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NDVI, suitability, and carrying capacity of Dieng Plateau Forests to sustain Dieng Kulon Village tourism, Central Java, Indonesia

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Abstract. *Lestari F, Tua IN, Muzanni A, Nugroho DF, Wibowo AA, Wartono T, Widanarko B, Saepullah A, Modjo R, Farida M, Erwandi D, Aryani DD, Kadir A, Widiatmoko AI, Hendra, Herwanto ZJ, Tejamaya M, Hamid RA, Fatmah, Gunawan EL, Setyowati DL, Hafids MF. 2023. NDVI, suitability, and carrying capacity of Dieng Plateau Forests to sustain Dieng Kulon Village tourism. Biodiversitas 24: 282-289.* Village tourism is a form of tourism that can support the conservation of an ecosystem. On the Dieng Plateau, Dieng Kulon is one of the tourism villages located in Banjarnegara district, Central Java, Indonesia. Despite the rapid growth of tourism in Dieng and its potential environmental consequences, information on tourism carrying capacity in Dieng is still limited. Here, this study aims to measure the suitability and carrying capacity of Dieng Kulon Village. The suitability for tourism is measured based on the Normalized Difference Vegetation Index (NDVI). Equation was used to calculate the carrying capacity. According to the findings, forest areas with a size of 23.9% and high NDVI values ranging from 0.87 to 0.91 were deemed very suitable for birdwatching and hiking activities. Agricultural land made up nearly half of the village (57.1%) with high NDVI values (ranging from 0.36-0.86) was deemed ideal for sightseeing activities. In comparison to other types of land, agricultural land had the highest carrying capacity, followed by forest land. Agricultural land can support 84.8-155.2 people per day for sightseeing activities. Forest areas are suitable for hiking and birdwatching activities. At least 51.6 to 334.9 people per day are allowed for hiking activities. Birdwatching in the forest is limited to 3.1-19.9 people per day. To conclude, carrying capacity information is very important for managing village tourism in a sustainable manner.

Keywords: Dieng, land use, NDVI, suitability, tourism village

INTRODUCTION

Indonesia is unquestionably one of the countries in the world with enormous tourism potential. Tourism is one of the industries that generate the most foreign exchange in Indonesia. According to BPS statistics from 2018, the amount of foreign exchange in the tourism sector surpassed US$ 16,426 billion, with international visitor expenditure having a substantial multiplier effect on employment creation and the local economy. Tourism has also aided community growth. Tourism villages arose as a result of the presence of legislation promoting growth based on local authority. Village tourism is one of the potential forms of tourism in Indonesia. These tourism activities offer an overall atmosphere that accentuates the authenticity of village natural scenery, culinary delights, souvenirs, and homestays (Kementerian Koperasi dan UKM Republik Indonesia 2017). A tourism village in the context of village tourism is an asset based on rural potential with all its uniqueness and attractiveness that can be empowered and developed as a product of tourism to attract tourist visits to the location of the village (Sudibya 2018). Currently, according to database provided by Ministry of Tourism and Creative Economy as available in https://jadesta.kemenparekraf.go.id/peta in Indonesia there are approximately 3,619 tourist villages across Indonesia.

Central Java, one of Indonesia's large provinces, was also known to have tourism potential. In 2017, this Central Java accounted first for the popular tourist destinations on Java Island, with 40,899,577 visitors and offering 665 tourist attractions. The tourists' interest in Central Java Province is more dominated by natural tourism in village settings. The tourism potentials in West Java have contributed to the significant economic dynamics and

growth. In 2015-2016, the revenues from tourism climbed from 238,373,330,846 rupiahs to 262,984,817,326 rupiahs, then declined to 212,570,844,806 rupiahs in 2017, then increased dramatically to 301,622,707,421 rupiahs in 2018 (Arifin 2021). This tourism contribution came from local tourism taxes or levies, as well as hotel and restaurant taxes. Tourists prefer village tourism in Central Java Province above other types of tourism (Fafurida et al. 2022).

