Forest Cover Mapping Using Interactive Dashboards with Google Earth Engine on Sentinel-2 Satellite Imagery

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Abstract. The study aims to develop an attractive web-based visualization dashboard for mapping forest land cover around the world. The dashboard map was created using the Google Earth Engine application with JavaScript programming language. The built-in map dashboard has several interactive features, including legend, zoom, search, composite index view selection, visualization date selection, and wipers. The results of the dashboard black box test show that the dashboard works well and provides good visualization in mapping forest land cover for better monitoring and analysis.

1. Introduction

Forest is an ecosystem unit in the form of a stretch of land containing biological natural resources dominated by trees in a natural alliance of their environment, which cannot be separated from one another [1]. Forest conservation and management is an important and complex process, which has significant implications for the environment (e.g., biodiversity protection and climate mitigation) and the economy (e.g., estimation of timber volumes for commercial use) [2].

As an ecosystem that plays an important role in the balance of life on earth, forest preservation is something that needs attention. The United Nations in the Sustainable Development Goals (SDG's) explained that the impacts arising from forest loss are the loss of several animal and plant species, global warming, and the emergence of diseases caused by viruses from animal contamination, such as the Zika, Ebola, and SARS-cov viruses.

Human daily activities cause changes that occur in forest land cover, especially and land cover in general very quickly. These changes usually occur due to changes in land use for human social and economic activities. Land use is the arrangement, activity, and input that people undertake in a particular type of land cover to produce, change, or maintain it. The definition of land use in this way establishes a direct relationship between land cover and the actions of people in their environment [3]. Land cover or land use change indicates changes that occur in land cover or land use over time. This may be a change in natural succession, a natural event or due to climate change or human intervention [4].

In Indonesia, many similar studies have been conducted to monitor and analyze changes in forest land cover and forest. By utilizing data related to spatial and forestry, one of which is the use of satellite imagery. This data is used because it has a wide geographical coverage at an efficient cost and can provide the latest earth surface information [5]. In addition, several composite indices are also used to support the results of the analysis obtained to be more accurate.

So far, results related to forest land cover change maps have only been presented in journals, proceedings, publications, or static map visualizations. Instead of static maps, stakeholders want interactive data presentations that allow them to select, explore, and display data in a user-friendly interface to facilitate analysis and decision-making[6][7]. Interactive map dashboards can meet this demand. Dashboards are condensed and displayed on a single screen so that information can be seen at a glance, a visual representation of the most relevant information needed to fulfill one or more objectives [8]. Dashboards can be presented in the form of maps called map dashboards.

We recommend an interactive map dashboard as one way to visualize and deliver the results of forest land cover mapping to solve stakeholder demands. The goal of the project is to develop an interactive website-based dashboard for forest land cover mapping. The construction of the dashboard utilizes the help of Google Earth Engine so that the results obtained are more up to date with a wide reach covering the entire world. The structure of this study is clearly shown in Figure 1.

