YA'AXCHÉ
CONSERVATION TRUST

LAND USE / LAND COVER CHANGE IN TOLEDO AND THE MAYA GOLDEN LANDSCAPE

REPORTING YEAR 2025




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Land Use/Land Cover change Toledo and the Maya Golden Landscape

Reporting year 2025

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Acknowledgement

This report serves to document the land use changes over time in the Toledo District and the Maya Golden Landscape, to assess where management interventions can have a positive impact on forest regeneration and deterring the degradation of natural standing forests in a protected landscape. We recognize the efforts of Ya'axché's rangers who patrol the protected areas monitoring for illegal activities, assist with mapping and ground truthing of illegal hotspots. We also recognize the efforts of the Community Outreach and Livelihoods team who assist in mapping exercises and on the ground verification of land uses within the farming landscape.

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List of acronyms

BCEP	Boden Creek Ecological Preserve
BFREE	Belize Foundation for Research and Environmental Education
BNR	Bladen Nature Reserve
CRFR	Columbia River Forest Reserve
FAO	Food and Agriculture Organization of the United Nations
FD	Forest Department
GEE	Google Earth Engine
GCFC	Green Creek Farmers' Cooperative
GIS	Geographic Information System
GSCP	Golden Stream Corridor Preserve
LULC	Land Use/Land Cover
MGL	Maya Golden Landscape
MMNFR	Maya Mountain North Forest Reserve
MSI	Multi-spectral Instrument
NPAS	National Protected Areas System
PPA	Privately Protected Area
PA	Protected Area
UTM	Universal Transverse Mercator
Ya'axché	Ya'axché Conservation Trust

Executive Summary

This report presents the findings of the annual Land Use/Land Cover Change (LULCC) assessment for the Toledo District, Maya Golden Landscape (MGL), and Ya'axché-managed Protected Areas for Reporting Year 2025. The assessment uses Geographic Information Systems (GIS) and Sentinel-2 satellite imagery to quantify spatial and temporal changes in land cover and land use, supporting evidence-based conservation planning, monitoring, and management within southern Belize (ESA 2022; Immitzer et al. 2016).

At the district level, forest remained the dominant land cover class in Toledo, covering approximately 760,856. acres (69.24%) in Reporting Year 2025. Compared to Reporting Year 2024, when forest cover totalled 732,925 acres (69.80%), the analysis indicates a net forest gain of 27,931.48 acres and an annual rate of change of +3.81%. Much of this increase is attributed to refinements in the 2025 land cover classification, which improved forest mapping accuracy although there were some gains in recovering forests and transitioning fallow areas. It should be noted that a portion of the apparent forest loss may be attributed to residual cloud cover, cloud shadow effects, or classification uncertainty associated with satellite image interpretation. Agriculture exhibited a decrease by approximately 6,258.25 acres across the district which is likely due to seasonal agriculture patterns. Savannas decreased by 726.22 acres likely due to the seasonal drying of wet savanna areas and localized land conversion associated with small-scale farming and cattle ranching along the forest agriculture frontier.

Within the Maya Golden Landscape, forest remained the dominant land cover class, covering 507,868.05 acres (74.62%) in Reporting Year 2025, compared to 492,633.19 acres (75.81%) in Reporting Year 2024. This represents a net forest gain of 15234.86 acres and an annual net gain of 3.09%. A small proportion of the observed forest loss may be associated with cloud contamination and classification limitations rather than actual land cover change. Agriculture (66,725.05 acres; 9.8%) and savanna (68,337.61 acres; 10.04%) together accounted for almost 20% of the landscape. Fire scar/regeneration areas covered 10,278.52 acres (1.51%), occurring primarily along forest–agriculture and forest–savanna interfaces.