In the terrestrial ecosystems, the village's tourism is relying on natural-based tourist activities, including camping, hiking, and even wildlife watching. The implementation of those activities depended on the presence of vegetated areas, including forests and agricultural lands. The quality of vegetated areas within tourism villages was assessed using the Normalized Difference Vegetation Index (NDVI). Singgalen and Manongga (2022) have used the NDVI method to assess the suitability of mangrove forests in Dodola Island, Morotai Island District, North Maluku Province, for village tourism purposes. The NDVI results confirm the NDVI ranges of 0.02-0.23. While in Chattogram, Bangladesh, Rafa et al. (2021) have used NDVI to assess the suitability of forest covers in a botanical garden and eco-park. Due to its capability of rapidly and accurately identifying both the quantity and quality of vegetated areas and forest covers that are the main features of village tourism, it is necessary to employ NDVI. Moreover, NDVI will provide accurate and rapid information on both the quantity and quality of vegetated areas and forest covers that will affect tourism by providing knowledge and raising awareness of the available vegetated areas. NDVI analysis within tourism practice is mandatory since it can indicate a threat to the remaining vegetation cover as a consequence of tourism infrastructure development. Then NDVI is a versatile tool to assist in controlling village tourism infrastructure development (Singgalen and Manongga 2022).

Carrying capacity is a tool and concept that provides information on how to optimize the arrangement and management of ecotourism areas based on their suitability, minimizing the impact of ecotourism activities, and creating rehabilitation effectiveness, preservation, protective, and natural resource conservation planning as well as enabling effective planning and development policies to carry capacity concepts (Sadikin et al. 2017). Carrying capacity is often defined as the greatest number of people who can visit a tourist location at the same time without affecting the physical, economic, and social environment or lowering the quality of the visitors' enjoyment. The idea of environmental carrying capacity is useful in managing wildlife and its environment within tourism activities (Suana et al. 2020).

The Dieng Plateau (Nugraha 2012) is an area in the center of Central Java that has geological, historical and agricultural characteristics that are considered distinctive. This plain is flanked by a range of hills on its North and South sides, which originate from the same volcanic activity and called the Dieng Mountains. The Dieng Mountains themselves are geographically located between the Rogojembangan Peak complex to the west and the pair of Mount Sindoro and Mount Sumbing on the east side. Roughly speaking, the Dieng Plateau area occupies an area measuring 4-6 km wide (North-South) and 11 km long (West-East). Basically, the Dieng Plateau is a caldera surrounded by surrounding mountains, including Mount Prahu (2,565 m) to the Northeast of the caldera, Sikunir Hill (2,463 m), Mount Pakuwaja (2,595 m), Mount Bismo (2,365 m) to the South of the caldera, as well as the Mount Butak-Dringo-Petarangan complex to the Northwest. Below the surface of the caldera, there is volcanic activity, such as Yellowstone or the Tengger Plateau. Here there are many craters, fractures, and vents which release the results of geological activity in various forms ranging from fumaroles, solfatara to gas sources, including CO_2 and CO (Priatna et al. 2020), and hot and cold springs, as well as volcanic lakes. Several craters are still very active, such as Sileri, Candradimuka and Sikidang (Sudarmadji et al. 2015), which are used as natural tourist objects.

Despite the growing numbers and potentials of village tourism in Central Java in general and in Dieng Plateau in particular, there is still a scarcity of data on the suitability and carrying capacity of tourism villages in Dieng Plateau. While this information is very important and required for the management of village tourism immediately. Here, this study presents an assessment of the suitability and carrying capacity of Dieng Kulon tourism village. The novelty of this study is incorporating NDVI to assist the carrying capacity assessments. This study will contribute both to the environment and humanity dimension by providing insight into sustainable tourism that can support livelihood of the community for the long term.

