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# The Greenhouse Gas Emissions Estimates of Hydropower Reservoirs in Vietnam Using G-res Tool: Bridging Climate Change Mitigation with Sustainability Frameworks



INITIATIVE ON  
Low-Emission  
Food Systems

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# Summary

Quantifying greenhouse gas (GHG) emissions in hydropower reservoirs is linked with national and international sustainability objectives. Deploying scalable and effective cloud-based technologies improves the accessibility, reproducibility, and timeliness of the quantification process. This novel strategy promotes global sustainability in the hydropower industry while making it easier to comply with environmental regulations. It can promote informed decision-making, increase transparency, and expedite the transition to clean energy sources. Considering the use of cloud computing in GHG quantification can support global efforts to mitigate climate change and advance the development of hydropower systems into more sustainable global infrastructure. Earth Observation (EO) data with cloud computing facilities such as Google Earth Engine (GEE) and G-res (an online tool by the International Hydropower Association) can help fill in the missing data gaps and calculate GHG emissions from hydropower reservoirs in Vietnam following IPCC recommendations for estimating GHG emissions. Seven hydropower reservoirs (Ban Ve, Binh Dien, Ho Ham Thuan, Ho Hoa Binh, Ho Song Hinh, Thac Ba and Yali) from different parts of Vietnam were selected as test cases for calculating GHG emissions using the G-res tool. The initial results from the analysis show that the Binh Dien reservoir reports the highest GHG aerial emission rate per year, while the lowest has been observed for the Thac Ba reservoir. Similarly, the highest emission rate has been observed for the Ban Ve reservoir, while the lowest has been recorded for the Thac Ba reservoir. The initial results reported here provide an understanding of GHG emissions from the hydropower reservoirs (test cases) and are needed to be verified with the respective reservoir authorities for actual emissions.

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# 1 Introduction

Natural and artificial water reservoirs can act as sources of greenhouse gas (GHG) emissions, contributing to climate change. Understanding and mitigating GHG emissions from large hydropower reservoirs can play a crucial role in achieving sustainable and low-carbon power generation. The multipurpose reservoirs serve various purposes, such as water storage, flood management, irrigation, along with power generation. However, the decomposition of organic matter in these reservoirs leads to the release of GHGs, primarily carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>), which are potent to escalate global warming (Yang et al., 2014). The GHG reduction potential of global hydropower is estimated to be around 8% of total anthropogenic emissions (Scherer and Pfister, 2016).

Several pathways contribute to their generation, including diffusion from the reservoir surface, bubble formation, and degassing in the downstream flow (Figure 1). Emissions from a growing number of artificial reservoirs are considered anthropogenic sources of emissions. More than 60 thousand large dams exist in the world (Adamo et al., 2020). Hydropower generation is a typical application of large artificial reservoirs, with power plants requiring substantial reservoirs for efficient operation. The International Hydropower Association (IHA) reports that East Asia and the Pacific have the highest installed capacity and power generation, closely followed by North and Central America, driven by the region's focus on clean and sustainable energy in response to climate change and increased energy demands. In contrast, Africa lags in terms of large-scale installations and power generation capacity (IHA, 2021).

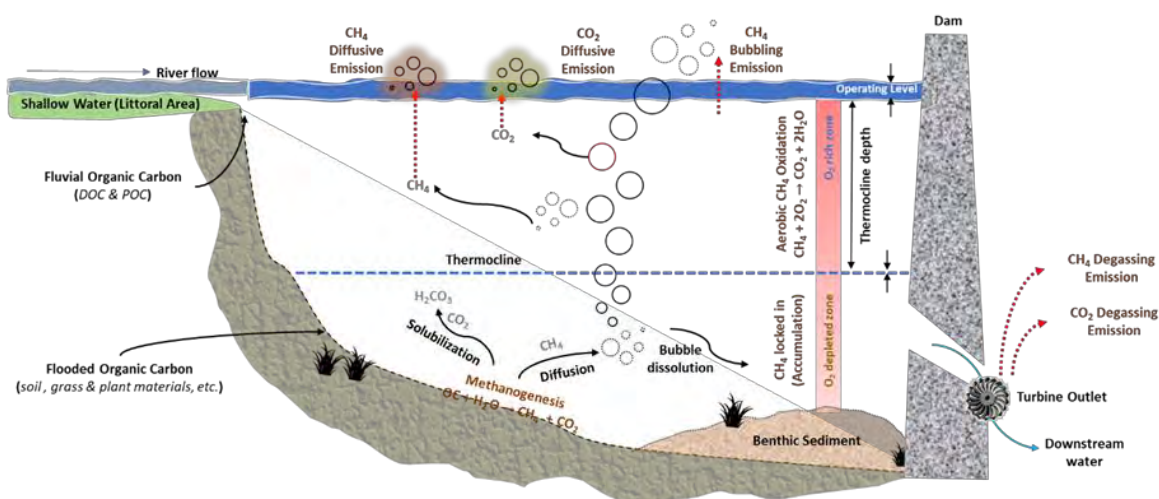


Figure 1. Schematics of large hydropower reservoirs and pathways leading to GHG emissions (CO<sub>2</sub> & CH<sub>4</sub>)

While hydropower is considered a clean, renewable energy source, it often requires building a dam (physical structure) that helps to collect water in a reservoir (behind the structure). The process of constructing dams leads to emissions due to various construction activities, but water reservoirs forming behind dams are often overlooked sources of continuous emissions. The movement of GHG emissions from hydropower reservoirs into the atmosphere is a complex process influenced by a combination of several factors. Mapping and understanding the impacts of these factors is crucial in mitigating GHG emissions during hydropower project development, especially in the context of climate change mitigation, low carbon development and energy transition goals. Factors that influence GHG emissions from hydropower reservoirs can be categorized into five main categories - (1) climatic drivers (temperature, wind speed, and precipitation), (2) water environmental factors (dissolved oxygen, organic matter, and nutrients), (3) reservoir and catchment characteristics (operating level, latitude, reservoir age, urbanization levels), (4) hydrological conditions (sedimentation), and (5) biological conditions (vegetation cover and microbial activity) (Rosa and Santos, 2000; Barros et al. 2011; Deemer et al., 2016). Thus, quantifying GHG emissions from large hydropower reservoirs involves considering various drivers, including the type and quantity of flooded vegetation, water temperature, duration of inundation, reservoir size and depth, location, land use changes, and other environmental conditions. However, quantifying GHG emissions is challenging given data availability constraints for reservoirs with limited biophysical and environmental inputs. Earth Observation (EO) data with cloud computing facilities such as Google Earth Engine (GEE) and G-res (an online tool by IHA) can help fill in the missing data gaps and calculate GHG emissions from hydropower reservoirs following IPCC recommendations.

Understanding the interplay of the driving factors and their effects on GHG emissions from large hydropower reservoirs is a prerequisite for developing effective mitigation strategies. By considering a combination of climate, water, reservoir, catchment, hydrological, and biological factors, it is possible to manage hydropower development for optimizing GHG emissions, supporting sustainable energy practices and implementing global climate action agenda at the sub-national level towards achieving Sustainable Developmental Goals (SDGs) 7, 12, 13, 16 and 17.

## 2 Overview of Global Hydropower Reservoirs

Hydropower is the largest renewable source of power generation, supplying more electricity than wind, solar thermal, solar photovoltaic, tide/wave/ocean and geothermal sources combined (2020 data; IEA, 2023). As such, sustainable hydropower projects can contribute to carbon reduction objectives while enhancing variable renewables with flexibility and storage. Hydropower, a pivotal source of electricity generation, has emerged as a prominent contributor to the global energy landscape. Accounting for approximately one-sixth of the world's electricity production, its significance surpasses that of nuclear energy and other renewable sources combined. This prevalence spans more than 150 nations, underscoring its widespread adoption and utilization globally. An additional testament to the extensive imprint of hydropower lies in the vast expanse of hydropower reservoirs, covering approximately  $3.4 \times 10^5$  sq. km (Barros et al., 2011). This substantial coverage encapsulates nearly 20% of the total global reservoir area, a noteworthy indication of the scale and impact of hydropower initiatives worldwide (Barros et al., 2011).

In 2021, global installed hydropower capacity reached almost 1400 GW, the highest among all renewable energy technologies, a noteworthy indication of the scale and impact of hydropower initiatives worldwide (IEA, 2022). As per the World Hydropower Outlook 2023, the leading contributors to this hydroelectric dominance include China, Brazil, United States, Canada, Russia and India, collectively dominating the top ranks in hydropower generation (IHA, 2023). Furthermore, recent statistics (Figure 2) as of 2022 reveal Vietnam's ascent into this echelon, firmly positioning itself among the top twenty producers of hydropower, contributing 1.2% of the global hydropower share (IHA, 2023), consolidating its role among the global energy leaders.



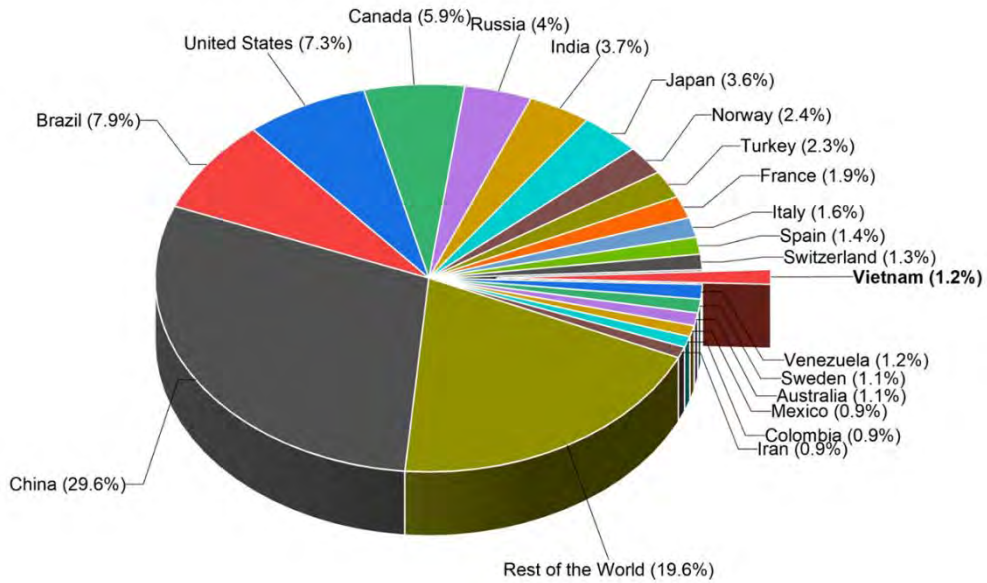


Figure 2. Hydropower installed capacity (GW; 2022) of the top 20 hydropower producers and the rest of the world, including pumped storage  
(Data source: IHA 2023)

It is becoming increasingly evident that the future of renewable hydropower will experience a fundamental change. Hydropower will continue to be valued for its flexibility and ability to support the enormous rise in wind and solar energy required to reduce global warming by providing low-cost, base-load electricity in many markets (IHA, 2021).

# 3 Bibliometric Analysis

Bibliometrics is a field of study that uses publications' bibliographic data and citation relations to evaluate and reveal the structure of a research field (Mallik and Ghosh, 2018). This section of the report outlines a bibliometric study conducted to assess the research landscape of GHG emission in relation to hydropower reservoirs applications within advanced geospatial research. Utilizing the SCOPUS database and VOSviewer (Van and Waltman, 2013) for data visualization and analysis, publication trends and thematic clusters in this interdisciplinary field were identified. SCOPUS is one of the largest abstract and citation databases for academic literature, which makes it a good source for articles for bibliometric studies (Burnham, 2006; Chowdhury et al., 2023). Information was retrieved from the SCOPUS database using a structured query of keywords related to greenhouse gases and hydropower reservoirs (( "GHG" OR "Greenhouse gas" OR "Green house gas" ) AND ( "Hydropower" OR "Hydroelectric" OR "Hydro-power" OR "Hydro electric" OR "Hydropower" OR "Hydro-electric" )). The search yielded a dataset that was then analyzed using VOSviewer to create network visualizations of co-authorship, co-citation, and keyword co-occurrence.

A reserved key for Scopus, TITLE-ABS-KEY, looks for a term in document titles, abstracts, and keywords. The information was taken from the "Scopus Preview database" for the years 1989–present (in December 2023). Several search strings have been created by combining crucial phrases legitimately connected to the 'reservoir' and 'greenhouse gas' used to find the publishing data on this subject. Initial findings indicate a robust increase in publications over the last decade, signalling growing interest in the field. The co-authorship analysis uncovered several key research clusters, while co-citation networks revealed foundational papers and emerging research fronts. Keyword analysis highlighted prevalent themes such as "greenhouse gases", "GHG emission" and "hydropower".

The analysis shows that researchers from 113 countries have contributed to the exploration of GHG emission and its twinging effects with hydropower over a span of more than 30 years (Figures 3 and 4). United States exhibits the highest number of scientific publications, accounting for 251 articles in the mentioned span. China shows the second highest number of publications (213), followed by Brazil (168), Canada (137) and India (117) in this research domain, securing a position among the top five countries in the world. 74 countries out of 113 countries have just published less than 10 articles over the studied period and in this domain of investigation. Vietnam, being in the top twenty hydropower producers globally, has contributed to only four research publications until the analysis period, providing a new avenue for forthcoming research to address climate action focusing on cleaner energy, sustainability, and a greener future.

