Consolidated Human Activities in the Western Maya Mountains

Presented by:
Wilmer Eaton Guerra

FCD
Friends for Conservation and Development

July 10, 2025

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Developed by: Mr. Wilmer Guerra, Biodiversity Research, Inventory and Monitoring Technician, Friends for Conservation and Development.

Date: July 10, 2025

Cover photo: Chief Ranger Ellsworth Sutherland
All maps Created by FCD

Recommended Citation:

Guerra, W. (2025). Consolidated Human Activities in the Western Maya Mountains. Friends for Conservation and Development. San Jose Succotz, Cayo, Belize.

Acknowledgements

Gratitude is extended to the FCD Ranger Unit, who with the cooperation of the Belize Defense Force (BDF), is tasked daily with patrolling and collecting ground data on anthropogenic activities, including cattle ranching, forest fires and agriculture.

To the FCD Data Analyst, Miss Mitzi Tzib we are thankful for the compilation of data.

FCD is grateful to the Protected Areas Conservation Trust (PACT) of Belize for funding this project, under the project title, "Strengthening Landscape Management in the Western-Maya Mountains."

Friends for Conservation and Development (FCD) is a non-governmental organization dedicated to the protection and sustainable management of the Belize's natural and cultural heritage, with a focus on the Chiquibul National Park (CNP). Based in the Cayo District, FCD works to combat threats such as illegal logging, wildlife trafficking, and cross-border encroachment through forest patrols, biodiversity monitoring, and environmental education. The organization collaborates with government agencies, local communities, and international partners, and is especially known for its recovery conservation efforts involving key species like the Scarlet Macaw and Jaguars.

The Protected Areas Conservation Trust (PACT)- is a national conservation finance mechanism established by the Government of Belize in 1996 to support the sustainable management and protection of the country's natural and cultural resources. Funded primarily through a conservation levy on tourism and other environmental-related fees, PACT provides financial support to protected areas, community-based organizations, and co-management partners across Belize.

Content

1. Introduction

The Chiquibul/Maya Mountain Massif (CM3) is one of the largest intact tropical forest systems in the region, north of the Amazon. The sheer size of it is impressive, spanning approximately 1,260,800 acres, representing approximately 22.2% of Belize's total land area (The Nature Conservancy, 2007). Situated in southwestern Belize, this contiguous forest extends from the Vaca Forest Reserve in the north to the Columbia River Forest Reserve in the south. This vast forested region is essential for maintaining coastal watersheds, which help sustain the Belize Barrier Reef. As the most prominent landform in Belize, CM3 is divided into 14 protected areas under different conservation categories, including the Forest Reserves: Chiquibul, Columbia River, Deep River, Maya Mountain, Mountain Pine Ridge, Sibun, Sittee River, and Vaca; National Parks: Noj Kaax Me'en Eligio Panti and Chiquibul. Other designated areas: Bladen Nature Reserve, Cockscomb Basin Wildlife Sanctuary, Caracol Archaeological Reserve, and Victoria Peak Natural Monument (Walker & Walker, 2009). Beyond its ecological significance, CM3 is a critical component of Belize's natural heritage, supporting biodiversity, water resources, and conservation efforts (Briggs 2013).

The western section of the CM3, which includes the Vaca Forest Reserve, Caracol Archaeological Reserve and Chiquibul National Park have been facing increased forest clearing since 2015, directly linked to Guatemalan agricultural settlements along the border and, in some cases, illegal settlements within Belize (Chicas et al. 2016). Population growth and poverty in Guatemala, and lack of law enforcement and border security in both Belize and Guatemala are largely responsible for the unabated and illegal forest clearing that has taken place along the border region over the past 3 decades (Chicas et al. 2016).

The Vaca Forest Reserve (VFR), managed by the Belize Forest Department (FD) is a 16,314-ha forest reserve that has quickly become a hotspot for illegal encroachments from both Guatemalans and Belizeans. There are 2 primary organizations in the VFR: the Belize Forest Department, as the official administrator and the Friends for Conservation and Development (FCD) who have been implementing various projects within the Vaca Forest Landscape since 2010 under a letter of understanding. Implemented projects have focused on best farm management practices with the objective of increasing crop yields using a more ecologically sustainable approach by implementing farming techniques such as inter-cropping, soil conservation, agroforestry, silvo-pastoral systems and organic farming. In 2007, A Technical Assessment Report by FCD noted that the VFR was the most threatened protected area in the CM3 because of multiple interests in the area ranging from agriculture expansion and intensification, the presence of a hydroelectric dam, to both legal and illegal logging practices (Manzanero and Melendez 2013). The Vaca Forest Reserve Management Plan (2017-2022) by Meerman and Boomsma 2017, noted that there were 48 farmers operating near the reserve (in the excised section, hereinafter referred to as the de-reserved area), while 21 farmers were inside the reserve boundaries, to the eastern section of the VFR.

The Chiquibul Ecosystem, covers an area of 176,999 ha (437,376 acres) and is comprised of three protected areas, namely the Chiquibul National Park (CNP), Chiquibul Forest Reserve (CFR) and the Caracol Archaeological Reserve (CAR). The approximately 43 kms of border shared between Belize's Chiquibul Ecosystem and Guatemala's La Reserva de Biosfera Montanas Maya-Chiquibul is not clearly demarcated and extends through a contiguous area

between both nations. Remote sensing and ground data demonstrates extensive deforestation on the Guatemalan side, with a relatively intact forest cover on the Belizean side. Inside the Chiquibul Ecosystem there is no permanent human settlement, but eleven Guatemalan communities lie in close proximity to the border, within easy reach of the Chiquibul Ecosystem and its resources. Most of the anthropogenic pressures within the protected area comes from across the border (Bridgewater et al. 2006). Along the western flank of the Chiquibul Ecosystem the major threat to the ecological integrity is deforestation due to forest conversion to crop farms and livestock pastures, through slash and burn farming. This phenomenon is detrimental to the local ecosystem, and at the international scale it has been associated with an increase in climate temperatures (Fearnside 1996, Arevalo 2011).

Friends for Conservation and Development (FCD) has jurisdiction to patrol the CNP, as the co-manager, and plays a monitoring role within the VFR, CAR and in the Bald Hills region of the Mountain Pine Ridge Forest Reserve.

FCD has collated data on illegal human activities and agricultural encroachments; documentations which are collected by Park Rangers through the Spatial Monitoring and Reporting Tool (SMART) software since 2012. In addition, FCD has been able to collect and analyse remote sensed data since 1987.

The Protected Areas Conservation Trust (PACT) has financed a multi-year investment with FCD titled "Strengthening Landscape Management in the Western-Maya Mountains". One of the project outputs is the development of an assessment of Human Activities in the Western Maya Mountains Landscape (5 protected areas). The report aims to present a combination of attributes from 2020-2024, including deforestation, agriculture, forest fires, logging and other illegal activities, with the aim of identifying the integrated human footprint effects within the VFR, CAR and CNP, and provide a situational analysis of forest fires in the MPRFR.

