the Dutch who like to travel in mountainous areas by building villas (Sidik, 2023).

The Puncak area is increasingly in demand to unwind Jakarta residents because it is relatively easy to reach with a distance of only 70 km from Jakarta and is on the regional crossing route (Jakarta-Bogor-Bandung) (Maulana, 2005). Today, the popularity of the Puncak area as a tourist spot is at an impressive stage with a rapid increase in economic value and the development of tourism areas in the area (Agung Martono & Widyastuti, 2017; Pujiastuti, 2019).

On the other hand, tourism activities and infrastructure development, in response to tourist expectations, are generally considered to have a negative impact on ecosystem services, especially in tourism sites (Widaningrum et al., 2020). Tourism is essentially a geographical phenomenon, which includes the movement and flow of people (demand) and spatial distribution patterns related to land use consumption (supply) (Boavida-Portugal et al., 2016).

As a result, land use in tourism areas will be dynamic and complex, with changes in demand and land use patterns that directly or indirectly disrupt the local environment (Mao et al., 2014). The Puncak area as an upstream area has a vital role in maintaining environmental balance. The Ciliwung River is the longest flowing river through Jakarta with upstream originating from the Puncak area. Land use change in the Puncak area affects the water discharge in the Ciliwung River (Lisnawati, 2006).

Modeling results show that land use change for 23 years in the upstream part of the Citarum River caused an increase in the water discharge of the Citarum River by 20% (Emam, 2016). Many environmental studies related to the Puncak area have been conducted to examine land use change (Lisnawati, 2006; Munibah, 2013; Emam, 2016; Jaya, 2021). Lisnawati and Emam studied land use change in the Ciliwung

River basin and its relation to river water runoff. Minibah is also still studying land use change in the upper reaches of the Ciliwung River. Meanwhile, Jaya studied land use change in three sub-districts in Bogor Regency, namely Ciawi, Cisarua and Megamendung. There has been no study that discusses land use change in the entire peak landscape where tourism activities influence, covering 8 sub-districts in Bogor Regency, and 4 sub-districts in Cianjur Regency.

So the purpose of this research is to analyze the dynamics of land cover/use change in the Puncak Area as a mountainous landscape for the last 10 years from 2013 to 2023. How tourism contributes to the economic level of the Puncak Area and facts about the rate of land use change are interesting topics for studying the dynamics of the Puncak Area landscape. The facts found in this study can be used as input in a targeted peak area regulation plan.

2. RESEARCH METHODS

2.1 Research Area

The research area is the peak tourism area consisting of Cijayanti Village, Babakan Madang Subdistrict, Bogor Regency; Gunung Geulis Village, Sukaraja Subdistrict, Bogor Regency; Ciawi Subdistrict, Bogor Regency; Caringin Subdistrict, Bogor Regency; Cijeruk Subdistrict, Bogor Regency; Cipanas Subdistrict, Cianjur Regency; Cisarua Subdistrict, Bogor Regency; Cugenang Subdistrict, Cianjur Regency; Megamendung Subdistrict, Bogor Regency; Pacet Subdistrict, Cianjur Regency; Sukamakmur Subdistrict, Bogor Regency; Sukaresmi Subdistrict, Cianjur Regency. The peak tourist area is at the foot of Mount Gede Pangrango, bordering the Jonggol Mountains to the north.

The west borders Mount Salak and the south borders Cianjur Regency. The peak tourist area is at an altitude between 700 to 1,800 meters above sea level with an average amount of annual rainfall for the last 3 years measured at the Citeko meteorological station in Bogor of 3,450 mm/year. The landscape in this study includes land cover and land system.

2.2 Material and Methods

The data used in this study include: (a) AOI of Puncak tourist area in the form of BIG administrative data; (b) BIG land system/landform data; (c) Landsat 8 OLI image in 2013; (d) Landsat 9 image in 2023. The data processing application is Google Earth Engine (GEE) which is used to perform cloud masking, mosaic, clip, and pan-sharpening of image data. The method used in data processing is Random Forest Classification.

To conduct kappa accuracy test, 70% of training data and 30% of testing data are needed until land cover data is obtained in 2013 and 2023. The tested land cover consists of residential/built environment, water bodies, agriculture/plantations, forests and vacant land. The land cover data test was carried out by manually interpreting several pixels/rasters of image data.