Across the four Ya'axché managed Protected Areas Bladen Nature Reserve (BNR), Maya Mountain North Forest Reserve (MMNFR), Golden Stream Corridor Preserve (GSCP), and Boden Creek Ecological Preserve (BCEP) combined forest cover reached 167,133 acres (97.14% of the total protected area extent) in Reporting Year 2025. Forest cover increased by approximately 6,608 acres compared to Reporting Year 2024, corresponding to an annual rate of change of + 4.12 %. This trend in forest cover is also observed across the landscape outside these four protected areas in the Toledo District. A significant proportion of the increase can be attributed to the classification modification made for this time period but there are areas that have also been in recovery since the 2024 fires that affected the farming landscape.

Overall, the 2025 assessment demonstrates that protected area management under Ya'axché's mandate continues to generate measurable, landscape-scale conservation outcomes. While there

were persistent pressures, including agricultural expansion, cross border encroachment, and fire disturbance, forest cover remains high. Sustained monitoring, strengthened enforcement along high-risk boundaries and continued investment in community-based livelihood initiatives will remain important for conservation success. The next reporting cycle should prioritise expanded ground truthing, enhanced near real time monitoring capacity in priority areas, and the formalisation of training sample protocols to further strengthen the analytical rigour and long-term consistency of this assessment.

Introduction

Land use and land cover (LULC) change analysis is a critical tool for understanding the spatial and temporal dynamics of land uses in the Toledo District, Belize, where expanding agriculture, infrastructure development, forest use and exploitation, and natural disturbances continue to influence one of the country's most biologically diverse landscapes. By quantifying changes in forest cover, wetlands, agricultural lands, and settlements over time, LULC analysis provides essential information for assessing habitat loss and fragmentation, watershed integrity, and forest integrity.

In a district that contains extensive protected areas and forested landscapes, monitoring land cover change can support evidence-based conservation planning and sustainable development. LULC analysis enables decision-makers to identify emerging threats, evaluate the effectiveness of conservation interventions, prioritize restoration efforts, and consider economic development opportunities for buffer communities. As climate change and human pressures continue to alter the landscape, regular LULC assessments provide an indispensable foundation for adaptive management, environmental monitoring, and long-term planning in Toledo District. This assessment focuses on the greater Toledo District with subset assessments for the Maya Golden Landscape (MGL) and Ya'axché managed and co-managed protected areas.

Ya'axché works primarily within the MGL, an area encompassing approximately 780,200 acres within the Toledo District of southern Belize (Hofman, 2013). The MGL contains twenty-eight known Protected Areas (PAs), of which Ya'axché currently manages or co-manages four. Together, these protected areas cover approximately 165,300 acres, representing about 15% of the Toledo District and 21% of the MGL.

The Bladen Nature Reserve (BNR) is the largest nature reserve in Belize and receives the highest level of protection under the National Protected Areas System (NPAS) Act. Encompassing approximately 99,600 acres within the core zone of the Maya Mountain Massif (Grant et al., 2017), BNR benefits from its remote location, which provides a natural barrier against many anthropogenic pressures affecting other protected areas. Ya'axché co-manages the reserve with the Government of Belize and is responsible for its day-to-day management.

The Boden Creek Ecological Preserve (BCEP) is a Privately Protected Area (PPA) located in the Toledo District. Historically used for citrus cultivation, banana production, and cattle ranching, the property was acquired for conservation purposes in the late 1990s and was formally established as a protected area in the early 2000s. Ownership and management were transferred to Ya'axché Conservation Trust in 2024. BCEP covers approximately 12,880 acres of predominantly secondary lowland broadleaf forest and, together with the Golden Stream Corridor Preserve, forms a critical component of the Southern Biological Corridor.

The Golden Stream Corridor Preserve (GSCP) was established in 1998 through collaborative efforts involving Ya'axché, local communities, and conservation partners. Spanning approximately 15,070 acres (Lenox et al., 2020), GSCP consists primarily of lowland broadleaf forest and serves as an important ecological corridor linking the foothills of the Maya Mountains to the coastal lowlands of southern Belize.