MATERIALS AND METHODS

Study area

The study was conducted in Dieng Kulon Village (Figure 1), Banjarnegara District, Central Java Province, Indonesia, with latitude from 7.190704^0 S to 7.223965^0 S and longitude of 109.899398^0 E and 109.919826^0 E. The village, sizing 2.20 km² is located within Dieng Plateau landscape with elevations of 2,000 m above sea level. This makes Dieng Kulon Village as the highest village in Java Island. Dieng Kulon Village was bordered by some geological and volcanic features as parts of Plateau. The North side of the village was bordered by Mount Prahu. While the South side was bordered by Sikidang volcanic crater. The air temperature of this village was 12-20°C on the day and 6-10°C at night. According to village database (https://www.dieng.desa.id/index.php/data-wilayah), the population of this village is 3,370 people. The population or equals 32.46% is dominated by farmers.

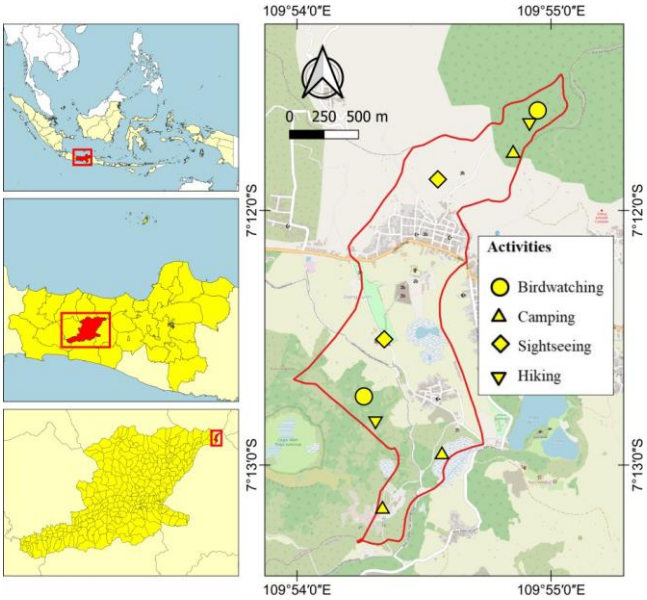


Figure 1. Location of Dieng Kulon Village, Banjarnegara District, Indonesia land uses, and tourism activities

Procedures

Land cover analysis

The land cover in the Dieng Kulon village was classified using the Geographical Information System (GIS) (Thoha and Triani 2021). The method starts with retrieving the Dieng Kulon boundary and Landsat 8 Operational Land Imager (OLI) images of this village with a spatial resolution of 30 m per pixel. The acquisition dates were from July to August 2022, a period with less cloud coverage. For preprocessing process, the image data sets were geometrically corrected using the World Geodetic System (WGS) 1984 datum and the European Petroleum Survey Group (EPSG) Geodetic Parameter Dataset 4326. The images were georeferenced using ground control points that were collected from a Banjarnegara district basemap. Meanwhile, the study area was determined by performing a subset operation with the Dieng Kulon village vector boundary as a guide.

The Landsat 8 OLI imagery of the Dieng Kulon village was then classified into several land-cover classes: forest, settlement, agricultural land, and bare land (Utami et al. 2017). The classification adopted supervised classification. Prior to the classification process, ground-truthing of land cover was carried out to create a training data set and a signature file—a set of data that defines a training sample or cluster. By applying the training data, a supervised classification approach was performed to produce a land cover map. The result is a thematic layer in the form of shapefiles (shps) of the Dieng Kulon village and land cover.

Forest NDVI analysis

NDVI (Normalized Difference Vegetation Index) measurement of forest cover (Alatorre et al. 2016; Ibharim et al. 2015; Rhyma et al. 2020) was parts of forest suitability index calculation. The method to measure NDVI of Dieng Kulon forest was followed Philiani et al. (2016), Kawamuna et al. (2017), and Sukojo and Arindi (2019). NDVI is described as a simple graphical indicator that can analyze remote sensing measurements, often from a space satellite platform, assessing whether the target being observed contains live green vegetation. The NDVI was measured by analyzing the wavelength of satellite images retrieved from Landsat 8 containing vegetation images and, in this study was forest cover. This measurement is possible since the cell structure of the vegetation leaves strongly reflects near-infrared light wavelengths ranging from 0.7 to 1.1 μm. The calculation of NDVI for each pixel of vegetation pixel was as follows:

