Global Forest Journal
Journal homepage: https://talenta.usu.ac.id/gfj

Analysis of land use (2013-2022) in the Gayo highlands, Aceh, Indonesia

Zulfan Arico[1,2], Rahmawaty[*2,3], Delvian[2,3], Hamdani Harahap[2,4], Mohd Hasmadi Ismail[5]

[1]*Department of Biology, Universitas Samudra, Jl. Prof. Dr. Syarief Thayeb, Meurandeh, Langsa Lama, Langsa 24416, Aceh, Indonesia*
[2]*Natural Resources and Environmental Management Study Program, Postgraduate School, Universitas Sumatera Utara, Kampus USU Medan 20155, North Sumatra.*
[3]*Forestry Study Program, Faculty of Forestry, Universitas Sumatera Utara, Kampus USU 2 Bekala, Pancur Batu, Deli Serdang, 20353, North Sumatra, Indonesia*
[4]*Department of Anthropology, Universitas Sumatera Utara, Medan, 20222, North Sumatra, Indonesia*
[5]*Faculty of Forestry and Environment, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor Darul Ehsan, Malaysia*
[*]Corresponding Author: rahmawaty@usu.ac.id

ARTICLE INFO

Article history:
Received 10 July 2023
Revised 20 July 2023
Accepted 24 July 2023
Available online 29 July 2023

E-ISSN: 3024-9309

How to cite:
Z. Arico, Rahmawaty, Delvian, H. Harahap, M. H. Ismail, "Analysis of Land Use (2013-2022) in the Gayo Highlands, Aceh, Indonesia", *Global Forest Journal*, vol. 01, no. 01, July 2023

https://doi.org/10.32734/gfj.v1i01.13252

ABSTRACT

Forest fragmentation is a threat to ecosystems in Indonesia caused by forest conversion to plantations. This study aims to analyze the use of land cover in the period 2013-2022. The research was conducted from November 2022 to January 2023 in the Gayo highland area by taking case studies in 2 regions including the Central Aceh District and Bener Meriah District. The research was carried out in several stages, namely: image pre-processing, image visual interpretation, making image classification class identifiers, and ground checking. The pre-processing stage is the preparation of tools and materials. Landsat 8 OLI imagery for the study area downloaded from the United States Geological Survey (USGS) website. The results of the research show that in the last 10 years there has been a decrease in the area of land cover in the exploration area of primary forest and secondary forest. Meanwhile, in the cultivation of dry fields, settlements, plantations and vacant land, land use has increased. Changes in the use of land cover are influenced by community activities in Central Aceh and Bener Meriah Regencies.
Keyword: Conservation, GIS, Gayo Highlands, Coffee Plantation

1. Introduction

Changes in land cover to coffee in the Gayo highlands could be a result of agricultural and plantation activities in the area. The Gayo highlands in Indonesia are renowned for the production of high-quality Arabica coffee. Over time, there may be an expansion of coffee plantations or other land use changes to coffee plantations. Changes in land cover to coffee plantations can have economic and environmental impacts. Economically, coffee plantations can provide a livelihood for local farmers and have the potential to be a significant source of income for the area. On the environmental side, it is necessary to pay attention to sustainable coffee plantation management to prevent land degradation, soil erosion, or water pollution due to the use of pesticides and fertilizers. The central highlands of Aceh include Bener Meriah district, Central Aceh district and Gayo Lues district. The area of coffee plantations in the three districts increased from 39,490 ha, 46,540 ha, and 2,474 ha in 2006 to 46,294 ha, 49,366 ha, and 4,930 ha in 2018 [1]. Forest conversion to coffee

plantations is a threat to forest fragmentation in Indonesia. This situation will cause a significant decrease in species for tropical forest biodiversity.