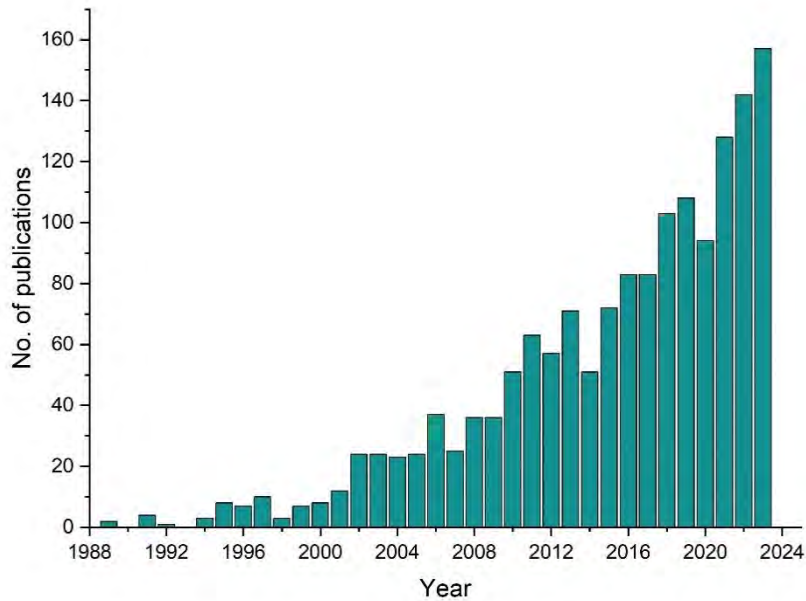


Figure 3. Number of publications during 1989-2023

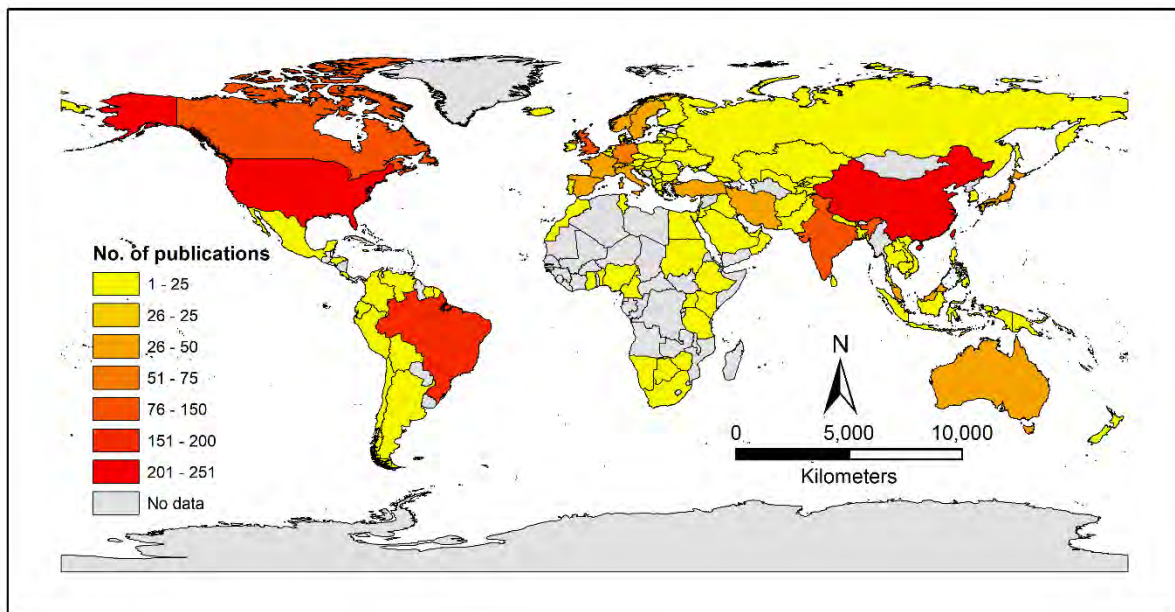


Figure 4. Number of publications globally during 1989-2023

The network visualization analysis (Figures 5 and 6) was created using the 1565 research articles downloaded from the Scopus database and VOSviewer software based on the co-occurrences and country-wise co-authorship analysis. The number of indexed keywords based on the articles obtained from the 1565 articles was 7358, out of which 88 keywords were utilized to create the network diagram based on 35 co-occurrences considering the top 2% of co-occurrence that occasioned 4 clusters and 3478 links. The keywords were then standardized using the standard nomenclature and generalization, such as *greenhouse gases* and *greenhouse gas* were considered as GHG.

Likewise hydroelectric, *hydro electric*, *hydro-electric*, *hydro power*, *hydro-power* were standardized to hydropower. A few more keywords were similarly standardized. The number of publications over the years (Figure 4) matched well with the countries of co-authorship, bringing out the top five co-authored countries as United States, China, Brazil, Canada, and India based on the size of circles in the network diagram (Figure 6).

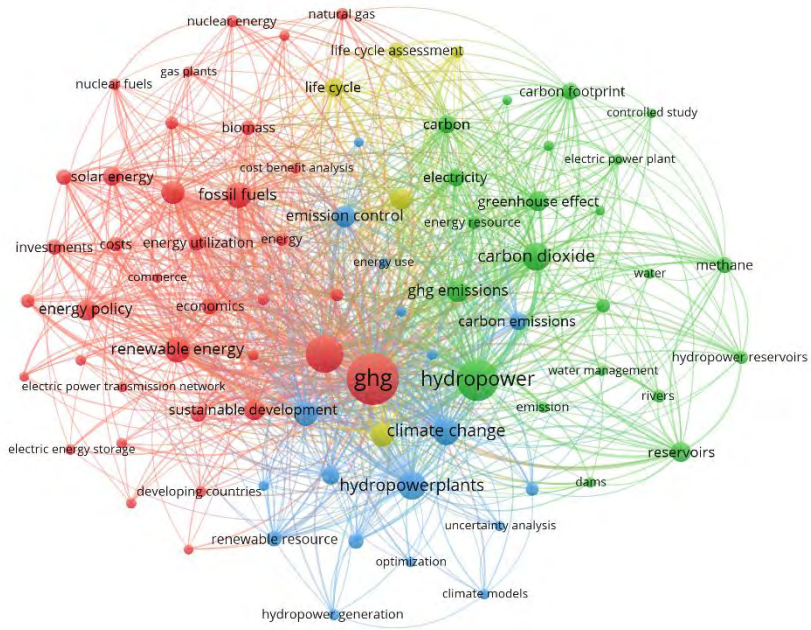


Figure 5. Network visualization diagram based on 35 co-occurrences of indexed keywords.

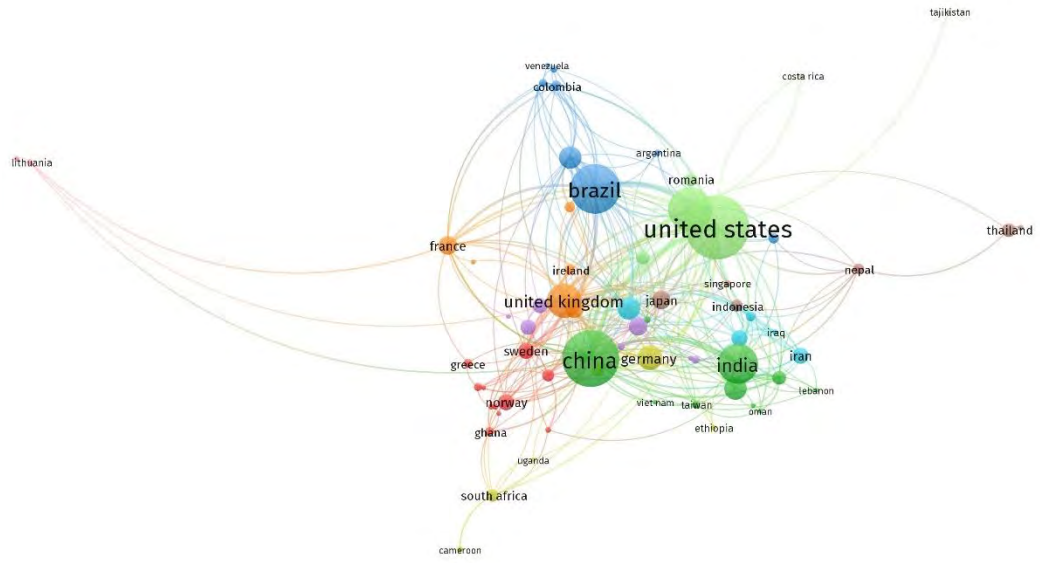


Figure 6. Network visualization diagram based on country-wise co-authorship.

In recent years, quantifying GHG emissions from hydropower projects has become an emerging point of research in Vietnam. Three pivotal studies that delve into the intricate relationship between hydropower development and GHG emissions in Vietnam have been highlighted in this section. Räsänen et al. (2018) evaluated GHG emissions from hydropower reservoirs in the Mekong Basin, including Vietnam. Amidst rapid hydropower expansion, this study quantified emissions from 141 existing and projected reservoirs using statistical models based on global data. Results showed a broad emission range (0.2-1994 kgCO<sub>2</sub>eMWh<sup>-1</sup>) over the reservoirs' 100-year lifespan, with a median of 26 kgCO<sub>2</sub>eMWh<sup>-1</sup>. Notably, irrigation-facilitating hydropower reservoirs exhibited significantly higher emissions, over 22,000 kgCO<sub>2</sub>eMWh<sup>-1</sup>. This study underscores the importance of considering climatic impacts alongside other effects of hydropower development. Nguyễn et al. 2017 focused on the Son La hydropower reservoir in Vietnam, employing regression analysis to correlate water quality metrics with GHG emissions. The study identified key factors influencing CO<sub>2</sub> (temperature, dissolved oxygen, alkalinity, pH) and CH<sub>4</sub> emissions (temperature, chemical oxygen demand, pH). Regression models based on actual water quality measurements provided accurate CO<sub>2</sub> and CH<sub>4</sub> emissions predictions, with correlation coefficients of 0.93 and 0.92, respectively.

The World Bank (2017) provided a comprehensive overview of GHG emissions from reservoirs, discussing the CO<sub>2</sub> and CH<sub>4</sub> cycles, spatial variation, and atmospheric interactions. The report included guidelines for dam project preparation, from initial screening to post-impoundment monitoring. It highlighted the application of the G-res tool and EO data for demonstrating emission estimates of the Trung Son reservoir, and the G-res tool with EO data for demonstrating emission estimates of the Trung Son reservoir in Vietnam. The report also included detailed input data and quantified emissions, offering valuable resources for future research. These studies underscore the need for comprehensive evaluations of climatic impacts in hydropower development, which are imperative to align with emission reduction goals, SDGs, and climate justice imperatives through integrating advanced technological tools, ensuring a holistic approach, and fostering equitable benefits. This conscientious integration of environmental considerations will not only act as a stepping stone in the pressing debate of climate action but also align with international efforts, promoting responsible and inclusive energy solutions in the pursuit of a resilient, low-carbon future.

# 4 Hydropower Energy Odyssey in Vietnam

Vietnam's journey towards hydropower energy has been motivating, involving major advancements in energy production, irrigation, legislation, policy, and the execution of large multipurpose hydropower projects. The nation has built a large network of dams and power plants by deliberately using its river systems (Nguyen et al., 2018). Vietnam, a nation endowed with abundant water resources, saw the opportunity to use hydropower to meet its expanding energy needs while tackling energy demand. Vietnam's hydropower journey has come to be accompanied by multipurpose hydropower projects representing a holistic approach to resource utilization (Bao et al., 2017). The upward trajectory is best illustrated by the Srepok 3 and 4 projects, which combine flood management, irrigation, and energy production (Ty et al., 2012). The hydropower projects at Son La and Hoa Binh stand out among them as outstanding accomplishments that significantly improve the nation's energy grid (Gencer and Spencer, 2012). These initiatives offer a reliable supply of electricity and substantially lessen Vietnam's dependency on fossil fuels, in line with international efforts to combat climate change (Urban et al., 2018).

Vietnam's hydropower journey has prioritized irrigation, meeting agricultural supply-demand equilibrium and improving food security in parallel with energy generation. Vietnam's dedication to striking a balance between its energy needs and the sustainable management of its water resources is demonstrated by this dual-purpose strategy (Batra, 2023). Vietnam's hydropower journey (Figure 7) is projected to stay strong in the years ahead as the government leadership delves into cutting-edge technologies and global partnerships to strengthen and maximize energy production and water management (Ha-Duong, 2023). A change towards a diverse and sustainable energy portfolio is imminent with the addition of renewable energy sources, such as solar and wind, to the hydropower environment (Kunkel et al., 2012). Vietnam's hydropower story is a strategic development that includes legislation, hydropower multipurpose projects, irrigation, energy production, and policy (Middleton et al., 2012). The nation is steadfast in its commitment to a sustainable and inclusive energy future even as it negotiates the challenges of striking a balance between environmental stewardship and economic growth (Waibel, 2010). This is attributable to the insights acquired and the progress accomplished during this voyage, guaranteeing the prudent use of hydropower. The legislative structure encourages transparency and accountability within the sector, making environmental impact evaluations and community consultations integral to project procedures (Huu et al., 2013).

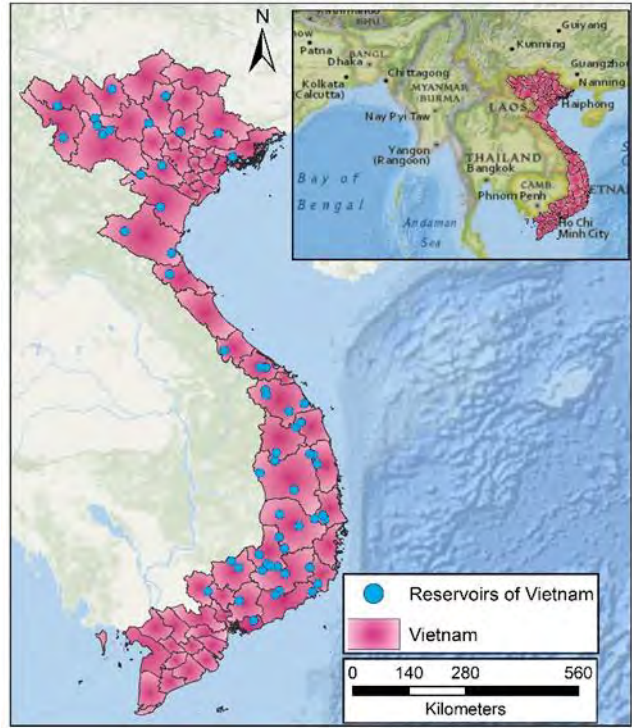


Figure 7. Location of Large Hydropower Dams in Vietnam (created by authors)  
*(Data source: GeoDAR Database on Dams version 11, 2022)*

# 5 Quantification Techniques

## Using EO Data: GHG Emissions from Hydropower Reservoirs

Several physical methods are available for assessing GHG emissions, including bubbling traps, ultra-portable GHG analyzers, infrared gas analyzers, eddy covariance, Gas chromatography, and floating chambers (Rosa and Santos, 2000; Kumar et al., 2021). However, these physical methods for estimating GHG emissions face limitations. They often require significant labour, resources, and on-site measurements, which can be time-consuming and expensive. These methods may not capture emissions comprehensively over large areas or extended periods due to spatial and temporal constraints, potentially leading to inaccuracies. Additionally, their invasive nature, requiring direct access to the sites, can disrupt ecosystems or industrial processes. They also might lack the ability to capture emissions at fine scales or resolutions, posing challenges in obtaining detailed and accurate data.

