RESEARCH ARTICLE Agricultural Science Digest, Volume 46 Issue 3: 498-503 (June 2026)

Vegetation Coverage Decline in Relation to Rapid Urbanization in Nghe an Province, Vietnam

T.N. Le[1], T.T.T. Nguyen[2]

10.18805/ag.DF-647

ABSTRACT

Background: Urbanization, a trend driven by socio-economic development, has led to a significant decline in vegetation cover and exacerbated ecological and environmental complexities worldwide. As a result, monitoring urban expansion has become crucial for efficient urban management and addressing ecological and environmental concerns. This study aims to investigate the spatial and temporal variations in vegetation cover in Nghe An province, Vietnam over the past two decades, focusing on the impacts of urbanization.

Methods: Using the Google Earth Engine platform, we analyzed the spatial and temporal changes in vegetation cover from remote sensing images based on the maximum likelihood method (MLM). Our accuracy assessment yielded high Kappa indexes, ranging from 0.87 to 0.91 and classification methods resulted in accuracy levels of 89.2% to 92.7%.

Result: The results indicate a significant decline in vegetation cover, with a total area decrease of 152,752 hectares at an average annual rate of 0.39% (approximately 6,364 hectares) per year. Concurrently, bare land and urban land areas increased by approximately 64,760 and 147,934 hectares, respectively, with average annual growth rates of 2,698 and 6,163 hectares over the period 2000-2024. These results highlight the pressing need for effective measures to mitigate the decline in vegetation cover and promote sustainable urban development in the study area.

Key words: Challenges, Coverage, Google earth engine, Remote sensing, Urbanization process.

INTRODUCTION

Rapid urbanization is a global trend that has led to significant decline in global forest cover, exacerbating environmental and societal challenges (Kelsey *et al*., 2018; Nurul *et al*., 2023). With over 50% of the world's population living in urban areas, projected to increase to 50% by 2050 (Gorelick *et al*., 2017), urban expansion not only affects regional air quality but also has a wide-ranging implication on the overall environment (Zurqani *et al*., 2018). Satellite remote sensing data has been widely employed in numerous studies to monitor changes in vegetation cover (Ibrahim and Al-Mashagbah, 2016; Le and Nguyen, 2022). However, traditional satellite remote sensing approaches are resource-intensive and time-consuming (Agarwal and Nagendra, 2019; Ghorbanian *et al*., 2020). In contrast, google earth engine has emerged as a valuable tool for analyzing satellite remote sensing information (Nyland *et al*., 2018; Nasiri *et al*., 2022). Google earth engine's cloud-based geospatial platform provides access to a vast repository of data, including Landsat and Sentinel imagery, as well as climate and meteorological datasets (Ghorbanian *et al*., 2020; Gorelick *et al*., 2017). Its high-speed parallel processing and machine learning algorithms enable efficient analysis and visualization of large geospatial datasets without the need for supercomputers or specialized coding expertise (Geeta and Abhay, 2022). Google earth engine has been successfully applied in various studies, such as monitoring land cover changes (Zurqani *et al*., 2018), habitat tracking, urban land mapping and anthropogenic activities analysis (Halmy *et al*., 2015).

[1]Thai Nguyen University of Education, Thai Nguyen City, Thai Nguyen Province, Vietnam.

[2]Department of Geography, College of Education, Vinh University, Nghe An Province, Vietnam.

Corresponding Author: T.T.T. Nguyen, Department of Geography, College of Education, Vinh University, Nghe An Province, Vietnam. Email: thanhntt@vinhuni.edu.vn

How to cite this article: Le, T.N. and Nguyen, T.T.T. (2026). Vegetation Coverage Decline in Relation to Rapid Urbanization in Nghe an Province, Vietnam. *Agricultural Science Digest.* **46(3):** 498-503. doi: 10.18805/ag.DF-647.