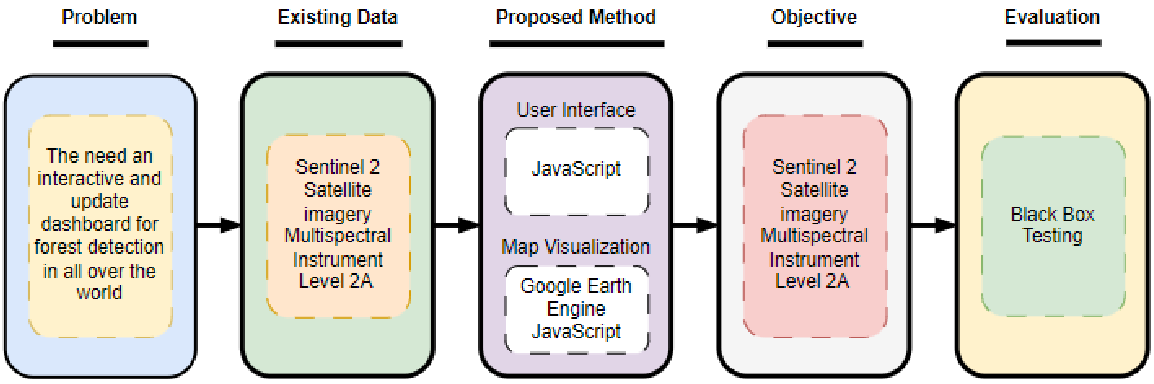

Figure 1. Research framework

2. Method

2.1. Data Used

The main data source in this study is the composite index which is the result of calculations utilizing a combination of several spectral bands from MSI Level 2A Sentinel-2 satellite imagery. The composite index is then constructed going to map the estimated location as a forest with non-forest land cover locations Other. The composite indices used, namely the Normalized Difference Vegetation Index (NDVI) which is used to describe vegetation areas, the Normalized Difference Built-up Index which is used to identify urban areas, built-up areas and other land cover, Panachromatic Normalized Difference Vegetation Index (PanNDVI) development of NDVI by reducing red emission in irrelevant NDVI billing formulas, Soil Adjusted Vegetation Index (SAVI) development of NDVI considering the effect of soil, the Modified Soil Adjusted Vegetation Index (MSAVI) which is basically the SAVI version which is aligned with correction factors to reduce soil effects on vegetation index calculations in the field, EVI-2 (Enhanced Vegetation Index-2) which is optimized designed to increase vegetation signals with better sensitivity in high biomass regions through canopy background signal separation and reduction of atmospheric influence, and the Infrared Percentage Vegetation Index (IPVI) which is used to assess vegetation health and strength and to provide estimates of proportions of vegetation cover and open water features Table 1 describes the data used to create forest land cover maps.

Table 1. Detailed data used to create forest land cover maps with MSI Level 2A Sentinel-2 satellite imagery

Data sources	Spatial resolution	Update period	Index	Calculation Formula	Reference
Sentinel-2	10m	5-10 days	NDVI	$\frac{NIR - Red}{NIR + Red}$	[9]
Sentinel-2	10m	5-10 days	NDBI	$\frac{Green - NIR}{Green + NIR}$	[10]
Sentinel-2	10m	5-10 days	PanNDVI	$\frac{NIR - (Red + Green + Blue)}{NIR + (Red + Green + Blue)}$	[11] [12]
Sentinel-2	10m	5-10 days	SAVI	$\frac{Blue - Red}{Blue + Red + 0.5} \times (1 + 0.5)$	[13]
Sentinel-2	10m	5-10 days	MSAVI	$\frac{2NIR + 1 - \sqrt{(2NIR + 1)^2 - 8(NIR - R}}{2}$	[13]
Sentinel-2	10m	5-10 days	EVI-2	$2.5 \times \frac{(NIR - Red)}{(NIR + 2.4 \times Red + 1)}$	[14] [15]
Sentinel-2	10m	5-10 days	IPVI	$\frac{\frac{NIR}{NIR + Red}}{2} \times (NDVI + 1)$	[16]

Forest cover mapping was carried out using MSI Level 2A Sentinel-2 satellite imagery. The composite index used is based on previous research that has been carried out and has succeeded in providing quite good results in mapping land cover. NDVI and EVI vegetation indices have been widely used in the analysis of satellite imagery data. Normalizing Difference Vegetation Index (NDVI) is a transformation using NIR and Red bands. This provides the ability to evaluate the presence of live vegetation in the observation target [17]. Enhanced Vegetation Index (EVI) is a transformation using NIR, Red, and Blue bands. This composite index simultaneously corrects NDVI results in overcoming atmospheric influences and ground signals, and is highly accurate in dense canopy areas [14]. In addition, other composite indices are also needed to distinguish the class of built-up areas. One composite index that is widely used to detect buildings is the Normalized Difference Built-up Index (NDBI). The PanNDVI index can also be used to detect buildings in an area.

