IMPACT-MAP: A gHM Visualization Tool

A Special Problem Presented to the Faculty
Of the Institute of Computer Science
University of the Philippines
Los Baños

In Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science in Computer Science

By:
Inno Jed V. Lisboa
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The Faculty of the Institute of Computer Science
University of the Philippines Los Baños
Accepts this Special Problem Entitled

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Submitted by:

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ABSTRACT

The rapid growth of human activities has led to significant alterations in terrestrial landscapes, resulting in deforestation and reduced biodiversity. To address these pressing issues, researchers require accessible tools to analyze and visualize anthropogenic impacts effectively. However, existing datasets, such as the Global Human Modification (gHM) dataset, present technical barriers that hinder their widespread utilization. This study introduces Impact-Map, a web application that uses the Google Earth Engine JavaScript API to provide researchers with a user-friendly interface for real-time computations and visualizations of the gHM dataset in the Philippines. Impact-Map empowers users to generate average gHM values and gHM distributions for specific areas using drawing tools, search functionality, and CSV imports. Developed using HTML, JavaScript, and various libraries, the application incorporates server-side processing through the Express framework and Google Earth Engine API, ensuring scalability and efficient handling of concurrent requests. The gHM layers are served as XYZ tiles from a Google Cloud bucket, enabling access to temporal and spatial data on anthropogenic stressors. Impact-Map underwent usability testing using the System Usability Scale, achieving an excellent score of 82.7 from a group of 30 students and researchers specializing in ecology, wildlife, and forestry. This high usability score demonstrates Impact-Map's potential to enhance research efficiency and data comprehension in the field of human modification studies. By providing an accessible platform, Impact-Map contributes to the development of informed conservation strategies and a deeper understanding of anthropogenic impacts on the environment.

INTRODUCTION

A. Background of the Study

Human activities have drastically altered numerous landscapes, primarily through the creation of infrastructure, agriculture, and cultivation, leading to significant deforestation and reduced biodiversity (Kennedy, 2019). These activities often result in a decline in the mean population size of native species due to genetic effects such as inbreeding, altered ecological dynamics, and habitat loss (Finger, 2014). To address these impacts, researchers have utilized datasets like the Global Human Modification (gHM) dataset to improve biodiversity conservation and estimate the extent of human terrestrial activity (Kennedy, 2019).

This data-driven approach aims to assess the modification of natural lands and promote sustainable land management practices. However, accessing this dataset and performing the necessary temporal and spatial computations requires intermediate to advanced coding knowledge. This technical barrier is highlighted by the lack of applications designed to support dynamic calculations using the scientifically cited gHM dataset. Consequently, researchers must invest significant time in learning cloud computing tools and programming languages, which can present a steep learning curve and hinder their research efficiency.

To overcome these challenges, the development of user-friendly software that addresses the current deficiencies in tools for analyzing the Global Human Modification dataset is essential. Such software would not only inform the general public but also empower researchers by streamlining the process of studying anthropogenic impacts on biodiversity. This, in turn, would contribute to more informed conservation strategies and a better understanding of how human activities affect natural ecosystems.

The utilization of geospatial analysis, especially in analyzing datasets such as the gHM dataset, plays a crucial role in comprehensively understanding the broader implications of human modification on landscapes and ecosystems. Geospatial analysis allows researchers to delve into the spatial and temporal patterns of human-modified areas, highlighting the interconnectedness between human activities and environmental changes. Traditional Geographic Information Systems (GIS) are fundamental tools in geospatial analysis and ecosystem conservation efforts. By integrating remotely sensed ecological data into GIS platforms, researchers can gain valuable insights into the dynamics of various ecological and Earth systems, particularly those exhibiting spatial or environmental connections (Yu, 2011).

However, while traditional GIS platforms offer powerful analytical capabilities, they come with challenges such as high costs and steep learning curves (Yu, 2011). Additionally, handling and integrating vast amounts of data from different sources can be complex and require manual effort. Despite these challenges, the integration of geospatial analysis techniques with datasets like the gHM dataset enhances our ability to assess the impacts of human activity on natural landscapes and ecosystems, reinforcing the critical role of data-driven approaches in conservation and environmental management (Wood, 2007). Hence, software engineers develop technologies in order to make geospatial analysis more user-friendly and approachable to the general public.

B. Statement of the Problem

Understanding the environment is crucial for our planet's health and the well-being of all living things. As environmental issues rise, spreading awareness about human impacts on nature becomes essential (Saura, 2004; Akindele, 2021). Google Earth Engine (GEE) is widely used in the Earth Science community for visualizations and large data computations, yet its potential for creating user-friendly apps to analyze anthropogenic stressors is underutilized (Mutanga, 2019). Notably, there is a lack of websites using GEE to showcase the Global Human Modification dataset or provide temporal data access and analysis on the Philippines. This gap forces researchers to learn coding and GEE utilization manually, creating a steep learning curve and limiting the accessibility of vital environmental data to policymakers, conservationists, and the public.

The absence of intuitive apps hinders public engagement and education on issues like urbanization, deforestation, and agriculture. This study aims to develop a web application with high usability for analyzing and visualizing spatial and temporal data from the Global Human Modification dataset, simplifying geospatial analysis and enabling researchers to study anthropogenic stressors. This will help researchers by providing them with an accessible tool to efficiently conduct geospatial analyses on the Global Human Modification Dataset, allowing them to focus on their core research activities rather than spending excessive time learning complex coding and data processing techniques.