Submitted: 16-07-2024 **Accepted:** 02-11-2024 **Online:** 09-01-2025

The google earth engine cloud-based computing platform can resolve the most significant problems related to vegetable cover change mapping (Betru *et al*., 2019; Phan *et al*., 2020). Google earth engine is an open-source platform that has a large storage capacity, substantial processing power, and self-programing classification algorithms (Zurqani *et al*., 2018). In Vietnam, the urbanization process of provinces such as Nghe An has led to a significant decline in vegetation cover, with the province experiencing a varied pattern of vegetation coverage decline dynamics and notable conversions of vegetation coverage into urbanization (Le and Nguyen, 2024). This study aims to investigate the dynamics of vegetation cover in Nghe An province from 2000 to 2024 using the google earth engine to provide a comprehensive understanding of the environmental implications of urbanization and to inform decision-making in land use planning and management in the region.

MATERIALS AND METHODS

Study area

Nghe An Province is situated in the North Central region of Vietnam, spanning from 18°33′-20°01′N and 103°52′-105°48′E, with a total area of 16,400 km^2 and a population of approximately 3,419,989 people (Dinh and Kazuto, 2022). The study area is characterized by a diverse geography, featuring mountains and hilly terrains with elevation fluctuations ranging from below 10 to over 1,500 m a.m.s.l (Fig 1). Nghe An is located in the tropical monsoon climate zone, marked by two distinct seasons summer and winter (Dinh and Shima, 2024; Le *et al*., 2024). During the summer months (April to August), the area experiences dry and hot southwesterly winds or commonly known as Foehn wind, while in winter (December to February), it is affected by cold and humid northeasterly winds (Dinh and Shima, 2024). The average annual temperature is approximately 23-24°C, with significant temperature fluctuations between the months approximately 19°C (coldest months average) while up to 42.7°C (maximum temperature). The province receives an average annual rainfall of between 1,200 to 2,000 mm per year (Dinh and Shima, 2024).

Method of approach

The study utilized a comprehensive dataset of Landsat 6 TM, 5 TM and 9 TM remote sensing images acquired from 2000, 2010 and 2024, respectively, with spatial resolutions ranging from 10 to 30 meters (Table 1). To ensure data quality, atmospheric correction was applied to images using the LEDAPS, which involved masking for clouds, shadows, water, snow, and per-pixel saturation. Additionally, due to the differences in characteristics between the TM and OLI sensors, DEM data was utilized for geometric correction of satellite images in the study area. Finally, the satellite images were georeferenced to the study area to ensure accurate spatial registration (Tesfaye *et al*., 2024). The remote sensing image data from 2000, 2010 and 2024 underwent radiometric and atmospheric corrections to remove geometric distortions caused by the sensor or Earth rotation (Agarwal and Nagendra, 2019; Arpitha *et al*., 2023). Relative geometric corrections were conducted to ensure accurate spatial alignment (Ahmed and Harishnaika, 2023; Tesfaye *et al*., 2024). Additionally, terrain correction and image stitching were performed to create a seamless mosaic (Agarwal and Nagendra, 2019).

The land use types were categorized into five classes: forest land, annual crops, urban land, bare land, and water body. Classification was carried out using the MLM and precision testing was conducted using the Kappa index and overall accuracy (Tesfaye *et al*., 2024; Zurqani *et al*., 2018). The image processing was based on the UTM-Zone-48N projection system, and the software ENVI 5.1 and ArcGIS 10.2 were used for data analysis. The analysis process involved three major steps: (1) data collection of remote sensing images, (2) classification of the images using the maximum likelihood classification (MLC) algorithm and (3) precision testing of the classification results using the Kappa index and overall accuracy. The results of the analysis were used to determine the vegetation coverage status for the

