Digging Deeper: Impacts of Block 43 ITT Oil Development on Yasuní National Park

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ABSTRACT

The increasing energy demand is driving increased oil production. An oil project that began development in 2016 in northeastern Ecuador is projected to produce over 120,000 barrels of oil per day. Referred to as Block 43, or Yasuní-ITT, the oil production is at the heart of one of the most biologically and culturally diverse regions in the world, Yasuní National Park. Given the relative abundance of research on emissions from oil use, this study aims to understand the holistic impacts of oil development in the Yasuní-ITT project in three regards: (1) climate change, (2) biodiversity, and (3) human health. This study uses a combination of emissions modeling to measure oil production emissions and satellite imagery analysis to understand forest cover loss and assess the development's impacts. Model results show that the three ITT oil fields emitted over 10 megatons of CO_2e between 2016 and 2022. Satellite imagery analysis shows that the forest has lost nearly 3 km^2 of primary cover during the construction of the oil access road and wells. Furthermore, I found that the climate, biodiversity, and human health damages go against the constitutional obligations outlined by the Government of Ecuador regarding the rights of nature and Indigenous communities. As pressures to extract more oil, gas, and other minerals increase, studies examining the effects of extraction on climate change, biodiversity, and human health will be critical for governments to decide whether to continue with such projects.

KEYWORDS

oil extraction, forest cover loss, Indigenous communities, satellite imagery, biodiversity

INTRODUCTION

The global energy demand is increasing as a result of rising residential, commercial, and industrial energy usage in both developed and developing countries. In 2021 alone, global energy demand has increased by 4.6%, and by 2050, total world energy use is expected to increase by 50% (IEA 2020). Therefore, rapidly scaling up energy production is perceived as a central goal for governments - to meet energy demand and promote economic growth. However, a significant concern is that non-renewable, heavily polluting, and environmentally damaging fossil fuels like coal, oil, and gas are being used to meet increasing energy demands (IEA 2020).

Oil and gas play a major role in global energy production. Estimates show that 56% of global energy consumption in 2020 was supplied by oil and gas (BP 2020). These dirty fuels cause significant greenhouse gas emissions in their production and usage. Oil and gas production alone—extracting and refining these fuels—has emitted over 15 billion tonnes of CO_2e or 5% of global emissions between 2015 and 2020 (Climate TRACE 2021). The emissions from the production and usage of oil and gas are causing changes in the climate, including the increasing extremity and frequency of heatwaves, heavy precipitation, droughts, and tropical storms (IPCC 2021, IPCC 2022). The latest climate science indicates that climate change is actively altering global ecosystems and that the biological responses of ecosystems are often incapable of dealing with these impacts (IPCC 2021, IPCC 2022). In addition, climate change is changing the resiliency of ecosystems, altering biodiversity, and causing local extinctions of many species (IPCC 2021, IPCC 2022). All of these damages to ecosystems directly affect the well-being of human communities, especially Indigenous people who rely heavily on their environment for sustenance (IPCC 2021, IPCC 2022). Indigenous communities are losing their traditional heritage sites, which has a cascading effect on their cultural identity, health, food security, and livelihoods (IPCC 2021, IPCC 2022).

There are other ways oil and gas can impact ecosystems and Indigenous communities. Oil and gas extraction—the physical process of constructing wells, drilling, and transporting products—directly causes habitat loss, ecosystem fragmentation, pollution, and displacement (Butt et al. 2013). New oil and gas development has rapidly expanded in scale and location, including highly biodiverse tropical rainforests. As such, tropical rainforests are being exposed to the harmful effects of oil and gas development. The primary environmental degradation of these systems comes from the construction of roads, pipelines, and wells, along with contamination from spills of waste and oil (Finer et al. 2008). New roads built for oil and gas infrastructure allow for easy access to previously remote primary rainforest, which often leads to further exploitation in the forms of deforestation and hunting. This was the case in the northern and central Ecuadorian Amazon, where access roads led to subsequent exploitation (Finer et al. 2008). Recent efforts have been to develop oil and gas infrastructure without road access in order to reduce the risk of biodiversity and habitat loss. An example is Peru's Camisea gas project, which avoided developing roads by using helicopters and other means of transportation to access the wells (Dallmeier et al. 2002). However, there have been too few studies to assess the effectiveness of these mitigation projects and holistically review all the impacts of oil and gas production on these sensitive tropical rainforests.