At this stage of interpretation, accuracy is required because different pixel/raster colors indicate differences in land cover. After obtaining the 2013 and 2023 land cover data, the next step is to overlay it with the land system/landform data using ArcMap 10.8 software. Then the two maps were analyzed and compared to obtain differences or changes in landscape and land cover, which were then calculated the area of each landscape and/or land cover change using the World Cylindrical Equal Area coordinate system in calculating the area.

Google Earth Engine (GEE) is a cloud computing platform designed to store and process large-scale datasets (in petabytes) for analysis and decision-making (Mutanga & Kumar, 2019). GEE is a web portal that provides access to global satellite imagery and vector data, cloud computing, and algorithms to process large amounts of data with relative ease. (Kumar & Mutanga, 2018). The GEE portal provides better opportunities for conducting earth observation studies (Kumar & Mutanga, 2018).

One of the main advantages of GEE is the ease with which global remote sensing data can be interpreted and the excellent computing power of the cloud (Sidhu et al., 2018). The majority of GEE applications include vegetation mapping and monitoring, land cover mapping, agricultural mapping, disaster management and earth science (Mutanga & Kumar, 2019).

GEE provides access to more than 40 years of historical satellite imagery data for the entire world, with many locations having two-week repeat data for the entire period. (Kumar & Mutanga, 2018). GEE provides access to a variety of satellite datasets such as Landsat, vector GIS data, social data, demographics, weather, digital elevation models, and climate data (Mutanga & Kumar, 2019).

Landsat is the most widely used imagery and is the largest component of the GEE data portal, with data from the first to the most recent Landsat series available for use and download (Kumar & Mutanga, 2018). Landsat satellite imagery is multispectral and has a spatial resolution of 30m x 30m.

Some Landsat images may contain cloud cover, so a cloud masking process is required, which is a stage of satellite image processing that is carried out to remove cloud cover covering the research area. In addition, to sharpen the quality of the spatial resolution of the bands in the Landsat image, a pan-sharpening process is also carried out in order to perform manual interpretation properly.

The land cover classification used the Random Forest method on the GEE platform. The Random Forest algorithm outperformed Classification and Regression Tree (CART) and Support Vector Machine (SVM) in Aldiansyah & Saputra's research, which used Sentinel-2 and Landsat 8 satellite images with an average Overall Accuracy of RF, CART, and SVM of 94.74%, 92.03%, and 83.54%, respectively.

Land cover classification is carried out using 70% training data and 30% testing data which is then used for validation. Validation is carried out using the kappa coefficient which shows and determines the accepted value between the model and the existing (Fitri et al., 2021). Validation of the built-up land model using the kappa coefficient can be calculated using the equation below:

$$\mathrm{K} = \frac{N\sum_{i=1}^{p} X_{ii} - \sum_{i=1}^{p} (X_{i+} \cdot X_{+1})}{N^{2} - \sum_{i=1}^{p} (X_{i+} \cdot X_{+1})} \tag{1}$$

where K is the kappa coefficient, N is the total number of observations in the matrix, r is the number of rows in the error matrix, Xii is the number of observations in row i and lane i (main diagonal), Xi+ is the number of observations in row i, X+i is the number of observations in lane i. The next step is analysis using ArcMap 10.8 software. The raster file of land cover classification results using GEE is converted into a layer so that it can be overlaid with land system or landform data and analyzed how much land cover changes from 2013 to 2023.

From the classification results

Table *1*, the Urban Expansion Intensity Index (UEII) will be calculated. UEII provides an overview of the development of urban areas, which in this case is adopted as built-up land by comparing the area of built-up land expansion to the total area of land in a spatial unit in a certain period (Sun et al., 2020). The equation of the index is as follows and also a description of the index (Ren et al., 2013; Wang et al., 2009):

$$U_i = \frac{U_a - U_b}{T \times U_c} \times 100 \qquad (2)$$

where Ui is the Urban Expansion Intensity Index in spatial unit i, Ua is the built-up land area in spatial unit i in period a, Ub is the built-up land area in spatial unit i in period b, Uc is the total land area of spatial unit i, and T is the time span from period a to period b in years.