C. Objectives

The aim of this study is to design and develop a web-app that aids in the analysis and visualization of the Global Human Modification dataset.

1. Create a usable system for analyzing and visualizing the Global Human Modification (gHM) dataset.
2. Successfully create tools and features that can be used to perform visualization and analysis.
3. Serve the gHM dataset and layers from a cloud server, ensuring access to the temporal and spatial data of anthropogenic stressors across terrestrial lands.
4. Successfully use GEE's cloud computing platform dynamically, allowing the web-app to query the GEE server through simple user inputs from the web-app.

D. Significance of the Study

The software developed offers significant support for research efforts regarding human land modification in The Philippines by improving the access to the Global Human Modification dataset. This will further aid studies related to analyzing trends in anthropological stress and its effects on nature. The software harnesses the extensive geospatial data available in Google Earth Engine, presenting a user-friendly interface. This facilitates researchers' and the general public's access to the necessary data without unnecessary complications, enabling them to focus directly on their conservation endeavors and sharing these endeavors to other people, in order to raise awareness.

Additionally, the software incorporates spatial and temporal visualization tools, aiding in comprehending intricate data quickly. This feature allows researchers to efficiently identify areas requiring urgent conservation measures and historic trends that can be utilized for further studies. Overall, the creation of this software holds immense promise for the protection of certain land masses, and boosting research efforts regarding the Global Human Modification dataset.

E. Scope and Limitation

The software created will only be limited to utilizing datasets and layers related to the anthropogenic stressors of the Global Human Modification dataset. In addition, the web-app will be limited to the latest data provided by the Global Human Modification dataset, and the resolution that the anthropogenic stressors will provide, which is 300m by 300m resolution (Kennedy, 2019). Lastly, the web app will only serve visualization and analysis capabilities in the country of The Philippines, and will only be usable through desktops and laptops.

REVIEW OF RELATED LITERATURE

A. Measures for Anthropogenic Stress and the Global Human Modification

Pham-Duc et al. (2023) noted a significant rise in Google Earth Engine (GEE) utilization since its inception in 2010, especially accelerating post-2018 across various scientific fields like agriculture (He et al., 2018) and hydrology (Sazib & Bolten, 2018). The surge in GEE's popularity is due to its versatility in handling diverse datasets globally. For instance, Theobald et al. (2020) showcased GEE's ability to analyze global land modifications from 1990 to 2017 using the Global Human Modification Dataset. GEE's accessibility via Google's App Engine has also enabled developers like Shringi et al. (2023) to create user-friendly web applications, such as interactive tree-height maps. Despite its potential, GEE's utilization for dynamically visualizing and analyzing the Global Human Modification dataset in the Philippines remains largely untapped. Developing a web application for this purpose could streamline researchers' efforts, allowing for more efficient investigations into anthropogenic stressors and yielding high-quality outputs.

B. The Direct Threats Classification v2

According to Salafsky et al. (2008), direct threats encompass immediate human actions or processes that cause or may cause harm to biodiversity targets, including activities such as unsustainable fishing or logging, which lead to the destruction, degradation, or impairment of ecosystems. These threats, also referred to as sources of stress or proximate pressures, can be historical, ongoing, or anticipated in the future. In some instances, natural phenomena are also considered direct threats.

The classification system for threats and actions utilized in the direct threats dataset was developed by merging and refining two pre-existing schemes from the Conservation Measures Partnership (CMP) and the IUCN Species Survival Commission. Though these schemes were developed independently and exhibit some differences, they were combined to create a unified global classification. The aim was to develop an ideal classification that is simple, hierarchical, comprehensive, consistent, expandable, exclusive, and scalable. This unified classification underwent extensive testing and revisions through real-world applications and feedback, culminating in the release of version 2.0.

Furthermore, the dataset that maps the degree of human modification of terrestrial ecosystems globally uses a direct threats classification based on an established approach applied at national, international, and global levels (Theobald et al., 2020). This classification system, detailed by Salafsky et al. (2008), categorizes anthropogenic drivers of ecological stress, or "stressors," into various types, encompassing activities that directly or indirectly alter natural systems. The classification system ensures simplicity by distinguishing between two spatial components—area of use and intensity of use. This distinction aids in accurately identifying and categorizing the types of human activities affecting ecosystems.

C. Application of The Global Human Modification Dataset on Google Earth Engine

The study conducted by Theobald et al. (2020) presents a comprehensive analysis of human land use modification on terrestrial lands from 1990 to 2015, with a supplementary estimate around 2017. The research reveals a significant loss of 1.6 million square kilometers (km2) of natural land during the studied period, indicating an annual depletion rate of 0.61% or roughly 178 km2 daily. This trend reflects an accelerating global rate of natural land loss over the past 25 years, with Oceania, Asia, and Europe experiencing the most substantial impacts, particularly affecting biomes such as mangroves and tropical forests.

The contemporary estimate highlights that 14.5% of lands globally have been completely modified by human activities, underscoring the magnitude of anthropogenic changes on terrestrial ecosystems. The datasets generated from this study exhibit a high level of detail (0.09 km2 resolution), temporal coverage, and incorporation of multiple change stressors, ensuring robustness and validation. These findings contribute significantly to the academic discourse on environmental conservation, mitigation strategies, and climate change adaptation, providing crucial insights for informed decision-making and policy formulation.