The Maya Mountain North Forest Reserve (MMNFR) is an extractive reserve for which Ya'axché assumed co-management responsibility in 2015. Covering approximately 37,700 acres, the reserve includes a community-based cacao agroforestry concession (Garcia et al., 2014) managed by Trio Farmers Cacao Growers Ltd. under the oversight of the Belize Forest Department.

Geographic Information Systems (GIS) and remote sensing techniques are widely used to quantify, map, and monitor Land Use/Land Cover (LULC) change over time (Valjarčević et al., 2018). Changes in LULC are among the primary drivers of biodiversity loss and are largely associated with anthropogenic disturbances (Falcucci et al., 2007). Globally, the expansion of agricultural lands, pasture, and urban areas has resulted in significant habitat loss and biodiversity decline (Foley et al., 2005).

A significant institutional development reflected in Reporting Year 2025 is the inclusion of the Boden Creek Ecological Preserve within Ya'axché's protected area portfolio following the transfer of ownership and management in 2024. Consequently, BCEP is incorporated into the protected area analyses presented in this report. In addition, growing recognition of Indigenous and Community Conserved Areas (ICCAs), including the Ya'ax Ha Livelihood Area of the Green Creek Farmers' Cooperative (GCFC), continues to influence conservation planning and monitoring priorities within the MGL. This aligns with increasing global evidence demonstrating the effectiveness of Indigenous and community led stewardship in maintaining biodiversity and ecosystem integrity (Garnett et al., 2018; Fa et al., 2020).

Goals and Objectives

The goal of this study is to assess land use, land cover, and land use change within the Toledo District and the Maya Golden Landscape for the 2025 reporting period through supervised classification of Sentinel-2 satellite imagery.

The specific objectives of the study are to:

- Detect changes in anthropogenic activities occurring in the Toledo District during the 2024-2025 reporting period.
- Map and quantify Land Use/Land Cover classes and changes across the study area.
- Identify areas of concern where Ya'axché can provide technical support to communities and farmers to prevent deforestation and forest degradation.

Methodology

Study Area

The Toledo District is the southernmost and least populated district in Belize, encompassing approximately 1,064,547 acres of terrestrial and inland aquatic ecosystems (Figure 1). The district experiences a tropical climate, with average annual maximum temperatures of approximately 85°F (30°C) and average minimum temperatures of approximately 73°F (23°C).

The study area is bounded by latitudes 16°07'48" N to 16°42'00" N and longitudes 88°28'48" W to 89°12'00" W. Within Toledo, the Maya Golden Landscape (MGL) represents the primary geographic focus of Ya'axché Conservation Trust's conservation and community development initiatives. Covering approximately 780,200 acres, the MGL comprises a mosaic of lowland and montane broadleaf forests, savannas, wetlands, agricultural lands, freshwater systems, and coastal and marine ecosystems. The landscape also encompasses twenty-four rural communities whose livelihoods are closely linked to the sustainable management of natural resources.