Table 1. Description of the UEII value

No.	Slope (%)	Descriptions
1	> 1.92	Very fast
2	1.05-1.92	Fast
3	0.59-1.05	Moderate
4	0.28-0.59	Slow
5	0-0.28	Very slow
6	< 0	Decrease in intensity

Source: Ren et al, 2013

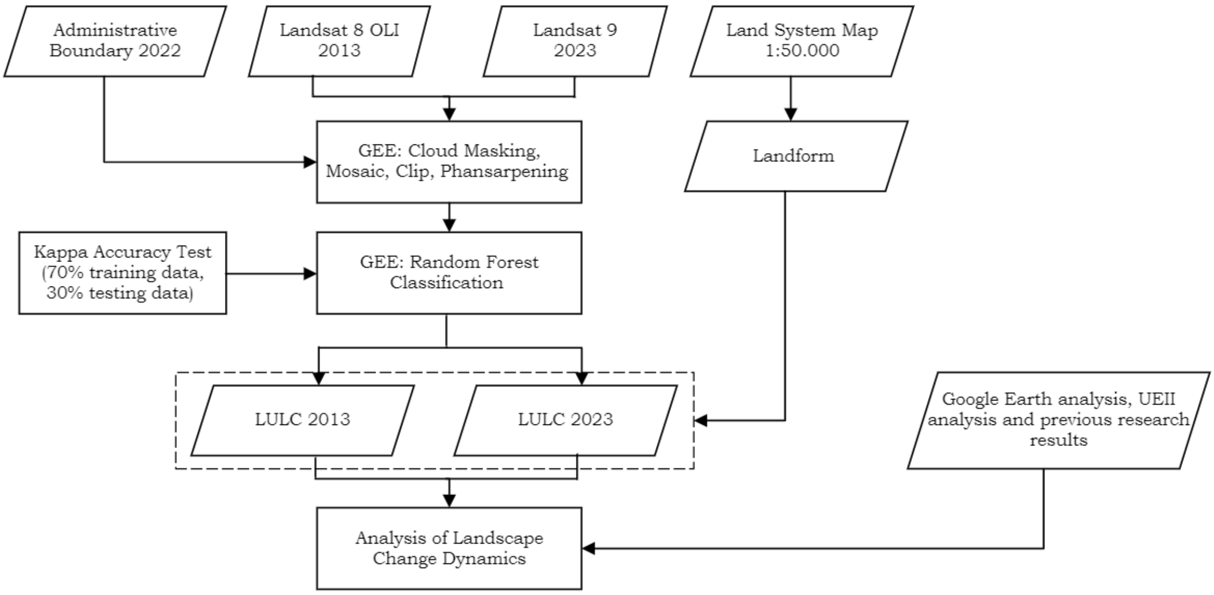

Figure 1. Research Flow Chart
Source: Analysis, 2023

3. RESULTS AND DISCUSSIONS

Classification with the random forest method on the GEE platform produces land cover in the form of built-up land, agriculture and forest. The results of the kappa classification accuracy test for 2013 land cover and 2023 land cover are 85.81% and 88.42%, respectively. While the Overall Accuracy of 2013 land cover and 2023 land cover is 90.67% and 88.42% respectively. **Figure 2** (a) and **Figure 2** (b) show that the landform of the peak tourism area is dominated by upper slope, middle slope, lower slope, slope, foot slope, dip slope, scarp slope, crater floor, crater wall, and escarpment.

Forest land cover is located on the upper slope and middle slope landforms. Agricultural land cover is on lower slope, slope, foot slope, dip slope, scarp slope landforms. While built-up land cover is generally on foot slope and lower slope landforms. Some definitions of landform types in the peak tourism area compiled from various sources include the following:

a. Upper Slope
   Very steep slope with a contour shape resembling the letter V and has a radial flow pattern usually has entisol and andosol soil types (Nurwadjedi, 2000).
b. Middle Slope
   Slightly steep slope with hilly undulating topography with contours resembling the letter U and has a semi-radial water flow

pattern and a good level of drainage (Nurwadjedi, 2000).

c. Lower Slope
A flat gentle slope with a semi-radial water flow pattern, showing a choppy flat topography with a depth of more than 1 meter (Nurwadjedi, 2000).

d. Crater floor
Crater is a circular concave-like shape on the surface of the ground which is mainly caused by volcanic activity or can be from a meteorite impact (Physicalgeography.net).

e. Crater wall
Crater wall is the interior part of the inner side of the rim of a volcanic crater which is usually formed due to erosion and collapse so that it forms a cliff or wall-like (Bray, 2015).

f. Rolling Plain
A plain that looks like it is rolling as referred to by tides, with irregular features. Most of the plain is flat with undulating slopes (Quetchenbach, 2017).

g. Undulating Plain
Consists of a complex of gently undulating and widespread lowlands containing many soil types with slopes of about 2-8%. The undulations are smoother than rolling plain (Victorian Resource Online, 2019).