Although the climate-related impacts of oil and gas production have been examined in academic literature and private efforts, there is a gap in understanding how extraction in tropical forests impacts biodiversity, the global climate, and the people who live there. Therefore, my study will investigate how oil development and production, specifically in the Yasuní-Ishpingo-Tambococha-Tiputini (Yasuní-ITT) oil project, has contributed to global climate change and impacted tropical forest cover. To answer this question, I will measure the total production emissions from Ishpingo, Tambococha, and Tiputini across their production lifetimes from 2016 through 2022. I will also measure forest cover loss using satellite imagery data across the entire Yasuní-ITT block from 2012 through 2022. I predict that oil and gas development will have a noticeable impact on the health of the surrounding forest. I hope that this novel approach, considering both climate and ecological impacts, will provide current local-level decision makers the knowledge to make informed decisions regarding oil and gas projects in these fragile and intrinsically valuable forest ecosystems.

BACKGROUND

A brief history of oil development in Ecuador

Located in the northwestern corner of South America, Ecuador is bordered by Colombia to the north, Peru to the south and southeast, and the Pacific Ocean to the west. It's divided into 3 geographic regions: the coast, the Andean highlands, and the Oriente (East). Ecologically, Ecuador has some of the most incredible diversity in both ecosystems and species, especially considering its relatively small land area compared to other Amazonian countries like Peru, Colombia, or Brazil. Historically, Ecuador's economy has been reliant on exporting agricultural products like cacao, coffee, banana, and oil palm (Britannica 2022). In addition to these, Ecuador is a major exporter of crude oil and mineral resources like copper, iron, and gold (Britannica 2022).

Since the 1970s, crude oil extraction and exports have been the primary driver of economic growth in Ecuador. The vast majority of Ecuador's oil comes from the Amazon basin in the Oriente region. Along with vast mineral and oil deposits, the Oriente is home to many groups of Indigenous people, including the Quichua, the Shuar, the Cofán, the Waorani (Huaorani), and even two uncontacted groups known as the Tagaeri and Taromenane people. The oil boom was driven by transnational corporations, most prominently the Texaco-Gulf corporation. Between 1964 and 1967, they made significant discoveries of oil deposits in the Oriente region, directly underneath primary rainforest. To begin oil extraction, Texaco began drilling many exploratory wells throughout the Ecuadorian Amazon, which, according to estimates, created around 4,000 cubic meters of waste each (Sebastien 2004). When productive wells were identified and oil production began, millions of gallons of wastewater were discharged. Both forms of toxic chemical waste were stored in unsafe open pits exposed to wildlife, waterways, and the surrounding ecosystems (Sebastien 2004). During Texaco's 30-year operating period in Ecuador from 1964 to 1992, 15 oil fields were developed, comprising over 339 wells and 627 known open-air waste pits (Pigrau 2012). Between 1972 and 1993, more than 30 billion gallons of toxic waste and crude oil were discharged directly onto the land and waterways of the Oriente (Sebastien 2004). In subsequent studies of the ecological and social impacts of the toxic waste and crude oil exposure, nearby streams were found to have 100-500 times the safe hydrocarbon concentrations identified by European community regulations. Exposure has led to significant health impacts for Indigenous people and their livestock, including skin rashes, livestock mortality, and increased cancer rates. A 1993 community health study found that communities in oil-producing areas had elevated morbidity rates, a higher occurrence of abortion, dermatitis, skin mycosis, and higher mortality rates when compared to non-oil-producing areas (Sebastien 2004). In addition, 32% of deaths in oil-producing regions were caused by cancer, three times Ecuador's national average (Pigrau

2012). Beyond the ecosystem contamination and health impacts, over 20,000 square kilometers of primary rainforest were deforested (Pigrau 2012).

Texaco's environmental and human health damages were at the center of several major transnational lawsuits aiming to hold the company accountable for its detrimental actions. The legal battle reached its peak when on February 14, 2011, an Ecuadorian court ruled that Chevron—the company which purchased Texaco—was required to pay more than 8.6$ billion USD in reparations which would be increased to 19$ billion USD if they did not release a public apology to the plaintiffs (Pigrau 2012). Chevron decided not to pay the fine, instead pulling its assets from Ecuador before they could be seized and counter-suing the Ecuadorian government and the lawyers involved in the prosecution (openDemocracy 2019). As of today, the case is still in limbo, with Chevron pushing for the Ecuadorian government to nullify the decision and the Indigenous communities still suffering from the damages without any reparations from Chevron.