NDVI = near invisible red wavelength - red wavelength / near invisible red wavelength + red wavelength

The NDVI was denoted as 0 (no vegetation) to 1 (high vegetation density). Using SAGA (System for Automated Geoscientific Analyses) GIS 2.1.2, the NDVI values were then overlaid and mapped into Dieng Kulon Village land cover layers (Pin et al. 2021). The forest covers are then categorized and classified by using NDVI as follows (Suwanto et al. 2021): (i) if 0< NDVI <0.3, then forest covers are <50%; (ii) if 0.31< NDVI <0.4, then forest covers are 50-69%; (iii) if 0.41< NDVI <1.0 then forest covers are 70-100%

Forest suitability

Forest suitability for tourism activities was determined based on the NDVI values (Sukuryadi et al. 2020). The NDVI values obtained were classified into 5 classes following likert (very low, low, moderate, high, very high) scales and using GIS classification function. The classifications of forest suitability are as follows: (i) if forest covers 0-20%, then the suitability is very low; (ii) if forest covers 21-40%, then the suitability is low; (iii) if forest covers 41-60% then the suitability is moderate; (iv) if forest covers 61-80% then the suitability is high; (v) if forest covers 81-100% then the suitability is very high.

Village tourism data collection

Data collection follows method by Sadikin et al. (2017) and Lelloltery et al. (2018). The data was collected in the form of primary and secondary data. Primary data were obtained directly from the studied village through observation, survey, interview, and focus group discussion (FGD). The secondary data was obtained from literature study and related institutions including previous research, official and unpublished documents, and websites. It also includes general management plan of the village, village zoning map and type, biodiversity range, area ecotourism slope, tourism hiking information and trail map, and tourism village object attractions. FGD was implemented to the local village authorities in tourism along with local tourism operators as the key informants. The FGD aimed to confirm the presence of tourism destinations, tourism activities, along with data on areas available and areas required by tourists in Dieng Kulon Village. The additional primary data was gathered from direct observation on the field or tourism village area. The observation on the location of tourism village was aimed to get information on the village tourism area condition, object range, and land

use or land cover. The area information of each tourism activity represented as points were collected using a Global Positioning System (GPS) receiver (Garmin Etrex) to ensure the area measure used for village tourism and related tourist activities.

Village tourism carrying capacity calculation

Calculation of village tourism carrying capacity was intended to elaborate the maximum level of use of an ecosystem, in the form of activities, and its quantities that can be accommodated in the area, before an ecological quality deterioration occurs. The carrying capacity (CC) calculation following Sadikin et al. (2017), Sari and Rahayu (2018), Wirakusuma and Ermawati (2018), and Sukuryadi et al. (2020) and can be modeled as follows (Lakspriyanti et al. 2020):

$$CC=[K \times A \times (1/a) \times (wt/wp) \times (1/cd)]/43.560$$

Where:

CC: the carrying capacity (people per day)

K : maximum visitors per unit of area (person)

A : areas available (m^2)

a : areas required by tourist (m^2)

wt : time allocated for tourism activities in one day (hours)

wp: time spent by visitors for certain activities(hours).

cd : capacity days are counted based on the closed season of the village due to cultural event or extreme weather. The capacity days were set to 31 days

43.560 = Douglass's constant

The standardized K, a, wt, and wp values were referenced to Douglass (2016) as can be seen in Table 1.

Data analysis

All the data collected were presented using table (Table 2, 3, 4), Sankey diagram (Etemad et al. 2014; Tydecks et al. 2018) and spatial data model. The visualization of spatial data model was aided by SAGA GIS 2.1.2 platform. Within data analysis, a Sankey diagram, which depicts flow to and from various nodes in a studied variable, has been most typically applied. In this study, the flow representing the size of land use can be divided and distributed into variables of NDVI, activity, and carrying capacity (Cuba 2015).