In contrast, integrating earth observation data with remote sensing methods offers wider spatial coverage, frequent monitoring, and the ability to capture emissions from inaccessible or remote areas, presenting a more holistic view of emissions while overcoming some limitations of physical methods. Earth observation data and modelling techniques emerge as a powerful lens, enabling researchers to explore, comprehend, and map the intricate tapestry of greenhouse gas dynamics across diverse landscapes and ecosystems, fostering a more profound understanding essential for informed environmental stewardship and global sustainability efforts.

The Intergovernmental Panel on Climate Change (IPCC) provides guidelines for estimating GHG emissions from large reservoirs (Figures 8 and 9). These guidelines recommend various methods to measure and estimate emissions. Direct measurements involve collecting water samples from the reservoir and analyzing them for dissolved CO<sub>2</sub> and CH<sub>4</sub>. Traditionally, GHG emissions from reservoirs are measured using sensors and bubble traps positioned at the water-air interface. These measurements need to consider spatiotemporal variations in emissions, which can vary significantly depending on the season and location (Räsänen et al., 2018).



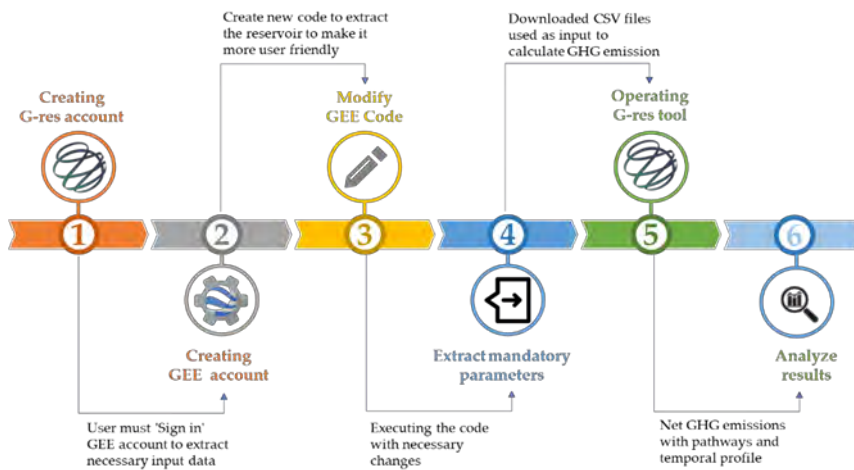


Figure 8. Methodology for estimating GHG emissions.

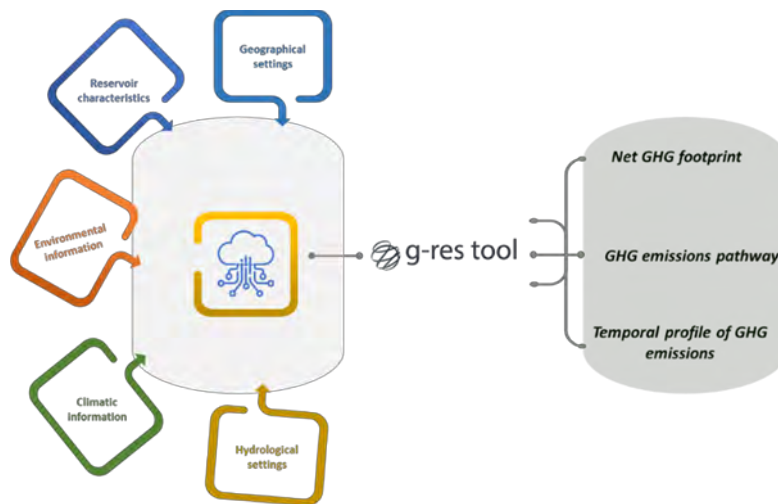


Figure 9. Approach to calculate GHG emissions using GEE and G-res tool.

In addition to direct measurements, statistical models are used to estimate GHG emissions from reservoirs (Abril et al., 2005). Such models consider factors such as flooded organic matter, water temperature, and environmental conditions to provide estimates of emissions. The complexities in measurement and modelling have hindered research efforts in this field. G-res tool has been developed to address these challenges (Prairie et al., 2021). G-res employs advanced modelling techniques that consider factors like hydrodynamics, sedimentation, and the carbon cycle to provide more robust estimations of GHG emissions from reservoirs using EO data via cloud platforms like GEE. EO data entails collecting data related to land cover, temperature, etc. These data types are then analyzed using algorithms and models to estimate the amount of flooded organic matter and assess the potential emissions of GHGs. Thus, integrating the G-res tool with the GEE platform enables better understanding and decision-making regarding reservoir management and mitigation strategies.

GEE, a cloud-based platform (Gorelick et al., 2017), contains valuable capabilities for environmental monitoring and modelling (Bhattacharya et al., 2022). It provides access to a large amount of remote sensing data, including satellite imagery, which can be used to analyze land cover changes and vegetation dynamics. Using GEE, researchers can estimate environmental and climatic drivers of potential CH<sub>4</sub> emissions resulting from its decomposition. The platform can also help to estimate the size and volume of water reservoirs, providing an assessment of how much water they can hold and the extent of their potential CO<sub>2</sub> emissions. Based on IPCC recommendations, the G-res tool is designed to estimate the net GHG footprint of reservoir creation (Prairie et al., 2021). It serves as a decision-making tool by facilitating the communication of potential impacts and identifying areas where mitigation measures may be necessary. The tool utilizes input data that does not require on-site measurements, leveraging parameters that can be accessed using specific codes in GEE. By combining the capabilities of the G-res tool and GEE (Figures 8 and 9), researchers and stakeholders can enhance their understanding of the environmental implications of reservoir development through informed decision-making and targeted interventions to support sustainable management practices.

Reliable estimation of GHG emissions from large reservoirs (World Bank, 2017) can provide new opportunities for developing effective climate change mitigation strategies through sustainable reservoir management. Utilizing tools like GEE and the G-res tool, stakeholders can understand linkages between factors such as vegetation cover, water temperature, reservoir characteristics and GHG emissions and make informed decisions to minimize the environmental impact of large reservoirs through evidence-based mitigation measures.

All the methods and data used in this study are based on IPCC-recommended guidelines (G-Res-Tool-User-Guide-v3.2)<sup>1</sup>. The data table that has been used in this study is provided in Table 1.

**Table 1. Important input variables and their sources to estimate net emission using G-res (modified from Prairie et al., 2021)**

	Variables	Units	Data Source
<b>Reservoir Variables</b>	<b>Climate zone</b>	--	Rubel and Kottek, 2010 (Köppen - Geiger climate classification)
	<b>Dam coordinates</b>	Degree Decimal	Field survey/Literature/GRand Database
	<b>Impoundment year</b>	yr	Reservoir authority/Literature/ GRanD Database
	<b>Reservoir area</b>	km <sup>2</sup>	Reservoir authority/Literature/ GRanD Database/Land use landcover map/Waterbodies boundary
	<b>Maximum depth</b>	m	Reservoir authority/Literature/ GRanD Database/ Hydrographic survey
	<b>Mean depth</b>	m	Reservoir authority/Literature/ GRanD Database/ Hydrographic survey
	<b>Reservoir area</b>	km <sup>3</sup>	Reservoir authority/Literature or can be estimated in G-res
	<b>Thermocline depth</b>	m	Reservoir authority/Literature or can be estimated in G-res
	<b>Littoral area</b>	%	Reservoir authority/Literature or can be estimated in G-res
	<b>Water residence time</b>	yr	Reservoir authority/Literature or can be estimated in G-res
	<b>Mean monthly and annual air temperature</b>	°C	Hijmans et al., 2005 or another climate database
	<b>Annual precipitation</b>	mm yr <sup>-1</sup>	Hijmans et al., 2005 or other climate database
	<b>Mean monthly and annual wind speed</b>	ms <sup>-1</sup>	Hastings et al., 1999 or other wind-related database
	<b>Reservoir mean global horizontal radiance</b>	kWh m <sup>-2</sup> d <sup>-1</sup>	NASA, 2008
	<b>Catchment Variables</b>	<b>Phosphorus concentration</b>	µg L <sup>-1</sup>
<b>Soil carbon content of the inundated reservoir area</b>		kgCm <sup>-2</sup>	SoilGrids - global gridded soil information (Hengl et al., 2017)
<b>Catchment area</b>		km <sup>2</sup>	Reservoir authority/Literature/ GRanD Database/Land use landcover map/Waterbodies boundary
<b>Mean annual runoff</b>		mm yr <sup>-1</sup>	Fekete et al., 2000 or Reservoir authority/Literature
<b>Population density</b>		person km <sup>-1</sup>	CIESIN, 2005
	<b>Annual discharge</b>	m <sup>3</sup> s <sup>-1</sup>	Reservoir authority/Literature or can be estimated in G-res
	<b>Land coverage</b>	%	ESA - CCI, 2017

<sup>1</sup> <https://g-res.hydropower.org/wp-content/uploads/2022/12/G-Res-Tool-User-Guide-v3.2.pdf> (Accessed December 19, 2023)

# 6 Test Cases

In GRanD Database version 1.3,<sup>2</sup> a total of 7,321 reservoirs have been registered from all over the world. From Vietnam, 40 reservoirs are included in the GRanD Database, ranging from the year of impoundment between 1964 to 2016. Among them, a total of seven hydropower reservoirs (Table 2) were selected from different parts of Vietnam (Figure 10). GHG emissions from these reservoirs are calculated using the G-res tool, which is demonstrated in the following sub-sections.

**Table 2. Hydropower Reservoirs of Vietnam**

Reservoirs	Long.	Lat.	GRanD Database Reservoir ID	GRanD Database Catchment ID	Impoundment Year	Installed Capacity (MW)
Ban Ve	104.49	19.34	22425	4060015260	2010	320
Binh Dien	107.50	16.32	22426	4060015430	2005	44
Ho Ham Thuan	107.89	11.31	22442	4060016810	2001	300
Ho Hoa Binh	105.22	20.78	22443	4061023270	1994	1920
Ho Song Chinh	108.95	12.89	22462	4060016210	2001	70
Thac Ba	105.02	21.75	22467	4061015370	1971	120
Yali	107.83	14.23	23445	4061128130	1996	720



Figure 10: Location maps of the selected reservoir

<sup>2</sup> <https://www.globaldamwatch.org/grand/> (accessed on December 19, 2023)

Table 3 provides information on the pre-impoundment GHG emissions for selected reservoirs. Pre-impoundment emission rates are negative for several reservoirs, indicating a sink of GHG. The reservoirs at Ban Ve (-63 gCO<sub>2</sub>e/m<sup>2</sup>/yr), Binh Dien (-455 gCO<sub>2</sub>e/m<sup>2</sup>/yr), and Ho Ham Thuan (-20 gCO<sub>2</sub>e/m<sup>2</sup>/yr) all exhibit negative emission rates, pointing to a sink of GHG. Positive emission rates for the reservoirs Ho Hoa Binh (4 gCO<sub>2</sub>e/m<sup>2</sup>/yr), Ho Song Hinh (33 gCO<sub>2</sub>e/m<sup>2</sup>/yr), Thac Ba (17 gCO<sub>2</sub>e/m<sup>2</sup>/yr) and Yali (23 gCO<sub>2</sub>e/m<sup>2</sup>/yr) are also not significantly high. The analysis of these values is crucial for understanding the carbon dynamics associated with reservoir formation.

**Table 3. Pre-Impoundment GHG Emission**

<b>Name of Reservoir</b>	<b>Emission Rate (gCO<sub>2</sub>e/m<sup>2</sup>/yr)</b>	<b>of which CO<sub>2</sub> Emission (gCO<sub>2</sub>e/m<sup>2</sup>/yr)</b>	<b>of which CH<sub>4</sub> Emission (gCO<sub>2</sub>e/m<sup>2</sup>/yr)</b>
<b>Ban Ve</b>	-63	-63	0
<b>Binh Dien</b>	-455	-455	0
<b>Ho Ham Thuan</b>	-20	-48	28
<b>Ho Hoa Binh</b>	4	-16	20
<b>Ho Song hinh</b>	33	-11	44
<b>Thac Ba</b>	17	0	18
<b>Yali</b>	23	-4	27

Table 4 presents the post-impoundment GHG emissions for various reservoirs. The post-impoundment emission rate of the Ban Ve reservoir is 606 gCO<sub>2</sub>e/m<sup>2</sup>/yr, of which 279 gCO<sub>2</sub>e/m<sup>2</sup>/yr is contributed by CO<sub>2</sub> emissions and 327 gCO<sub>2</sub>e/m<sup>2</sup>/yr by CH<sub>4</sub> emissions. Similarly, for the Ho Ham Thuan reservoir, the post-impoundment emission rate is 289 gCO<sub>2</sub>e/m<sup>2</sup>/yr, of which 88 gCO<sub>2</sub>e/m<sup>2</sup>/yr is contributed by CO<sub>2</sub> emissions and 201 gCO<sub>2</sub>e/m<sup>2</sup>/yr by CH<sub>4</sub> emissions. The largest post-impoundment emission rate is found in the Binh Dien reservoir, i.e., 999 gCO<sub>2</sub>e/m<sup>2</sup>/yr, of which 299 gCO<sub>2</sub>e/m<sup>2</sup>/yr is contributed by CO<sub>2</sub> emissions and 700 gCO<sub>2</sub>e/m<sup>2</sup>/yr by CH<sub>4</sub> emissions. While the lowest post-impoundment emission rate is observed in the Thac Ba reservoir (48 gCO<sub>2</sub>e/m<sup>2</sup>/yr) of which 17 gCO<sub>2</sub>e/m<sup>2</sup>/yr is contributed by CO<sub>2</sub> emissions and 31 gCO<sub>2</sub>e/m<sup>2</sup>/yr by CH<sub>4</sub> emissions.