The methodology involves quantifying human modification (H) of terrestrial landscapes by considering factors such as the proportion of a pixel occupied by stressors (F), the probability of stressors occurring at specific locations (p(Cs)), and the intensity of stressors (I) calculated using the equation below.

$$H s = Fs * p(Cs) * Is,$$

These factors are combined using a fuzzy algebraic sum formula shown below to account for temporal changes between 1990 and 2015 and for current conditions, minimizing bias associated with non-independent stressors.

$$\mathrm{H} = 1 - \prod_{s=1}^{n} (1 - \mathrm{Hs}),$$

Human modification mapping covers all terrestrial lands excluding Antarctica, including areas inundated by reservoirs but excluding other water bodies. Water bodies are mapped using satellite data sources to differentiate between inland water bodies and ocean-land interfaces. Results are summarized across various geographic units using statistics like median (H med) and mean (H mean).

The formula below was used to capture the temporal change in the degree of human modification of terrestrial landscapes

$$Had = (Hu - Ht) / (u - t)$$

where u and t represent the years of the datasets (e.g., u=2015, t=1990), and u > t. This formula captures how H values change over time, emphasizing the mean statistic to better reflect changes in locations where H values have increased significantly due to factors like urbanization. The increase in H represents natural habitat loss, calculated by multiplying the per-pixel value by the pixel area and summing across a given unit of analysis.

Google Earth Engine served as the central platform for processing, modeling, and analyzing spatial data in the described project. It enabled the processing of diverse spatial datasets, including satellite imagery, using geodesic algorithms to calculate distances and areas accurately in decimal degrees. Additionally, Earth Engine facilitated modeling tasks such as projecting data to the Mollweide equal-area projection, simplifying calculations and ensuring precise spatial representation. All data sets and maps produced adhered to Google Earth Engine's terms of service, ensuring compliance and ethical data usage. Using Google Earth engines's cloud computing capability, the per pixel calculation for each formula was feasible.

In summary, Theobald et al. (2020) showcased the utility of Google Earth Engine (GEE) as a robust and versatile platform for spatial data processing, modeling, and analysis in academic and research contexts. The study's findings highlight the importance of advanced geospatial tools like GEE in advancing scientific knowledge and addressing complex spatial challenges effectively. The study also displayed how GEE is capable of performing per pixel calculations of the Global Human Modification dataset.

D. Google Earth Engine in Analysis and Software Creation

The Google Earth Engine (GEE) portal provides enhanced opportunities for undertaking earth observation studies. Established towards the end of 2010, it provides access to satellite and other ancillary data, cloud computing, and algorithms for processing large amounts of data with relative ease (Kumar & Mutanga, 2018). Furthermore, GEE has an independent Application Programming Interface (API) that allows users to create and run custom algorithms. The API allows for parallelized analysis so that many processors are involved in any given computation, thus significantly hastening the process considerably. This enables global-scale analysis to be performed with considerable ease, as compared to desktop computing. One such example is the work by Hansen et al. (2013) where the authors identified global-scale forest cover change between the years 2000 and 2012 using 654,178 Landsat 7 scenes (30 m spatial resolution), totaling 707 terabytes of data. A feat that should have required a powerful personal desktop, but was instead computed via GEE's cloud processing capabilities.

E. Vegetation Mapping and Monitoring

Several studies highlighted the utility of Google Earth Engine (GEE) in global vegetation mapping. The estimation of key biodiversity variables, such as Leaf Area Index (LAI), Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Fraction Vegetation Cover (FVC), and Canopy Water Content (CWC), was achieved using MODIS historical data. GEE, coupled with MODIS, facilitated planetary-scale vegetation mapping in Vietnam, Chinese nature reserves, the United States, and a Brazilian semi-arid landscape, showcasing its effectiveness in diverse ecosystems (Tsai et al., 2018). Additionally, GEE played a crucial role in rangeland monitoring, producing accurate pastureland maps in Brazil and mapping sea grasses in the Aegean and Iron seas (Goldblatt et al., 2017).

F. Landcover Mapping

Studies demonstrated GEE's capability in enhancing land cover mapping dynamics. Bayesian Updating of Land Cover (BULC) algorithm integration with Landsat data and GlobCover 2009 improved global output resolution from 300 m to 30 m in Brazil (Lee et al., 2018). GEE's cloud computing facilitated the analysis of huge datasets, including over 6000 Landsat images, for assessing land cover changes and their impact on surface urban heat islands. The platform addressed challenges like cloud cover and terrain effects in mapping land cover in a Chinese protected area. Additionally, high-resolution Sentinel 1 and 2 satellite data on GEE enabled the first detailed regional wetland map in Newfoundland, Canada (Hansen et al., 2013).

G. Agricultural Applications

GEE's cloud computing capabilities were leveraged for various agricultural applications. It enabled the estimation of crop yield, crop area mapping, and vulnerability assessments across different scales (He et al., 2018). Studies showcased GEE's effectiveness in fusing Terra MODIS data and Landsat for crop productivity estimation in the USA, mapping smallholder cropland areas in Mali using Worldview 2 data, and mapping cropland areas for the entire African continent using Sentinel and Landsat data. The platform's high processing capabilities optimized classification accuracy and yielded results comparable to FAO reports (Aguilar et al., 2018).

H. Disaster Management and Earth Sciences

Earth science research and disaster management studies worldwide utilized GEE. A snow-cloud hydro model was developed for environments in Chile, Spain, and the USA, forecasting monthly stream flows and mapping snow cover areas using MOD10A1 (Sproles et al., 2018). GEE facilitated the creation of a flood prevention and response system, integrating various datasets for managing Typhoon Soudelor in August 2015. The platform also assessed drought occurrence using soil moisture indicators at a global scale and was applied to study surface sediment monitoring, cloud masking, and mining area mapping (Sazib & Bolten, 2018).