RESULTS AND DISCUSSION

Land use and NDVI

Land uses related to tourism purposes in Dieng Kulon Village consisted of forest, settlement, agricultural land and bare land (Figures 1 and 3). Forest areas were fragmented located in the North and South sides. The forest areas in the North was parts of Mount Prahu foothill sizing 92,263 m^2 and the forest areas in the South were parts of Sikidang crater with size of 456,855 m^2 and with a total of 549,118 m^2. The forest fragments in the North have NDVI higher than the fragments in the South with values of 0.91 (Figure 2). Another significant land uses in the Dieng Kulon Village was the agricultural land. This agricultural land use sizing 462,928 m^2 was located in the North side near the Mount Prahu foothill. Another agricultural land fragment sizing 846,784 m^2 was observed in the South side near the forest areas of Sikidang crater. Total areas of agricultural lands were 1,309,712 m^2. The NDVIs of agricultural land were varied. Agricultural lands in the North having NDVI higher with values of 0.86 and are considered very high suitable. The North and South agricultural lands were separated by the settlement sizing 977 m^2 and 164,137 m^2 in the middle. Settlement land uses having the lowest NDVI ranged from 0.06 to 0.09. Besides covered land uses, bare and abandoned lands were also observed in Dieng Kulon Village. There were three bare land fragments observed, first fragment sizing 92,689 m^2 was observed in the North side near the forest fragments. Second and three fragments of bare lands were observed in the South side with size of 50,221 m^2 and 55,283 m^2. The total bare lands were 198,193 m^2. The NDVI for bare lands was ranging from 0.11 to 0.64. The NDVI values in bare lands that were overlapped with NDVI values of other vegetated areas due to the presences of fragmented bushes and sapling trees that contribute to the NDVI.

Land use suitability and tourism activities

Forest fragments in the north and south parts of the Dieng Kulon tourism villages were deemed very suitable for tourism activities based on NDVI values (Table 2). In this forest (Figures 2 and 3), the tourism activities were primarily birdwatching and hiking. Other land uses with high suitability according to NDVI values were bare land and agricultural lands. Bare land near the forest was available for camping. While large fragments of agricultural land were available and suitable for sightseeing and picnic activities, Settlement was the only land use identified as very unsuitable. Due to its function, there are no tourist attractions and activities in this settlement inhabited by the local people and residents of Dieng Kulon Village.

Dieng Kulon Village tourism carrying capacity

The spatial distribution of carrying capacity in Dieng Kulon Village is available in Figure 4. It can be seen that agricultural land has the highest carrying capacity (Table 3). This land use can support 84.8-155.2 people per day for sightseeing activities (Figure 3). Another land use that has a high carrying capacity is forest. This land use can support 51.6-334.9 people per day for hiking purposes. Another activity that can be done in a forest is birdwatching, which has a capacity of 3.1-19.9 people per day. The lowest carrying capacity was observed for bare land use. This land use designated for camping activities can only support 1.8-3.3 campers per day.

Table 1. The standardized K, a, wt, and wp values (Douglass 2016)

Activities	K	a (m^2)	wt	wp
Birdwatching	1	67	8	2
Hiking	1	4	8	2
Sightseeing/picnic	1	16	8	2
Camping	5	100	24	24

Table 2. Land use, NDVI, and tourism suitability in Dieng Kulon Village, Banjarnegara District, Indonesia