2. Objectives

- To compile and integrate spatial data on various human activities from 2020 to 2024—including deforestation, agriculture, forest fires, logging, and other illegal activities—into a consolidated shapefile representing the human footprint within the CAR, CNP, and VFR and provide a situational analysis of Forest Fires in the MPFR.

- To identify and highlight hotspots inside the VFR, CAR and CNP.

- To provide recommendations for regulatory agencies to be able to better address these illegal activities.

3. Methodology

To quantify the acreage deforested in the VFR, CAR and CNP, Sentinel-2 imagery dated November 11, 2024. The images were digitized and analyzed using Sentinel-2, 10 m resolution images, with a blue (band 2), green (band 3), red (band 4), RGB, band combination. The European Sentinel consist of a fleet of satellites dedicated to providing imagery for Earth observation purposes. Deforested patches were manually digitized in ArcGIS and their size (in hectares [ha]) was calculated using the program's geo-processing tool.

To quantify the 2020, forest fires, which were the most significant fires for the time period of the project (2020-2024), Landsat 8 imagery from prior and after the 2020 fires were used to calculate the damage caused to the Chiquibul Ecosystem. The process was executed through a Normalized Burn Index (NBI). The burnt areas were then digitized and their acreage was subsequently calculated.

Previous deforestation analyses and fire scar analyses from dated from 2020 up to 2024 were also used to create a consolidated shapefile of human footprint within the CAR, CNP and VFR. Point features of human activities occurring inside the VFR were collected, throughout the life of the project, through the use of SMART. The data is hosted in a local SMART Database and is analyzed through the joint use of other spatial analysis software like ArcMap and QGIS. The SMART mobile app was also used to monitor and document activities by the farmers operating within the protected area. Imagery collected through the Chiquibul Aerial Survey Program were also used in the study as a form of verification. Imagery is collected and later collated in Agisoft. Rasters created in Agisoft provide imagery of a 3-m resolution that provides a Natural Color raster of the 45-Kms extent of the Belize-Guatemalan border inside the Chiquibul Ecosystem. Following the Belize Collect Earth/Open Foris Land Use and Land Use Change Assessment Protocol (Forest Department 2019) what was considered a forest, and no longer deforested, is defined as a plot of land with an area of 0.5 hectares or more, with trees 5 meters or higher, and a canopy cover of 30% or more. When digitizing, wherever areas had gained substantial secondary forest growth to a point that it was no longer prominent in the remote sensing data, ground truthing through the Chiquibul Aerial Survey Program was done.

4. Results and Discussion

Understanding the historical, active, and potential threats to the protected areas and the integrity of the biodiversity in general is important to devise sound conservation and management strategies.

Human activities inside the VFR are a combination of both legally permitted or legally recognized activities and illegal activities. With regards to legally allowed activities, the entire eastern section between the de-reserved area and the Macal River can be regarded as a multiple use zone with human activities that include agriculture, tourism and power generation (management by BECOL of the Vaca and Mollejon Hydro lakes) (Meerman and Boomsma 2017). To the north, an area immediately south of Arenal Village, has been farmed for decades (Boomsma 2017) and has also been severely affected by forest fires over the years. Furthermore, based on data collected through FCD's CASP, the southwest of the reserve, there are also a few

cattle ranches, that have not been formally recognized by the Forest Department, and which have seen some financial investments by the ranchers over the years. Illegal activities in the area include, illegal hunting, illegal wildlife trade, illegal extraction of non-timber-forest produce, illegal logging, amongst other.

In the Chiquibul National Park, which has been the focus for many FCD related studies, at a historical basis, deforestation for agricultural use was first detected in 1989, when approximately 232 hectares had been converted from tropical broadleaf forest to agricultural fields (Guerra 2023). Subsequent analysis of the historical data gathered from remote sensing indicate that deforestation due to forest conversion for agricultural and/or pasture had been steadily increasing over the years, reaching its peak at around 2015, when deforestation for agricultural use was approximately 4,140.67 ha. Communities, on the Guatemalan side of the border, that lie adjacent to the Adjacency Line, place the major threat to the integrity of the Chiquibul ecosystem. Drivers such as limited land availability, which is exacerbated by the rapid population growth in Guatemala, and the limited patrols by Belizeans authority have allowed deforestation to remain a threat that is relatively difficult to address. Below is a discussion of the monitored human activities inside the VFR and the Chiquibul Ecosystem (CAR and CNP).

Picture 1: *Showing a Recently Cleared Forest in the Vaca Forest Reserve.*

DEFORESTATION FOR AGRICULTURE

- Vaca Forest Reserve:

Digitization of the November 11, 2024, Sentinel 2 image indicate that a total of 3,836.59, or 23.51% of the entire territory of VFR, is affected by deforestation for agriculture. In 2022, deforestation was at 2,513.23 hectares, and in 2023 the deforestation was at 3,736.69 hectares, *see figure 1*. This indicates that since 2022, there has been a sharp increase of 52.65% in the total deforested encroachments in the VFR. Deforestation was more pronounced and increasing in the north western part of the reserve, with multiple pastures having more financial investments for corals, house structures and fences, *see map 1*. Deforestation, however, had also increased in the southwest area, a hotspot for cattle ranching. Compared to 2022, deforestation in 2023 and 2024 within the eastern section—where FCD has been implementing multiple projects—was

actually reduced, and areas that had previously been burnt began regenerating. In this eastern section, however, continued farming poses a threat to potentially disrupt the functioning of the area as a biological corridor linking the Noj Kaax Meen Elijio Panti National Park through the VFR to the Chiquibul Ecosystem. In this regard, the terminology "agricultural encroachments" does not distinguish between crop agriculture, cattle ranching, or abandoned early regenerating crop farms, but rather is a generalized term for any visible plot of land that has been devoid from, or has limited, forest cover.