**Table 4. Post-Impoundment GHG Emission**

Name of Reservoir	Emission Rate (gCO <sub>2</sub> e/m <sup>2</sup> /yr)	of which CO <sub>2</sub> Emission (gCO <sub>2</sub> e/m <sup>2</sup> /yr)	of which CH <sub>4</sub> Emission (gCO <sub>2</sub> e/m <sup>2</sup> /yr)
<b>Ban Ve</b>	606	279	327
<b>Binh Dien</b>	999	299	700
<b>Ho Ham Thuan</b>	289	88	201
<b>Ho Hoa Binh</b>	94	44	50
<b>Ho Song hinh</b>	296	43	254
<b>Thac Ba</b>	49	17	31
<b>Yali</b>	149	31	118

Table 5 offers a comprehensive analysis of the post-impoundment GHG emissions for different reservoirs based on different paths. CH<sub>4</sub> emission via diffusive, bubbling, and degassing processes and CO<sub>2</sub> emission via diffusive pathway only are measured in the study. The figures show how the reservoirs would affect the environment, especially in terms of GHG emissions. Significant emissions are found in all three categories for the Binh Dien reservoir; CH<sub>4</sub> degassing has especially significant emissions (603 gCO<sub>2</sub>e/m<sup>2</sup>/yr) when compared to other processes. In contrast, Thac Ba showed lower emissions (27 gCO<sub>2</sub>e/m<sup>2</sup>/yr) overall. Reservoirs such as Ban Ve and Binh Dien have comparatively large CO<sub>2</sub> diffusive emissions, indicating the release of CO<sub>2</sub> through the water surface contributes to the greenhouse effect and climate change.

**Table 5. Detailed GHG Post-Impoundment Emission from Different Pathways**

Name of Reservoir	CH <sub>4</sub> Diffusive (gCO <sub>2</sub> e/m <sup>2</sup> /yr)	CH <sub>4</sub> Bubbling (gCO <sub>2</sub> e/m <sup>2</sup> /yr)	CH <sub>4</sub> Degassing (gCO <sub>2</sub> e/m <sup>2</sup> /yr)	CO <sub>2</sub> Diffusive (gCO <sub>2</sub> e/m <sup>2</sup> /yr)
<b>Ban Ve</b>	73	9	244	279
<b>Binh Dien</b>	82	15	603	299
<b>Ho Ham Thuan</b>	49	27	125	88
<b>Ho Hoa Binh</b>	35	2	14	44
<b>Ho Song hinh</b>	86	25	142	43
<b>Thac Ba</b>	27	1	4	17
<b>Yali</b>	56	12	50	31

Subtracting the Pre-Impoundment emissions from the post-impoundment ones provides the Net GHG Footprint impression. A summary of the net GHG footprint connected to each of the seven test case hydropower reservoirs can be found in Table 6, which allows standardized comparison among the hydropower reservoirs. Out of all the reservoirs listed, Binh Dien reservoir has the highest net GHG footprint (1454 gCO<sub>2</sub>e/m<sup>2</sup>/yr) with specific emissions of CO<sub>2</sub> (754 gCO<sub>2</sub>e/m<sup>2</sup>/yr) and CH<sub>4</sub> (700 gCO<sub>2</sub>e/m<sup>2</sup>/yr). A net GHG footprint of 32 gCO<sub>2</sub>e/m<sup>2</sup>/yr, of which 18 gCO<sub>2</sub>e/m<sup>2</sup>/yr contributed by CO<sub>2</sub> and 14 gCO<sub>2</sub>e/m<sup>2</sup>/yr contributed by CH<sub>4</sub> emissions, lead the Thac Ba reservoir to be the lowest areal emitter of GHG. Net GHG footprint for the reservoirs Ho Ham Thuan (309 gCO<sub>2</sub>e/m<sup>2</sup>/yr), Ho Hoa Binh (90 gCO<sub>2</sub>e/m<sup>2</sup>/yr), Ho Song Hinh (263 gCO<sub>2</sub>e/m<sup>2</sup>/yr), Thac Ba (31 gCO<sub>2</sub>e/m<sup>2</sup>/yr) and Yali (126 gCO<sub>2</sub>e/m<sup>2</sup>/yr) provide a thorough understanding of their effects on the environment.

**Table 6. Net GHG Footprint**

<b>Name of Reservoir</b>	<b>Emission Rate (gCO<sub>2</sub>e/m<sup>2</sup>/yr)</b>	<b>of which CO<sub>2</sub> Emission (gCO<sub>2</sub>e/m<sup>2</sup>/yr)</b>	<b>of which CH<sub>4</sub> Emission (gCO<sub>2</sub>e/m<sup>2</sup>/yr)</b>
<b>Ban Ve</b>	669	342	327
<b>Binh Dien</b>	1454	754	700
<b>Ho Ham Thuan</b>	309	135	173
<b>Ho Hoa Binh</b>	90	61	30
<b>Ho Song hinh</b>	263	53	210
<b>Thac Ba</b>	31	18	14
<b>Yali</b>	126	35	91

## Data Access

In the G-res tool, the input parameters can be saved or exported in *.mer* file format. These *.mer* files can be reused to optimize the input datasets to estimate the emissions for different scenarios. The initial results presented in Tables 3, 4, 5 and 6 in this report can be accessed through the G-res tool using the *.mer* files from Ghosh et al. (2024) (<https://zenodo.org/records/10511354>). The datasets can be modified with localized datasets for better accuracy. The initial results reported here provide gross estimations and are needed to be verified with the respective reservoir authorities for actual emissions.

# 7 Policies for Curbing GHG Emissions

Global policies have become essential to combat climate change by setting international standards for reducing GHG emissions and fostering global cooperation to address environmental crises. Such agreements are crucial for ensuring a sustainable and habitable world for succeeding generations. The principle of net zero or carbon neutrality necessitates that any activity releasing CO<sub>2</sub> be offset by another that eliminates an equal amount (Ahluwalia et al., 2021). For a nation to be considered carbon-negative, it must extract more CO<sub>2</sub> from the atmosphere than it emits. In the aftermath of the Kyoto Protocol, several developed nations, notably Britain, Canada, United States and Japan, are aiming to achieve "net zero" emissions by 2050.

Vietnam recently acknowledged the importance of addressing GHG emissions as part of its commitment to global climate action goals (Hoa and Matsuoka, 2017). Policy and legislation have been key factors forming Vietnam's hydropower environment (Can, 2002). Considering multiple government agencies and regulations involved, Vietnam has a complex institutional framework for reducing GHG emissions that aims to promote sustainable development and lessen the nation's carbon footprint (Lam, 2016). Policies about GHG emissions (Table 7) are primarily shaped and carried out by the Ministry of Natural Resources and Environment (MONRE). A significant policy framework managed by MONRE is the National Green Growth Strategy<sup>3</sup>, which was introduced in 2012. By including climate change adaptation and mitigation in national planning, it seeks to advance sustainable development. The initiative lays forth goals for cutting GHG emissions and highlights the importance of moving towards a low-carbon, green economy.

<sup>3</sup> [https://cidd2015.sciencesconf.org/file/BTC2015\\_GG\\_in\\_VN\\_Final\\_Summary.pdf](https://cidd2015.sciencesconf.org/file/BTC2015_GG_in_VN_Final_Summary.pdf) (Accessed: December 22, 2023).



Vietnam's Nationally Determined Contributions (NDCs) demonstrate its adherence to international agreements, especially the Paris Agreement. The NDCs set forth precise goals for mitigating and reducing greenhouse gas emissions in several industries. Coordination between MONRE, Ministry of Industry and Trade (MOIT), and other pertinent ministries is part of the institutional responsibility for implementing the NDC. These cooperative initiatives demonstrate the all-encompassing strategy used to address GHG emissions in the nation. The Ministry of Planning and Investment (MPI) in Vietnam plays a role in the institutional framework by supervising the planning of socioeconomic growth. The five-year socioeconomic development plans include targets for reducing greenhouse gas emissions and combating climate change, which balance environmental sustainability with economic growth (Ninh, 2014). This integration ensures that Vietnam's development policies incorporate climate factors. One of the most important organizations in putting environmental protection and climate change policies into action is the Vietnam Environment Administration (VEA), which is an agency under MONRE<sup>4</sup>. The Environmental Protection Planning, which includes steps to reduce GHG emissions, is supervised by the VEA. For projects and industries, this planning framework contains evaluations of the environmental effects, including GHG emission considerations.

Renewable energy development is crucial to Vietnam's plan to reduce GHG emissions. The procedures for promoting the growth of solar power projects are delineated in the Prime Minister's Decision No. 11/2017/QĐ-TTg (USAID, 2018). MOIT is in charge of coordinating these initiatives and creating rules and regulations for the energy industry. Vietnam wants to boost the proportion of renewable energy in its overall energy mix to lessen its dependency on fossil fuels and reduce greenhouse gas emissions. Vietnam's provinces and cities have created their climate action plans and programs to address local sources of greenhouse gas emissions in addition to the country's efforts. To effectively execute ambitious GHG reduction initiatives, there are still obstacles to overcome, such as the need for improved capacity building, knowledge transfer, and financial resources. Vietnam's carbon reduction goals depend on the corporate sector, civic society, and government agencies continuing to work together. In conclusion, Vietnam's institutional structure for reducing GHG emissions reflects a thorough and cooperative strategy encompassing numerous ministries and agencies. Vietnam has demonstrated its commitment to tackling the intricate issues of climate change and supporting worldwide efforts to reduce greenhouse gas emissions through incorporating climate considerations into development planning, adherence to international agreements, and prioritization of renewable energy sources.

<sup>4</sup> <https://www.trade.gov/country-commercial-guides/vietnam-environmental-technology> (Accessed: December 22, 2023).

**Table 7. List of Legislations for Environmental Protection related to the Hydropower sector in Vietnam.**

Legislation/Regulation	Ministries	Description/How it Relates
<b>Environmental Protection Law (2014) No. 55/2014/QH13</b>	Ministry of Natural Resources and Environment (MONRE)	Provides a comprehensive legal framework for environmental protection, including principles and regulations for environmental impact assessment (EIA), planning, and natural resource management <sup>5</sup> .
<b>Law on Water Resources Law (2012) No: 17/2012/QH13</b>	MONRE	Governs the management and protection of water resources, applying to hydropower projects. It aims to ensure sustainable water use while minimizing adverse environmental impacts <sup>6</sup> .
<b>Decree No. 120/2017/ND-CP</b>	MONRE	Focusing on sustainable and climate-adaptive development of the Mekong Delta, which is researching and applying agro-economic models as well as new agricultural technologies to develop sustainable and climate-adaptive production systems and high-value good sectors <sup>7</sup> .
<b>Circular No. 27/2012/TT-BTNMT</b>	MONRE	Offers guidance on the environmental impact assessment (EIA) process, specifying the required contents of an EIA report and procedures for approval with relevance to hydropower projects <sup>8</sup> .
<b>Decree No. 83/2014/ND-CP</b>	MONRE	Specifies penalties for administrative violations in environmental protection, establishing fines and sanctions for non-compliance of conventional petroleum engine fuels and biofuels businesses <sup>9</sup> .
<b>Renewable Energy Development Strategy and Planning (2068/QD-TTg)</b>	Ministry of Industry and Trade (MOIT)	Focus on renewable energy such as hydropower, wind power, solar power, biomass energy and biogas. Development is built upon resources and socioeconomic development needs and tied in with national and local resources and energy needs <sup>10</sup> .

<sup>5</sup> <https://faolex.fao.org/docs/pdf/vie168513.pdf> (Accessed: December 22, 2023).

<sup>6</sup> <https://waterpartnership.org.au/wp-content/uploads/2020/12/Vietnam-Law-on-Water-Resources-2012.pdf> (Accessed: December 22, 2023).

<sup>7</sup> <https://english.luatvietnam.vn/resolution-no-120-nq-cp-dated-november-17-2017-of-the-government-on-sustainable-and-climate-resilient-development-of-the-mekong-river-delta-118378-doc1.html#:~:text=120%2FNQ%2DCP%20dated%20November%2017%2C%202017%20on%20sustainable,coverage%20will%20reach%20over%209%25> (Accessed: December 22, 2023).

<sup>8</sup> <https://faolex.fao.org/docs/pdf/vie206254.pdf> (Accessed: December 22, 2023).

<sup>9</sup> <https://www.global-regulation.com/translation/vietnam/2954301/decreed-83-2014-nd-cp%253a-about-petroleum-trading.html> (Accessed: December 22, 2023).

<sup>10</sup> [https://policy.asiapacificenergy.org/sites/default/files/Decision%20No.%202068-QD-TTG%20on%20Development%20Strategy%20of%20Renewable%20Energy%20of%20Vietnam%20by%202030%20with%20a%20vision%20to%202050\\_EN.pdf](https://policy.asiapacificenergy.org/sites/default/files/Decision%20No.%202068-QD-TTG%20on%20Development%20Strategy%20of%20Renewable%20Energy%20of%20Vietnam%20by%202030%20with%20a%20vision%20to%202050_EN.pdf) (Accessed: December 22, 2023).

# 8 Conclusion and Way Forward

The findings from the seven test cases hydropower reservoirs, demonstrated notable variation in GHG emissions, highlighting the necessity of tailored mitigation plans specific to their geographic and environmental settings. The results emphasized upon the critical need to consider phenomena such as land use and land cover patterns, climatic conditions, local hydrological features, and environmental settings while crafting and implementing mitigation strategies for reducing GHG emissions from hydropower reservoirs.

Vietnam can gain invaluable insights by conducting thorough scientific investigations into GHG emissions from hydropower reservoirs leveraging EO data, G-res and empirical models. Contiguous spatiotemporal datasets, including satellite imagery and other EO data, are helpful for building robust GHG emissions monitoring systems. Standardized approaches for GHG quantification from hydropower reservoirs need to be developed to enable the establishment of benchmark data. This practice enables researchers to overcome data unavailability and formulate precise mitigation strategies, which is crucial for optimizing hydropower's potential while minimizing its environmental impact.

The present report paves the way for informed decision-making and sustainable development, contributing to a commitment to reducing its carbon footprint and fostering a greener and more environmentally responsible energy sector through mitigation strategies. Collaboratively, researchers, policymakers, and local communities can devise and execute mitigation solutions congruent with climate change's aims and sustainable development. This entails ensuring the long-term viability of mitigation measures by taking the socioeconomic repercussions and embracing community input into account.

Furthermore, the creation of creative ways to lower GHG emissions from the hydropower reservoirs depends heavily on investments in research and technology. Reforestation and other sustainable land management techniques are examples of nature-based solutions that can be integrated to reduce emissions and improve ecosystem health. Advancing renewable energy sources and creating low-carbon energy substitutes can also support reservoir management's overall sustainability. This research yields policy insights that emphasize the need for strengthening the policies pertaining to cleaners' renewable energy, emission standards, and environmental protection initiatives to achieve the SDGs.