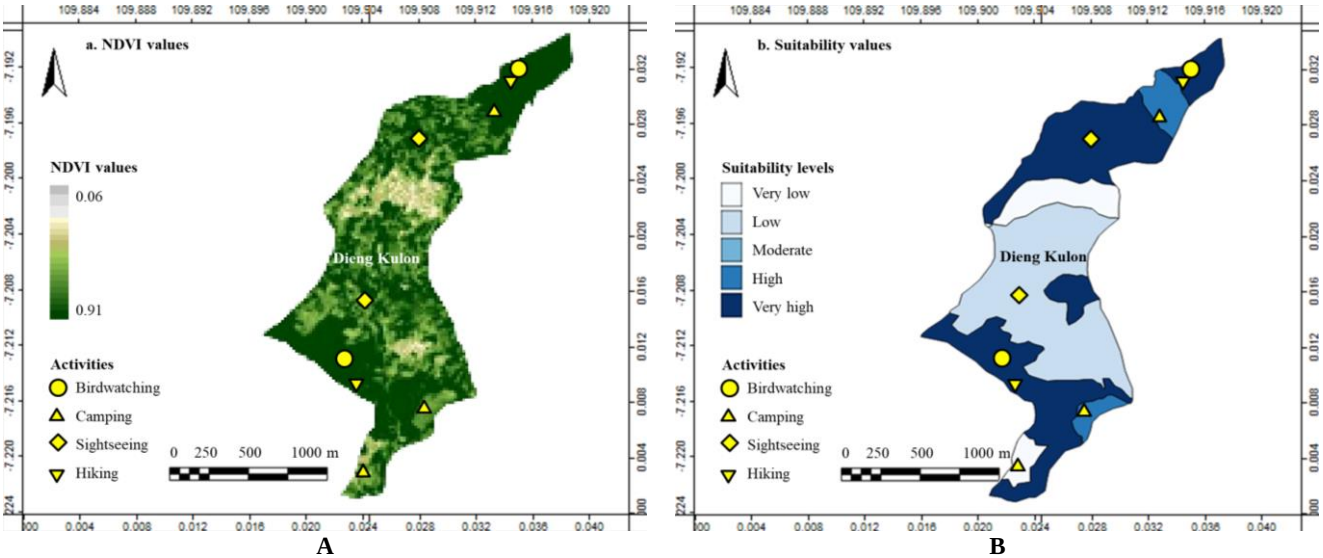
Land use	Total areas (m²)	NDVI ranges	Suitability	Activities
Forest	549,118	0.87-0.91	Very high	Birdwatching, hiking
Agricultural land	1,309,712	0.36-0.86	Low-very high	Sightseeing
Bare land	198,193	0.11-0.64	Very low-moderate	Camping
Settlement	165,114	0.06-0.09	Very low	None

Table 3. Tourism carrying capacities in Dieng Kulon Village, Banjarnegara District, Indonesia

Activities	Areas available (m²)	Carrying capacity (people per day)	Land use
Birdwatching	70,502-456,855	3.1-19.9	Forest
Hiking	70,502-456,855	51.6-334.9	Forest
Sightseeing/picnic	462,928-846,784	84.8-155.2	Agricultural land
Camping	50,221-92,689	1.8-3.3	Bare land

Table 4. Tourism carrying capacity comparisons.

Activities	Carrying capacity (people per day)	Location	Land use	Remarks
Birdwatching	3.1-19.9	Dieng Kulon Village	Terrestrial forest	*This study*
	648	Blekok Village, Mangrove Area	Mangrove forest	Insani et al. (2019)
Hiking	51.6-334.9	Dieng Kulon Village	Forest	*This study*
	98- 986	Kawah Putih Forest Recreation	Forest	Jamin and Rahmafitria (2022)
Sightseeing/picnic	84.8-155.2	Dieng Kulon Village	Agricultural land	*This study*
	423	Gunung Pancar Natural Park	Recreational park	Wandhira (2021)
Camping	1.8-3.3	Dieng Kulon Village	Bare land	*This study*
	60.0-69.0	Selabintana, Gunung Gede Pangrango National Park	Camping ground	Sofiyudin et al. (2021)



A **B**

Figure 2. NDVI values (A) and tourism suitability levels (B) in Dieng Kulon Village, Banjarnegara District, Indonesia