Each composite index used in this study provides its own interpretation and usefulness. NDVI is a vegetation index to represent the level of vegetation density in an area [9]. NDVI results between -1 to 1 where -1 is in non-vegetative areas and 1 is high vegetative areas [18]. NDBI is a spectral composite index typically used to map settlements and the area of surrounding buildings [11]. The maximum value of NDBI is 1 representing the built-up area while the minimum value is -1 representing the body of water. PanNDVI is a spectral index that can also be used to detect building areas in the region [13]. SAVI is used to correct NDVI for the effect of soil brightness in areas of low vegetative cover. MSAVI is used to minimize the effect of vacant land on SAVI [13]. EVI2 is used to identify changes in vegetation areas [19]. In thematic maps, negative values EVI2 represent areas of water bodies. At the same time positive values of EVI2 represent areas of high vegetation (scale 0.4 to 0.8) [15]. IPVI is functionally equivalent to NDVI and RVI used to update the NDVI formula because red light reduction of NDVI quantifiers is irrelevant [16].

2.2. Development Dashboard

Dashboard built with a two-dimensional data visualization approach using the Google Earth Engine platform. The data used are the length of the spectral band of MSI Level 2A Sentinel-2 satellite imagery and boundary maps of each country obtained from The Global Administrative Unit Layers (GAUL). The appearance of the website is built by utilizing the JavaScript programming language (js). The features added to the forest cover mapping dashboard are intended to monitor forest areas based on the features shown by each Sentinel-2 composite index around the world.

2.3. Evaluation

Black box testing involves running tests on dashboards created to assess the functionality of the system. This approach ignores the underlying mechanisms and ensures intended functionality by concentrating on the output produced in response to the specified input and execution state [20]. The evaluation carried out to validate the functionality of the dashboard in this study was to use black box testing. Black box testing is often referred to as functional testing, i.e. by designing a set of test cases based on information from predetermined specifications [21]. This black box testing is carried out in order to meet the needs of end users who play an important role in handling valid and invalid processes from the user's point of view [22].

3. Result

3.1. User Interface

The dashboard that has been built can be accessed through https://221911179.users.earthengine.app/view/forest-land-cover-mapping-dashboard link using any device. However, it is recommended to use a PC or computer to get maximum results. After being directed to the website link, users will immediately be presented with an interactive map of the entire surface of the earth.

The view is divided into two main panels that can display different indexes either at the same or different points in time. In addition, regional boundaries are also added to facilitate place recognition and analysis. The results of dashboard construction can be seen in figure 2.