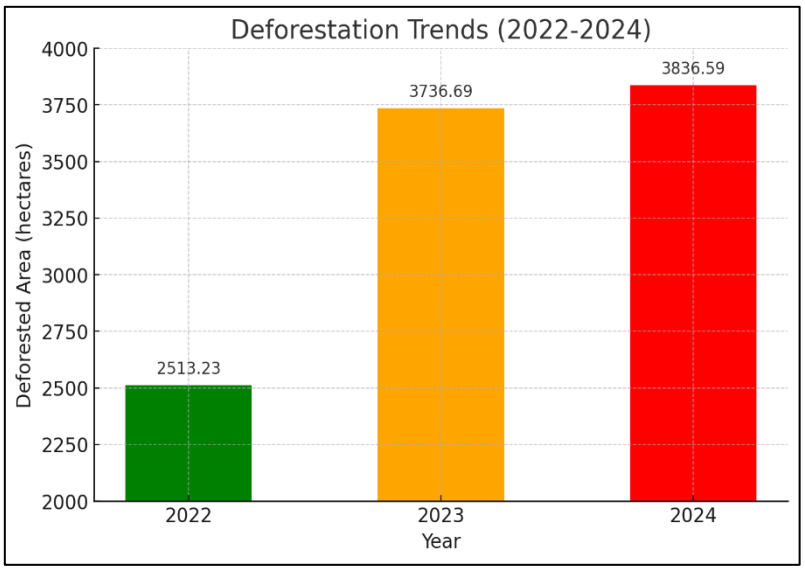

***Figure 1**: Bar chart illustrating deforestation trends from 2022 to 2024. The data shows an increasing trend, with deforested areas rising from 2,513.23 hectares in 2022 to 3,736.69 hectares in 2023, and further to 3,836.59 hectares in 2024.*

Deforestation was spread over the entire area and affects mostly the valleys throughout the Forest Reserve but was more pronounced and conspicuous in the Northwestern region of the reserve. Evidently, most of the deforestation threats to the reserve is being exerted by Arenal farmers and Guatemalans occupying areas along the Adjacency Zone of the western flank of the Belize/Guatemalan border. The northern section of the reserve, contains some very steep areas that are unsuitable for agricultural cultivation and is likely to degrade even further as a result of escaped agricultural fires.

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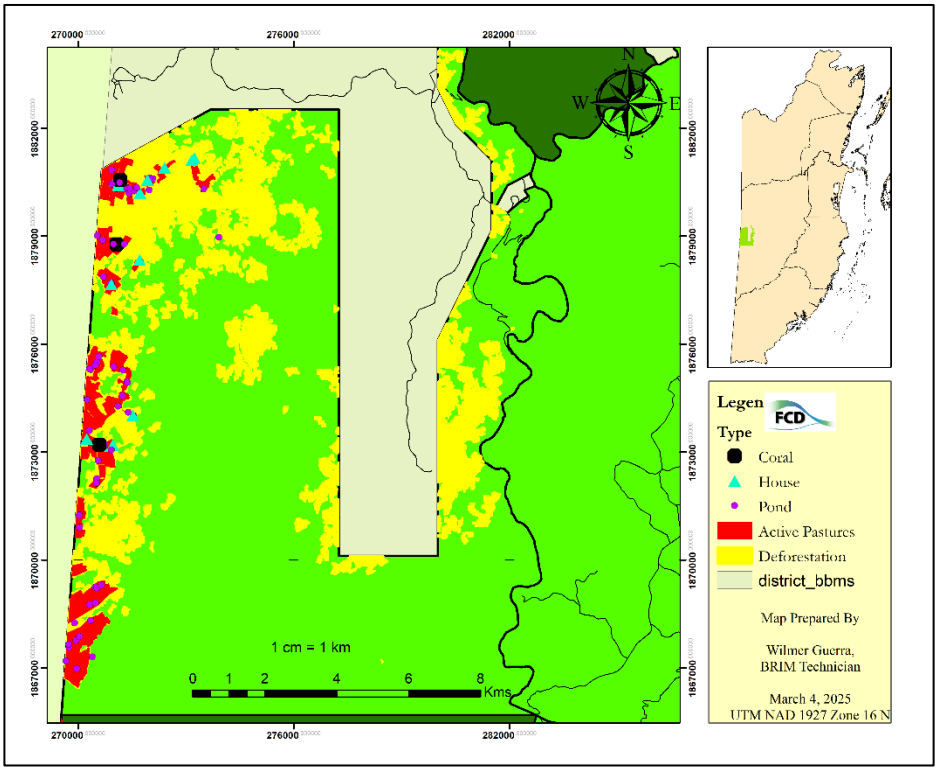


***Map 1**: Showing Deforestation (yellow shapefile) in the Vaca Forest Reserve for the year 2024. In Red Shapefiles is active cattle pastures. Also portrayed are features such as corals, ponds and house structures.*

- Chiquibul Ecosystem (CE):

The digitization of the November 11, 2024, Sentinel-2 imagery indicates that the total deforested encroachment in the CNP was 1,061.00 hectares, representing a mere 0.92% of the total acreage of the National Park, and 902.06 hectares in CAR, representing approximately 8.92% of the total CAR area. Henceforth, the cumulative deforestation for 2024 for the CE amounts to approximately 1,963.06 hectares, which is a slight increase from the total deforested in 2023; about 1.85% increase. This slight increase can be attributed to fires originating from established cattle pastures that have gradually encroached upon regenerating *wamils*, particularly in the Caballo area. In this area, notably, *wamils* that began regenerating since 2015 have been burned twice—first in 2023 and again in 2024—resulting in their reversion to barren land. Once a regenerating area is repeatedly burned, it struggles to recover, leading to desertification or permanent grassland conversion. This can encourage further expansion of cattle pastures, perpetuating a cycle of deforestation and habitat destruction. In cases of repeated fires, the landscape in the Chiquibul also become plagued with tiger fern, a pioneer specie, often colonizing disturbed areas, dominating regenerating landscapes, particularly after disturbances like fire or deforestation and limiting regrowth of productive vegetation.

At a historical level, analysis of data gathered from remote sensing indicate that deforestation due to forest conversion for agricultural and/or pasture had been steadily increasing over the years, reaching its peak at around 2015, when deforestation for agricultural use was approximately 4,140.67 ha, *See Figure 2*. Past 2015, the satellite imagery analysis clearly shows a

decrease in the accumulative deforested area from 2016 up to 2018 (Arevalo 2018) and from 2018-2021 and has remained stable from 2021-2023, with a slight increase now in 2024.