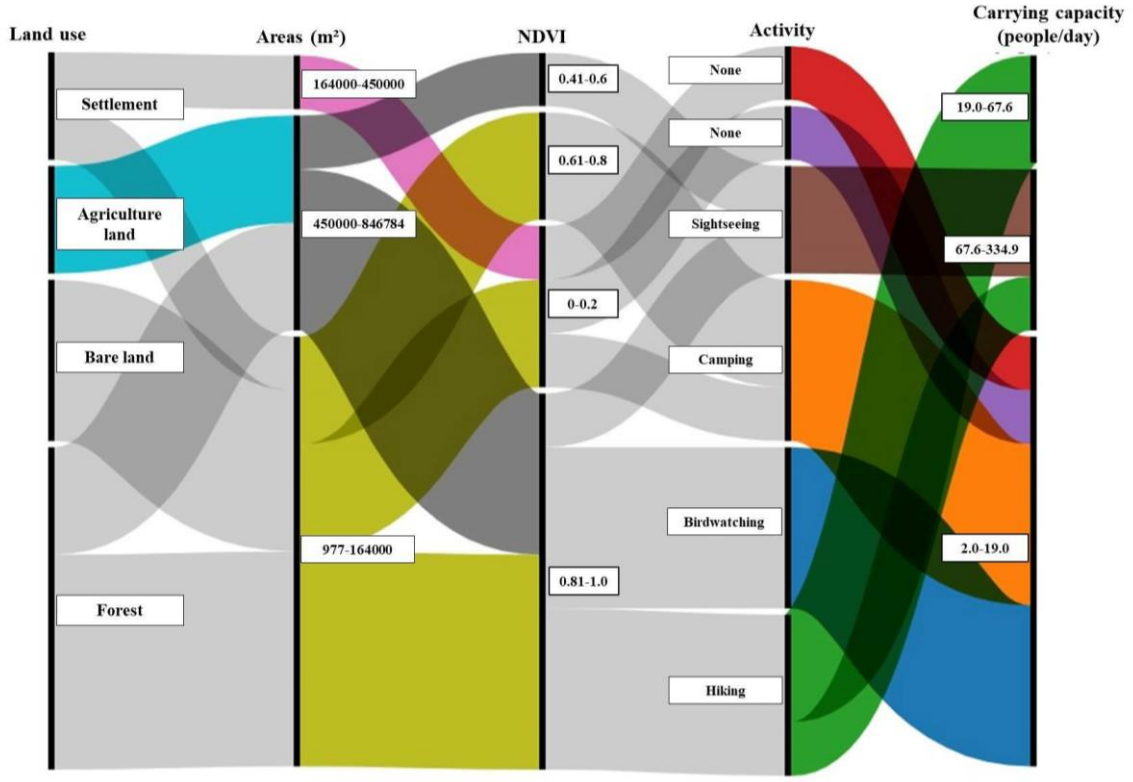


Figure 3. Sankey diagram depicting correlations of land use, areas, NDVI, activity, and carrying capacity in Dieng Kulon Village, Banjarnegara District, Indonesia

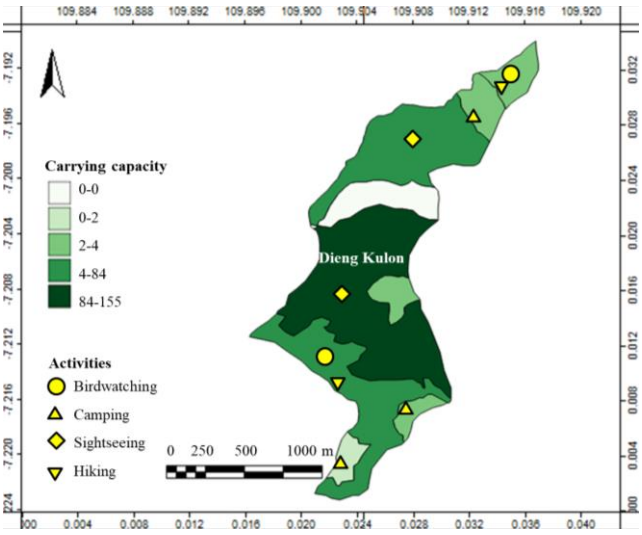


Figure 4. Village tourism carrying capacity (people per day²) in Dieng Kulon Village, Banjarnegara District, Indonesia