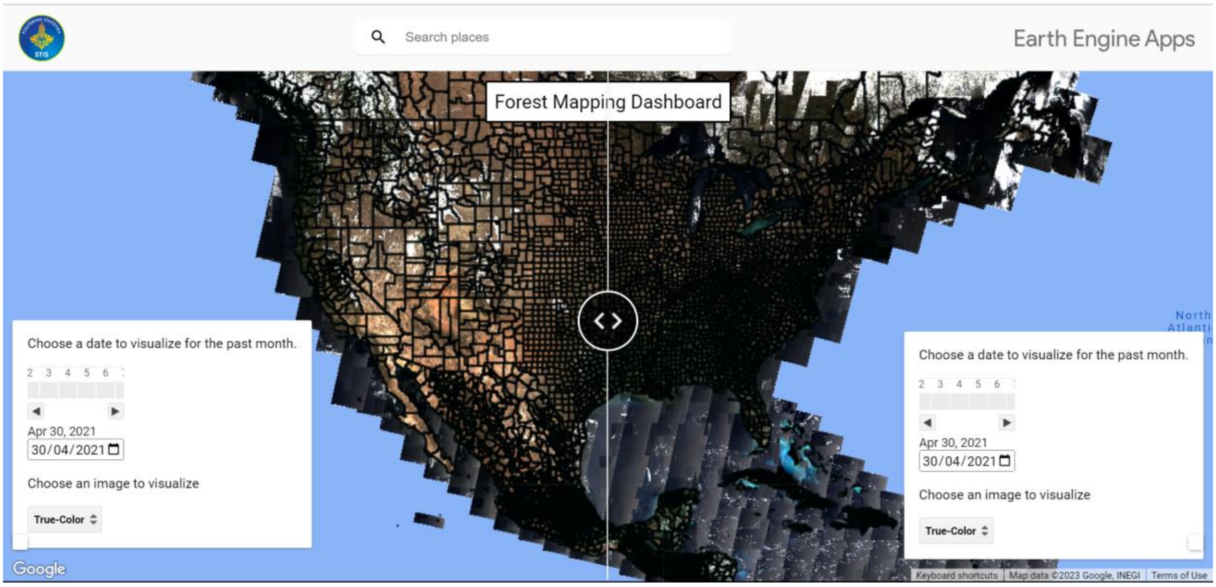

Figure 2. Main View of Dashboard

On this dashboard there are several features built to support the function of the dashboard shown in figure 3.

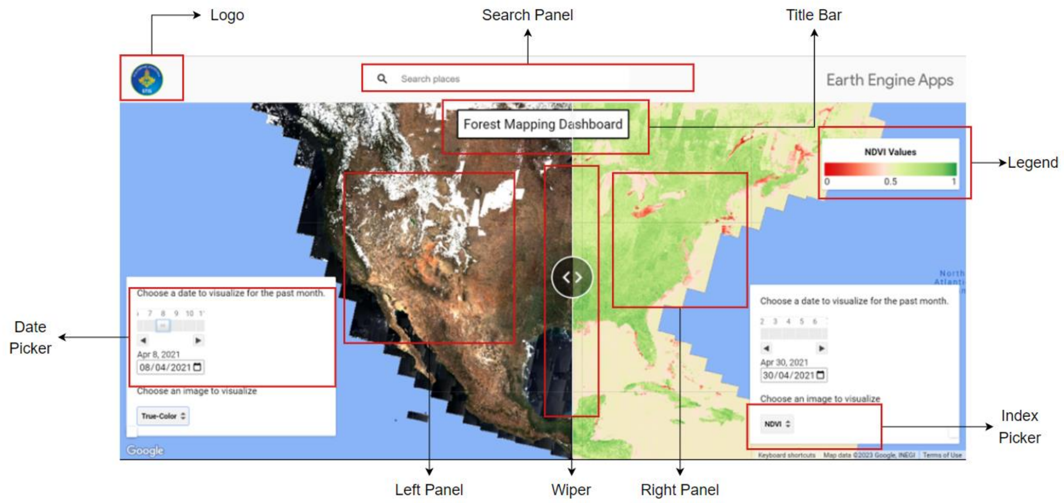

Figure 3. Features on Dashboard

Here is the explanation.

a. Logo
Displaying the logo of the STIS Statistics Polytechnic as an institution that houses research in making this dynamic dashboard. The logo is placed in the upper left corner of the dashboard

b. Search Button
The search panel is used to make it easier for users to be directed directly to the location they want to see and analyze. Users only need to enter the location they want to go to then the dashboard will immediately display a visualization of the area they are looking for.