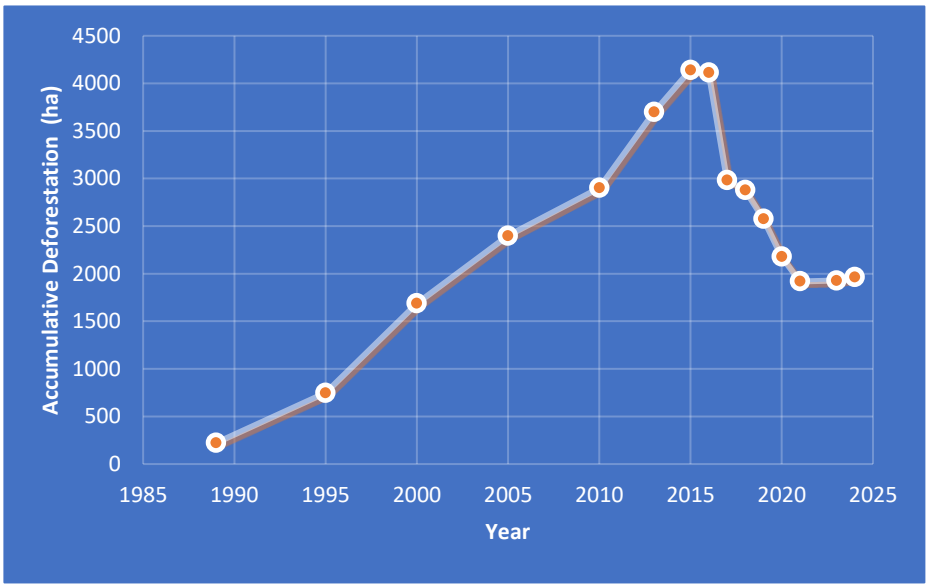
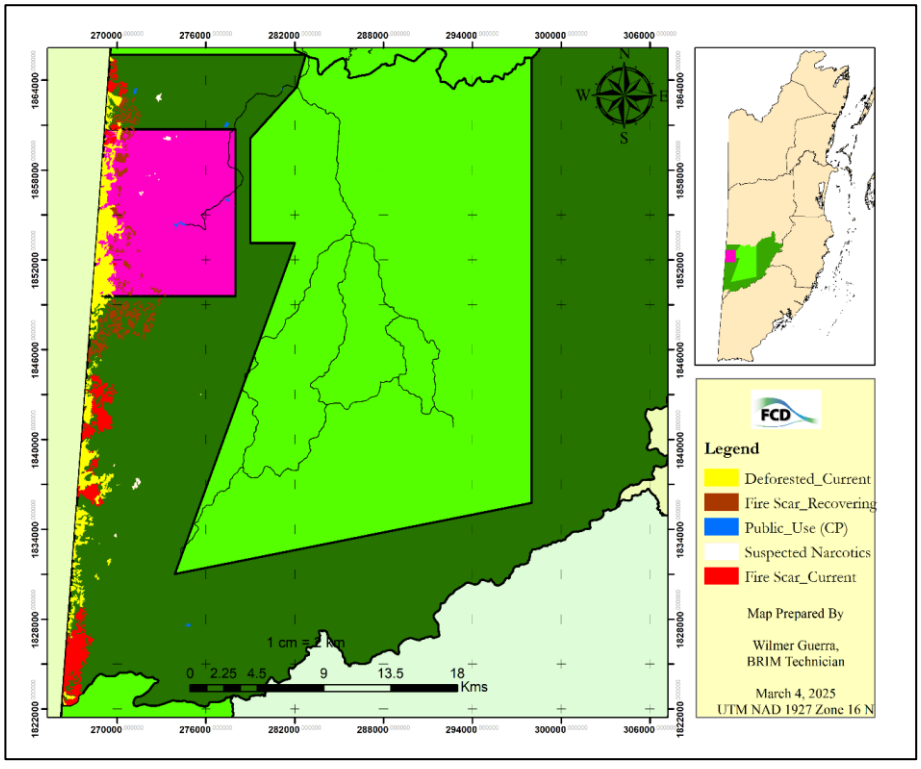


Figure 2: *Showing historical deforestation in the Chiquibul from 1989-2024.*



Map 2*: Showing deforestation in the Chiquibul Forest (CNP and CAR) for 2024*

FIRES (2024)

In this area of the CM3, as in many rural places of Guatemala and Belize, slash-and-burn agriculture, is the dominant form of subsistence farming by farmers. Slash and burn involves the progressive cutting and burning of primary or secondary forests (Smith et al. 1999) for the planting of rotational crops. In converted pasture lands; areas where primary forests have been converted into pasture lands, the burning of grass is common. In the Chiquibul Ecosystem and Vaca, fires are not prescribed or managed properly, leading to uncontrollable fires that ravage both encroached and standing forests.

Performing a normalized burn ratio provides an estimate of the fire scar for a specific period. The below is the estimated fire scars for both the CE and the VFR;