Discussion

Diverse land use observed in the Dieng Kulon was related to the development of this area for tourism purposes. As a result, Dieng Kulon intact lands have been intensively converted into the various land use system, ranging from land potatos cultivation, settlements and tourist activity. One of the significant land uses in the Dieng Kulon Village was the agricultural land. This land use was located in the North side near the Mount Prahu foothill. Another agricultural land was observed in the South side near the forest areas of Sikidang Crater. The North and South agricultural lands were separated by the settlement in the middle. The settlements were dominated by farmers that manage the agricultural lands. Agricultural land in Dieng Kulon Village was dominated by potato farming. High altitude, low air temperature, soil dominated by Andisol, and various land slope ranges of 0->4% are considered suitable for potato farming. Then, Dieng Plateau is ideal land for horticultural cultivations (Susilawati et al. 2016).

Notably, the NDVI observed in the potato farming in Dieng Kulon Village was related to the presence of trees planted within the farms. The presence of trees was associated with the implementation of agroforestry in these areas (Pradana et al. 2015). Recently, agroforestry practices were considered an alternative tourism activity that could contribute to climate change mitigation. Agrotourism, as an alternative form of tourism proposed in Dieng Kulon Village, can balance the relationship between forest and people, especially when land is seen as an important partner rather than an exploitable asset. Agrotourism should be part of village tourism in Dieng Kulon, which may help to increase awareness among the local community on the critical roles of the lands and how to manage them in a sustainable way in the long term to fight against climate change (Suryandari et al. 2020).

Recommended activities in Dieng Kulon include birdwatching. This activity should be promoted considered that the Dieng Plateau is known for having high avifaunal diversity. The presences of avifaunal species in here were supported by the presences of intact forests. The forest types consisted of dominances of mixed forests that accounted for 54.6%, 29.1% of pine forests, and 10.7% of puspa forests (Damayanti et al. 2021). In the Dieng Plateau, birds were the most frequently encountered fauna and constituted 90.06% of the total animals inhabiting Dieng. According to Hadisusanto et al. (2022), aside from avifauna, the Dieng Plateau is also infamous for diverse mammals and reptiles. Approximately, there were 48 bird species, 11 mammal species, and three herpetofauna species. The presence of diverse species surrounding Dieng Kulon Village has potential to be developed as birdwatching tourism. The carrying capacity for birdwatching obtained here is in comparison to a previous study (Manalo et al. 2016, Hidayat et al. 2020) (Table 4). In Kerandangan Natural Park, Lombok, Indonesia, Suana et al. (2020) estimated that the carrying capacity for birdwatching is between 10 and 93 people per day. Birdwatching activities then should be promoted as one of potential village tourism activities in Dieng Kulon. Birdwatching is a sustainable tourism product and an important component of village tourism, and recognizing its recreational value is critical for improving human well-being and recognizing the local benefits of ecosystem services for areas at village level focused on biodiversity conservation, particularly in bird species. In fact, birdwatching tourism has a larger marginal value than general tourism and provide greater social, economic, and environmental advantages, resulting in a higher level of growth for the local tourism business at village levels (Liu et al. 2021).

Dieng Kulon Village has significant potential to be developed as village tourism purposes in sustainable manner. To achieve sustainable tourism, village tourism practices here should consider suitability and carrying capacity aspects. The effect of carrying capacity on tourism activities is significantly different from the standard value within tourism practices since carrying capacity can limit the environmental degradation resulting from tourism activities. This study on carrying capacity, in particular, will have interdisciplinary implications for the tourism industry by providing insights into sustainable tourism. As a conclusion and in comparison to other types of land, agricultural land had the highest carrying capacity, followed by forest land. Agricultural land can support 84.8-155.2 people per day for sightseeing activities. Forest areas are suitable for hiking and birdwatching activities. At least 51.6 to 334.9 people per day are allowed for hiking activities. Birdwatching in the forest is limited to 3.1-19.9 people per day. To conclude, the implementation of village tourism practices in Dieng Kulon Village should consider the carrying capacity of each unique land use to guarantee the sustainability of village tourism in Dieng Kulon in the future while supporting the conservation of its forest ecosystem.

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