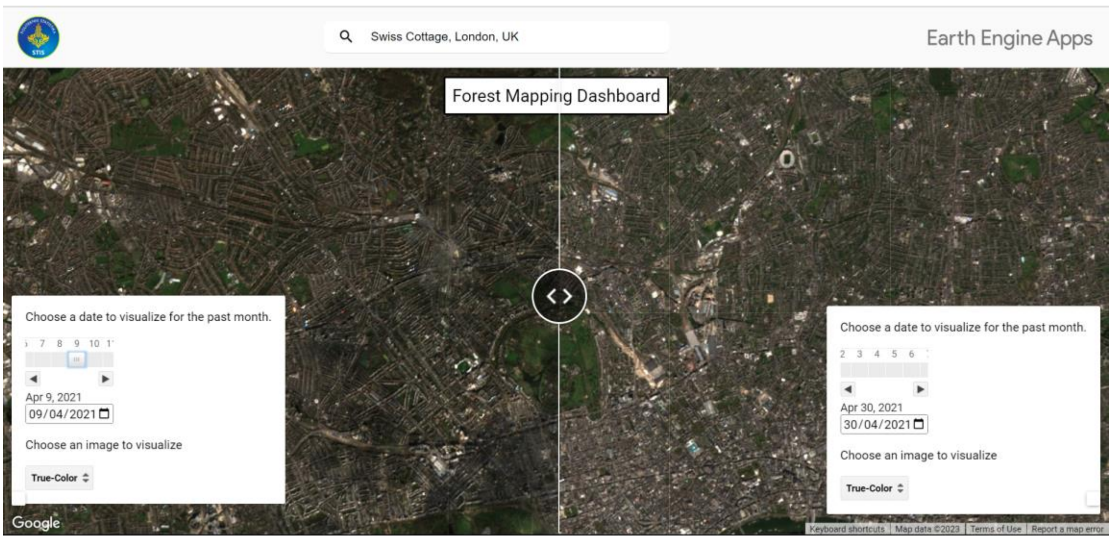

Figure 4. Search Feature Usage Visualization

c. Title Bar
The title bar is a section that displays the title or brief description of the dashboard being built, namely "Forest Mapping Dashboard"

d. Index Picker
This section is used to select the index to display on each desired panel. When the user has selected the index to be displayed, the dashboard will then display the index according to the user's wishes. Users can choose to display the same index or different indexes in both dashboard panels. Some of the indices that can be displayed by this dashboard are NDVI, NDBI, EVI-2, SAVI, MSAVI2, Pan NDVI, and IPVI, as well as Red, Green, and Blue spectral bands to display true colour from the map.

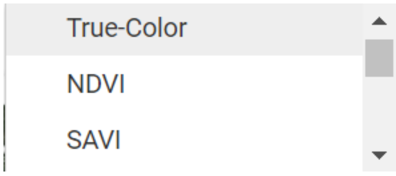

Figure 5. Composite Index Selection View

e. Legend
The legend is the part that explains the meaning of each color displayed by each index. The visualization displayed by each index will provide a different range of colors so that it has different meanings. Legend will provide knowledge and guidance to users in interpreting the meaning of the index color displayed. The legend will change as the selected index also changes.

f. Wiper
Wipers are used to adjust the width of each panel by sliding it left or right. To get a full view of the panel can be done by sliding the wipers maximally to the right or left. An example of a full view of the panel can be seen in figure 6.

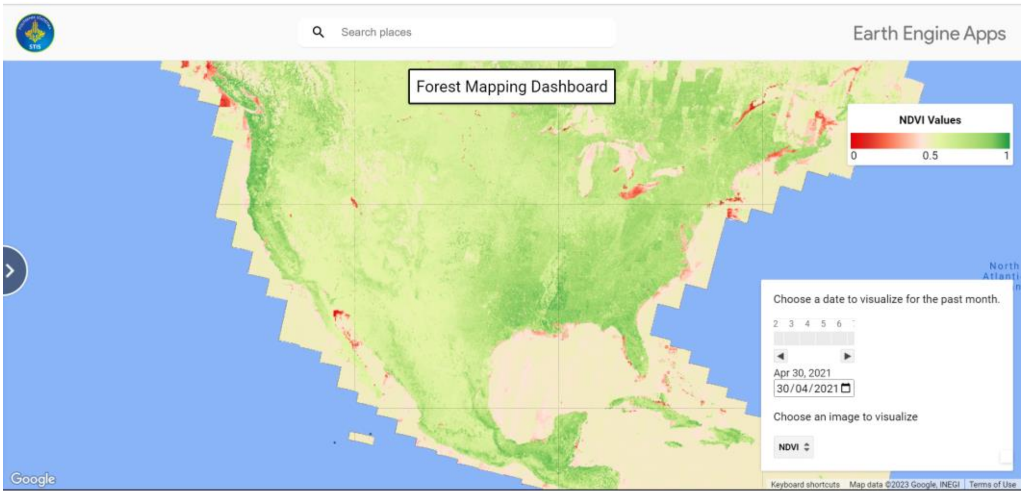

Figure 6. Use of Wiper Feature

g. Panel (Left/Right)
The panel is a section that serves to display the results of the visualization of the selected index. There are two main panels on the dashboard that have been built. Each panel can display the same or different indexes depending on the needs and desires of the user.