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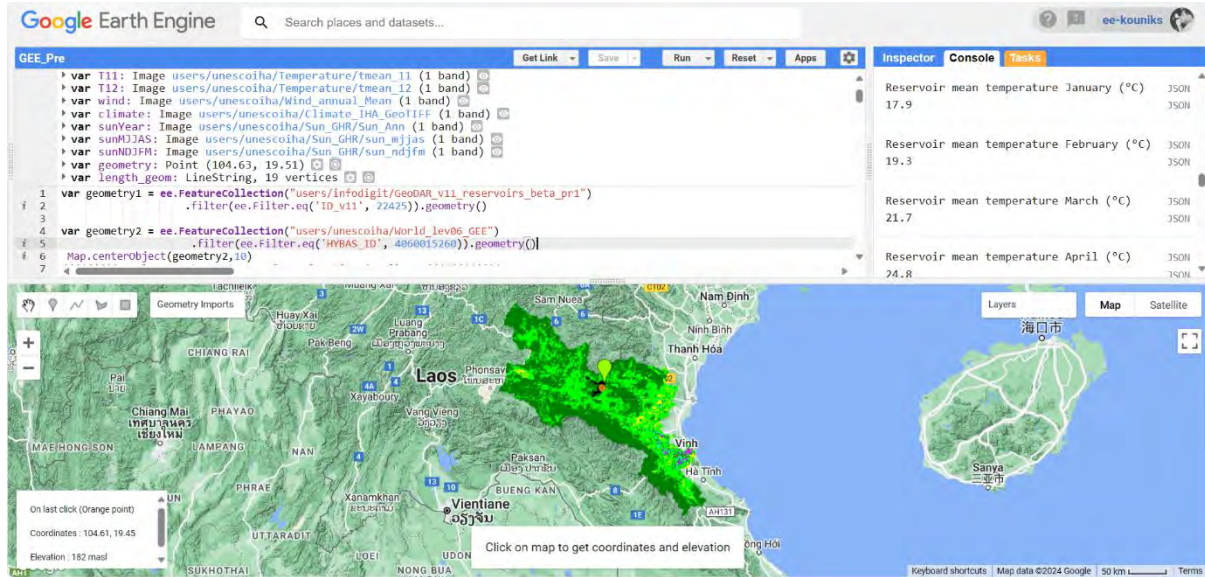
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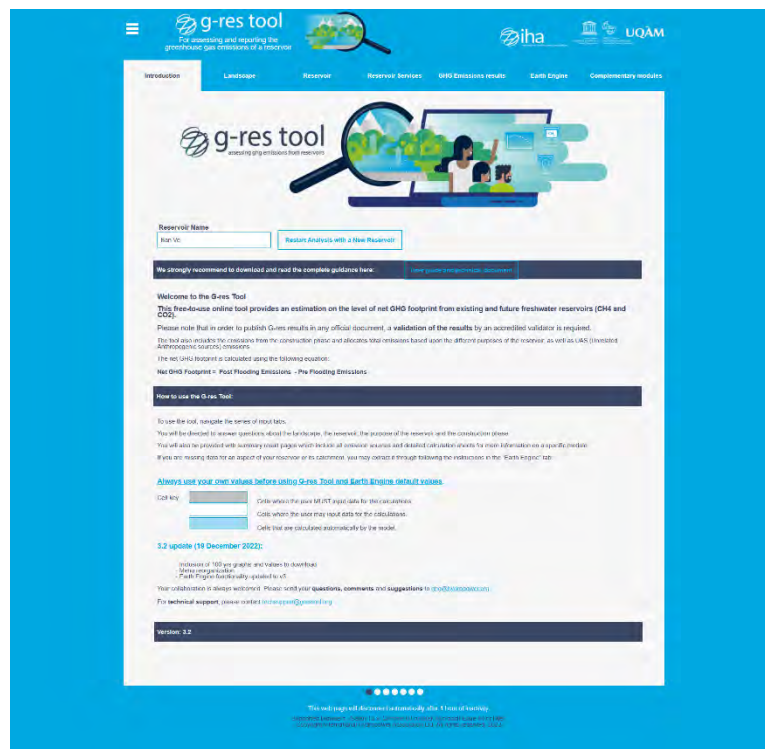
# Annex 1

## AI.1. Ban Ve

GEE Code for extracting mandatory input parameters.



## G-res Interface





## Reservoir Details

**Input Page 10 - Landscape Data**

On this sheet, enter data on the land cover types in the catchment area and the reservoir area.

**Current Totals**    **ICO-4/yr**

FGH Impoundment: 1854  
 FGH Impoundment: 1950  
 UAS

**Land Cover in the Catchment Area**

Percent (above catchment of total)	%	Area	% Land Use Intensity	100% = All Newly Managed Land	Area
Barren/Low	2.8%	1251.8			
Grassland	47.1%	19371.8			
Water Bodies	0.7%	291.3			
Wetlands					
Urban/Industrial	0%				
No Data					

**Pre-impoundment Land Cover in the Reservoir Area**

Area	% Mineral Soil	% Organic Soil	% of Organic Soil that is 100% = All Newly Managed Land	%	Area
Barren/Low	4.16%			0.0%	1.7
Grassland	19.2%			19.2%	8.5
Deciduous/Highland	75.57%			75.5%	33.4
Perennial Rice/lowland					
Settlements					
Forest/lowland/Impoundment					
Wetlands					
Urban/Industrial	0%			0.0%	0.0
No Data					

**User Guidelines**

If User Area Land Use Intensity is a custom value, please provide the user guidelines for the use of the user area land use intensity in the reservoir area. The user guidelines should be provided in the form of a table below the impoundment.

(User Length before Impoundment (hr))

## Catchment Details

**Input Page 23 - Reservoir Data**

On this sheet, enter the key parameters that describe the reservoir.

**Current Totals**    **ICO-4/yr**

FGH Impoundment: 1854  
 FGH Impoundment: 1950  
 UAS

**Reservoir Data**

Country: Vietnam  
 Latitude of dam (CO): 104.52  
 Latitude of dam (CO): 15.51  
 Climate Type (Reservoir Area): Tropical  
 Reservoir Area (km²): 26.8  
 Reservoir Volume (km³): 200  
 Water Level (in above sea level): 121  
 Mean Depth (m): 7.5  
 Catchment Area (km²): 1200  
 Catchment Length (km): 10  
 Soil Carbon Content Under Impoundment Area (kg/ha): 5.72  
 Wetland Area (km²): Yes

**User Guidelines**

- 1) If Reservoir Area and Volume are available, Mean Depth will be calculated.
- 2) If Volume and Mean Depth are available, Reservoir Area will be calculated.
- 3) If Reservoir Area, Mean Depth, Volume, and Catchment Area are available, Mean Depth will be calculated.
- 4) If Mean Normal Operating Level and Water Intake Elevation are available, Water Intake Depth will be calculated.
- 5) If Reservoir Area, Mean Depth, and Catchment Area are available, Volume will be calculated.
- 6) If Reservoir Area, Mean Depth, and Catchment Area are available, Volume will be calculated.
- 7) If Catchment Land Use, Volume, Discharge, Reservoir Area, and Catchment Area are available, Reservoir Area will be calculated.

**Annual Discharge from Reservoir (mm)**

Month	Value
January	17.5
February	19.9
March	23.7
April	24.6
May	27.7
June	27.8
July	27.9
August	27.2
September	26.4
October	24.9
November	19.6
December	18.6
Mean Annual Air Temperature (°C)	26.7

# Estimated Emission

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a reservoir

ihia UQAM

Introduction Landscape Reservoir Reservoir Services **GHG Emissions results** Earth Engine Complementary modules

**Results Pages:** 1. Total Footprint 2. Reservoir Emissions by Pathway 3. Temporal Emissions

**Predicted Emissions**

Net Predicted Annual CO<sub>2</sub>e Emission

	Post- Impoundment	-	Pre- Impoundment	-	Unrelated Anthropogenic Sources	=	Net GHG Footprint
Emission Rate (tCO <sub>2</sub> e/yr)	15 564	-	-1 955	-		=	13 609
of which CO <sub>2</sub>	8 993	-	-1 900	-	n/a	=	10 547
of which CH <sub>4</sub> *	10 081	-	-0	-		=	10 081

Emission Rate (gCO<sub>2</sub>e/m<sup>2</sup>/yr)

	866	-	-63	-		=	803
of which CO <sub>2</sub>	279	-	-53	-	n/a	=	244
of which CH <sub>4</sub> *	327	-	-0	-		=	327

Tick to Account for

Get 50% Confidence Interval

Compare only to reservoir from same climate:

**Detailed CH<sub>4</sub> Post-Impoundment Emissions**

Relative contribution to CH<sub>4</sub> Post-Impoundment Emissions (%)

- % CH<sub>4</sub> diffusive
- % CH<sub>4</sub> bubbling
- % CH<sub>4</sub> degassing

Water Level or Thermocline not Uplifted. Degassing Considered Zero.  
Warning: CH<sub>4</sub> Degassing Emissions Manually Included.

This reservoir CH<sub>4</sub> and CO<sub>2</sub>e emissions compared to worldwide reservoirs

CH<sub>4</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 73

CH<sub>4</sub> Bubbling Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 9

CH<sub>4</sub> Degassing Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 244

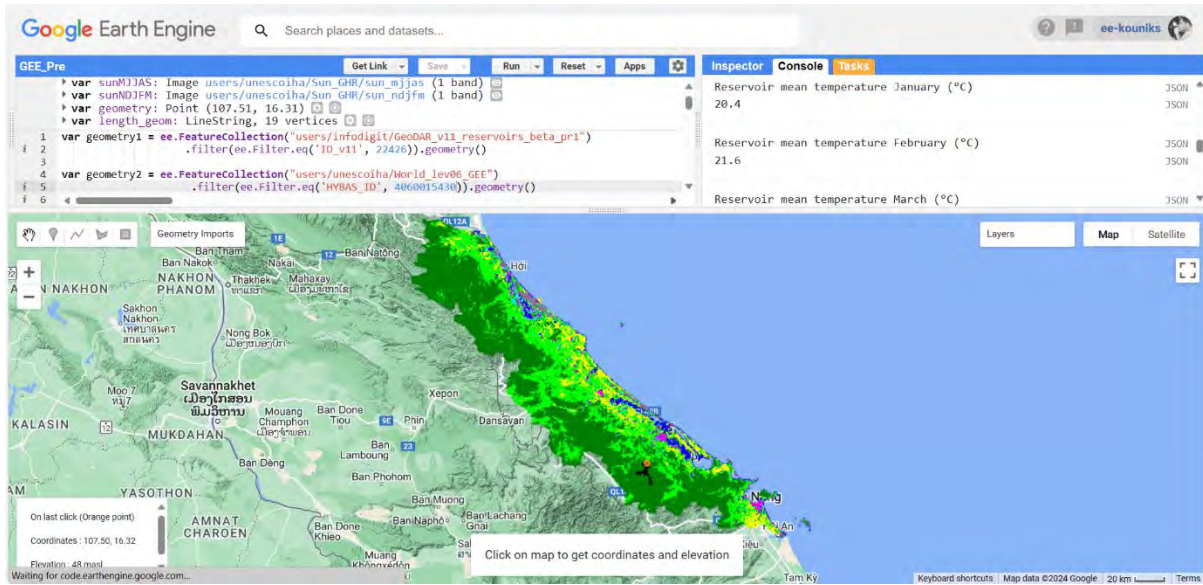
CO<sub>2</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 279

Manually include CH<sub>4</sub> Degassing Emissions:

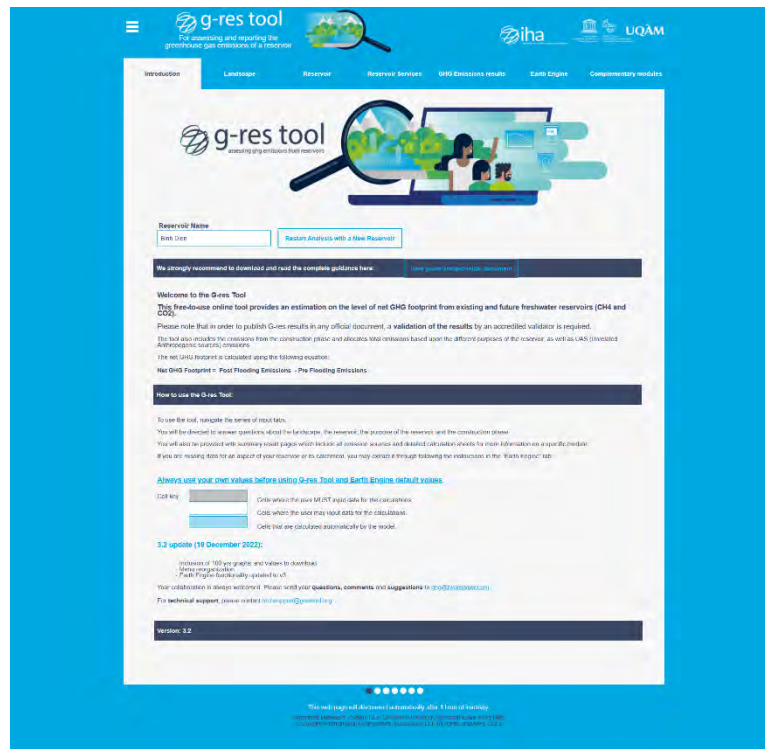
The web page will disconnect automatically after 1 hour of inactivity.

## AI.2. Binh Dien

GEE Code for extracting mandatory input parameters.



## G-res Interface



## Reservoir Details

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a reservoir

**Input Page 10 - Landscape Data**

Use this sheet, enter the key parameters that describe the reservoir.

**Current Totals ICD=1yr**

Final Impoundments: 3758  
Final Reservoirs: 4607  
UAS

**Land Cover in the Catchment Area**

Percent (choose units of total) %

Land Use	%	Area	100% = All Newly Managed Land
Barren/Low	1.1%	192.1	0.0%
Grasslands	12%	1757.6	0.0%
Forest	86.9%	7568.3	100%

Wetlands: 4.8% (292.2)  
Pasture/Pasture: 1.2% (212.9)  
No Data: 0%

**Pre-impoundment Land Cover in the Reservoir Area**

Reservoir Area (km²): 0.5

Land Use	% Mineral Soil	% Organic Soil	% of Organic Soil that is 100% = All Newly Managed Land	%	Area
Barren/Low	0%	0%	0%	0%	0.0
Grasslands	0%	0%	0%	0%	0.0
Forest	100%	0%	0%	100%	0.5
Disturbed/Barren	0%	0%	0%	0%	0.0
Pasture/Pasture	0%	0%	0%	0%	0.0
Settlements	0%	0%	0%	0%	0.0
Final Reservoir Impoundment	0%	0%	0%	0%	0.0
Final Reservoir Impoundment	0%	0%	0%	0%	0.0
Disturbed/Pasture	0%	0%	0%	0%	0.0
No Data	0%	0%	0%	0%	0.0

**User Guidelines**

If Over Area Length Exposed with a reservoir, please provide the length of the reservoir in the same units as the area. If the reservoir is a dam, provide the length of the dam in the same units as the area. If the reservoir is a lake, provide the length of the lake in the same units as the area.