***Picture 2**: Showing Farmers outing fires in the Vaca Forest Reserve.*

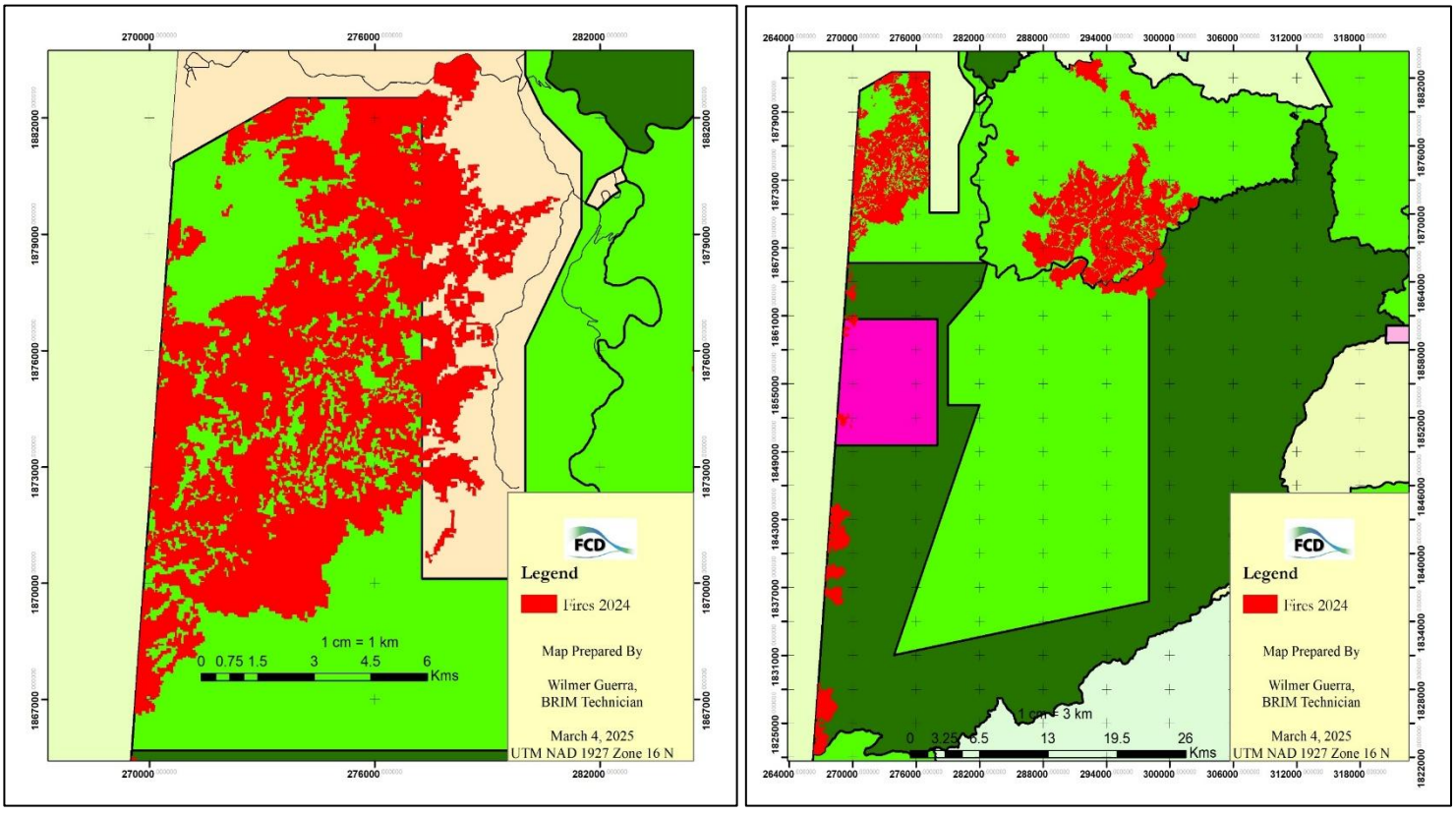
- **Vaca Forest Reserve**

A total of 6,037.46 hectares was affected by forest fires in 2024 inside the Vaca Forest Reserve. One of the worse recent fires inside the reserve was in 2020 when a total of 5,670.00 was affected. Since then, fires have been a constant threat throughout the dry season, each year. The sharp increase in deforestation since, and even before 2020, could be attributed to the massive forest fires that affects the VFR. Since the area has been affected multiple times by forest fires it has made way for secondary *wamil* forests that are characterized by a less developed canopy structure, smaller trees, and less diversity. Due to the lack of a full canopy, more sunlight reaches the floor, supporting vigorous ground vegetation, which makes these areas more susceptible to fires during the dry season. The forest fires of 2024, decimated most areas where there was substantial secondary forest growth. The subsequent fire scar was more pronounced to the north of the reserve. The area has been extensively encroached for agricultural use and fires are exclusively ravaging as a result of escaped agricultural fires (Guerra 2022). Essentially the whole northern section of the VFR has been affected by fires frequently enough that the forest structure has been devoid of healthy forest canopy, to the extent that it is detectable from Satellite imagery. Wildfires are a major issue in the management of the VFR. Virtually all fires in the area start as agricultural fires. Farmers are careless on the use of fire. Many fires are left unattended and get

out of hand. There is a direct link between fires and the areas affected by agriculture. Important to notice is the fact that since 2016 the number of fires has increased dramatically. This increase is not linked to weather conditions, or to the impact of hurricanes, but rather to a rapidly increasing amount of land clearing within the VFR (Meerman and Boomsma 2017).

- **Mountain Pine Ridge Forest Reserve**

In May of 2024, the Mountain Pine Ridge Forest Reserve experienced significant wildfires. Approximately 11,255.95 Hectares, accounting for about 25.58% of the reserve, was affected by the fires. At the time, multiple stakeholders coordinated to suppress the fires and prevented damage to private property. The MPR ecosystem is a fire-dependent community dominated by Caribbean Pine (*Pinus caribaea*) with a variable component of Honduran pine (*Pinus oocarpa*) (Colatskie 2011). Hence, with the exception of damage to infrastructure, the fires are good for maintaining the health of the Mountain Pine Ridge ecosystem. In retrospect, however, uncontrolled, frequent, or extreme fires can be destructive. The MPR is currently in transition following the devastating 2001 outbreak of the southern pine beetle (SPB) (*Dendroctonus frontalis*) and is now a patchwork of pine regeneration from dense regeneration to open savannahs invaded by tiger fern (Colatskie 2011), which becomes highly flammable, contributing to fire spread.



***Map 3**: A.) Showing Fire Scars in the Vaca Forest Reserve for 2024. B.) Showing Fire Scars in the CE, and MPFR.*

- **Chiquibul Ecosystem**

Fires in the Chiquibul Ecosystem were particularly pronounced in the southern region, as shown in Figure 3B, with significant fire activity recorded near the Jimenez Farm and South Cebada. Both locations are well-known hotspots for cattle ranching, an activity that often contributes to deforestation and land degradation.

In 2024, approximately 2,366.58 hectares (Ha) of forest were affected within the Chiquibul National Park (CNP), with an additional 83.79 Ha in the Caracol Archaeological Reserve (CAR). The extent of these fires highlights the ongoing threats that land-use changes and human encroachment pose to the region's fragile ecosystem.

Typically, agricultural fires in this area originate from the Guatemalan side of the border, where slash-and-burn practices are commonly used for clearing land for farming or livestock. These fires often spread across the border, gradually creeping into the Chiquibul Ecosystem. This cross-border fire movement presents a significant challenge for forest management and conservation efforts.

The fires in Southern Cebada were particularly severe, extending as far as 2 kilometers into the protected area. Due to the rugged terrain and remote location, firefighting operations were exceedingly difficult. Limited accessibility and the absence of infrastructure for fire suppression further compounded the challenge, allowing the fires to spread unchecked for extended periods.

These recurrent fires not only contribute to habitat loss and biodiversity decline but also pose a direct threat to fragile watersheds in the southern section of the Chiquibul, as well as other vulnerable wildlife dependent on the Chiquibul ecosystem. The increasing frequency and intensity of these fires highlight the urgent need for enhanced fire prevention strategies, cross-border collaboration, and enforcement of conservation regulations to protect this critical habitat.

CATTLE RANCHING

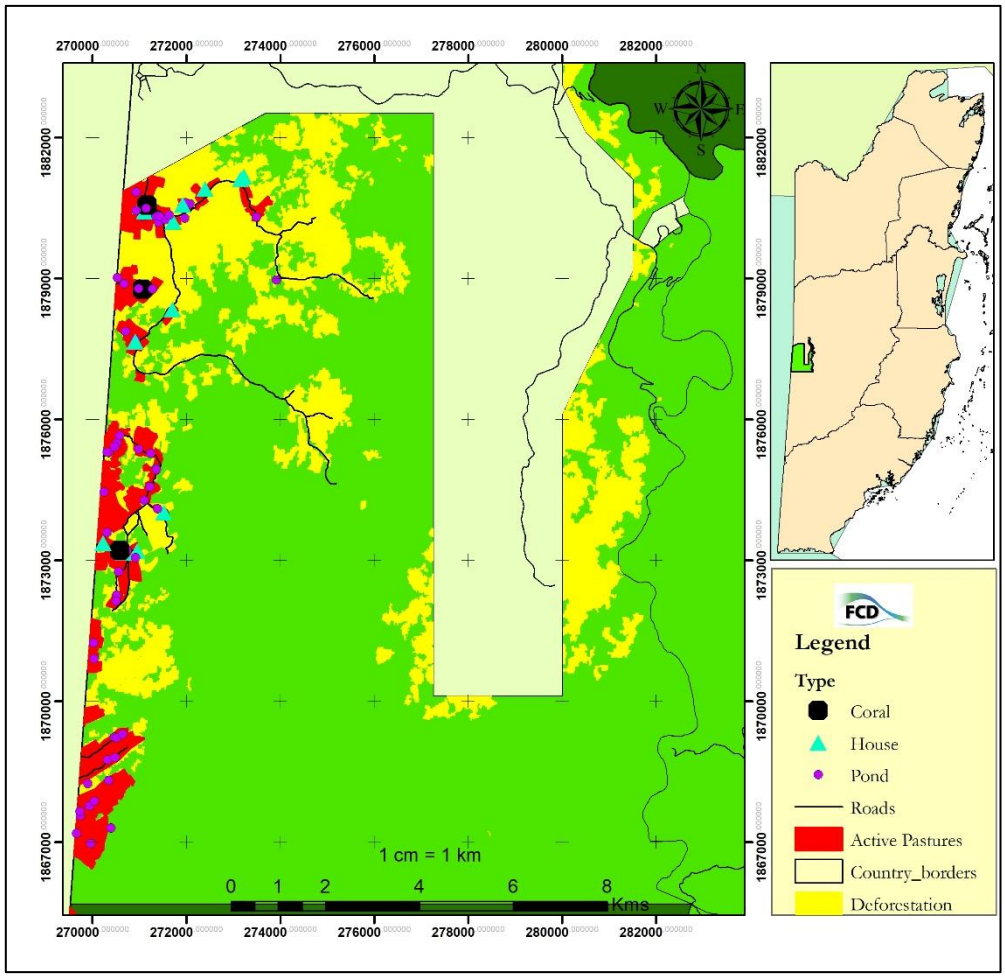
Deforestation along the Belize-Guatemala border has been a persistent issue for the past 30 years, but it has shifted from peasant farming through slash and burn to intensive and vast cattle pastures that have become increasingly difficult to address.