h. Date Picker

Date picker is a feature that allows dashboard users to select dates to be collected by satellite imagery to be displayed. The imagery displayed is a recording of satellite imagery collected one month in advance from the date selected by the user. Users can select the desired date by using the day slider at the top of the date picker panel or by selecting the specific date they want to display using the date selection feature below it. Basically, the date used is April 2021 following the chosen research time.

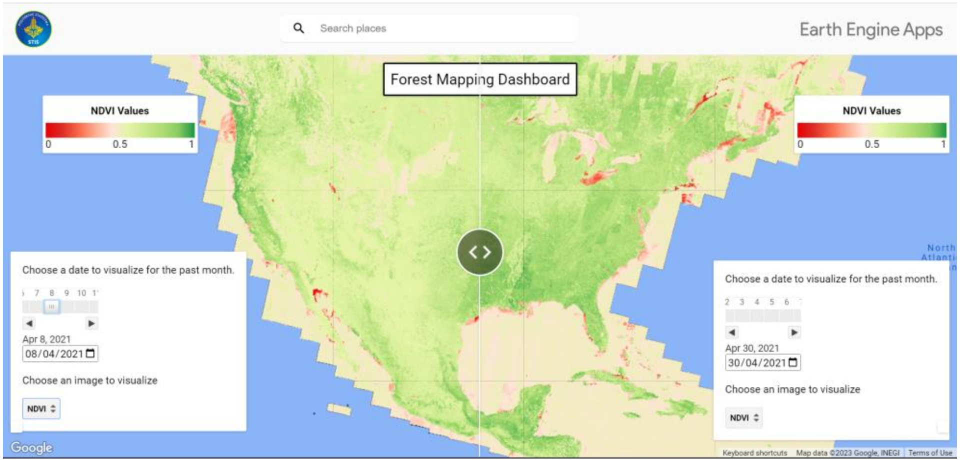

Figure 7. Use of Date Picker Feature

i. Zoom

The zoom feature is used to zoom in or out of the visualization display on the panel. Users can zoom by sliding the mouse wheel or pinching the touchpad on a PC. With the zoom feature, users can make observations and observations in more detail on a specific area.

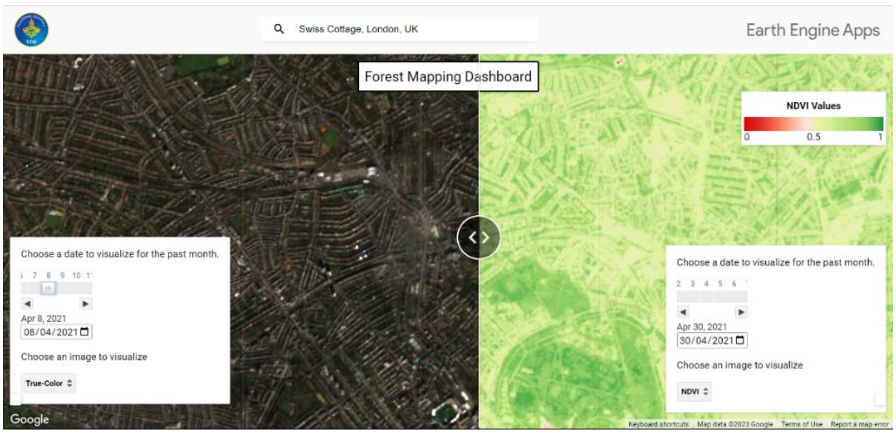

Figure 8. Use of the Zoom Feature

3.2. Evaluation Results

A black box test is then performed when the website-based map dashboard has been successfully completed to ensure that the system features are working as intended. The test results are shown in Table 2 below. According to the test findings, the important features of the dashboard work as intended.