Yasuní National Park and recent oil development

Yasuní National Park is located at the intersection of the Andes, the Amazon rainforest, and the equator in northeastern Ecuador. It is a 9,820 km^2 park with a 10 km buffer zone surrounding its perimeter. Climatically, Yasuní is relatively stable, with warm temperatures, a large amount of rainfall, and a consistently high humidity level throughout the year. This has allowed the region to maintain incredibly high levels of species diversity. Compared to other land areas globally, Yasuní is one of the richest areas for amphibian species, the second richest for reptiles, within the top nine richest for vascular plants, rich in fish and mammal species, and among the richest for birds (Bass et al 2010). In addition, Yasuní is home to around one-third of the entire Amazon Basin's amphibian and reptile species, even though it covers less than 0.15% of the total area (Bass et al 2010). In addition to its tremendous biodiversity, Yasuní National Park overlaps with historical Waorani, Tagaeri, and Taromenane territory, resulting in its designation as a UNESCO Man and Biosphere reserve in 1989 (Bass et al 2010). Since the early 2000s, Yasuní has been the site of oil exploration and extraction, with oil concessions covering the majority of its area and four oil-access roads entering the park. The development is threatening the exceptional wildlife and the lives of the Indigenous people living within the park.

The most well-known and studied Indigenous group within Yasuní are the Waorani people—a community of forest foragers, hunters, and agriculturalists who first came into contact with people from outside their community in 1958 (Pappalardo et al 2013). They are the closest relatives to the Tagaeri and Taromenane people, both uncontacted Indigenous communities living within Yasuní who have decided to live in isolation. In the past, the Ecuadorian government and transnational corporations interested in mining and oil extraction in Yasuní made attempts to push all three communities out of the national park into Peru and southern Ecuador. After backlash from local Indigenous rights leaders and the international community, Ecuador created the Zona Intangible Tagaeri Taromenane (ZITT)—a protected area to prevent interactions with outside people—within Yasuní National Park to protect these groups (Pappalardo et al 2013). However, the expansion of oil extraction in the park has decreased the available territory for all three Indigenous groups to survive and live, directly impacting their migration and increasing conflict between themselves, oil workers, and farmers in the region. On the ground, research among Waorani communities has found that mechanical noises from oil extraction and vehicles have caused them to move away from their historical territory, especially because mammals and other sources of food flee the same sounds. To avoid conflict, Indigenous communities like the Waorani seek new places within the ZITT that are secluded and furthest from the development.

The Waorani people have also been vocal in defending their territory and rights to free and prior informed consent (FPIC). For example, Block 22, west of Yasuní National Park but within the historical Waorani territory, was a controversial oil lease that was put on pause in April of 2019 after the Waorani community argued in Ecuadorian courts that they had not been contacted regarding oil development in their territory (AmazonFrontlines 2019, Scazza 2021). This legal victory led to the reconsideration of over 16 other oil block leases across the Ecuadorian Amazon (AmazonFrontlines 2019, Scazza 2021).

One of the more recent oil concessions in Yasuní is known as Block 43, or Ishpingo-Tambococha-Tiputini (ITT). In response to the pressures from Indigenous communities to prevent oil development and from the climate scientists to decrease dependence on fossil fuels in the face of climate change, then President Rafael Correa proposed keeping over 9.2$ billion USD of Block 43's oil reserves in ground, in exchange for 3.6$ billion USD from international funders (Koenig 2007). According to Correa, the funding would guarantee that northeastern Yasuní would remain safe from oil development and that it would be used to bolster Ecuador's National Development

Program, expanding energy efficiency, green infrastructure, social spending for homes and schools, public transportation, development of ecotourism, and an environmental remediation program to address existing oil-related contamination (Koenig 2007). It would also help Ecuador decrease its reliance on exporting oil and prevent Ecuador from taking on the additional national debt from international banks to extract oil. However, the proposal didn't gain financial backing, so Block 43 began development in 2016 by Petroecuador, the national oil company of Ecuador.

As of today, 89% of Amazonian oil is being produced in Ecuador. In 2019, Ecuador produced around 540,000 barrels of crude oil per day, 66% of which came and continues to come to the United States and California to be refined due to their unique heavy oil refining capabilities (AmazonWatch 2021). As a result, 1 in 9 gallons of Californian gas is from Ecuadorian oil - meaning that the state of California and the United States both play significant roles in their oil supply chain (AmazonWatch 2021). Therefore, the damage Ecuador subjects on its biodiverse rainforests depends in many ways on US and Californian policy.

Research framework

Study site

I have selected Block 43 - the Ishpingo, Tambococha, and Tiputini oil fields to be my study site. I chose this oil block because it is a relatively recent development (2016) in the highly biodiverse and culturally significant Yasuní National Park. It was also part of the proposal to forgo drilling for oil in return for international financing. I am using the Rio Tiputini in the north as the upper boundary for measuring forest cover loss.

Modeling emissions using the OPGEE model

There is an assortment of approaches to measuring oil and gas production emissions. Most fall into two categories: top-down and bottom-up emissions tracking. Top-down approaches use towers, fly-by (satellites, drones, planes), and drive-by methods to measure emissions from fields. Bottom-up methods incorporate equipment counts and leak factors of specific components in the oil and gas extraction process (Climate TRACE 2021).