## Catchment Details

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a reservoir

**Input Page 20 - Reservoir Data**

Use this sheet, enter the key parameters that describe the reservoir.

**Current Totals ICD=1yr**

Final Impoundments: 3758  
Final Reservoirs: 4607  
UAS

**Reservoir Volume Data**

Volume (km³): 0.0  
Volume (m³): 0.0  
Volume (acre-ft): 0.0

**Reservoir Area Data**

Area (km²): 0.0  
Area (m²): 0.0  
Area (acre-ft): 0.0

**Reservoir Temperature Data**

Mean Depth (m): 0.0  
Temperature (°C): 0.0

**Annual Discharge Data**

Annual Discharge (km³/yr): 0.0  
Annual Discharge (m³/yr): 0.0  
Annual Discharge (acre-ft/yr): 0.0

**Reservoir Mean Annual Reservoir Temperature (MART)**

Month	Temperature (°C)
January	25.8
February	24.6
March	22.8
April	24.2
May	28.2
June	28.5
July	28.5
August	28.8
September	28.8
October	28.8
November	28.8
December	28.8
Mean Annual Air Temperature (°C)	28.8

**User Guidelines**

1) If the reservoir is a dam, provide the length of the dam in the same units as the area. If the reservoir is a lake, provide the length of the lake in the same units as the area. If the reservoir is a reservoir, provide the length of the reservoir in the same units as the area.

# Estimated Emission

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a reservoir

ihia UQAM

Introduction Landscape Reservoir Reservoir Services **GHG Emissions results** Earth Engine Complementary modules

Results Pages: 1. Total Footprint 2. Reservoir Emissions by Pathway 3. Temporal Emissions

**Predicted Emissions**

Net Predicted Annual CO<sub>2</sub>e Emission

	Post- Impoundment	-	Pre- Impoundment	-	Unrelated Anthropogenic Sources	=	Net GHG Footprint
Emission Rate (tCO <sub>2</sub> e/yr)	5 793	-	-4 467	-		=	14 250
of which CO <sub>2</sub>	2 929	-	-4 497	-	n/a	=	7 309
of which CH <sub>4</sub> *	6 894	-	-0	-		=	6 894

Tick to Account for

Get 95% Confidence Interval

Emission Rate (gCO<sub>2</sub>e/m<sup>2</sup>/yr)

	999	-	-465	-		=	-1 454
of which CO <sub>2</sub>	299	-	-595	-	n/a	=	754
of which CH <sub>4</sub> *	700	-	-0	-		=	700

Compare only to reservoir from same climate:

**Detailed CH<sub>4</sub> Post-Impoundment Emissions**

Relative contribution to CH<sub>4</sub> Post-Impoundment Emissions (%)

- % CH<sub>4</sub> diffusive
- % CH<sub>4</sub> bubbling
- % CH<sub>4</sub> degassing

Water Level or Thermocline not Uplifted. Degassing Considered Zero.  
Warning: CH<sub>4</sub> Degassing Emissions Manually Included.

This reservoir CH<sub>4</sub> and CO<sub>2</sub>e emissions compared to worldwide reservoirs

CH<sub>4</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 82

CH<sub>4</sub> Bubbling Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 15

CH<sub>4</sub> Degassing Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 893

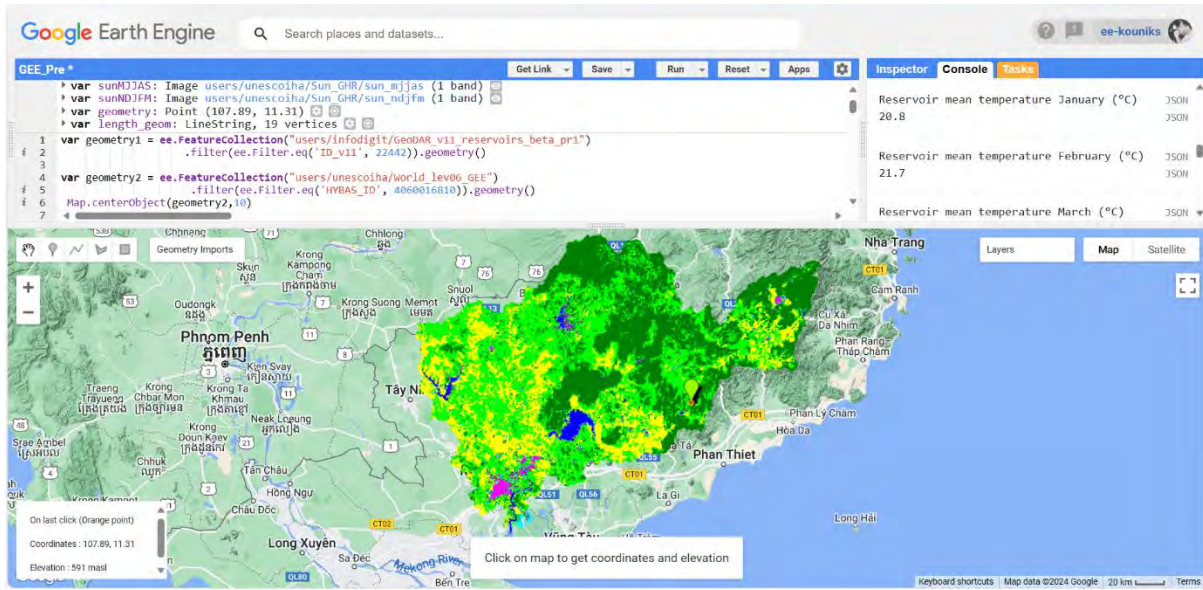
CO<sub>2</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 299

Manually include CH<sub>4</sub> Degassing Emissions:

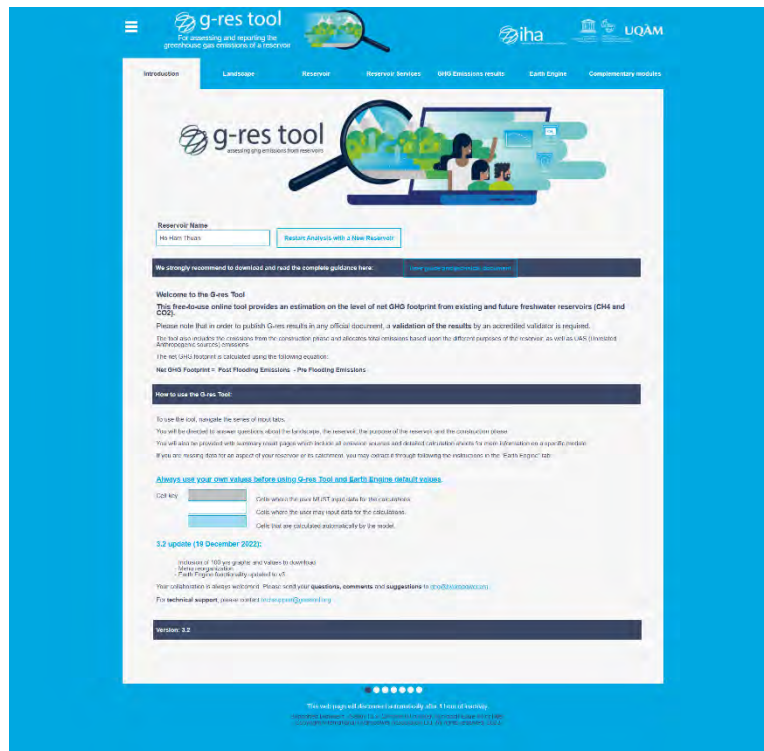
The web page will disconnect automatically after 1 hour of inactivity.

### AI.3. Ho Ham Thuan

GEE Code for extracting mandatory input parameters.



### G-res Interface



## Reservoir Details

**Input Page 19 - Landscape Data**

Use this sheet, enter the data for the landscape types of the catchment area and the reservoir area.

**Current Totals CO<sub>2</sub>e/yr**

Forest Impoundment	2150
Pre-impoundment	-3/2
UAS	

**Land Cover in the Catchment Area**

Percent (above total of 100%)

Land Cover	%	Area
Forest	25%	1433.8
Grassland	42%	2653.1
Wetlands	2.3%	124.3
Wetlands	3.2%	163
Pasture/Pasture	8%	418
No Data	0%	

**Pre-impoundment Land Cover in the Reservoir Area**

Reservoir Area (km<sup>2</sup>): 23.3

Land Cover	%	Area
Forest	23.3%	5.43
Grassland	10.2%	2.38
Wetlands	3.2%	0.74
Pasture/Pasture	10.2%	2.38
Settlements		
Forest and Wetland Impoundment	23.3%	5.43
Wetlands		
Pasture/Pasture		
No Data	30.1%	6.92

## Catchment Details

**Input Page 27 - Reservoir Data**

Use this sheet, enter the key parameters that describe the reservoir.

**Current Totals CO<sub>2</sub>e/yr**

Forest Impoundment	2150
Pre-impoundment	-3/2
UAS	

**Reservoir Data**

Country: Vietnam

Latitude of Dam (°N): 10.89

Volume of Dam (m<sup>3</sup>): 11.31

Catchment Area (km<sup>2</sup>): 2000

Reservoir Area (km<sup>2</sup>): 28.3

Reservoir Volume (m<sup>3</sup>): 263

Water Level (m above sea level): 142

Reservoir Depth (m): 142

Mean Depth (m): 142

Catchment Area (km<sup>2</sup>): 1119

Reservoir Depth (m): 142

Soil Carbon Content (Under Impounded Area) (kg/ha): 6.39

Wind action from Farm Region: Yes

**Monthly Reservoir Data**

Annual Precipitation (mm): 1900

Mean Water Elevation (m): 142

Secondary Mean Water Elevation (m): 142

Annual Discharge from Reservoir (mm): 1900

Reservoir Level (m): 142

Reservoir Mean Water Elevation (m): 142

Mean Reservoir Level (m): 142

Mean Annual Air Temperature (°C): 30.7

# Estimated Emission

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a Reservoir

ihia UQAM

Introduction Landscape Reservoir Reservoir Services **GHG Emissions results** Earth Engine Complementary modules

**Results Pages:** 1. Total Footprint 2. Reservoir Emissions by Pathway 3. Temporal Emissions

**Predicted Emissions**

Net Predicted Annual CO<sub>2</sub>e Emission

Tick to Account for

	Post- Impoundment	Pre- Impoundment	Unrelated Anthropogenic Sources	=	Net GHG Footprint
Emission Rate (GCO <sub>2</sub> e/yr)	8 195	-572	-	=	8 728
of which CO <sub>2</sub>	2 479	-1 354	n/a	=	3 833
of which CH <sub>4</sub>	5 695	-781	-	=	4 915

Get 95% Confidence Intervals

	Post- Impoundment	Pre- Impoundment	Unrelated Anthropogenic Sources	=	Net GHG Footprint
Emission Rate (gCO <sub>2</sub> e/m <sup>3</sup> /yr)	293	-20	-	=	309
of which CO <sub>2</sub>	88	-68	n/a	=	136
of which CH <sub>4</sub>	201	-28	-	=	173

Compare only to reservoir from same climate:

**Detailed CH<sub>4</sub> Post-Impoundment Emissions**

Relative contribution to CH<sub>4</sub> Post-Impoundment Emissions (%)

% 0

Water Level or Thermocline not Defined. Degassing Considered Zero.  
Warning: CH<sub>4</sub> Degassing Emissions Manually Included

This reservoir CH<sub>4</sub> and CO<sub>2</sub> emissions compared to worldwide reservoirs:

CH<sub>4</sub> (Inflative Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr)) = 45

CH<sub>4</sub> (Bubbling Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr)) = 27

CH<sub>4</sub> (Degassing Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr)) = 125

CO<sub>2</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 88

Manually Include CH<sub>4</sub> Degassing Emissions:

The web page will disconnect automatically after 1 hour of inactivity.



## AI.4. Ho Hoa Binh

GEE Code for extracting mandatory input parameters.

The screenshot shows the Google Earth Engine (GEE) interface. The top panel displays the GEE code editor with the following code:

```

var sunMJJAS = Image users/unescoiha/Sun_GHR/sun_mjjas (1 band)
var sunNDJFM = Image users/unescoiha/Sun_GHR/sun_ndjfm (1 band)
var length_geom = LineString, 19 vertices
1 var geometry1 = ee.FeatureCollection("users/infodigit/GeoDAR_v11_reservoirs_beta_pr1")
2   .filter(ee.Filter.eq("ID_v11", 22443)).geometry()
3
4
5 var geometry2 = ee.FeatureCollection("users/unescoiha/World_lev96_GEE")
6   .filter(ee.Filter.eq("HYBAS_ID", 4061023270)).geometry()
7 Map.centerObject(geometry2,10)
8 ////////////// Please enter water surface elevation (masl) ///////////////////
9

```

The right panel shows the Inspector and Console. The Inspector displays the following data:

- Reservoir mean temperature January (°C) 350N 16.0 350N
- Reservoir mean temperature February (°C) 350N 17.5 350N
- Reservoir mean temperature March (°C) 350N 19.8 350N

The map below shows a satellite view of Vietnam with a reservoir highlighted in green. A tooltip indicates: "Click on map to get coordinates and elevation". The coordinates are 105.32, 20.81 and the elevation is 118 masl.