I. Conclusion

The utilization of Google Earth Engine (GEE) has revolutionized spatial data analysis and mapping across diverse fields, as evidenced by the studies discussed. From environmental monitoring to disaster vulnerability mapping and conservation efforts, GEE's advanced capabilities in cloud computing, extensive data archives, and efficient processing tools have enabled researchers to address complex challenges and generate impactful insights.

Moreover, the validation of GEE's usage with datasets like the Global Human Modification Dataset highlights its robustness in handling diverse spatial and temporal data. The integration of GEE in disaster vulnerability mapping, conservation mapping, and land surface phenology estimation demonstrates its versatility and effectiveness in addressing critical environmental challenges.

In conclusion, Google Earth Engine has become a cornerstone in spatial data analysis, offering powerful tools that enable researchers to map, analyze, and visualize datasets with unprecedented accuracy and efficiency. Its impact spans across disciplines, driving innovation and facilitating informed decision-making in environmental conservation, disaster risk management, and land use planning. As GEE continues to evolve, its role as a transformative platform for spatial data analysis is poised to grow, contributing significantly to advancements in scientific research and environmental studies.

METHODOLOGY

A. APIs and Technologies

   a. Google Earth Engine API: This API will allow the usage of GEE processes client libraries and the publishing of the app itself.
   b. Leaflet: This JavaScript library will allow for custom map tools and map overlays.
   c. Google Cloud Platform: A cloud platform will host the map tiles for 1990 gHM to 2017 gHM.
   d. Render: A cloud deployment platform that offers an easy and efficient way to deploy Impact-Map.
   e. JavaScript and HTML: JavaScript is crucial for adding interactivity to web applications, while HTML provides the structure and content presentation.
   f. GeoJsons: The administrative boundaries used in this map are provided by Faeldon (2023). These GeoJsons are based on the Philippine Standard Geographic Code (PSGC) vector maps (shapefiles) provided by the Philippines Statistics Authority.
   g. ChartJs: A JavaScript library for creating interactive charts and graphs.
   h. QGIS: A platform used to create XYZ tiles or slippery map tiles.

B. Features

a. Landing page: The web-app will have a landing page that will contain the necessary background knowledge needed in using Impact-Map. This includes a user manual, brief descriptions of gHM, and scientific literature.

b. Single Page Web App (SPA): The web-app will be an SPA, not requiring the need for page navigation when accessing different features.

c. Generating the Average gHM of an area: This feature allows users to generate the average gHM of an area for the years 1990, 1995, 2000, 2005, 2010, 2015, and 2017. There are three ways of generating the average gHM:

    i. Drawing Tool: Users can draw polygons on the map, enabling the calculation of average gHM within the defined area.

    ii. Search Functionality: The search feature lets users find provinces, cities, and regions for gHM generation.

    iii. CSV Export: Users have the option to upload a CSV file containing LatLng bounds to generate gHM for specific areas.

d. Generating the gHM distribution of an area: This feature allows users to generate the gHM distribution of an area for the years 1990, 1995, 2000, 2005, 2010, 2015, and 2017. There are three ways of generating the average gHM:

    i. Drawing Tool: Users can draw polygons on the map, enabling the calculation of gHM distribution within the defined area.

    ii. Search Functionality: The search feature lets users find provinces, cities, and regions for gHM distribution.

iii. CSV Export: Users have the option to upload a CSV file containing LatLng bounds to generate the gHM distribution for specific areas.

e. Layer viewing: The web app will allow the users to visualize the gHM dataset in The Philippines. The layers will show the dataset for the years 1990, 1995, 2000, 2005, 2010, 2015, and 2017 in The Philippines.

f. Graphs: The web-app will display a line graph for the average gHM calculations and pie chart for the gHM distribution. This will aid in visualizing trends and analyzing patterns.

g. Sidepanel: The sidepanel will contain a color reference that will describe the gHM index of an Area and some additional information.

C. Computations

The average gHM computation and gHM distribution are based on the formulas outlined in the work of Theobald et al. (2020), where the average global gHM was calculated. To simulate this calculation, per-pixel computation for obtaining the average gHM was performed using Google Earth Engine's built-in libraries, including ee.Reducer.mean() and ee.Reducer.frequencyHistogram(). The proportions for the intensity of each stressor in the gHM are already computed in the study conducted by Kennedy et al. (2019) and Theobald et al. (2020), ensuring that the calculated average gHM accurately reflects the distribution of stressors across the Philippines.

Fig 1. Activity Diagram

RESULTS

A. Development

The landing page of the web app was created using HTML, while the web app itself was developed using HTML, JavaScript, and multiple libraries alongside community-sourced solutions. For instance, the drawing tools utilized in the UI were part of the default control features available in the Leaflet library. Community-sourced solutions were also employed for features such as the search function and its integration with GeoJSONs fetched from a Google Cloud bucket, which were then customized by the developer to fit specific use cases. Leveraging these community and default libraries facilitated the flexible integration of custom tools, enabling efficient searching of predefined administrative borders and drawing polygons for faster area capture.