Table 2. Black box test results

No.	Test Scenarios	Expected Results	Test Results
1	User panning/moving map view	The system displays a map corresponding to the movements made by the user	Succeed
2	User shifts wipers left/right	Panel size may change according to the position of the wiper being driven	Succeed
3	The user selects the index they want to display	The system displays an index visualization according to what the user chooses	Succeed
4	User scrolling through the page	The map view will enlarge or shrink according to the user's scroll	Succeed
5	The user selects a date for the visualization they want to display	The system successfully displays the results of satellite imagery according to the date entered by the user	Succeed
6	Users search for areas with a search bar	The system will display on the map the area in question of the user	Succeed

4. Discussion

The development of a website-based map dashboard by this study is expected to facilitate and improve stakeholder decision making, especially through area mapping to monitor and map land cover conditions, especially forest lands around the world over time. From the information that appears, users are expected to be able to analyse which areas have good forest areas or which areas need attention for relocation and forest maintenance so that the sustainability of forest areas can continue to be maintained.

For example, in the Central Kalimantan region, in October 2019, the NDVI index still has a fairly high value. This can be seen from the visualization results of the NDVI index which displays a fairly dense green colour. When compared to April 2021, the value of the NDVI index in the Central Kalimantan region is moderate. This is evidenced by the results of visualizations that display bright green. Changes in land cover can be caused by various factors, namely human daily activities, logging for settlements, logging for agricultural and plantation areas, and other social and economic activities.

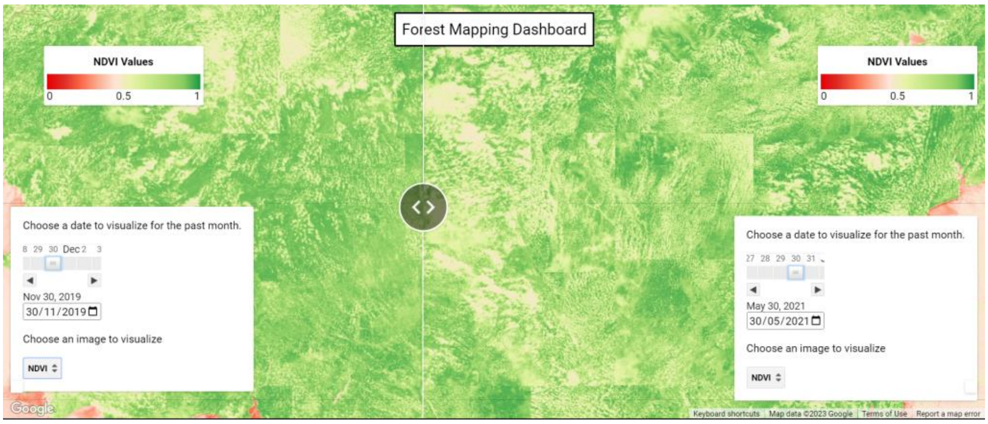

Figure 9. Comparison of NDVI Composite Index Appearance between October 2019 and April 2021

Seeing these conditions, through this interactive dashboard should be used as a guide for the government in making decisions related to development planning, for example. areas that are forest areas must be reconsidered for development expansion, while areas that were once forest areas must be reconsidered for reconsideration. In addition, the government can also use this information to provide input to decision-making processes that require information about land cover areas in an area.

5. Conclusion

This research has succeeded in building an interactive dashboard to map land cover, especially forest land detection. This dashboard that is built uses a two-dimensional (2D) visualization approach. This dashboard has features that include canvas which is the area used to display maps. Then the zoom feature is used to zoom in and out of the map. Furthermore, the index and date selection feature so that users can perform analysis as desired. This dashboard also comes with a search feature that is used to search for specific areas on the map. In addition, there is also a legend feature to display the layer that is being displayed and as a dictionary to see the meaning of each color on the map associated with the index displayed. Thus, using the forest cover mapping dashboard that has been built can be used as a supporting instrument for the government in monitoring land cover change and as input in determining policies.

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