I chose to use the bottom-up approach for my study due to the lack of accurate, field-specific, and frequently measured emissions data required for a top-down-based analysis. There is an abundance of publicly available field data, such as field age, field depth, production volumes, and chemical parameter data, like gas composition, API gravity, and production methods, to use as model inputs for a bottom-up model. This data is generally accessible from peer-reviewed scholarly articles in geology or oil-specific research journals or, in some cases, directly from oil and gas operators (Climate TRACE 2021).

The Oil Production Greenhouse gas Emissions Estimator (OPGEE) is a peer-reviewed, bottom-up approach to measuring oil and gas production emissions. It takes publicly available site and chemical parameter data to estimate oil and gas production emissions. Based on the provided inputs and integrated statistical modeling, OPGEE can auto-fill smart default inputs from pre-loaded, peer-reviewed scholarly articles (Brandt et al 2021, Masnadi et al 2018). For example, OPGEE can apply the smart default to the Water-to-Oil ratio input based on previous statistical analysis conducted on fields in California and Alberta (El-Houjeiri 2017). After downloading publicly available field data, I used OPGEE to model emissions for each field from their production start date till the present.

Measuring forest cover loss using satellite imagery and ArcGIS

I will use Planet's PlanetScope satellite image technology and ArcGIS Pro 2.8.6 software to examine forest health by measuring forest fragmentation and forest cover. Planet's imagery is ideal as it has some of the highest resolution (3m/pixel) and highest frequency of observation (1 observation/day) imagery available. The satellite imagery is collected as a series of overlapping scenes in 4 bands: red, green, blue, and near-infrared. These images were then uploaded to ArcGIS Pro 2.8.6 to measure the number of pixels that show signs of forest loss and the number of pixels that show continuing forest cover across the extent of the Yasuní-ITT oil block.

METHODS

Data collection

OPGEE

To collect the necessary oil field data to input to OPGEE, I used Google Search to find a combination of academic papers, oil and gas industry reports, and non-governmental organization reports with the relevant figures. I used "field name + input name + year" to search. I found that the vast majority of the input data, such as production volume, field age, and gas-to-oil ratio could be sourced from Petroecuador's annual oil reports. I also found important information regarding the water-to-oil ratio, water reinjection, and field depth from Oilwatch. To calculate the emissions involved with moving the extracted oil via pipeline and ship to export, I calculated the length of the pipeline and the distance of the export shipping route using Google Maps. Other supplemental information was sourced from academic literature and oil and gas industry news.

Satellite imagery

I used the Planet Explorer online platform to collect the satellite data for image analysis. The platform allows users to set search parameters regarding the satellite data such as date, percent cloud cover, ground sample distance, and area coverage. I set area coverage to 100%, cloud cover percentage to 5%, the date range from January 2012 to May 2022, and left the other parameters at their default values. With these parameters, I searched Planet's available satellite imagery data and chose images that had the highest clarity and that were roughly 2 years apart in interval. I found images that fit my criteria for 2012, 2016, 2018, 2020, and 2022. After selecting these data files, I ordered them through Planet's Explorer interface and downloaded them directly to my computer.

Data Analysis

OPGEE

I first set the model parameters to run OPGEE and get emissions estimates. Under the input tab, I set the functional unit to oil and the oil boundary to refinery. Under the constants tab, I set the model to run using the 20-year global warming potentials. From here, I allocated 14 columns in the inputs tab for each field, and each year oil was being produced. As Tiputini began production in 2016, I created 7 columns to cover production between 2016 and 2022. Similarly, Tambococha began production in 2018, so I created 5 columns to cover production between 2018 and 2022. As Ishpingo only began production in 2022, it had a single column. I then systematically inserted the input data I found into each respective cell in OPGEE. I left the cells blank for inputs where I had no data to allow OPGEE to use its default smart inputs. From here, I set OPGEE to run columns 1 through 14 and ran the model.

After running the model, I made a copy of the Results tab and the VFF Summary tab in a new Excel spreadsheet. To get the total methane (CH_4) emissions per day, I took the sum of the Process-level CH_4 emissions from the VFF Summary tab and the CH_4 emissions from the non-combusted gas in the Flaring tab. To get the total carbon dioxide (CO_2) emissions per day, I took the sum of CO_2 emissions from the VFF Summary tab, CO_2 emissions from the Flaring tab, and the CO_2 emissions from the non-combusted gas, also in the Flaring tab. To get the total carbon dioxide equivalents (CO_2e) emissions per day, I took the product of the lifecycle GHG emissions from the Results tab and the Denominator for computing carbon intensity from the VFF Summary tab. To get the annual emissions, each of the daily emissions was multiplied by 365 days.