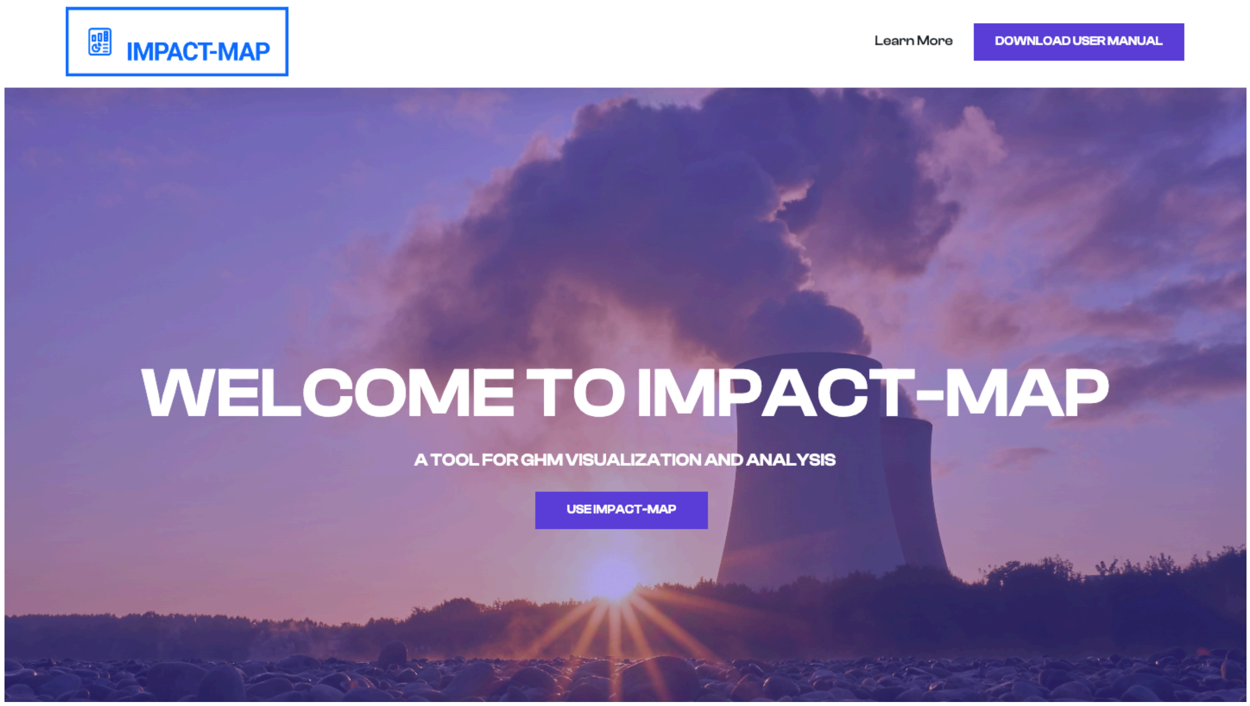

Fig 2. Landing Page

On the server side, the application was built using the Express framework, incorporating the Google Earth Engine (GEE) API. Express provided an easier setup for endpoints and environment variables, enhanced scalability, asynchronous calls, and deployment. By handling Earth Engine processes server-side, the burden on clients was reduced, allowing multiple users to perform calculations simultaneously.

An authoritative account setup handled GEE API calls on behalf of the clients, eliminating the need for users to log in, thus offering a more convenient, open-access experience. This setup also abstracted the server-side formulas and calculations, protecting the algorithm from malicious alterations. Additionally, GEE has a JavaScript library which allowed for a better coding experience and implementation of logic and structures. However, the GEE API has Quotas such as having a maximum of 40 concurrent requests and 6000 requests per minute. Nonetheless, these limits were not reached during testing since there were only a limited number of concurrent users and the calculations performed did not perform constant requests from the GEE API.