Picture 3: *Showing vast areas of deforestation for cattle pastures within the Chiquibul National Park.*

- **Cattle Ranching in VFR**

As of August 30, 2024, a total of 674.45 hectares were being actively encroached for cattle ranching along the western flank of the Vaca Forest Reserve, *See map 4*. Relative to the total 2024 deforestation in the VFR, this figure merely represents approximately 18% of the entire cleared forest. The study classified active farms, characterized by relatively barren land, apart from pastures that have been abandoned and/or are in early succession, characterized by growing *wamils*. To the north of the VFR, the pressures due to cattle ranching seem to be inserted by the community of Arenal which, unique as it is, is a village that is divided by the Belize-Guatemalan border. The northern area of the reserve has a total of seven (7) identifiable buildings, 13 machine-constructed ponds, and one corral along with a network of 20 Km of roads that connect from Arenal to the number of pastures that have been constructed, *See figure 4*. The construction of housed structures indicates the intended permanency of these pastures within the protected forest reserve. These pastures, as opposed to those in the southern region of the reserve, seem to be Belizean owned.

Cattle pastures in the south of the VFR, along the western flank bordering the Chiquibul Maya Mountain Biosphere Reserve in Guatemala, are direct extensions of cattle pastures from the Guatemalan side, where pastures extend vastly. These pastures are typically large-scale operations to accommodate extensive grazing, but smaller plots also exist as part of mixed-use farming systems. These pastures are generally used for low-input extensive cattle ranching, with minimal supplemental feeding or land improvement. Financial investments can also be observed in the area with the construction of mechanized ponds for watering cattle, well-defined, fenced-off pastures, and the construction of roads.



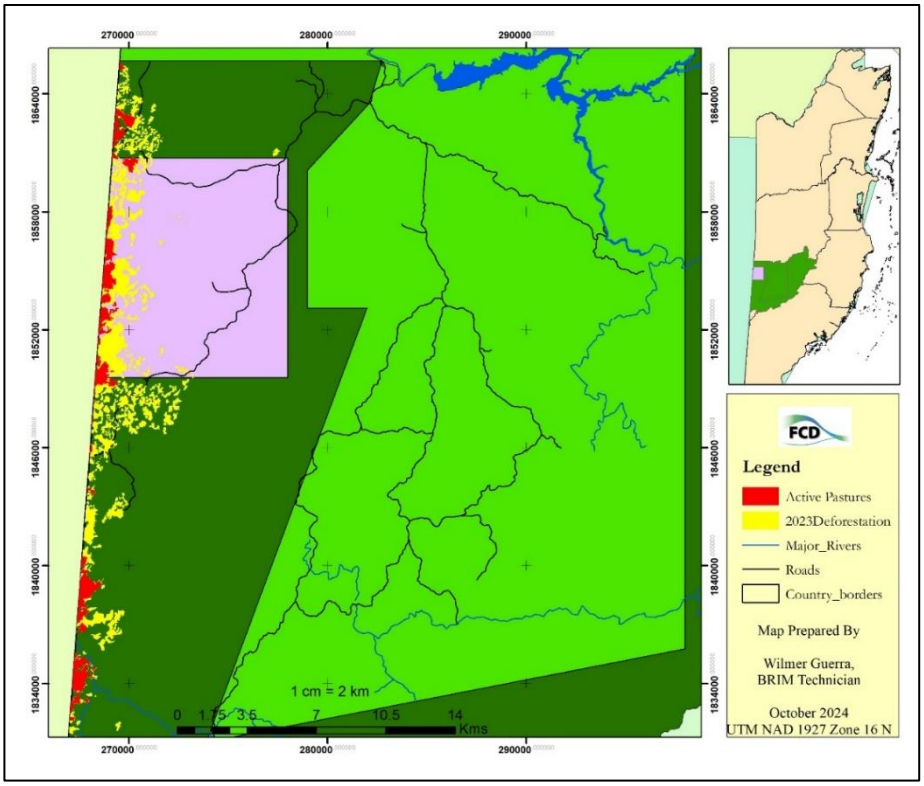
***Map 4**: Map showing active cattle pastures along the western flank of the Vaca Forest Reserve.*

- **Cattle Ranching in the Chiquibul Ecosystem (CNP & CAR)**

Cattle ranching in the Chiquibul Ecosystem remains a critical issue, largely due to incursions from Guatemala. Illegal ranching has intensified, with herds of cattle seen grazing in areas such as Valentin Camp in the CAR, the Southern flank of the Caballo CP and the Northern flank of the Rio Blanco CP. In 2024, approximately 766.62 ha were encroached for active cattle pastures, *See map 5*. These activities are often linked to Guatemalan communities near the border, many of which lack sufficient land for their livestock and are thus expanding inside the CE. The impact is compounded by newly built roads on the Guatemalan side, which are believed to have been constructed with heavy machinery by wealthy interests, enabling easier access for ranchers.
In the CE, a sensitive ecosystem, cattle ranching is no longer an emerging threat but is now the dominant form of agricultural encroachment along its western flank. There have been diverse financial investments which, as in Vaca, indicates the perceived permanency of the pastures by the ranchers. Due to a lack of land availability in Guatemala, cattle pastures are developed adjacent to (and inside the) Chiquibul Ecosystem frontier, which often leads to increased fragmentation and disturbance by deforestation inside the Belizean protected area. Cattle ranching is typically a practice in which pastures are managed by rural Guatemalan settlements

(in close proximity to the protected area) but are owned by wealthy and powerful individuals, who use financially disadvantaged families in these rural communities as proxies to advance into new lands. It appears that some poor villagers in southern Peten are giving up their lands due to pressure from these wealthy individuals. Cattle ranching near the border to Belize's Chiquibul ecosystem has become pronounced and formidable, which often places great pressure on the integrity of the ecosystem.