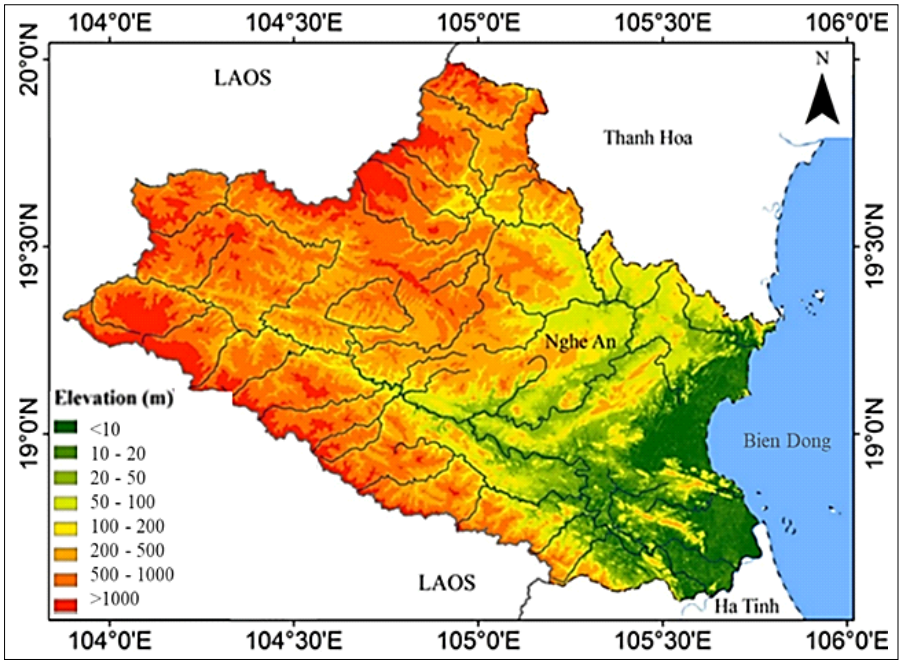

Fig 1: Map of the study area.

years 2000, 2010 and 2024 (Agarwal and Nagendra, 2019; Tesfaye *et al*., 2024).

RESULTS AND DISCUSSION

Classification results of the preprocessed images in 2000, 2010 and 2024 are presented in Fig 3. According to the classification results, the statistics for the three years of different types of land use areas and their proportions are shown in Table 2. It can be drawn from Table 2 and Fig 3 that the area of forest land is the largest in the study area. The forest land area is 1130880 ha, 1052270 ha and 978128 ha in 2000, 2010 and 2024, respectively, followed by urban land with 290389 ha, 472957 ha and 438323 ha in 2000, 2010 and 2024, respectively.

Urban land increases strongly during the 24 years from 2000 to 2024, which is characteristic of the urbanization process in Nghe An province. The annual crop land area shows a trend of decreasing in the stage 2000-2010 (approximately 8.28%) but then increasing in the stage 2010-2024 (approximately 4.90%). According to the images of the years and relevant data, bare land increased approximately 3.93%, from 7902 ha in 2000 to 72662 ha in 2024. Vegetation cover and annual land area reduction correlate with urban expansion and forest cutting.

The validation data are randomly and manually chosen based on Google Maps and the Forest Management Inventory. Fig 2 contains the evaluation results of the three periods of images. Producer's accuracy and user's accuracy are obtained by a confusion matrix. Overall classification accuracy in 2000, 2010 and 2024 are 89.2%, 91.4% and 92.7%, respectively, with Kappa indexes of 0.87, 0.89 and 0.91, respectively. In terms of the distribution of land cover types in the study area, forest cover area constituted the largest portion in 2000, accounting for 68.71%. Annual crop land and urban land accounted for approximately 11.92% and 17.64%, followed by water bodies at 1.25% and bare land at 0.48%. In 2010, forest cover encompassed the largest area at 63.93%, followed by urban area at 28.73%, annual crop land at 3.64%, bare land at 2.90%, and water bodies at 0.81% (Table 2).