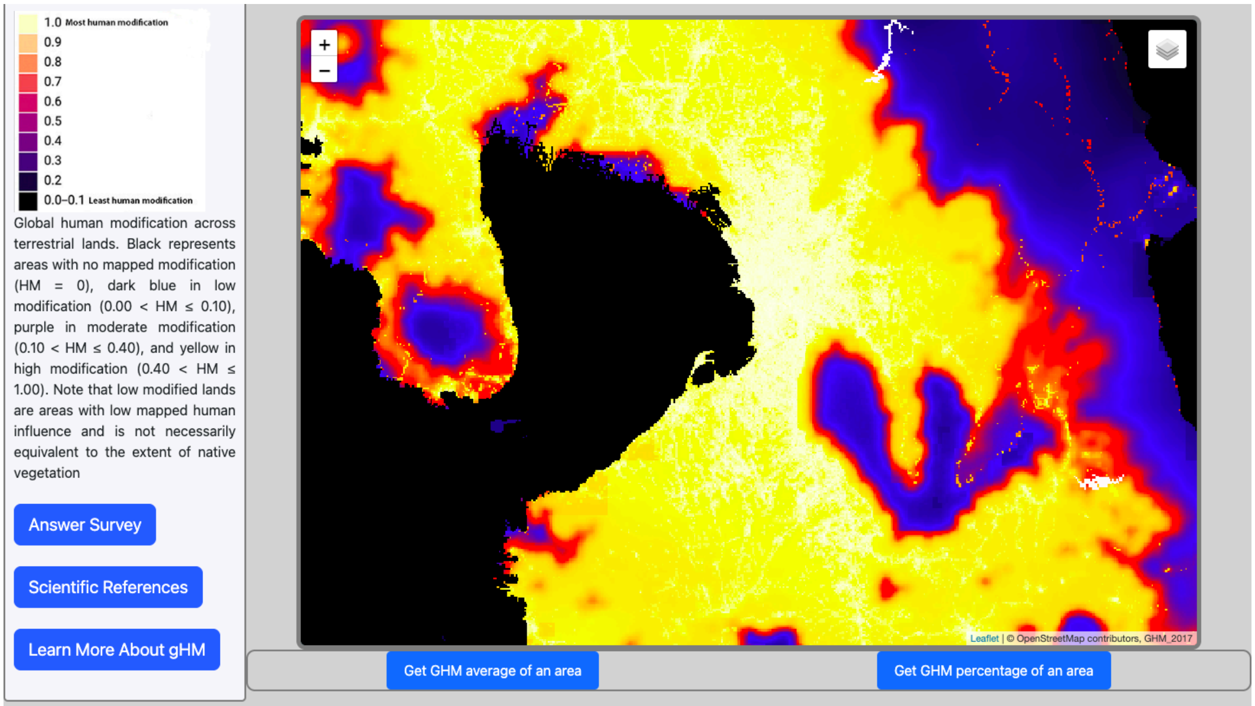

Fig 2. Impact-Map gHM layer display

Additionally, slippery map tiles were created to efficiently display the Global Human Modification (gHM) layers. The XYZ tiles were generated by extracting the dataset directly from the latest TIFF files provided by Theobald et al. (2020), and converting these files into XYZ tiles using QGIS. This conversion enabled dynamic pixel rendering and efficient load times per zoom level. The XYZ tiles were served from a free tier Google Cloud bucket and accessed directly by the Leaflet library, streamlining the process of displaying map tiles. Similarly, the GeoJSONs for the administrative boundaries were served from a cloud bucket and accessed via AJAX calls, ensuring efficient data retrieval and rendering.

Lastly, the web-app was deployed using a Render on a free-tier plan, which provided testers with the capability to use it on their own devices and in the comfort of their own homes.

This approach enabled broader public access to the web-app, significantly increasing its reach. By leveraging Render's deployment platform, the web-app benefited from enhanced scalability, reliable performance, and automatic scaling, ensuring that it could handle varying levels of user traffic without compromising on speed or functionality.

B. Web-App

The web- App had the following feature successfully implemented:

1. Landing page: Users can view a responsive landing page and the resources written on the page.
2. Web-app: Users can access the web-app from their desktops and laptops.
3. Map container: The map is interactive and is capable of displaying the different gHM layers in The Philippines.
4. Tools: The drawing tool is functional and the search tool is capable of searching for cities, regions, and provinces.

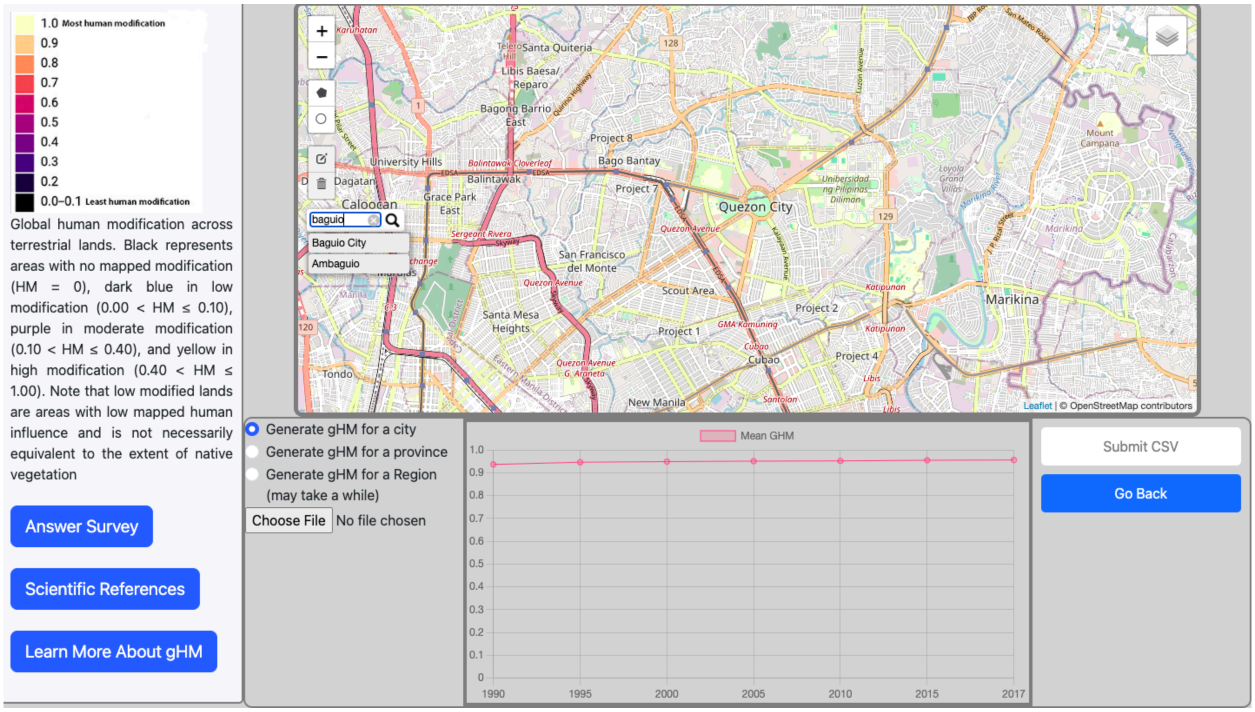

Fig 4. Search Feature

5. gHM generation: The average gHM and the gHM distribution is processed successfully by the server and the GEE API.