Referring to the source Schoeneberger, P. J., Wysocki, D. A., & Olson, C. G. (1998). Glossary of landform and geologic terms:

a. Slope
(Also called slope gradient or gradient) The slope of the land surface from the horizontal. Percent slope is the vertical distance divided by the horizontal distance, then multiplied by 100.

b. Scarp slope
A slope, cliff, or steep slope with a defined boundary along the edge of a plateau, mesa, terrace, or structural bench. A scarp can be of any height. Compare - steep slope.

c. Dip slope
The slope of a land surface, roughly defined by and roughly corresponding to the slope of the bedrock; (i.e., a long, gently inclined cuesta surface).

d. Foot slope
The position of the slope profile that forms a concave surface at the base of the hillside. It is a transition zone between the upslope site of erosion and transportation (shoulder, backslope) and the downslope site of deposition (toe slope).

e. Escarpment
A relatively continuous and steep slope or cliff produced by erosion or faulting and so topographically interrupting or breaking the general continuity of a more gentle land surface. The term is most commonly applied to cliffs produced by differential erosion.

f. Valley
An elongated, relatively large, outwardly drained major portion of the earth's surface developed by river erosion or glacial activity.

g. Alluvial Plain
A large assemblage of fluvial landforms (braided rivers, terraces, etc.,) that form low-slope, regional slopes along the sides of mountains and are very distant from their source (e.g., North American Plateau). (b) (not recommended, use floodplain). An informal generic term for low gradient floodplains or deltas.

h. Foot plain
A nearly level plain that borders a river and can be inundated under flood stage conditions unless artificially protected. It is usually a constructed landform built up from sediments deposited during overflow and lateral migration of the river.

i. Water Body
A generalized map unit for any permanent open body of water (pond, lake, reservoir, etc.) that does not support rooted plants.

j. Flat Plain
A group of three-dimensional base cuts or areas of flat terrain. In descending order of elevation, the geomorphic components of simple flat plains (e.g., lake plains, low coastal plains, etc.) are slopes (broad, slightly elevated areas with relatively greater gradients (e.g., 1-3% slopes), and talfs (relatively level (e.g., 0-1% slopes), laterally extensive, non-fluvial areas), and dips (slight depressions that are not permanent water bodies or part of an integrated drainage network).

Built-up land cover dominates the foot slope and lower slope landform areas. There is no built-up land on the crater floor, crater wall, and water body landforms. Agricultural land cover dominates in the lower slope, floor slope, slope, and upper slope landform areas. There is no agricultural land cover on the crater floor and crater wall landforms. Forest land cover dominates in the upper slope, middle slope, slope, and lower slope landforms.