Between 2000 and 2010, there was a significant increase in urban land area by 14.61%, followed bare land area by 2.41%. However, there was a decline in forest cover area by 4.77% and annual crop area by 8.28%. By 2024, vegetation cover area once again dominated, covering 59.43% of the study area, followed by urban land at 26.63%, annual crop area at 8.54%, bare land area at 2.41% and water bodies at 0.44%. The decline in forest cover areas

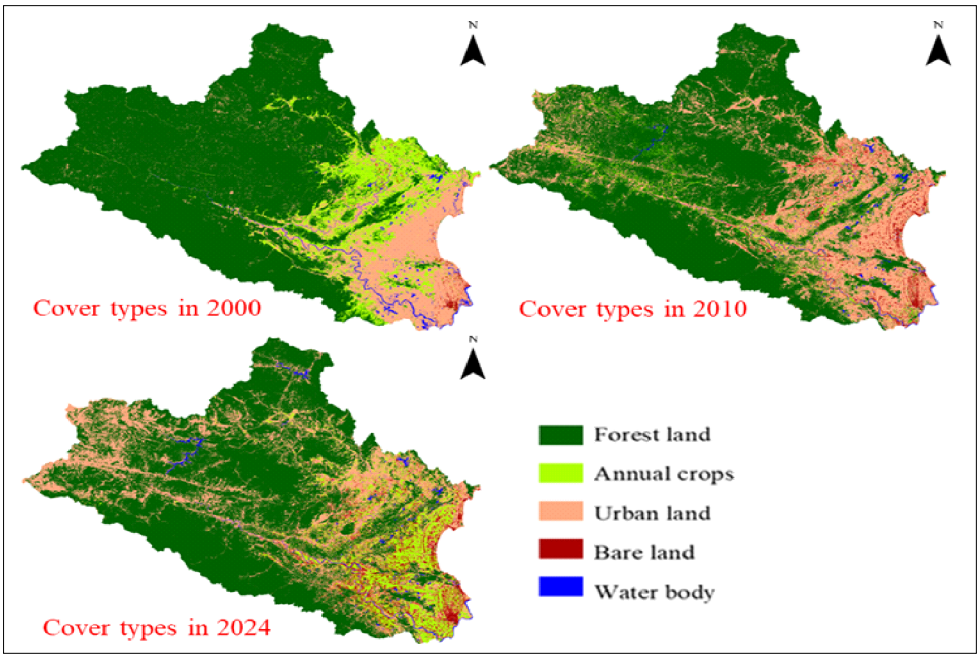

Fig 2: Spatial distribution of cover types entire the study area in the period 2000-2024.

Table 1: Data of multispectral satellite sensors used for the purpose of the study.

Imagery data	Projection	Acquisition data	Spatialr esolution	Data source
Landsat 6 TM	UTM-Zone-48N	2000	30 m	https://earthexplorer.usgs.gov
Landsat 5 TM	UTM-Zone-48N	2010	30 m	https://earthexplorer.usgs.gov
Landsat 9 OLI	UTM-Zone-48N	2024	10 m	https://scihub.copernicus.eu

during the 2000-24 period raises concerns about potential ecological imbalances in the study area, attributed to urban expansion and deforestation activities.

However, there was a subsequent decrease in forest cover area by 4.77% in the 2000-10 period and continued to decrease 4.50% (74142 ha) in the stage 2010-24 (Fig 4).

Table 2: Temporal variation trend of vegetation covers the study area in the period 2000-2024.