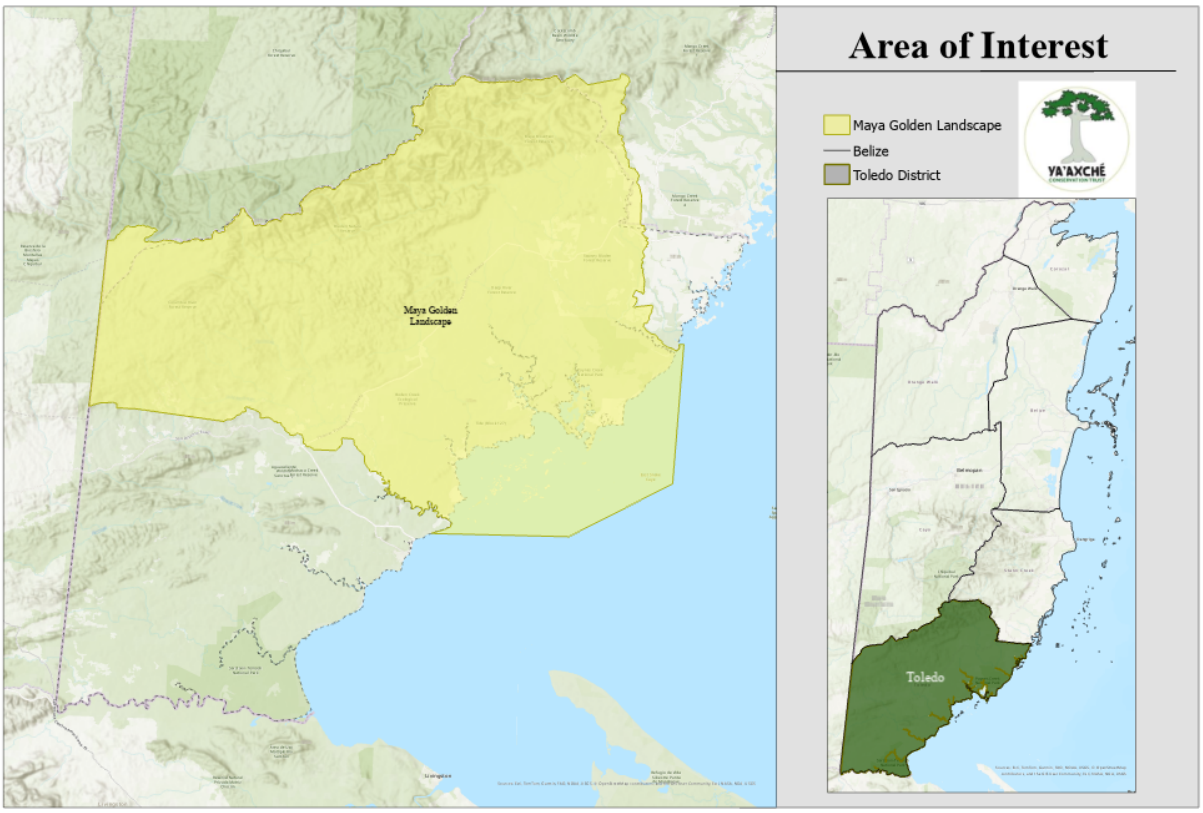

Figure 1. Map of the study area including the MGL and Toledo.

Data Sources

2024 data: The primary data source was Sentinel-2 Multi Spectral Instrument Level-2A (MSI L2A) imagery providing atmospherically corrected surface reflectance data. Imagery acquired between

January and April 2024 was accessed through Google Earth Engine using the COPERNICUS/S2_SR_HARMONIZED dataset. Cloud contamination was minimised using the Sentinel-2 Cloud Probability dataset (COPERNICUS/S2_CLOUD_PROBABILITY), applying a cloud probability threshold of less than 30 percent prior to mosaicking. A median composite was generated and clipped to the Toledo District boundary obtained from internal Ya'axché spatial datasets. Sentinel-2 imagery includes 13 spectral bands covering visible, near-infrared, and short-wave infrared regions, with spatial resolutions of 10 m, 20 m, and 60 m depending on the band.

2025 data: Sentinel-2 imagery was accessed and processed using Google Earth Engine (GEE). Imagery covering the Toledo District was obtained from the European Union's Copernicus Programme for the period 1 February 2025 to 31 May 2025 and 1 August 2025 to 31 December 2025. These periods were selected to maximize image availability while minimizing cloud contamination and capturing land cover conditions representative of the 2025 assessment period. The Sentinel-2 Surface Reflectance Harmonized dataset (COPERNICUS/S2_SR_HARMONIZED) was used, with images filtered spatially to the Toledo District boundary and temporally to the defined study periods prior to processing.

Images with cloud cover greater than 40% were excluded from the analysis. Cloud and shadow masking, image compositing, and preparation of the final Sentinel-2 imagery for land use and land cover classification were performed in Google Earth Engine. The detailed image processing workflow is described in the following section.