G-res Interface

The screenshot shows the G-res tool website interface. The header includes the G-res tool logo and navigation links: Introduction, Landscape, Reservoir, Reservoir Services, GHG Emissions Results, Earth Engine, and Complementary Results. The main content area features a large illustration of a person using a laptop and a magnifying glass over a globe. Below the illustration, there is a form for "Reservoir Name" and a "Run Analysis with a New Reservoir" button. A message states: "We strongly recommend to download and read the complete guidance here" with a link to "New user instructions document". The "Welcome to the G-res Tool" section explains that the tool provides an estimation of net GHG footprint from existing and future freshwater reservoirs (CH4 and CO2e). It includes instructions on how to use the tool, such as downloading the tool and reading the guidance. The "Always use your own values before using G-res Tool and Earth Engine default values" section provides input fields for "Grid Size" and "Grid Resolution". The "2.2 update (19 December 2022)" section lists updates, including the addition of a "New user instructions document" and the "Earth Engine" link. The footer includes the version number "2.2" and a note: "The tool requires all datasets continuously after 11:00 AM (GMT+7) on 19 December 2022." and "The tool requires all datasets continuously after 11:00 AM (GMT+7) on 19 December 2022.".

# Reservoir Details

**Input Page 19 - Landscape Data**

Use this sheet, enter the key parameters that describe the landscape.

**Current Totals**    **ICD=lyr**

Total Impoundment: 3853  
Pre-impoundment: 396  
UAS

**Land Cover in the Catchment Area**

Please choose units of forest: **Area**

Land Cover	%	Area	% Land Use Intensity	ICD=lyr	ICD=lyr
Forest	34.9%	8710.5	100%	All Newly Managed Land	100%
Barren					
Grassland	10.1%	2540			
Other					

**Pre-impoundment Land Cover in the Reservoir Area**

Land Cover	%	Area	% Land Use Intensity	ICD=lyr	ICD=lyr
Forest	34.6%	8710.5	100%	All Newly Managed Land	100%
Barren					
Grassland	10.1%	2540			
Other					

# Catchment Details

**Input Page 20 - Reservoir Data**

Use this sheet, enter the key parameters that describe the reservoir.

**Current Totals**    **ICD=lyr**

Total Impoundment: 3853  
Pre-impoundment: 396  
UAS

**Reservoir Volume Data**

Reservoir Volume (ICD): 119  
Mean Depth (ICD): 18.3  
Maximum Depth (ICD): 21

**Annual Discharge from Reservoir Intake (ICD)**

Annual Discharge from Reservoir Intake (ICD): 186.3

**Mean Annual Air Temperature (°C)**

Month	Mean Annual Air Temperature (°C)
January	18.6
February	17.6
March	15.9
April	12.9
May	10.5
June	8.3
July	7.8
August	12.1
September	16.8
October	14.1
November	11.3
December	11.9
Mean Annual Air Temperature (°C)	12.9

# Estimated Emission

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a reservoir

**iha** **UQAM**

Introduction Landscape Reservoir Reservoir Services **GHG Emissions results** Earth Engine Complementary modules

**Results Pages:** 1. Total Footprint 2. Reservoir Emissions by Pathway 3. Temporal Emissions

**Predicted Emissions**

Net Predicted Annual CO<sub>2</sub>e Emission

Tick to Account for

	Post- Impoundment	-	Pre- Impoundment	-	Unrelated Anthropogenic Sources	=	Net GHG Footprint
Emission Rate (tCO <sub>2</sub> e/yr)	8 681	-	386	-		=	8 295
of which CO <sub>2</sub>	4 059	-	-1 500	-	n/a	=	5 559
of which CH <sub>4</sub> *	4 583	-	1 984	-		=	2 729

[Get 50% Confidence Interval](#)

Emission Rate (gCO<sub>2</sub>e/m<sup>2</sup>/yr)

	94	-	4	-		=	90
of which CO <sub>2</sub>	44	-	-15	-	n/a	=	31
of which CH <sub>4</sub> *	56	-	20	-		=	30

Compare only to reservoir from same climate:

**Detailed CH<sub>4</sub> Post-Impoundment Emissions**

Relative contribution to CH<sub>4</sub> Post-Impoundment Emissions (%)

- % CH<sub>4</sub> diffusive
- % CH<sub>4</sub> bubbling
- % CH<sub>4</sub> degassing

Water Level or Thermocline not Uplifted. Degassing Considered Zero.  
**Warning: CH<sub>4</sub> Degassing Emissions Manually Included.**

This reservoir CH<sub>4</sub> and CO<sub>2</sub> emissions compared to worldwide reservoirs

CH<sub>4</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 35

CH<sub>4</sub> Bubbling Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 2

CH<sub>4</sub> Degassing Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 14

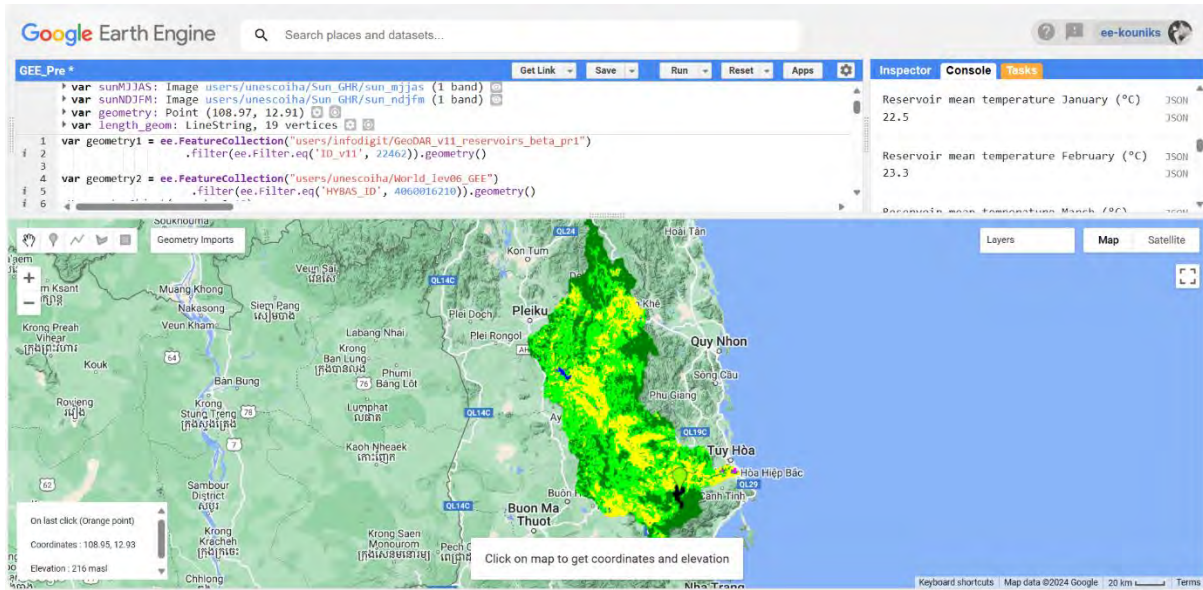
CO<sub>2</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 44

Manually include CH<sub>4</sub> Degassing Emissions:

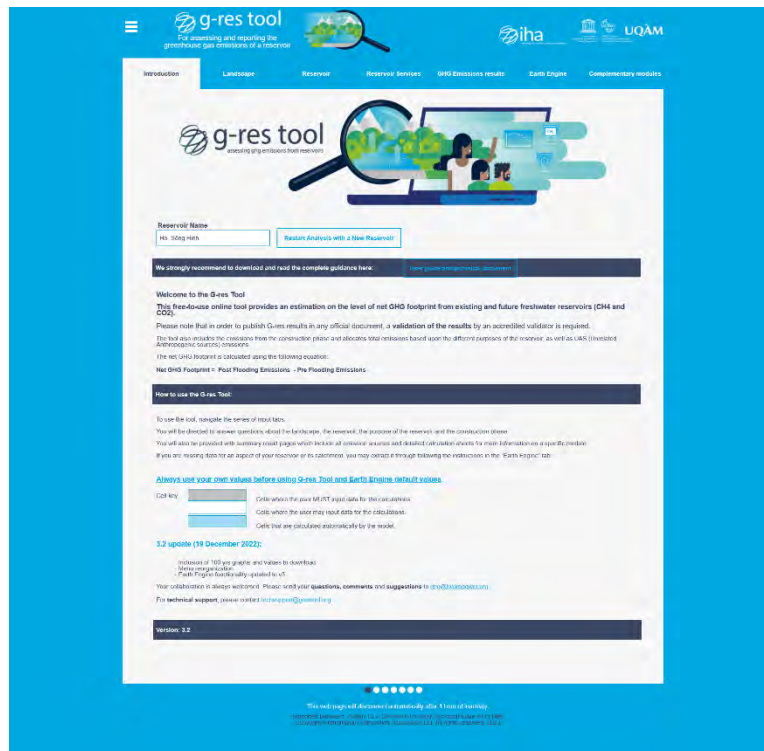
The web page will disconnect automatically after 1 hour of inactivity.

## AI.5. Ho Song Hinh

GEE Code for extracting mandatory input parameters.



## G-res Interface



## Reservoir Details

**Input Page 19 - Landscape Data**

Use this sheet, enter the data on the landscape level of the catchment area and the reservoir area.

**Current Totals** ICD=lyr

Pre-impoundment: 2000  
Post-impoundment: 1617  
UAN

**User Guidelines**

The user should select the most appropriate category for the land cover in the catchment area and the reservoir area. The user should also select the most appropriate category for the land cover in the reservoir area. The user should also select the most appropriate category for the land cover in the reservoir area. The user should also select the most appropriate category for the land cover in the reservoir area.

**Land Cover in the Catchment Area**

Please choose units of land:

Barren: 29.4% (10745)  
Forest: 20.6% (7548)

**Pre-impoundment Land Cover in the Reservoir Area**

Reservoir Area (km<sup>2</sup>):

Barren: 4.6% (16)  
Forest: 36.8% (1318)

## Catchment Details

**Input Page 20 - Reservoir Data**

Use this sheet, enter the key parameters that describe the reservoir.

**Current Totals** ICD=lyr

Pre-impoundment: 2000  
Post-impoundment: 1617  
UAN

**User Guidelines**

The user should select the most appropriate category for the land cover in the catchment area and the reservoir area. The user should also select the most appropriate category for the land cover in the reservoir area. The user should also select the most appropriate category for the land cover in the reservoir area. The user should also select the most appropriate category for the land cover in the reservoir area.

**Reservoir Data**

Catchment Area:

Reservoir Volume:

Mean Depth:

Annual Discharge from Secondary Intake:

Annual Discharge from Main Intake:

Annual Discharge from Tertiary Intake:

Annual Discharge from Quaternary Intake:

Annual Discharge from Quintary Intake:

Annual Discharge from Sextary Intake:

Annual Discharge from Septary Intake:

Annual Discharge from Octary Intake:

Annual Discharge from Nonary Intake:

Annual Discharge from Decary Intake:

Annual Discharge from Undecary Intake:

Annual Discharge from Duodecary Intake:

Annual Discharge from Tredecary Intake:

Annual Discharge from Quattuordecary Intake:

Annual Discharge from Quindecary Intake:

Annual Discharge from Sexdecary Intake:

Annual Discharge from Septuaginta Intake:

Annual Discharge from Octoginta Intake:

Annual Discharge from Nonaginta Intake:

Annual Discharge from Centum Intake:

# Estimated Emission

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a reservoir

**iha** **UQAM**

Introduction Landscape Reservoir Reservoir Services **GHG Emissions results** Earth Engine Complementary modules

Results Pages: 1. Total Footprint 2. Reservoir Emissions by Pathway 3. Temporal Emissions

**Predicted Emissions**

Net Predicted Annual CO<sub>2</sub>e Emission

	Post- Impoundment	Pre- Impoundment	Unrelated Anthropogenic Sources	Net GHG Footprint
Emission Rate (tCO <sub>2</sub> e/yr)	9 930	1 117	-	8 813
of which CO <sub>2</sub>	1 430	369	n/a	1 061
of which CH <sub>4</sub>	8 499	1 478	-	7 021

	Post- Impoundment	Pre- Impoundment	Unrelated Anthropogenic Sources	Net GHG Footprint
Emission Rate (gCO <sub>2</sub> e/m <sup>3</sup> /yr)	296	33	-	263
of which CO <sub>2</sub>	43	11	n/a	32
of which CH <sub>4</sub>	254	44	-	210

Get 95% Confidence Intervals

Tick to Account for

Compare only to reservoir from same climate:

**Detailed CH<sub>4</sub> Post-Impoundment Emissions**

Relative contribution to CH<sub>4</sub> Post-Impoundment Emissions (%)

- % CH<sub>4</sub> diffusive
- % CH<sub>4</sub> Bubbling
- % CH<sub>4</sub> Degassing

Water Level or Thermocline not Define. Degassing Considered Zero.  
Warning: CH<sub>4</sub> Degassing Emissions Manually Included

This reservoir CH<sub>4</sub> and CO<sub>2</sub>e emissions compared to worldwide reservoirs:

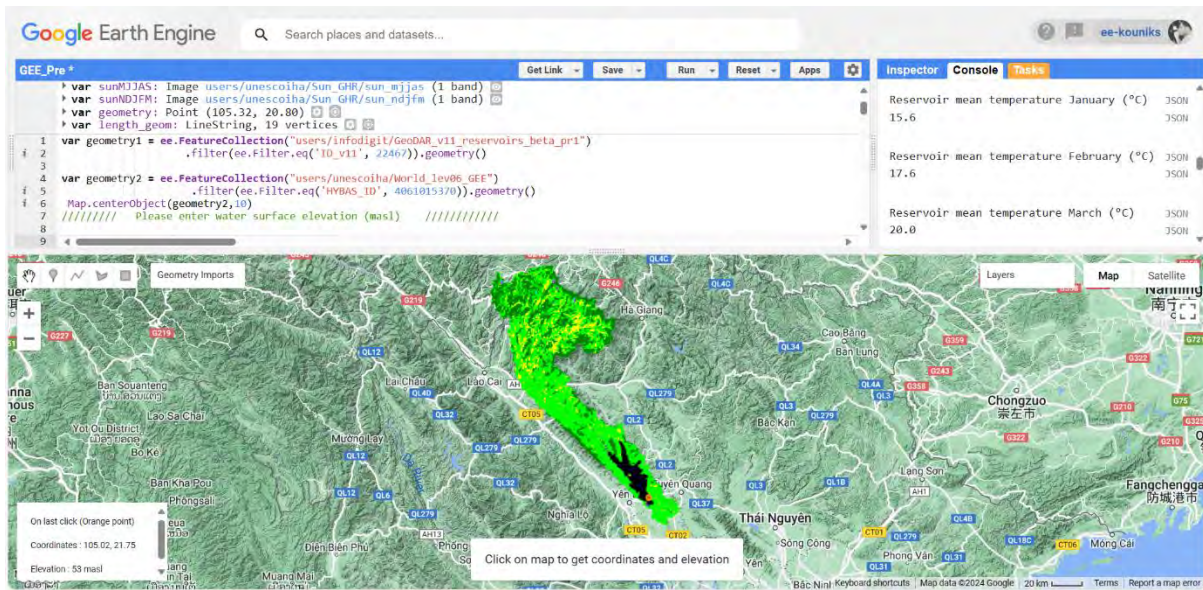
- CH<sub>4</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 96
- CH<sub>4</sub> Bubbline Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 25
- CH<sub>4</sub> Degassing Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 142
- CO<sub>2</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 43