The tropical forest of the Gayo highlands has endangered plant species that must be preserved. Many discoveries of new and endemic species in the Gayo highland forest area are the basis for how this area should be conserved. The results of the research [2] have collected new types of orchid species in the wild, namely *Bulbophyllum acehense*, *Dendrobium gayoense*, *Nephentes lavicola* with IUCN status as endangered, Nephentes lavicola with IUCN status as threatened, and *Nephentes reinwardtiana* with IUCN status Least Concern [3]. Excessive loss of habitat due to forest conversion and damage will greatly affect the population and rare plants that are endangered in the Gayo highlands.

Increasing number of human activities causes land use and land cover change (LULCC) to be unavoidable due to the increasing number of people in meeting the needs of land use which results in increasing forest clearance for plantations [4]. Thus analyzing changes in land cover is important because it can determine changes in forest land into plantations. This study aims to analyze the use of land cover in the periods of 2013-2022 so that the research results will be used as reference data for local government stakeholders in developing forest conservation areas in the Gayo Highlands.

2. Method

The research was conducted in November 2022 - January 2023 in the Gayo highlands by taking case studies in 2 regions including Central Aceh and Bener Meriah. Determining the location of the research using the purposive sampling method, namely determining the location based on the forest area that experienced the greatest fragmentation [5,6]. In research related to land use change, use three years of LULC classification analysis for better understanding. The use of three time periods to analyze changes in land use has also been carried out in previous studies [5,7] so that in this study land changes were used in the year 2013 – 2022. The research was carried out in several stages, namely: image pre-processing, image visual interpretation, making image classification class identifiers, and ground checking. The pre-processing stage is the preparation of tools and materials. Landsat 8 OLI imagery for the study area downloaded from the United States Geological Survey (USGS) website. The tools used in this study were GPS as the coordinates of the research location and a camera for documentation. So that the data obtained is analyzed spatially using GIS (Geographic Information System). The output of the spatial analysis and the data obtained are grouped based on the assessment criteria for land use and land cover change.

The method used in this research is descriptive method, which aims to obtain information and make a systematic description of situations and events. The research stages were divided into 3 stages, namely the pre-field stage, the field check stage, and the after-field stage. At this stage, a Geographic Information System (GIS) is used with an overlay technique to analyze land change (2013-2022) [8-12]. Checking the image coordinates with the actual coordinates at the research location and checking the results of land use identification on the image data with the actual conditions at the research location. The last stage is to analyze changes in land use from 2013-2022 using the overlay method of land use maps from the classification results of Landsat Landsat 8 OLI imagery for 2013-2022 using ArcGIS 9.3 software, including changes in area and distribution of objects.

3. Result and Discussion

3.1. Land use in 2013 – 2022

Spatially, land use in the Gayo Highlands can be seen on the land use map in Bener Meriah District and Central Aceh District. Land use interpretation results from Landsat Imagery resulted in the classification of land use into seven types of land use, namely primary forest, secondary forest, farm/moor, settlements, plantations, ricefields and vacant land. Changes in land use every year experience very significant changes (Figure 1). Changes in land use can experience significant variations every year. Gayo Lues Regency experienced a change from forest to agricultural land in 2005 covering an area of 2,361.36 ha (0.48%), in 2010 covering an area of 8,823.71 ha (1.83%) and in 2015 26,301.54 ha (5.56%). Gayo Lues Regency has experienced a change in agricultural land to non-agriculture in 2005 to 2010 covering an area of 3,641.34 ha (9.05%) and from 2010 to 2015 covering an area of 1,218.31 ha (1.56%) [7]. On the other hand, there are also conservation efforts that encourage the return of unproductive agricultural land or damaged land back to its natural state, such as efforts to preserve rare plants and build arboretums carried out by local governments. Significant annual changes in land use can have far-reaching impacts, including changes in ecosystems,

biodiversity, air and water quality, and impacts on climate change. Therefore, regular monitoring and mapping of land use change is essential for a better understanding of change trends and to inform appropriate policies in land management.