6. Graphing: Graphs are successfully created from the data received from the server and displayed on the client side.

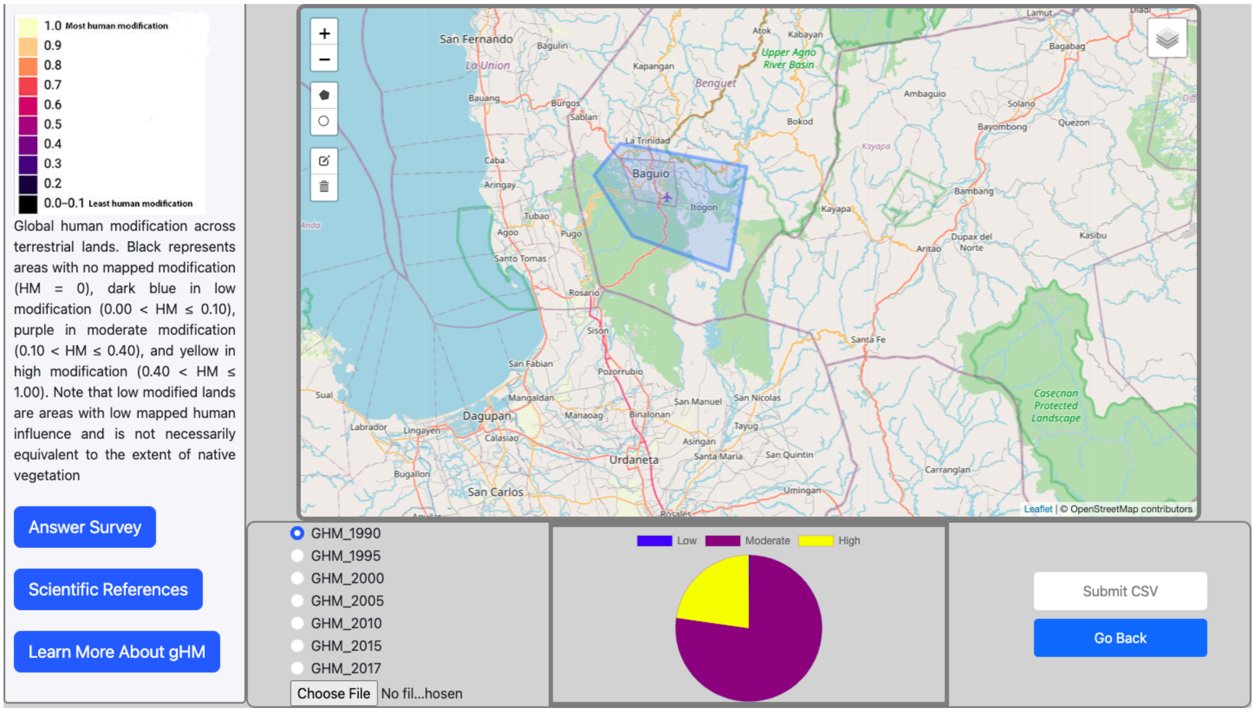

Fig. 5 Pie chart example

7. CSV importing: Users can import a CSV and the LatLng bounds in the CSV will be drawn on the map.

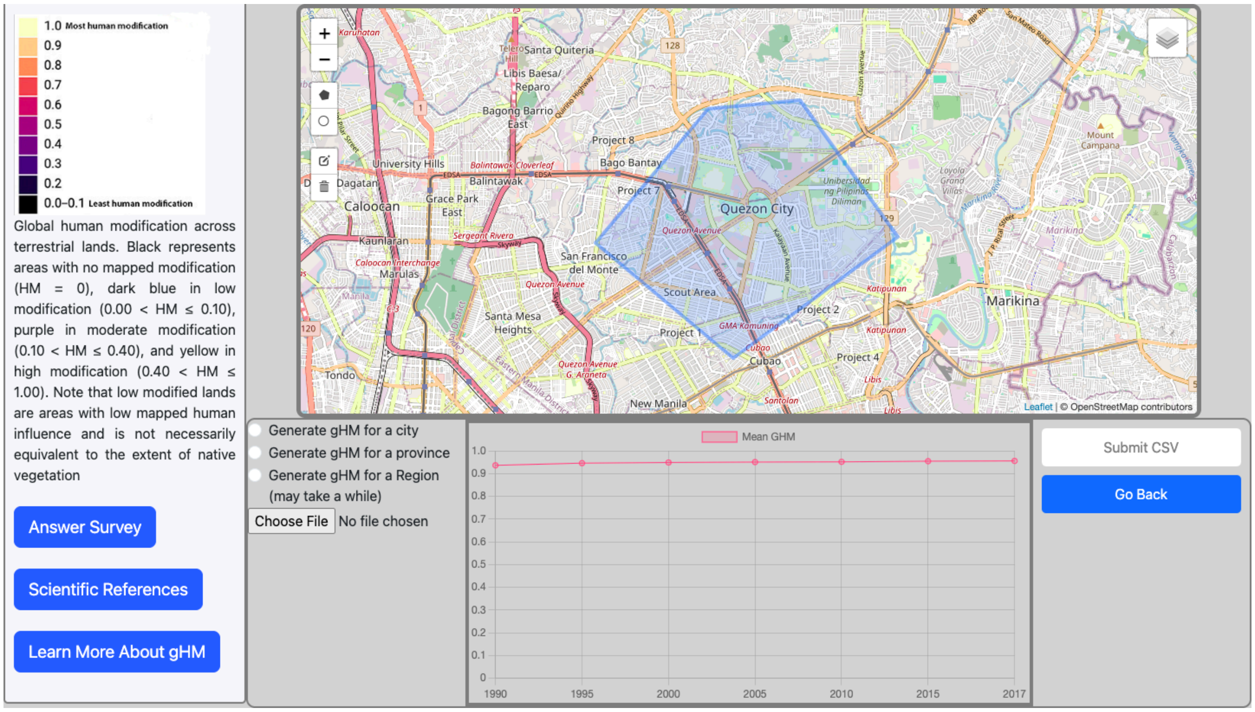

Fig 6. Drawing example

C. Testing

The Impact-Map assessment included 30 participants, comprising students specializing in ecology, wildlife, and forestry, alongside researchers. These participants were chosen for their active engagement in conservation research and their focus on studying anthropogenic stressors.

The assessment used the System Usability Scale (SUS) to gauge the usability of the web application. The SUS uses a questionnaire with 10 statements that evaluates an application's usability. Participants would rank these statements using a 5-point Likert scale spanning from "Strongly Agree" to "Strongly Disagree". The statements in the questionnaire were as follows:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.

4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very awkward to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
4	2	4	2	4	3	4	2	5	2
4	2	5	1	5	2	5	2	4	2
5	2	4	2	5	1	5	1	4	2
4	1	4	2	4	1	4	1	4	4
5	2	5	1	4	2	4	2	4	2
4	1	5	2	4	1	4	1	4	2
4	1	5	1	4	2	4	2	5	3
4	2	4	2	4	2	4	2	4	2
5	1	5	1	5	1	5	1	5	2
5	2	4	2	4	2	4	2	5	2
4	2	4	1	4	2	4	2	4	3
2	2	4	2	4	2	4	2	4	2
4	1	5	2	5	2	5	2	4	2
4	1	4	1	5	2	5	2	5	3
4	2	5	1	5	1	5	1	5	2
4	2	4	2	4	2	4	2	4	3
5	3	5	1	4	1	5	1	5	2
5	1	5	1	4	1	5	2	5	2
4	3	5	2	5	1	4	2	4	3
5	1	5	2	5	1	4	2	5	3
								Mean SUS score:	82.75

Fig 7. SUS results

Individual scores were used to calculate the Average SUS score, which was computed to 82.7, indicating that the web application has an excellent usability score. Table 1 shows the average SUS scores per participant.

CONCLUSION AND RECOMMENDATIONS

The development of Impact-Map, a web app aimed at displaying Global Human Modification (gHM) layers for The Philippines, was successful. Created using HTML, JavaScript, and multiple libraries, the application leverages community-sourced solutions to enhance functionality. The drawing tools in the UI were implemented using the Leaflet library, and the search function integrated GeoJSONs from a Google Cloud bucket. These elements facilitated efficient searching of predefined administrative borders and drawing polygons for area capture. On the server side, the application was built using the Express framework and the Google Earth Engine (GEE) API, ensuring scalability and the ability to handle asynchronous calls. By offloading Earth Engine processes to the server, the burden on clients was reduced, allowing multiple users to perform calculations simultaneously without needing to log in, thus offering a more convenient, open-access experience. GEE’s