Cover types	2000		2010		2024		Changed cover trends		
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)	2000-10 (%)	2010-24 (%)	2000-24 (%)
Forest land	1130880	68.71	1052270	63.93	978128	59.43	-4.77	-4.50	-9.28
Annual crops	196199	11.92	59871	3.64	140590	8.54	-8.28	4.90	-3.37
Urban land	290389	17.64	472957	28.73	438323	26.63	+11.09	-2.10	8.98
Bare land	7902	0.48	47715	2.90	72662	4.41	+2.41	1.52	3.93
Water body	20607	1.25	13268	0.81	16133	0.98	-0.44	0.17	-0.27
Total	1645977	100%	1646081	100%	1645836	100%	-	-	-

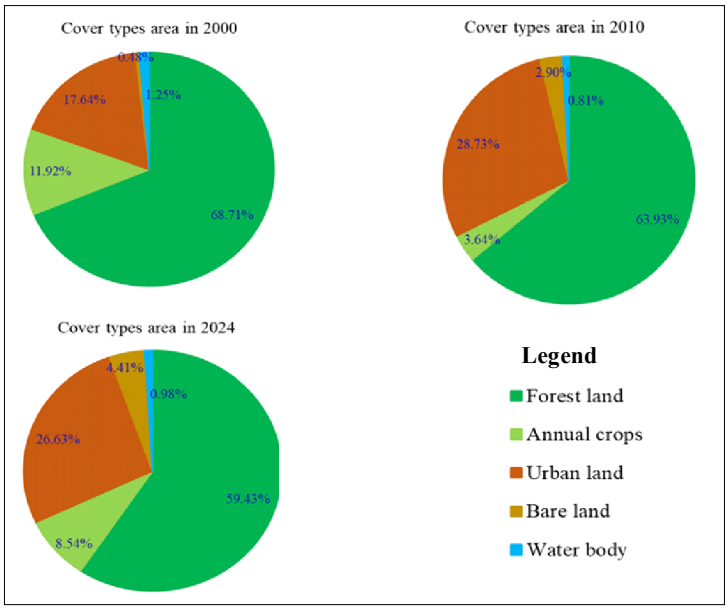

Fig 3: Land cover changes across Nghe an province during the period 2000-2024.

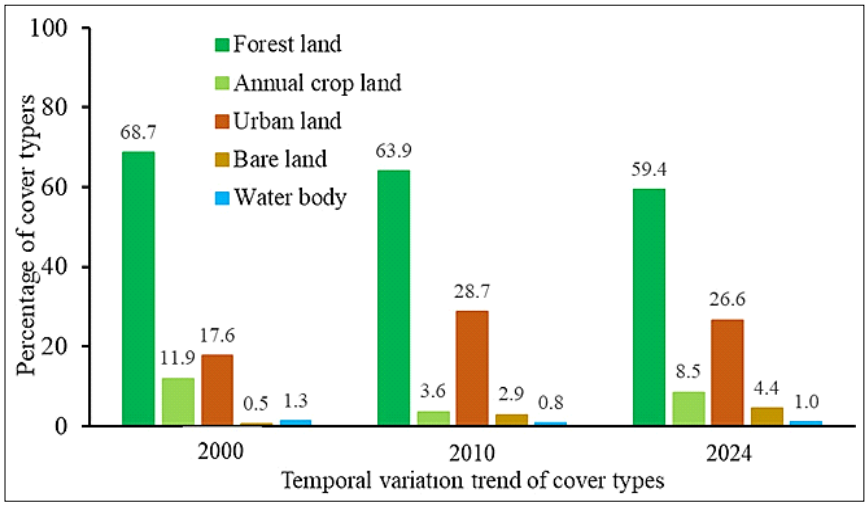

Fig 4: Percentage of land cover types across Nghe an province during the period 2000-2024.