Image Processing, Cloud Masking, and Mosaicking

Cloud masking was performed in Google Earth Engine (GEE) using the Sentinel-2 Scene Classification Layer (SCL). Pixels identified as cloud shadows (Class 3), medium probability clouds (Class 8), high probability clouds (Class 9), cirrus clouds (Class 10), and snow or ice (Class 11) were masked and excluded from the analysis. Additionally, only Sentinel-2 images with a scene level cloud cover of less than 40% (CLOUDY_PIXEL_PERCENTAGE < 40) were included in the image collection to ensure adequate image availability while minimizing cloud contamination across the study area.

Following cloud masking, a single median composite mosaic was generated using all available Sentinel-2 images acquired between 1 February and 31 May 2025 and between 1 August and 31 December 2025. Combining imagery from these two periods increased image availability and reduced the effects of persistent cloud cover, resulting in a cloud-minimized composite for land use and land cover classification. The median compositing approach was used to reduce residual cloud effects and other atmospheric noise while retaining representative surface conditions. The resulting composite incorporated six spectral bands (Blue, Green, Red, Near Infrared, Shortwave Infrared 1, and Shortwave Infrared 2), were clipped to the Toledo District boundary, and was exported at a spatial resolution of 10 m for use in the subsequent land use and land cover (LULC) classification.

Rationale for the 40% image-level cloud threshold: A threshold of 40% was selected to balance image availability and data quality in a tropical environment such as Belize, where persistent cloud cover can substantially reduce the number of usable observations. Since additional pixel-level cloud masking was applied using the SCL layer, images with up to 40% scene cloud cover could be retained while still producing a high-quality median composite.

Exporting and Masking Images

Prior to image export, the dataset was re-projected from WGS 1984 UTM Zone 16N to NAD 1927 UTM Zone 16N (EPSG:26716) to ensure spatial consistency with existing GIS datasets. The twelve spectral bands used in the analysis (Table 1) were loaded as individual raster layers and combined into a composite image using ArcGIS Image Analysis tools.

Table 1. Characteristics of Sentinel-2 Multi-Spectral Instrument (MSI).

Band	Resolution (m)	Wavelength (nm)	Description
B1	20	443	Aerosols
B2	10	490	Blue
B3	10	560	Green
B4	10	665	Red
B5	20	740	Red Edge 1
B6	20	783	Red Edge 2
B7	20	842	Red Edge 3
B8	10	842	Near Infrared (NIR)
B8a	20	865	Red Edge 4
B9	60	940	Water Vapor
B11	20	1610	Short-Wave Infrared (SWIR) 1
B12	20	2190	Short-Wave Infrared (SWIR) 2

Collecting Training Samples

Training samples were developed and managed in ArcGIS Pro using the Training Sample Manager toolbar. Samples were generated by manually digitising polygon features directly over the cloud-free Sentinel-2 composite imagery to ensure accurate representation of spectral variability within each land cover class. The development of training samples involved an iterative process of testing, evaluation, and refinement. Initial classification outputs revealed areas of class confusion, particularly in heterogeneous landscapes, which informed subsequent adjustments to the number, size, and spatial distribution of training samples.

For the Toledo District classification, more than 100 training samples were collected for each land cover class, ensuring adequate representation of the spectral characteristics and geographic distribution of each class across the study area. Training polygons were distributed throughout the district to capture variations in vegetation condition, land management practices, topography, and environmental gradients. The total training area varied by class depending on the extent and heterogeneity of the land cover type.

Editing Classes

To improve class separability during image classification, several Land Use/Land Cover (LULC) categories were initially subdivided into more detailed subclasses during the training process. Agricultural land, for example, was separated into cropland, milpa farming, and cattle farming before being merged into a single Agriculture class in the final classification output. No changes were made to LULC class definitions or subclass groupings during Reporting Year 2025, ensuring consistency and comparability with previous assessments. The final LULC map therefore comprises eight primary classes: Agriculture, Forest, Savanna, Wetland, Water Bodies, Residential, Roads, and Fire Scar/Regeneration Areas (Table 2).

Table 2. Classes and subclasses used in the Random Trees LULC classification and their descriptions.