JavaScript library also improved the coding experience, although API quotas were not a limitation during testing. Additionally, XYZ tiles were generated from the latest TIFF files provided by Theobald et al. (2020) and served from a Google Cloud bucket, ensuring efficient load times per zoom level. The GeoJSONs for administrative boundaries were also efficiently served and rendered via AJAX calls. The deployment on Render's free-tier plan allowed for broader public access. This deployment platform facilitated continuous updates and ensured the app could handle varying levels of user traffic without compromising performance.

The web app's usability was assessed using the System Usability Scale (SUS) with 30 participants from fields such as ecology, wildlife, and forestry. The web app achieved an excellent average SUS score of 82.7, indicating high usability. Key objectives of the web app included creating a usable system for analyzing and visualizing the Global Human Modification (gHM) dataset, ensuring the web app had accessible tools, serving the gHM dataset and layers from a cloud server, and using GEE's cloud computing platform dynamically. These objectives were met as follows: The interface was designed using HTML, JavaScript, and the Leaflet library, enabling users to interact with the gHM dataset easily. The integration of community-sourced solutions for drawing and searching tools further enhanced the user experience.

The web app was developed to cater to users with varying levels of technical expertise by incorporating drawing tools and a search function that could handle GeoJSONs from a Google Cloud bucket. This ensured that even users with minimal technical skills could navigate and utilize the app effectively. The gHM layers were converted into XYZ tiles using QGIS and served from a free-tier Google Cloud bucket. This approach ensured access to comprehensive temporal and spatial data on anthropogenic stressors across terrestrial lands. By leveraging the Express framework and GEE API, the web app allowed users to query the GEE server through simple inputs. This dynamic interaction was achieved without placing excessive demands on the client side, ensuring a smooth and efficient user experience.

Future improvements could include expanding the scope of the application beyond its current geographical focus. Additionally, a feature to provide a more in-depth analysis of the different stressors contributing to the cumulative GHM score could be implemented in future versions. This individual measurement can be expressed in graphs, allowing researchers to assess each stressors. This would offer valuable insights into the individual impact of each stressors, helping to better understand and mitigate the factors contributing to human modification.

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