Table 1. Changes in land use in 2013, 2018, 2022

Land Cover	2013	2018	2022
	Area (ha)	Area (ha)	Area (ha)
Primary forest	1,453.18	1,265.62	1,192.65
Secondary forest	696.14	648.01	631.63
Farm/moor	3,035.48	3,146.17	3,213.29
Settlement	204.00	215.20	225.78
Plantation	1207.21	1,206.56	1,208.23
Ricefield	26.34	24.77	23.81
Vacant land	61.75	60.27	70.23

Technologies such as satellite imagery and spatial analysis play an important role in monitoring land use change efficiently and accurately. Using this data, researchers, policy makers and environmentalists can identify changes, assess their impacts and develop strategies for sustainable land management. There has been a decrease in the area of land cover in the primary forest exploration area over a period of 10 years, in 2013 the area covered was 1,453.18 ha and decreased in 2022 to 1,192.65 ha. The same thing happened to the secondary forest exploration area in 2013 of 696.14 ha and decreased in area in 2022 to 631.63 ha. The change in the use of fields/moor land has increased in 2013 to 3,035.48 ha and in 2022 it has increased to 3,213.29 ha. High human activity, ecological and economic factors [9] have changed land use over a period of 10 years, this can be seen in the increase in residential area where in 2013 it was 204.00 ha to 225.78 in 2022. This result is in line with the increase in the area of plantations and vacant land, where the area of plantations in 2013 was 1,207.21, increasing to 1,208.23 in 2022. This is in line with the increase in vacant land which has increased in area in 10 years by 61.75 ha in 2013 to 70.23 ha in 2022.

3.2. Land Use Change Map

Patterns of land use change can be seen by previous land use [11]. Changes in land use can include conversion of agricultural land to urban areas, deforestation to open new agricultural land, industrial expansion, and changes in natural ecosystems to agricultural land or plantations. Land conversion can have a significant impact on ecosystems and the environment. [12] Deforestation reduces habitat for native flora and fauna, increases greenhouse gas emissions, and contributes to climate change. Changes from agricultural land to urban areas can reduce the availability of land for food production, while industrial expansion can disrupt sensitive ecosystems.

It is important to pay attention to sustainable land management, including conservation efforts, ecosystem restoration, efficient land use, and environmentally friendly agricultural practices. This can help minimize the negative impacts of land use change and maintain a balance between human needs and environmental sustainability. Monitoring and mapping of land cover change is important for a better understanding of land change trends, their impacts, and development of appropriate solutions. This involves using technologies such as satellite mapping and image analysis to obtain more accurate information about land changes over time. Changes in land use can experience significant variations every year. Factors such as population growth, urbanization, agricultural expansion, industry, and changes in government policies can cause rapid changes in land use. For example, some areas may experience a rapid increase in land use for urban development, leading to conversion of agricultural or forest lands into settlements and urban infrastructure. On the other hand, there are also conservation efforts that encourage the return of unproductive agricultural land or damaged land back to its natural state, such as forest or wetland restoration. Significant annual changes in land use can have far-reaching impacts, including changes in ecosystems, biodiversity, air and water quality, and impacts on climate change. Therefore, regular monitoring and mapping of land use change is essential for a better understanding of change trends and to inform appropriate policies in land management. Technologies such as satellite imagery and spatial analysis play an important role in monitoring land use change efficiently and accurately. Using this data, researchers, policy makers and environmentalists can identify changes, assess their impacts and develop strategies for sustainable land management.

Changes in forest [13] this process usually involves cutting down forests to clear land which is then used to grow coffee plants. These changes can have significant consequences, both environmental and social. The possible impact is loss of habitat and biodiversity. Deforestation of primary forest for coffee plantations can result in loss of natural habitat for various species of flora and fauna. This has an impact on reducing

biodiversity and can threaten the sustainability of ecosystems. Forests have an important role in maintaining the water cycle and preventing soil erosion [14]. Deforestation for coffee plantations can change water flow patterns, reduce water absorption by the soil, and increase the risk of erosion. There is a need for forest management and opening of coffee plantations by local governments so as to create sustainable plantation management. This involves sustainable agricultural practices, forest restoration, protection of important habitats, and participation of local communities in land-use decisions. Monitoring of changes in land cover from the local government needs to be carried out to ensure forests in the Gayo highlands are maintained properly.