Final Class	Subclass (Training Phase)	Description
Agriculture	Cropland	Actively cultivated land used for crop production with identifiable planting patterns.
Agriculture	Milpa Farm	Shifting cultivation areas characterized by mixed crops, fallow stages, and variable canopy cover.
Agriculture	Cattle Farm	Pastureland dominated by grasses and low vegetation used for livestock grazing.
Forest	—	Land dominated by trees with continuous or near-continuous canopy cover.
Savanna	—	Naturally occurring grassland with scattered trees and shrubs.
Residential	—	Areas dominated by individual housing structures and associated cleared spaces.
Roads	—	Paved or cleared transportation corridors, including highways and secondary roads.
Wetland	Wetland	Areas characterized by saturated soils and hydrophytic vegetation, including seasonally flooded zones.
Wetland	Waterbodies	Inland water features such as rivers, streams, ponds, lagoons, and lakes.
Sea/Ocean	—	Coastal and marine waters beyond the shoreline, including the Caribbean Sea and associated nearshore waters.
Cloud	—	Residual cloud cover and atmospheric obstructions not removed during image preprocessing, retained as a separate class to prevent misclassification of underlying land cover.
Fire Scars/ Regeneration	—	Areas of burned vegetation identifiable by darkened surfaces, exposed soil, and reduced vegetation cover and/or new vegetation that is starting to emerge.

Classification

The Random Trees classifier, based on the Random Forest Algorithm, was used as the supervised classification method (Figure 2). The pixel-based classification was executed on the Image Classification toolbar in ArcGIS Pro with a maximum of 100 trees and a maximum tree depth of 30, consistent with methodology applied in previous assessments.

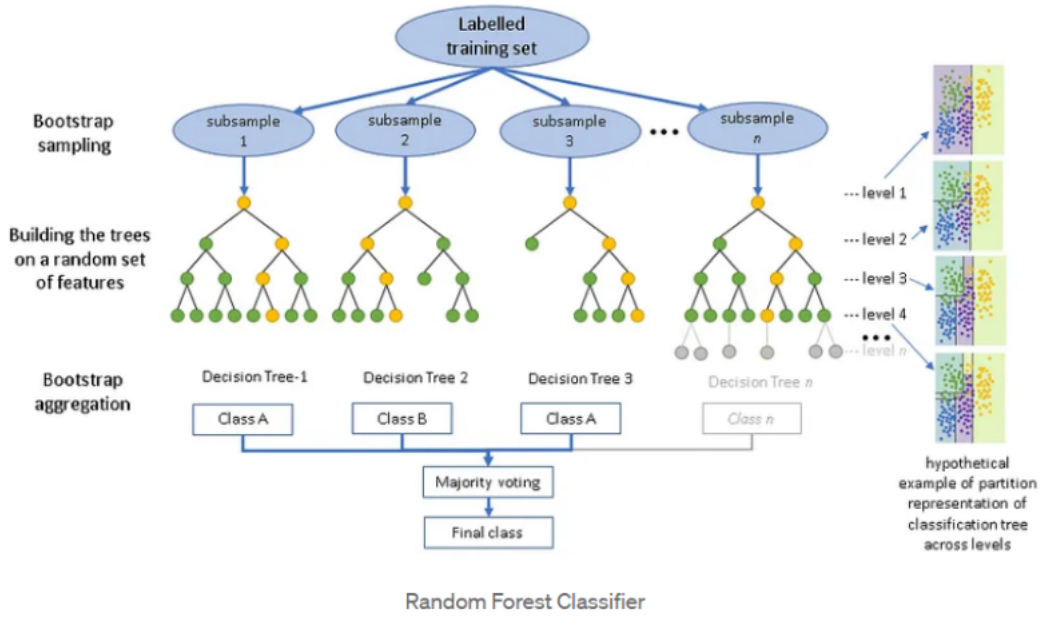

Figure 2. Random Forest Algorithm used for LULC classification.