Satellite imagery

To analyze the satellite imagery data and obtain a measure of forest cover loss per year, I took the downloaded satellite imagery data and uploaded it to ArcGIS Pro 2.8.6. Then, I created an individual project file for each year's satellite imagery. The first step consisted of taking the individual raster images and creating a single mosaic dataset. From there, I took a polygon which covered the extent of the Yasuní-ITT oil block and used it to clip the mosaic dataset. I then reclassified the clipped mosaic dataset to be able to count the pixels affected by forest loss. Finally, I exported the attribute table for the reclassified clipped mosaic dataset and took the sum of pixels with forest loss. I repeated this process for each year. After getting the pixels deforested for each year, I converted pixels to km^2 by multiplying the pixel count with the pixel resolution of the satellite imagery and dividing by 1,000,000.

$$Forest\ loss\ km^2 = (Pixels\ with\ Forest\ Loss * 3.125m * 3.125m)/1000000$$

RESULTS

Emissions estimates from Yasuní-ITT oil production

After modeling the emissions from Ishpingo, Tambococha, and Tiputini across their production years, I found that the total emissions from oil production between 2016 and 2022 were greater than 10 megatons (Mt) of CO_2e. Out of the three fields, Tiputini began production first in 2016 reaching 0.2 Mt CO_2e for the year. It reached peak production emissions of 1 Mt CO_2e in 2017 and slowly decreased to 0.5 Mt CO_2e by 2022. Tambococha began production in 2018, reaching 0.6 Mt CO_2e in its first year. In 2019, it reached peak production emissions of 1.1 Mt CO_2e before decreasing and leveling off to 0.8 Mt CO_2e by 2022. The latest field to begin production, Ishpingo, has the highest expected annual production emissions. In 2022, it is projected to reach close to 2.0 Mt CO_2e in production emissions.

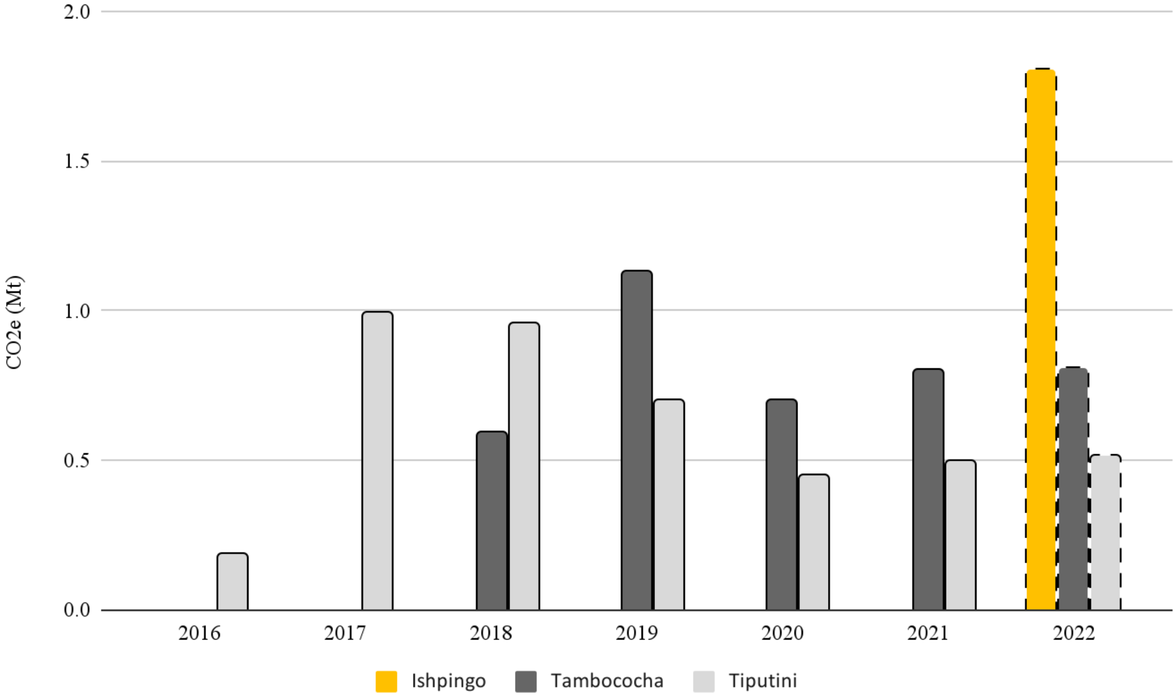

Figure 1. Annual Field-Level Production Emissions in Mt CO_2e between 2016 and 2022. Modeled emissions estimates from each of the three ITT fields. 2022 estimates are based on planned oil production volume.