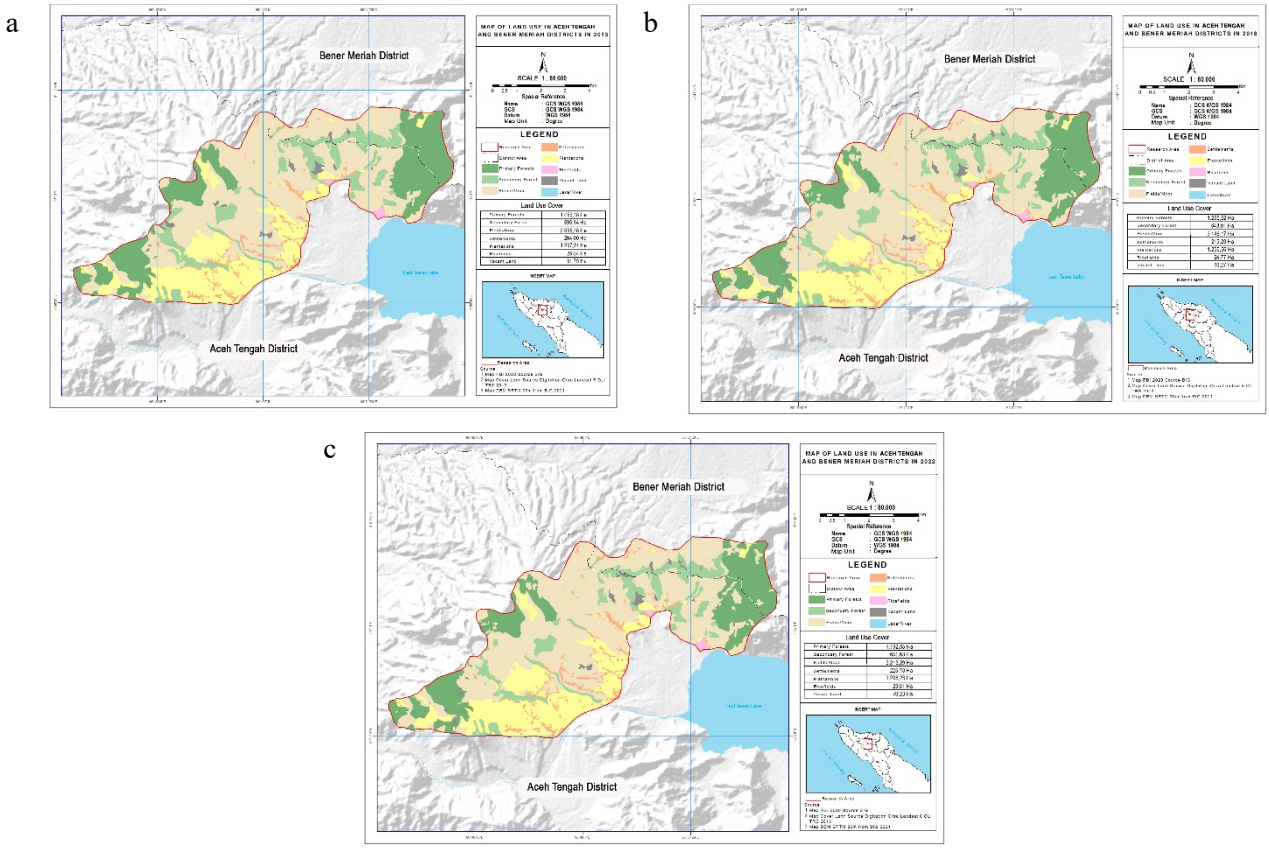

Figure 1. (a) Map of Land Use 2013; (b) Map of Land Use 2018; (c) Map of Land Use 2022

Patterns of land use change can be seen by previous land use [15]. Changes in land use can include conversion of agricultural land to urban areas, deforestation to open new agricultural land, industrial expansion, and changes in natural ecosystems to agricultural land or plantations. Land conversion can have a significant impact on ecosystems and the environment [16]. Deforestation reduces habitat for native flora and fauna, increases greenhouse gas emissions, and contributes to climate change. Changes from agricultural land to urban areas can reduce the availability of land for food production, while industrial expansion can disrupt sensitive ecosystems.