Manually include CH<sub>4</sub> Degassing Emissions:

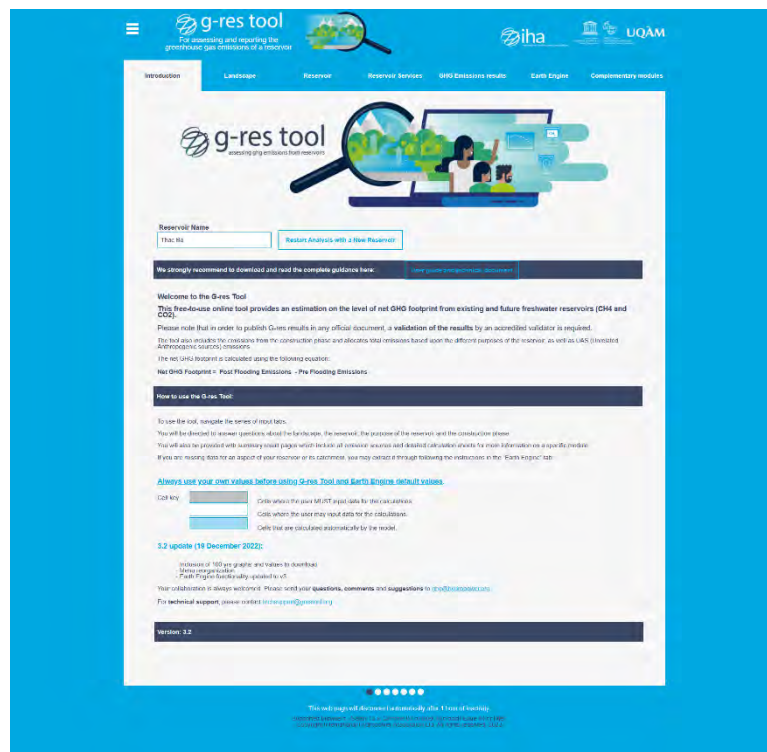
The web page will disconnect automatically after 1 hour of inactivity.

## AI.6. Thac Ba

GEE Code for extracting mandatory input parameters.



## G-res Interface



# Reservoir Details

**Input Page 10 - Landscape Data**

Use the sheet, enter the data for the landscape cover of the catchment area and the reservoir area.

**Current Totals CO<sub>2</sub>e/yr**

Forest Impoundments	7148
Pre-impoundments	2860
UAS	

**Land Cover in the Catchment Area**

Percent (above total of total)	ha	100% = All Newly Impounded Land
Dry forest	17.4%	1005.7
Pines	20.4%	1550.4

**Pre-impoundment Land Cover in the Reservoir Area**

Reservoir Area (ha)	% Mineral Soil	% Organic Soil	% of Organic Soil that is 100% = All Newly Impounded Land	%	ha
Forest	59.7%			683.7	683.7
No Data	47.9%			552.9	552.9

# Catchment Details

**Input Page 23 - Reservoir Data**

Use the sheet, enter the key parameters that describe the reservoir.

**Current Totals CO<sub>2</sub>e/yr**

Forest Impoundments	7148
Pre-impoundments	2860
UAS	

**Reservoir Data**

Parameter	Value
Reservoir Area (ha)	107.6
Forest (%)	683.7
No Data (%)	552.9

**Water Temperature (°C)**

Month	Temperature (°C)
January	15.6
February	17.6
March	20
April	23.2
May	27.1
June	28.5
July	29.3
August	28.9
September	27.3
October	24.4
November	21.2
December	18.2
Mean Annual (All Temperature) (°C)	26.5



# Estimated Emission

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a reservoir

ihia UQAM

Introduction Landscape Reservoir Reservoir Services **GHG Emissions results** Earth Engine Complementary modules

Results Pages: 1. Total Footprint 2. Reservoir Emissions by Pathway 3. Temporal Emissions

**Predicted Emissions**

Net Predicted Annual CO<sub>2</sub>e Emission

	Post- Impoundment	-	Pre- Impoundment	-	Unrelated Anthropogenic Sources	=	Net GHG Footprint
Emission Rate (CO <sub>2</sub> e/yr)	8 141	-	2 525	-		=	5 216
of which CO <sub>2</sub>	2 909	-	-20	-	n/a	=	2 927
of which CH <sub>4</sub> *	5 232	-	2 553	-		=	2 279

Emission Rate (gCO<sub>2</sub>e/m<sup>2</sup>/yr)

	48	-	17	-		=	31
of which CO <sub>2</sub>	17	-	-0	-	n/a	=	18
of which CH <sub>4</sub> *	31	-	16	-		=	14

Tick to Account for

Get 95% Confidence Interval

Compare only to reservoir from same climate:

**Detailed CH<sub>4</sub> Post-Impoundment Emissions**

Relative contribution to CH<sub>4</sub> Post-Impoundment Emissions (%)

- % CH<sub>4</sub> diffusive
- % CH<sub>4</sub> bubbling
- % CH<sub>4</sub> degassing

Water Level or Thermocline not Uetline. Degassing Considered Zero.  
Warning: CH<sub>4</sub> Degassing Emissions Manually Included.

This reservoir CH<sub>4</sub> and CO<sub>2</sub>e emissions compared to worldwide reservoirs

CH<sub>4</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 27

CH<sub>4</sub> Bubbling Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 1

CH<sub>4</sub> Degassing Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 4

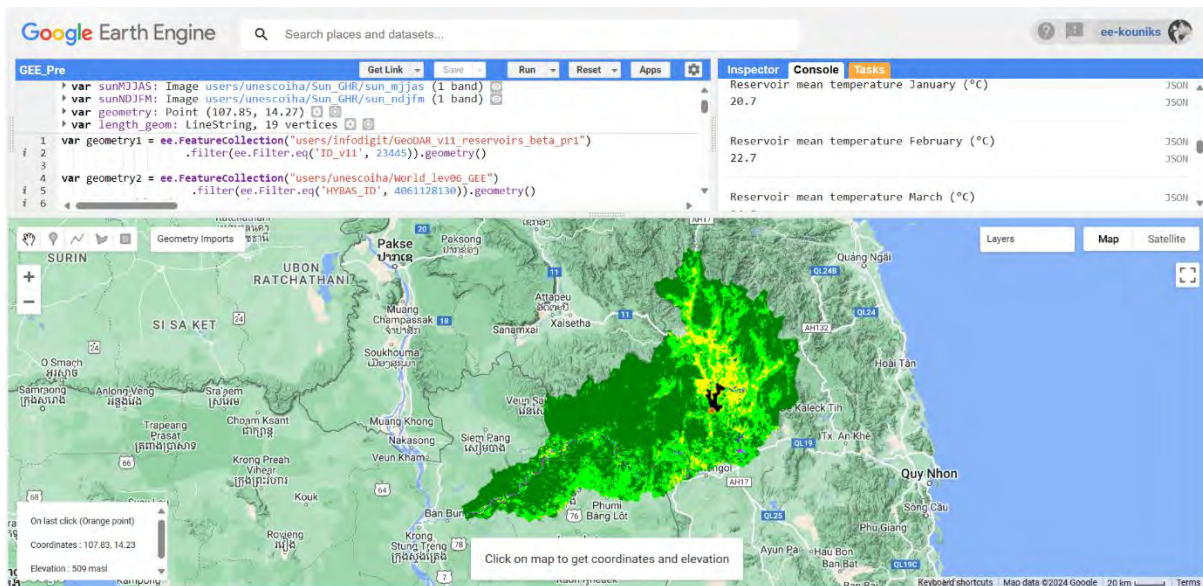
CO<sub>2</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>2</sup>/yr) = 17

Manually include CH<sub>4</sub> Degassing Emissions:

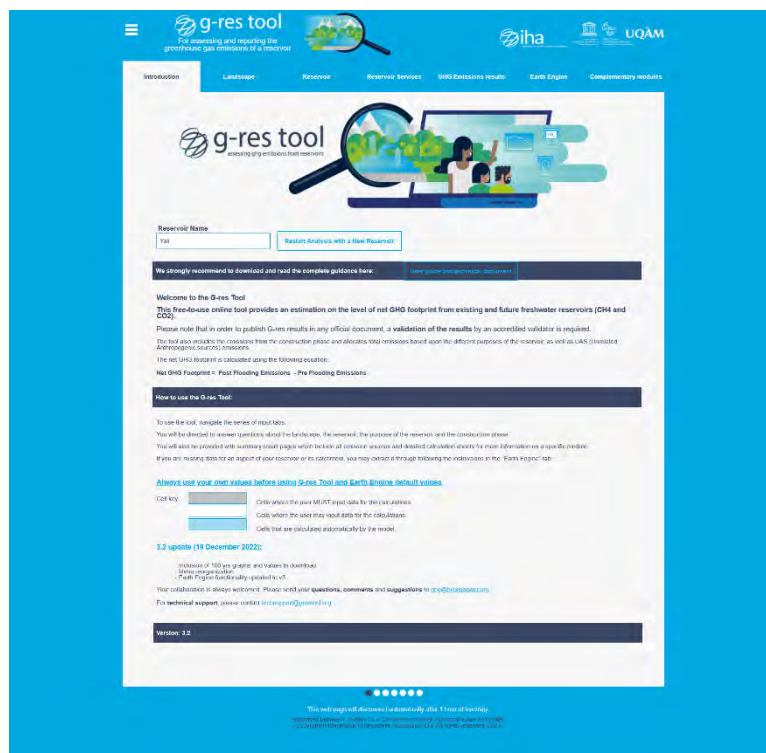
The web page will disconnect automatically after 1 hour of inactivity.

## AI.7. Yali

GEE Code for extracting mandatory input parameters.



## G-res Interface



## Reservoir Details

**Input Page 10 - Landscape Data**

On this sheet, enter data on the land cover types of the catchment area and the reservoir area.

**Current Totals** (ICD=lyr)

Final Impoundment	374
Pre-impoundment	583
UAS	

**Land Cover in the Catchment Area**

Pre-impoundment (ICD=lyr)

Land Cover	%	Area (km <sup>2</sup> )
Barren	6%	1074.2
Deciduous	10.1%	1995.1
Evergreen	36.4%	7074.2
Water Bodies	0.7%	137.8
Wetlands	0%	
Urban/Industrial	0%	
No Data	0%	

**Pre-impoundment Land Cover in the Reservoir Area**

Reservoir Area (km<sup>2</sup>)

Land Cover	%	Area (km <sup>2</sup> )
Barren	0%	
Deciduous	0.0%	
Evergreen	0.0%	
Water Bodies	0.0%	
Wetlands	0.0%	
Urban/Industrial	0.0%	
No Data	0.0%	

## Catchment Details

**Input Page 23 - Reservoir Data**

On this sheet, enter the key parameters that describe the reservoir.

**Current Totals** (ICD=lyr)

Final Impoundment	374
Pre-impoundment	583
UAS	

**Reservoir Data**

City: Uthmaniyah

Latitude of Dam (ICD): 30.83

Latitude of Dam (DO): 34.33

Catchment Area (km<sup>2</sup>): 1074.2

Impoundment Area (km<sup>2</sup>): 1074.2

Reservoir Volume (km<sup>3</sup>): 1074.2

Water Level (m above sea level): 506

Maximum Depth (m): 80

Mean Depth (m): 17.9

Latitude (°N): 33.91

Longitude (°E): 44.2

Soil Carbon Content Under Impoundment Area (kgC/m<sup>2</sup>): 0.14

Water Volume from Earth (km<sup>3</sup>): 1074.2

**Reservoir Area**

Month	Temperature (°C)
January	30.7
February	31.7
March	32.8
April	34.4
May	35.6
June	36.8
July	37.9
August	38.6
September	37.6
October	35.7
November	33.5
December	31.9
Mean Annual Air Temperature (°C)	34.9

# Estimated Emission

**g-res tool**  
For assessing and reporting the greenhouse gas emissions of a Reservoir

**iha** **UQAM**

Introduction Landscape Reservoir Reservoir Services **GHG Emissions results** Earth Engine Complementary modules

**Results Pages:** 1. Total Footprint 2. Reservoir Emissions by Pathway 3. Temporal Emissions

**Predicted Emissions**

Net Predicted Annual CO<sub>2</sub>e Emission

Tick to Account for

	Post- Impoundment	+	Pre- Impoundment	-	Unrelated Anthropogenic Sources	=	Net GHG Footprint
Emission Rate (tCO <sub>2</sub> e/yr)	8 794	+	1 643	-	-	=	5 761
of which CO <sub>2</sub>	7 413	-	176	-	n/a	=	1 690
of which CH <sub>4</sub>	5 981	+	1 220	-	-	=	4 181

---

		+		-		=	
Emission Rate (gCO <sub>2</sub> e/m <sup>3</sup> /yr)	143	+	23	-	-	=	126
of which CO <sub>2</sub>	28	-	4	-	n/a	=	35
of which CH <sub>4</sub>	118	-	27	+	-	=	91

Get 95% Confidence Intervals

Compare only to reservoir from same climate:

**Detailed CH<sub>4</sub> Post-Impoundement Emissions**

Relative contribution to CH<sub>4</sub> Post-Impoundement Emissions (%)

% 0

Water Level or Thermocline not Define (Degassing Considered Zero)  
Warning: CH<sub>4</sub> Degassing Emissions Manually Included

This reservoir CH<sub>4</sub> and CO<sub>2</sub>e emissions compared to worldwide reservoirs:

CH<sub>4</sub> (Inflative Emissions) (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 55

CH<sub>4</sub> Bubbline Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 12

CH<sub>4</sub> Degassing Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 50

CO<sub>2</sub> Diffusive Emissions (gCO<sub>2</sub>e/m<sup>3</sup>/yr) = 91

Manually include CH<sub>4</sub> Degassing Emissions:

This web page will disconnect automatically after 1 hour of inactivity

**Surajit Ghosh, Researcher**, [s.ghosh@cgiar.org](mailto:s.ghosh@cgiar.org)

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