Generating Statistics from Classification

Once the LULC classification was created, the colour coded classified image was converted to a polygon layer using the Raster to Polygon tool. The area covered by each class was obtained using the Summary Statistics tool. For specific protected areas, the classification was clipped to the desired boundaries before running Summary Statistics.

Rate of Deforestation

The annual rate of forest change was calculated using the FAO compound-interest formula (FAO, 1996; Puyravaud, 2003), comparing forest area at the beginning and end of the reporting period:

$$r = (1/(t_2 - t_1)) \times \ln(a_2/a_1)$$

Where r is the annual rate of change, and a_1 and a_2 are the forest cover estimates at times t_1 (2024) and t_2 (2025), respectively. This approach remains widely used in forest monitoring studies because it provides a standardized and comparable measure of proportional forest cover change across different time periods and geographic regions (FAO, 2020; Puyravaud, 2003).

Accuracy Assessment

An accuracy assessment was conducted to evaluate the reliability of the LULC classification produced for the Reporting Year 2025. A stratified sample-based approach was applied using training data generated during the supervised classification process in ArcGIS Pro.

Training samples were divided into two subsets: approximately 80% of samples for each LULC class were used to train the Random Forest classifier, while the remaining 20% were withheld for validation. These validation samples were not included in model training and served as an independent reference dataset for assessing classification performance.

The withheld validation samples were compared against the final classified LULC map using the Accuracy Assessment tools in ArcGIS Pro. This process produced a confusion matrix and associated accuracy metrics, including overall accuracy and Cohen's Kappa coefficient. Cohen's Kappa was used to evaluate the level of agreement between the classified output and reference data while accounting for agreement occurring by chance.

The Reporting Year 2025 results indicate a strong overall classification performance, with high agreement between reference samples and classified land cover categories. Minor misclassification was observed in transitional and heterogeneous zones, particularly between forest, savanna, and agricultural land uses, where spectral similarity and mixed pixels are common in tropical landscapes. Cloud contamination and shadow effects in some Sentinel-2 scenes also contributed to localized classification uncertainty despite cloud masking procedures.

To improve thematic consistency, targeted pixel level refinement was applied in selected areas where classification noise was identified. Overall, the classification provides a reliable representation of land cover patterns for Reporting Year 2025 and supports robust comparison across reporting cycles.

Results

Classification

The LULC classification of the Toledo District for Reporting Year 2025 produced eight primary land cover classes: Forest, Agriculture, Savanna, Wetland/waterbodies, Residential, Roads, and Fire Scar/Regeneration Areas and Cloud Cover. These classes were derived through the iterative supervised classification process described in the Methodology section, with subclasses subsequently merged to reduce classification noise and improve landscape level interpretability.

As in previous years, in 2025, forest remained the dominant land cover class across the district, consistent with findings from previous reporting periods (Figure 3A). Agriculture and savanna represented the next most extensive land cover classes. The spatial distribution of land cover reflects the mixed-use character of the Toledo District, with extensive forested areas concentrated within the Maya Mountains and southern portions of the district, while agricultural and other anthropogenic land uses are primarily associated with transportation corridors, settlements, and community boundaries.

Compared to Reporting Year 2024, the Reporting Year 2025 classification indicates a noticeable decrease of agricultural land with localized expansions and contraction (Figure 3B and Table 3). Savanna cover decreases across portions of the central district, consistent with ongoing landscape transitions occurring along the forest–savanna ecotones. The combined Wetland/Waterbodies class increased from approximately 18,673 acres in Reporting Year 2024 to 29,832 acres in Reporting Year 2025. This increase is likely influenced by seasonal hydrological conditions, differences in water levels, and classification sensitivity associated with distinguishing wetlands/waterbodies and open water features from surrounding vegetation. Fire Scar/Regeneration Areas were more spatially concentrated during Reporting Year 2025, occurring primarily along the western boundary of the Columbia River Forest Reserve and other areas affected by recent fire activity and subsequent vegetation recovery.