Changes in forest cover to coffee plantations are an example of land use change that is common in several regions of the world [17]. This process usually involves cutting down forests to clear land which is then used to grow coffee plants. These changes can have significant consequences, both environmental and social. The possible impact is loss of habitat and biodiversity. Deforestation of primary forest for coffee plantations can result in loss of natural habitat for various species of flora and fauna. This has an impact on reducing biodiversity and can threaten the sustainability of ecosystems. Forests have an important role in maintaining the water cycle and preventing soil erosion [18]. Deforestation for coffee plantations can change water flow patterns, reduce water absorption by the soil, and increase the risk of erosion. It is important to consider sustainability and responsible management practices in converting forest cover to coffee plantations. This involves sustainable agricultural practices, forest restoration, protection of important habitats, and participation of local communities in land-use decisions. Strict monitoring, supervision and regulations also need to be implemented to ensure that land use changes are carried out taking into account sustainable environmental and social impacts.

4. Conclusion

Spatial changes in land use in the Gayo Highlands can be seen on the land use map in Bener Meriah District and Central Aceh District. Land use interpretation results from Landsat Imagery resulted in the classification of land use into seven types of land use, namely primary forest, secondary forest, fields/moor fields, settlements, plantations/gardens, paddy fields and vacant land. There was a decrease in the area of primary forest, secondary forest and paddy fields. As for the use of fields, settlements, plantations and vacant land there has been an increase in area. Sustainable agriculture needs to be developed in the Bener Meriah district and Central Aceh district because these two districts directly intersect with forest areas. Meanwhile, in the cultivation of dry fields, settlements, plantations and vacant land, land use has increased. Changes in the use of land cover are influenced by community activities in Central Aceh and Bener Meriah Regencies.

References

[1] Anhar, Rasyid U. H., Muslih, A.M., Romano, Abubakar, Y. A. "Sustainable arabica coffee development strategies in Aceh, Indonesia," IOP Conference Series: Earth and Environmental Science, vol. 667, no. 1, p. 012106, 2021. doi:10.1088/1755-1315/667/1/012106.

[2] Metusala, "Bulbophyllum acehense (Orchidaceae), a new species of section beccariana from Aceh, Sumatra, Indonesia," *Jurnal Biologi Tropis*, vol. 20, no. 1, pp. 111–115, 2020.

[3] M. Victoriano, "A new species of Nepenthes (Nepenthaceae) and its natural hybrids from Aceh, Sumatra, Indonesia," *REINWARDTIA*, vol. 20, no. 1, pp. 17–26, 2021. doi:10.14203/reinwardtia.v20i1.3932.

[4] W. Nega, B. T. Hailu, and A. Fetene, "An assessment of the vegetation cover change impact on rainfall and land surface temperature using remote sensing in a subtropical climate, Ethiopia," *Remote Sensing Applications: Society and Environment*, vol. 16, p. 100266, 2019. doi:10.1016/j.rsase.2019.100266.

[5] Rahmawaty, A. Rauf, M. M. Harahap, and H. Kurniawan, "Analysis of land-use change over five- and ten-year periods in Hamparan Perak, North Sumatra, Indonesia," *Geocarto International*, vol. 37, no. 27, pp. 15037–15062, 2022a. doi:10.1080/10106049.2022.2093991.

[6] M. T. Kurrahman, S. Sugianto, and A. Karim, "Perubahan Hutan Dan Lahan Pertanian di Kabupaten Gayo Lues Dalam Kurun Waktu 11 tahun (2005 - 2015)," *Jurnal Ilmiah Mahasiswa Pertanian*, vol. 4, no. 4, pp. 588–595, 2020. doi:10.17969/jimfp.v4i4.12797

[7] Kafy et al., "Modeling the relationship between land use/land cover and land surface temperature in Dhaka, Bangladesh using Ca-Ann Algorithm," *Environmental Challenges*, vol. 4, p. 100190, 2021. doi:10.1016/j.envc.2021.100190.