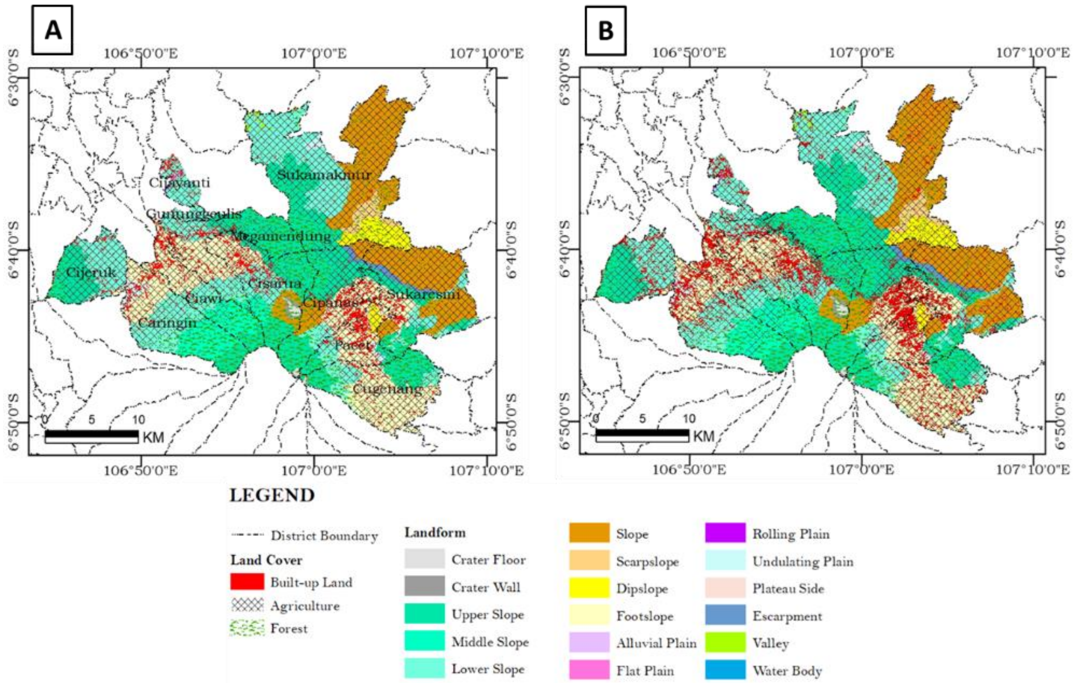

Figure 2. Tourism Landscape of Puncak (a) 2013 (b) 2023
Source: Analysis, 2023

There is no land cover in the flat plain, rolling plain, and alluvial plain landforms. In the crater floor and crater wall landforms, there is only forest land cover. The middle slope and upper slope landforms are also dominated by forest land cover. Landform lower slopes, foot slopes, slopes, dip slopes, scarp slopes, undulating plains, escarpments, valleys, and water bodies are dominated by agricultural land cover.

Landform plateau side, flat plain, rolling plain, and alluvial plain are also dominated by agricultural land cover but have a very small area. The land cover area in Puncak is depicted by landscape type in 2013 and 2023 in **Table 2**.

Table 2. Landscape atribute 2013 and 2023

Landform	Build-up Land			Agriculture			Forest			Total Landscape Area
	2013	2023	Δ	2013	2023	Δ	2013	2023	Δ	
Crater Floor	0	0	0	0	0	0	219	219	0	219
Crater Wall	0	0	0	0	0	0	310	310	0	310
Upper Slope	295	784	489	8,467	8,989	522	11,633	1,0621	-1,011	20,395
Lower Slope	1,195	2,644	1,449	15,753	14,842	-910	2,786	2,247	-539	19,734
Foot slope	2,950	5,014	2,063	12,514	10,836	-1,678	793	408	-386	16,257
Slope	103	521	419	10,560	10,417	-144	2,868	2593	-275	13,531
Middle Slope	6	0	-6	587	1,252	665	3,440	2,781	-659	4,033
Dip slope	15	74	59	1,207	1,425	218	555	278	-278	1,777
Scarp slope	6	20	14	672	743	71	253	168	-85	931
Undulating Plain	180	295	115	659	550	-109	7	1	-6	846
Escarpment	3	12	9	498	484	-14	107	111	5	607
Valley	8	9	2	136	134	-2	0	0	0	143
Water Body	0	0	0	105	108	4	6	3	-4	111
Plateau Side	5	10	5	73	70	-3	7	4	-2	85
Flat Plain	7	24	17	50	33	-17	0	0	0	58

Landform	Build-up Land			Agriculture			Forest			Total Landscape Area
	2013	2023	Δ	2013	2023	Δ	2013	2023	Δ	
Rolling Plain	1	0	-1	13	14	1	0	0	0	14
Alluvial Plain	2	1	-1	2	4	1	0	0	0	4
Total Landcover Area	4,776	9,409	4,633	51,295	49,902	-1,393	22,984	19,744	-3,239	79,055

Source: Analysis, 2023

Table *2* shows the area of each land cover in the Puncak area in 2013 and 2023. The largest land cover change is in built-up land with an additional area of 4,633 hectares. Meanwhile, agricultural and forest land cover decreased by 1,393 hectares and 3,239 hectares respectively. There is no change in land cover area in the crater floor and crater wall landforms because both landforms are located in the crater of Mount Gede Pangrango.

The most extensive addition of land cover is found on the foot slope landform with built-up land cover and agriculture. Furthermore, the second most extensive land cover change is on the lower slope landform with built-up land cover. And the third is on the upper slope landform with changes in the reduction of forest land cover area. Followed by lower slope land cover on agricultural land cover and middle slope on agricultural and forest land cover.