After breaking down the production emissions by process, I found that 75.1% is attributed to crude extraction, while 12.5% is attributed to oil drilling. Maintenance and crude transport represent 4.8% each, while surface processing makes up 2.8% of total production emissions.

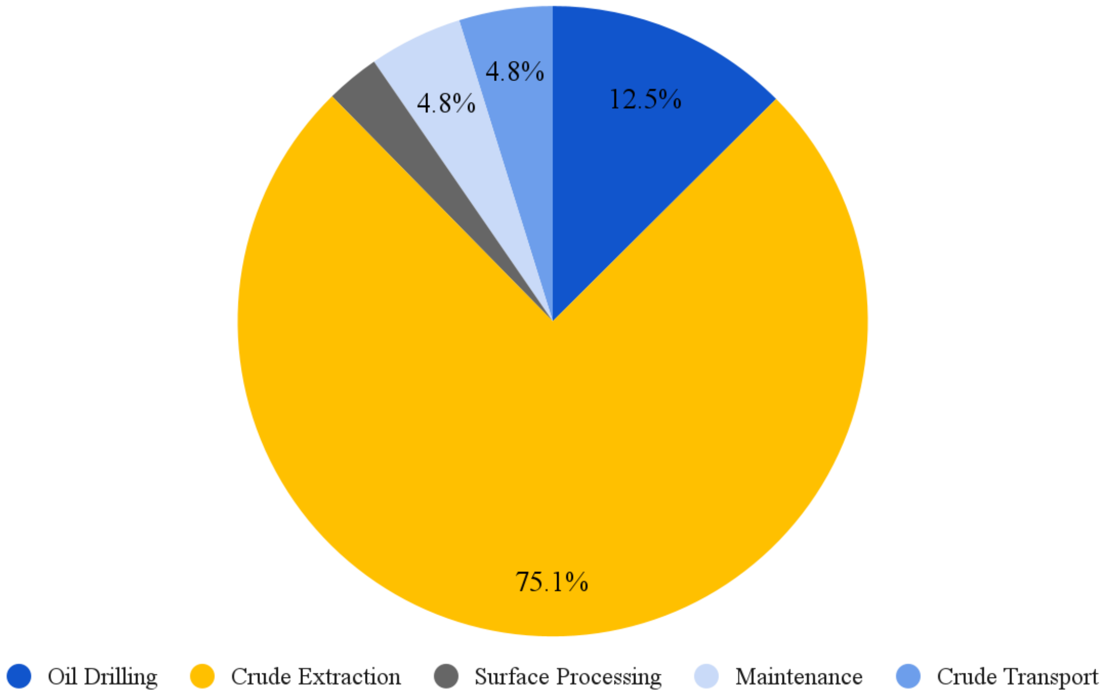

Figure 2. Average Proportion of Production Emissions by Process. Across the three ITT fields and every production year, crude extraction represented 75% of production emissions while oil drilling made up 12.5%.

Forest cover loss from Yasuní-ITT oil production

Within the Yasuní-ITT block, forest cover loss increased rapidly between 2012 and 2022. In 2012, the area of forest cover lost to exploration was less than 80,000 m^2, but by 2016 it reached over 770,000 m^2. By 2018, nearly 1.4 km^2 had been deforested, which scaled to over 2.1 km^2 by 2020. As of 2022, around 3 km^2 of forest has been lost.