While cattle ranching is distributed, at a spatial level, throughout the western flank of the Chiquibul Ecosystem, it is more pronounced in the Caracol Archaeological Reserve, where up to 348 hectares of forest are being actively encroached for cattle pastures. The North Rio Blanco zone, known locally as the Jimenez Farm, is also a major hotspot where up to 156 ha have been converted into cattle pastures. Another area that has been identified as a hotspot for cattle ranching is the Caballo area, where up to 90 ha are actively being occupied for cattle pastures. In these areas, but especially in the Valentin area and the Jimenez Farm, there have been considerable financial investments including fences, troughs, corals, and mechanized constructed ponds and cattle pastures remain ever so grounded and permanent.

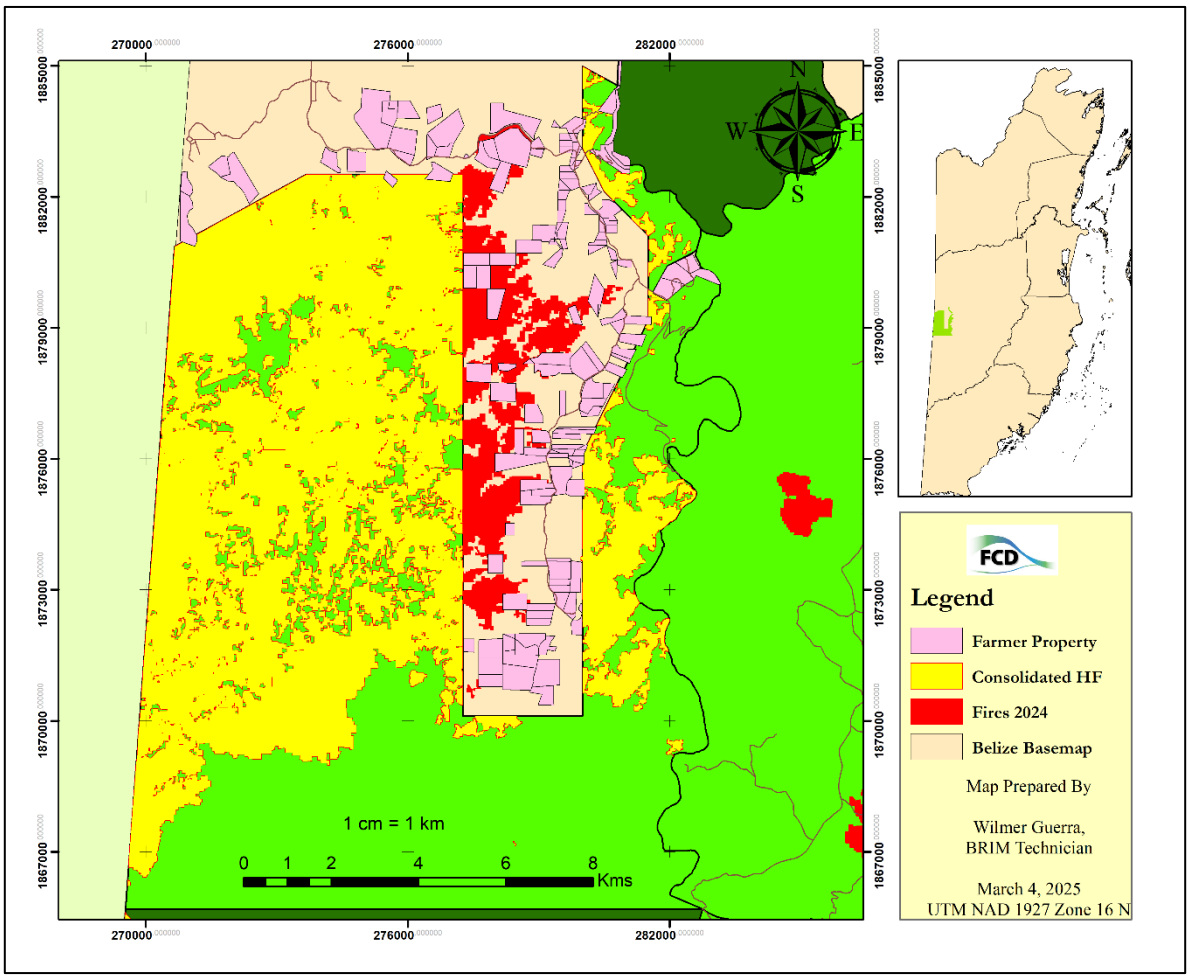


***Map 5**: Showing active cattle pastures compared to total deforestation in the CF.*

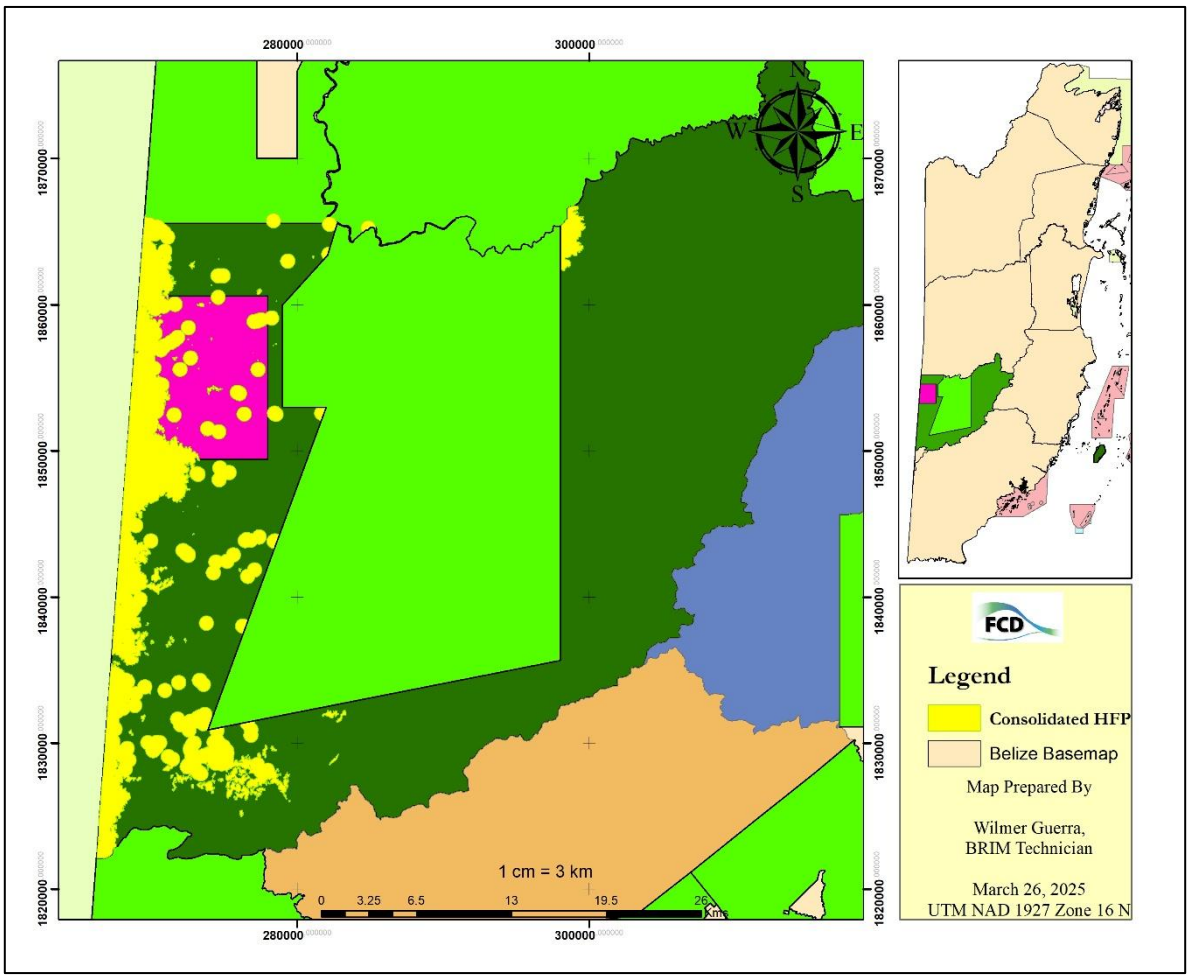
Consolidated Human Footprint in the Vaca Forest Reserve and the Chiquibul Ecosystem

Monitoring and patrol efforts by FCD indicate that as of 2024, the cumulative footprint of human activities within the Vaca Forest Reserve has expanded to 9,675.24 hectares, accounting for 66.97% of the total area of the protected reserve, *See map 6*. This substantial proportion underscores the increasing influence of anthropogenic factors on the region. Key activities driving this expansion include deforestation, agricultural expansion, cattle ranching, forest fires, and other land-use changes that contribute to habitat fragmentation and ecological degradation. In 2022, the affected area within the VFR was estimated at 8,460.59 hectares (or 51.86% of the reserve) (Guerra 2022), indicating a 15.11% increase within just two years—an alarming rate of expansion that poses significant challenges to conservation efforts. Most of the expansion is due to repeated uncontrolled fires within the reserve, which is impacting large portions of the reserve. The footprint due to hunting and other point features that are not conspicuous through aerial images could be much higher. The high percentage suggests that conservation efforts must address these pressures to ensure the long-term viability of the protected area's biodiversity and ecosystem functions.

The human footprint in the Chiquibul Ecosystem has expanded significantly over the years. Based on data from 2020 to 2024, approximately 11,773.00 hectares of the Chiquibul National Park have been impacted by human activities, accounting for 11.02% of the park's total area. Within the Caracol Archaeological Reserve, a total of 3,693.93 hectares has been affected, representing 36.54% of the reserve. It is important to note that the figures presented are non-cumulative; some areas affected in 2020 may have since recovered by 2024. However, because they were disturbed at any point during the study period, they were included in the analysis. As a result, the actual cumulative human footprint in 2024 may be lower than the total impact observed across the entire 2020–2024 period. It is estimated that up to 71.14% of what was impacted due to illegal human activities within 2020-2024 is recovering in the Chiquibul Ecosystem, without any form of direct human intervention, other than continued patrol, evaluation and monitoring. In fact, most areas impacted by the 2020 fires, required intervention to speed up recovery, except that further disturbance such as removal of material from the forest or opening up of the forest shrubby layer must be avoided at all costs in order to preserve the levels of humidity needed to inhibit fire propagation and to keep fuel coverage on the forest floor at low levels (Cho 2022). In VFR, tis figure cannot be estimated as the fires that occurred in 2024, were recent during the analysis of data and would require further analysis post 2024.