[8] Rahmawaty, A. Rauf, M. M. Harahap, and H. Kurniwan, "Land cover change impact analysis: An integration of remote sensing, GIS and DPSIR framework to deal with degraded land in Lepan watershed, North Sumatra, Indonesia," *Biodiversitas Journal of Biological Diversity*, vol. 23, no. 6, 2022. doi:10.13057/biodiv/d230627.

[9] Rahmawaty, M. M. Harahap, H. Kurniawan, and A. Rauf, "Assessment of land cover change over a period of five years in Deli Serdang, North Sumatra," IOP Conference Series: Earth and Environmental Science, vol. 782, no. 3, p. 032007, 2021. doi:10.1088/1755-1315/782/3/032007.

[10] Rahmawaty, M. M. Harahap, H. Kurniawan, and D. Mandasari, "DPSIR model approach to address land-use changes in Deli Serdang District, North Sumatera Province," IOP Conference Series: Earth and Environmental Science, vol. 724, no. 1, p. 012028, 2021. doi:10.1088/1755-1315/724/1/012028.

[11] Rahmawaty, M. M. Harahap, H. Kurniawan, and A. Rauf, "Land use changes monitoring over a period of ten years in Panjang Island, Pangkalan Susu, Langkat, North Sumatra," IOP Conference Series: Earth and Environmental Science, vol. 782, no. 3, p. 032008, 2021. doi:10.1088/1755-1315/782/3/032008.

[12] Rahmawaty, M. M. Harahap, A. Rauf, and H. Kurniawan, "Changes in dryland forest cover in several sub-districts in Deli Serdang Regency," IOP Conference Series: Earth and Environmental Science, vol. 752, no. 1, p. 012041, 2021. doi:10.1088/1755-1315/752/1/012041.

[13] T. Tieng, S. Sharma, R. A. MacKenzie, M. Venkattappa, N. K. sasaki , A. Collin, "Mapping mangrove forest cover using landsat-8 imagery, sentinel-2, very high resolution images and Google Earth engine algorithm for entire Cambodia," IOP Conference Series: Earth and Environmental Science, vol. 266, p. 012010, 2019. doi:10.1088/1755-1315/266/1/012010.

[14] Rahmawaty, J. Siahaan, A. Nuryawan, M. M. Harahap, M. H. Ismail, A. Rauf, H. Kurniawan, S. Gandasecagan, M. Karuniasa, "Mangrove cover change (2005-2019) in the northern of Medan city, North Sumatra, Indonesia," *Geocarto International*, pp. 1–32, 2023. doi: 10.1080/10106049.2023.2228742.

[15] K. Winkler, R. Fuchs, M. Rounsevell, and M. Herold, "Global land use changes are four times greater than previously estimated," *Nature Communications*, vol. 12, no. 1, 2021. doi:10.1038/s41467-021-22702-2.

[16] K. R. Shivanna, "Climate change and its impact on Biodiversity and Human Welfare," *Proceedings of the Indian National Science Academy*, vol. 88, no. 2, pp. 160–171, 2022. doi:10.1007/s43538-022-00073-6

[17] T. G. Ango, K. Hylander, and L. Börjeson, "Processes of forest cover change since 1958 in the coffee-producing areas of southwest Ethiopia," *Land*, vol. 9, no. 8, p. 278, 2020. doi:10.3390/land9080278.

[18] R. Blanco Sepúlveda and A. Aguilar Carrillo, "Soil erosion and erosion thresholds in an agroforestry system of coffee (coffea arabica) and mixed shade trees (Inga spp and Musa spp) in northern Nicaragua," *Agriculture, Ecosystems & Environment*, vol. 210, pp. 25–35, 2015. doi: 10.1016/j.agee.2015.04.032.