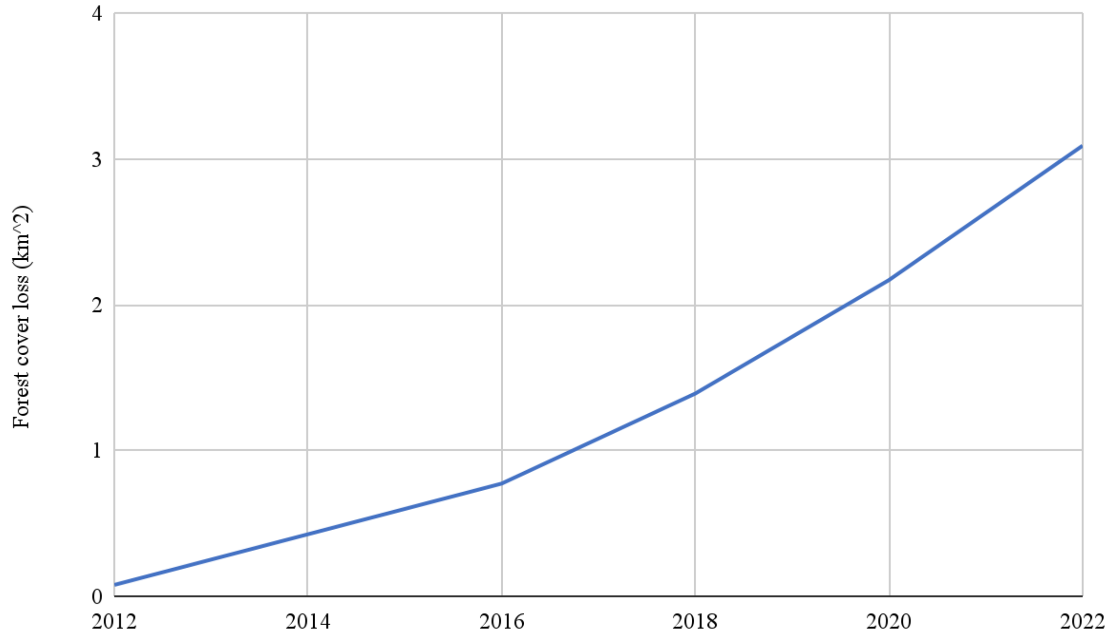

Figure 3. Forest Cover Loss (km^2) between 2012 and 2022 in the Yasuní-ITT oil block. In 2012, forest loss was less than 0.07 km^2 but by 2022 it reached over 3 km^2.

DISCUSSION

When I began my study, my goal was to understand how oil extraction in Block 43 (ITT) of Yasuní National Park impacts the global climate, biodiversity, and people who live there. I found that between 2016 and 2022, the cumulative emissions of the ITT fields were over 10 megatons of CO_2e. Including Ishpingo, the field that began production early this year, the three ITT fields are projected to release over 3.1 megatons of CO_2e in 2022. As Ishpingo begins to reach maximum production and as more wells are drilled across the three ITT fields, that the annual emissions will likely increase over time. Furthermore, the analysis revealed that the development of the ITT fields led to 3 km^2 of primary forest loss, which is projected to increase significantly with the expansion of Ishpingo deeper into Yasuní National Park. In addition, as local people begin to use the oil access road developed for the ITT project, it is likely that further forest loss along the road will occur, which entails severe consequences for the biodiversity of the park. The people who stand to lose most from the ITT development and expansion are the Indigenous Waorani, Tagaeri, and Taromenane people.They all rely on their extensive territories and Yasuní's pristine biodiversity to survive and live. As ITT expands, Indigenous people will be forced to migrate away from some of their historical territories creating conflict between them, local farmers, and oil workers. Indigenous people will be subject to toxic waste, unsafe drinking water, loss of food, and other forms of damage that will impact their culture and way of life.

Yasuní-ITT production emissions and Ecuador's climate goals

In 2020, Ecuador emitted 95 megatons of CO_2e across its major sectors including, land use, oil, agriculture, waste, power generation, and more (ClimateTRACE 2022). Assuming that Ecuador's total emissions in 2022 are similar to those of 2020, the emissions from oil production at ITT in 2022 represent 3.2% of Ecuador's total annual emissions. Ecuador is a signatory to the United Nations Framework Convention on Climate, which makes it responsible for publishing a report on its Nationally Determined Contributions (NDCs) every 4 years. NDCs are a record of a country's efforts to reduce its greenhouse gas emissions and adapt to climate change. The Ecuadorian government hopes to decrease their annual emissions by 9% with no international help and by 21% with international help by 2025. Ecuador's government needs to find new ways to develop its economy outside of land and resource-intensive industries to achieve this goal. However, Ecuador's recently elected president Guillermo Lasso is making significant plans to maximize foreign investment in oil and mining concessions, which are clearly at odds with the nation's climate goals and constitutional obligations which will be addressed in more detail in the broader implications.

Yasuní-ITT and forest cover loss

To understand the impact of the Yasuní-ITT project on biodiversity, I used forest cover loss as a proxy. I found that between 2012 and 2022, over 3 km^2 of highly biodiverse primary tropical rainforest was lost as a result of ITT's development. Compared to Yasuní National Park's total land area of around 9,820 km^2, the loss of 3 km^2 of forest cover may seem insignificant. However, the calculated forest cover loss included the 15+ km oil access road constructed from the Rio Tiputini in the north entering Yasuní National Park towards the south. Roads, especially when they are constructed in previously inaccessible primary rainforest, are a major cause of deforestation and habitat fragmentation. For every kilometer of road built in a region, an average of 1.2 km^2 is lost to agricultural expansion. Shushufindi, a major oil development in the Ecuadorian Amazon from the 1980s, experienced 19.3% of forest cover loss between 1986 and 2001 (Save America's Forests 2004). Additionally, it has been found that new access roads could not be adequately controlled or managed, especially in regard to the actions of local people (Finer et al 2008). Therefore, the current area of lost forest does not represent the permanent extent of forest loss along the ITT road, especially considering the planned expansion of the Ishpingo field and the effects of expansion from increased access to the forest. The increased risk of deforestation and oil expansion will have profound effects on Yasuní National Park and its biodiversity. Along with habitat destruction, visual and noise disturbance, pollution from extraction, other indirect forms of damage can occur such as soil erosion, water pollution, illegal hunting, and the introduction of invasive species and pathogens (Butt et al 2013). All of these effects need to be considered when assessing the extent to which ITT's development has impacted the wildlife in Yasuní.