***Map 6**: Showing Consolidated Human Footprint in the Vaca Forest Reserve. Fires of 2024 outside the reserve are also portrayed since it poses a major risk for the reserve.*



Map 7: *Showing Consolidated Human Footprint in the Chiquibul Ecosystem.*

5. Conclusion and Recommendation

The findings highlight the rapid and expansive nature of the human footprint within both the Vaca Forest Reserve (VFR) and the Chiquibul Ecosystem. As of 2024, human activities have impacted 9,675.24 hectares in the VFR, accounting for 66.97% of the reserve, with a 15.11% increase in just two years. Similarly, 11,773.00 hectares of the Chiquibul National Park (11.02%) have been affected, primarily due to escaped fires. In the CAR, a total of 3,693.93 hectares has been affected, representing 36.54% of the reserve. No human activities were quantified in the CFR. These trends underscore the escalating pressures from deforestation, agricultural expansion, cattle ranching, and uncontrolled fires, which continue to degrade critical ecosystems and fragment wildlife habitats. Additionally, the impact of hunting and other inconspicuous activities is likely underestimated due to limitations conducted via aerial surveillance.

Without immediate and targeted conservation interventions, the unchecked expansion of human activities could result in irreversible biodiversity loss, habitat degradation, and weakened ecosystem functions within these protected areas.

Recommendations

To mitigate further degradation and ensure the long-term sustainability of the Vaca Forest Reserve and the Chiquibul Ecosystem, the following actions are recommended:

- Implement forest fire early detection systems and fire risk analysis.
- Continue the development of community-based fire control programs (including community fire brigades) to engage local stakeholders in fire prevention and rapid response strategies.
- Increase on-the-ground patrols and use remote sensing and aerial monitoring to detect illegal activities more effectively.
- Create a highly effective Ranger team to assess and address human footprint constantly and vigorously.
- Revisit the role of CPs located along the AZ for efficiency and control agents
- Address the evolution of cattle ranching with more proactive interventions.
- In Vaca, continue to develop alternative livelihoods for local communities to reduce dependence on activities that contribute to deforestation and habitat loss.
- Institute a patrol system in Vaca and address illegal settlements inside the reserve.
- Enforce fire regulations in order to prosecute persons leaving unattended fires.

- Expand and focus environmental education and outreach programs to raise awareness about the long-term impacts of habitat destruction.

- Re-invigorate the binational efforts with Guatemalan institutions that can provide support in areas of community development, application of the law and community education.

By implementing these measures, FCD can reduce the rate of habitat loss, improve ecosystem resilience, and ensure the long-term viability of biodiversity within the Vaca Forest Reserve and the Chiquibul Ecosystem.

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