These land changes include changes in settlements to toll roads; changes in agricultural land to residential or housing development, factory construction, construction of the Bogor - Ciawi - Sukabumi toll road located in Caringin District (Figure a). Housing development in the Caringin Sub-district area is influenced by the construction of a toll road connecting Bogor - Ciawi - Sukabumi.

Housing that has close access to the toll road has proven to attract many buyers who are used as investment land. In addition, consideration of building factories close to toll road access can also reduce transportation costs. Another example of land cover change is the reduction of forest areas to villas such as those in Pacet Sub-district (Figure b). The majority of land change is in areas close to highways and residential development areas.

The land change also occurs in areas close to tourist centers such as Cisarua District, Bogor, and Pacet District, Cianjur. Land cover changes in several landforms can be seen in Figure 3.

(a) Change of agricultural land cover to built-up land

(b) Change of forest land cover to built-up land

(c) Land cover change on upper slope landform, Cipanas sub-district, Cianjur district

(d) Land cover change on scarp slope landform Pacet sub-district, Cianjur district

(e) Land cover change on escarpment landform Cipanas sub-district, Cianjur district

(f) Land cover change in valley landform, Sukaresmi sub-district, Cianjur district

Figure 1. Example of Land Cover Change 2013 (left) and 2023 (right)
Source: Google Earth Image, 2023

There are constraints in image interpretation due to the low resolution of Landsat satellite image data. This made it difficult for the author to distinguish the color of land cover pixels for built-up land and agriculture because both have almost the same color, making the author hesitant in interpreting. For future research, it is recommended to use satellite image data that has a higher spatial resolution to facilitate image interpretation.

$$U_i = \frac{9.484,41 - 4.476,48}{10 \times 79.005,47} \times 100 = 0.63 \qquad (3)$$

It can be seen that the UEII calculation value results in 0.63 (Equation 3). This indicates that the increase in built-up land area was moderate over the 10-year period or at least experienced positive expansion. This is clearly a phenomenon of urbanization and other driving factors such as the economy and tourism that force natural land cover to become built-up land, in line with previous studies of land change in the Puncak corridor conducted by Firman (2009) and Jatayu (2020). In this situation, vegetation cover is most often converted to built-up land.

4. CONCLUSIONS

Based on the results obtained, Puncak Area has landforms of upper slope, middle slope, lower slope, slope, foot slope, dip slope, scarp slope, crater floor, crater wall, escarpment, upper slope, middle slope, lower slope, slope, foot slope, dip slope, scarp slope. The largest land cover change between 2013 and 2023 was in built-up land cover with an additional area of 4,633 hectares with the largest area of additional change in the foot slope and lower slope landform types.

While agricultural land cover decreased by 1,393 hectares with the largest reduction area in the foot slope landform. Forest landcover decreased by 3,239 hectares with the largest reduction area in upper slope landforms. There is no change in land cover in the crater floor and crater wall landforms because the landform is located at the top of Mount Gede Pangrango.

Research into the dynamics of land cover change in the Puncak area over the past 10 years reveals significant transformations in land use. Using technologies such as Google Earth Engine and Landsat imagery, Random Forest Classification analysis provides a clear picture of these changes. While the rapid economic growth associated with tourism has increased the popularity and economic value of the area, its impact on the local ecosystem needs to be considered.

The decrease in agricultural and forest land along with the increase in built-up area is a major point of concern. Constraints in the interpretation of low-resolution Landsat imagery highlight the need for high-resolution imagery data for more accurate research. Urbanization and economic drive are the main drivers of change from vegetated land to built-up land.

Therefore, wise management that considers the balance between economic growth and environmental preservation is crucial in maintaining the sustainability of the Puncak area as a beautiful and sustainable tourist destination. Based on the research findings, there are suggestions that can be used for further research references or local government policy making in order to maintain a balance between economic growth and environmental preservation in the Puncak area.

First, it is necessary to consider the use of higher resolution satellite imagery data for a more precise analysis of land cover change. This will allow for more accurate interpretation in identifying land transformation from vegetation to built-up areas. Secondly, intensive environmental monitoring is essential to understand the impacts of tourism activities and infrastructure on local ecosystems, especially on important rivers such as the Ciliwung River.

Finally, further research that is more focused on specific aspects of land cover change in the Puncak Area may provide deeper insights to formulate more appropriate policies to maintain environmental and economic balance in this region.

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