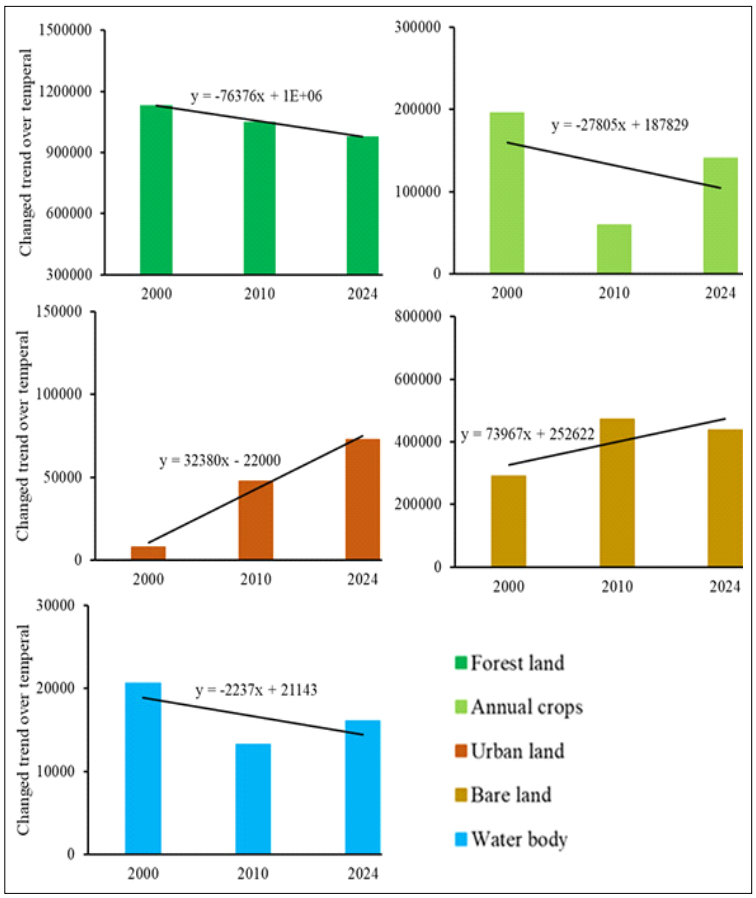

Fig 5: Changed trends of land cover types across Nghe an province during the period 2000-2024.

The conversion of vegetation coverage areas into urban spaces has led to a considerable loss of vegetation cover and a decline in ecological areas, which can have detrimental environmental effects such as intensified urban heat island phenomena and diminished air quality. The trend of decreasing annual crop land decreased 8.28% in the stage 2000-2010 and then increased 4.90% (approximately 80179 ha) in the stage 2010-24.

In contrast, urban land areas continuously increased over the 24-year study period, with a rise of 8.98% from 2000 to 2024. This indicates a rapid urbanization trend, possibly due to population growth, economic development as well infrastructure expansion. Bare land areas experienced a strong upward trend of 11.09% from 2000 to 2010 but then saw a slight decrease of 2.10% from 2010 to 2024. This change is positive for soil conservation and ecosystem health (Dinh and Shima, 2024). The water body areas showed relatively minor changes, with slight increase (0.98%) in the stage 2000-2010 and then an increasing trend only 0.17% recorded in the stage 2010-2024 (Fig 5). In general, the analysis of land use changes in the study area reveals a significant decrease in forest land and annual crop land, rapid urbanization, and fluctuations in bare land and water body areas.

These findings highlight the need for effective land management strategies to mitigate the negative environmental impacts associated with urbanization and ensure sustainable development in Nghe An province of Vietnam.

CONCLUSION

The study analyzed vegetation coverage decline in relation to the urbanization process in Nghe An province based on the maximum likelihood classification algorithm integrated into the Google Earth Engine platform in the period 2000-24. The errors of the approach method with high accuracy ranged from 87.6% to 92.17%. The results revealed a decrease in forest land area by 152752 hectares from 2000 to 2024, with an average annual down rate of 931008 ha per year while urban land area increased by 147934 hectares from 2000 to 2024, with an average annual growth rate of 6163.9 ha per year. During this period, the area of annual crops and bare land showed a slight decrease and increase with an average annual rate of 0.14% and 0.16%, respectively. These findings highlight the potential risks associated with expanding urban areas in the study area and emphasize the urgent need for appropriate measures to address this issue.