Yasuní-ITT and impacts to Indigenous communities

Without having visited the Indigenous communities close to the Yasuní-ITT project, it is difficult to precisely quantify and assess the impact of oil extraction on them. However, it can be assumed that ITT's infringement on Indigenous territory has led to the migration of Waorani, Tagaeri, and Taromenane people into smaller, more confined, and isolated territories. As a result of this territorial loss, it is likely that the natural resources these communities depend upon have become more scarce and volatile. This has likely resulted in negative impacts on local livelihood strategies, essentially forcing many of these Indigenous communities to shift their cultural way of life and succumb to a more Western approach to living. It is also very likely that the oil extraction has had direct impacts on their health - specifically in terms of exposure to waste from drilling wells and extracting oil from the ground, along with exposure to toxic gasses flared during the extraction process.

Limitations and Future Directions

To understand the impacts of the Yasuní-ITT oil project on global climate change, biodiversity, and human health, my approach was to use a combination of emissions modeling and satellite imagery to measure forest cover loss. Neither approach is on-the-ground, direct field research, which is a significant limitation when trying to quantify the extent of the oil extraction's environmental and human health impacts. Therefore, it would have been a unique opportunity to visit the Yasuní-ITT project and conduct ecological surveys of tracts of Yasuní with no history of oil development, and compare those with tracts where oil extraction is active. Similarly, I would have cherished the opportunity to talk directly with Indigenous communities to understand how the ITT project has impacted their health, survival strategies, and livelihoods. In terms of my study's scope and relevance, I asked the correct questions to be able to identify patterns in how oil development across tropical forests impacts climate, biodiversity, and human health. However, there will be unique differences in impacts depending on where the oil or gas is being extracted and what processes are being used to extract those products.

There exist various pathways to build on the findings from this study. First and foremost, the Yasuní-ITT project is yet to be completed, so it will be imperative to continue monitoring the fields, especially to see how expansion will impact forest cover loss. In addition, there needs to be continued monitoring of the ITT fields to assess the extent to which secondary impacts from increased access such as agriculture, logging, and hunting play a role in forest loss. Moreover, an important pathway for future research concerns on-the-ground ethnographic research to evaluate how the Indigenous communities surrounding ITT are being impacted. Similarly, it would be important to see how toxic waste from the oil extraction is being managed and do ecological assessments to understand if and how toxic chemicals are making their way into the ITT fields' ecosystems.

Broader Implications

Oil extraction in the Yasuní-ITT case has many downsides. There are significant climatic effects from the production of oil, forest loss of intrinsically valuable and highly biodiverse tropical forests, increased risk of accelerated forest loss from increased access to the primary forest, and direct harm to Indigenous communities and their culture. These impacts directly contradict Ecuador's most recent constitution, which was passed in 2008. There are legally enforceable rights in the constitution to allow nature to “exist, flourish, and evolve.” Article 14 states that people have the right to live in a healthy and ecologically balanced environment, where the protection of ecosystems is central. Article 15 states that the Ecuadorian government must make an effort to promote environmentally friendly technologies, and Article 414 states that the government must attempt to mitigate climate change by limiting greenhouse gas emissions, deforestation, and other forms of atmospheric pollution. Therefore, my research clearly shows how these constitutional obligations and Ecuador’s Yasuní-ITT oil project are contradictory. To live up to its 2008 constitution, Ecuador needs to strongly consider scaling back oil and mining development in the Amazon instead of accelerating it. Nevertheless, there are reasons for hope. On February 4th, 2022, Ecuador’s Supreme Court ruled to expand Indigenous communities’ rights to receive free and prior informed consent (FPIC), “whereby the community has the final decision on whether or not to allow any extractive activity” on their territory. Although this is a significant legal and political win for Indigenous people, more needs to be done to grant these communities more substantial rights. Additionally, the Ecuadorian government needs to align its rhetoric with its actions when it comes to resource extraction-based development projects.

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