Author contributions

T.N. Le and T.T.T. Nguyen: methodology; L.T. Nguyet: formal analysis; T.T.T. Nguyen: information collection and investigation; T.N. Le: writing-original draft preparation; T.T.T Nguyen: reviews and editing. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

Authors declare no conflict of interest.

REFERENCES

Agarwal, S. and Nagendra, H. (2019). Classification of Indian cities using google earth engine. *J. Land Use Sci.* **14:** 425-439.

Arpitha, M., Ahmed, S.A. and Harishnaika, N. (2023). Land use and land cover classification using machine learning algorithms in google earth engine. *Earth Sci. Inf.* **16(5):** 1-17.

Dinh, K.H.T. and Shima, K. (2024). Soil properties variation valued in relation to land use and management practices in Vietnam. *Indian Journal of Agricultural Research*. **58(4):** 634-641. doi: 10.18805/IJARe.AF-818.

Geeta, T.D. and Abhay, N. G. (2022). Automatic land cover classification with SAR imagery and machine learning using google earth engine. *International Journal of Electrical and Computer Engineering Systems*. **13(10):** 909-916. doi: 10.32985/ijeces.13.10.6.

Ghorbanian, A., Kakooei, M., Amani, M., Mahdavi, S., Mohammadzadeh, A. and Hasanlou, M. (2020). Improved land cover map of Iran using Sentinel imagery within Google Earth Engine and a novel automatic workflow for land cover classification using migrated training samples. *SPRS J. Photogramm. Remote Sens.* **167:** 276-288.

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D. and Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sens. Environ.* **202:** 18-27.

Halmy, M.W.A., Gessler, P.E., Hicke, J.A. and Salem, B.B. (2015). Land use/land cover change detection and prediction in the north-western coastal desert of Egypt using markov-CA. *Applied Geography*. **63:** 101-112.

Ibrahim, M. and Al-Mashagbah, A. (2016). Change detection of vegetation cover using remote sensing data as a case study: Ajloun area. *Civil and Environmental Research*. **8:** 1-5.

Kelsey, E.N., Grant, E.G., Nikolay, I.S., Ryan, N.E. and Dmitry, A.S. (2018). Land cover change in the lower yenisei river using dense stacking of lands at imagery in google earth engine. *Remote Sens*. **10(8):** 1226. https://doi.org/10.3390/rs10081226.

Le, T.N., Dang, T.A. and Hoang, T.V.H. (2024). Assessment of soil property alteration caused by unsustainable reclamation activities. *Brazilian Journal of Agricultural and Environmental Engineering*. **29(2):** e279919.

Le, T.N., Nguyen, D.D. and Nguyen, D.T. (2024). Land cover change assessment in Thai Nguyen Province, Vietnam using GIS and remote sensing techniques. *Res. on Crops*. **25:** 280-285.

Nasiri, V., Deljouei, A., Moradi, F., Sadeghi, S.M.M. and Borz, S.A. (2022). Land use and land cover mapping using sentinel-2, landsat-8 satellite images and google earth engine: A comparison of two composition methods. *Remote Sensing.* **14(9):** 1977. https://doi.org/10.3390/rs14091977.

Nurul, S.M.A., Pauziyah, M.S. and Zaharah, M.Y. (2023). Leveraging google earth engine (GEE) for determining land use and land cover changes around Tasik Chini Malaysia. *IOP Conf. Series: Earth and Environmental Science*. **1240:** 012017. doi: 10.1088/1755-1315/1240/1/012017.

Tesfaye, W., Elias, E., Warkineh, B., Tekalign, M. and Abebe, G. (2024). Modeling of land use and land cover changes using google earth engine and machine learning approach: Implications for landscape management. *Environ. Syst. Res.* **13:** 31. https://doi.org/10.1186/s40068-024-00366-3.

Zurqani, H.A., Post, C.J., Mikhailova, E.A. and Allen, J.S. (2019). Mapping urbanization trends in a forested landscape using google earth engine. *Remote Sens. Earth Syst. Sci.* **2:** 173-182.