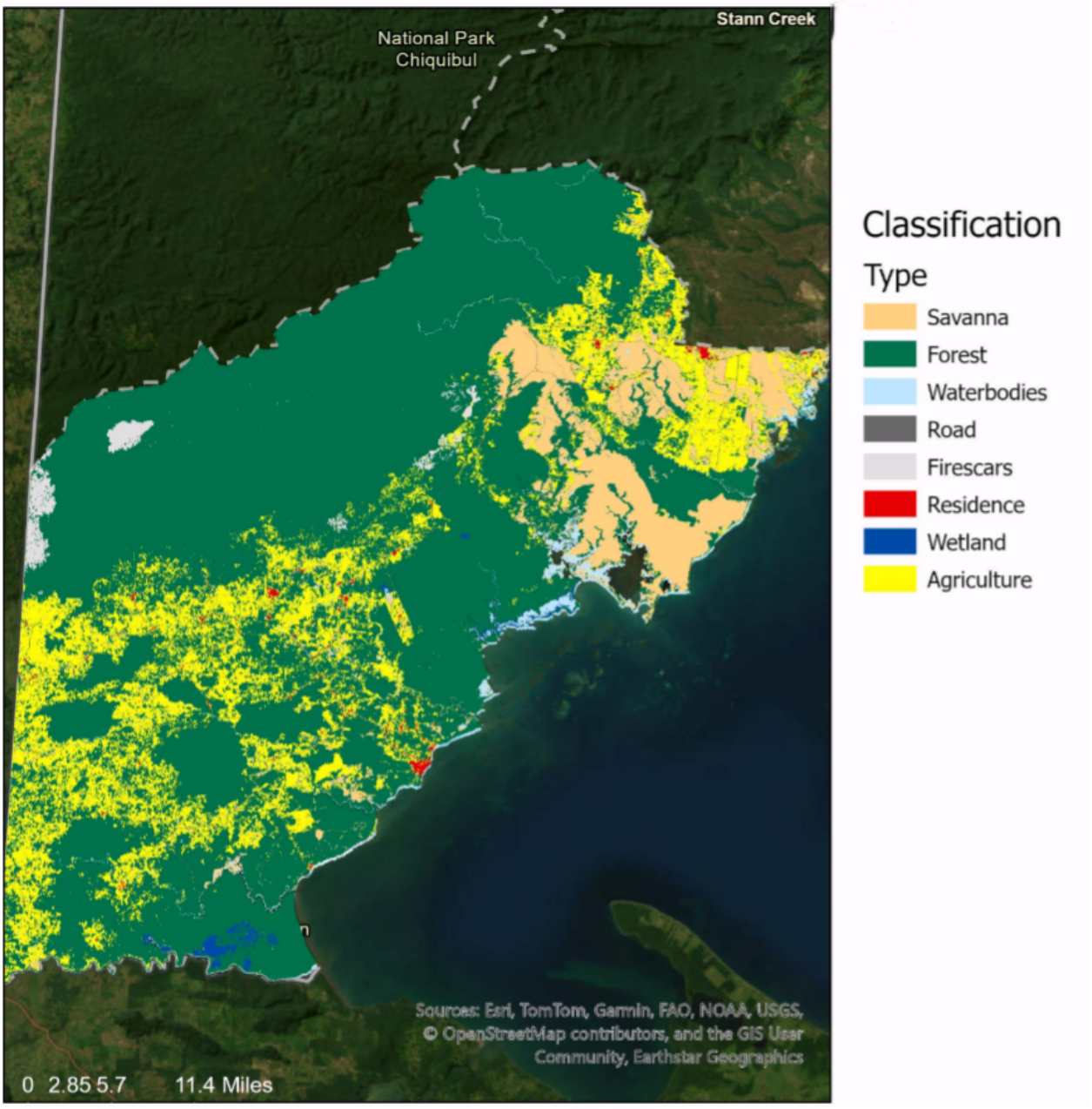

Figure 3A. Land Use/Land Cover classification for the Toledo District, Reporting year 2024.

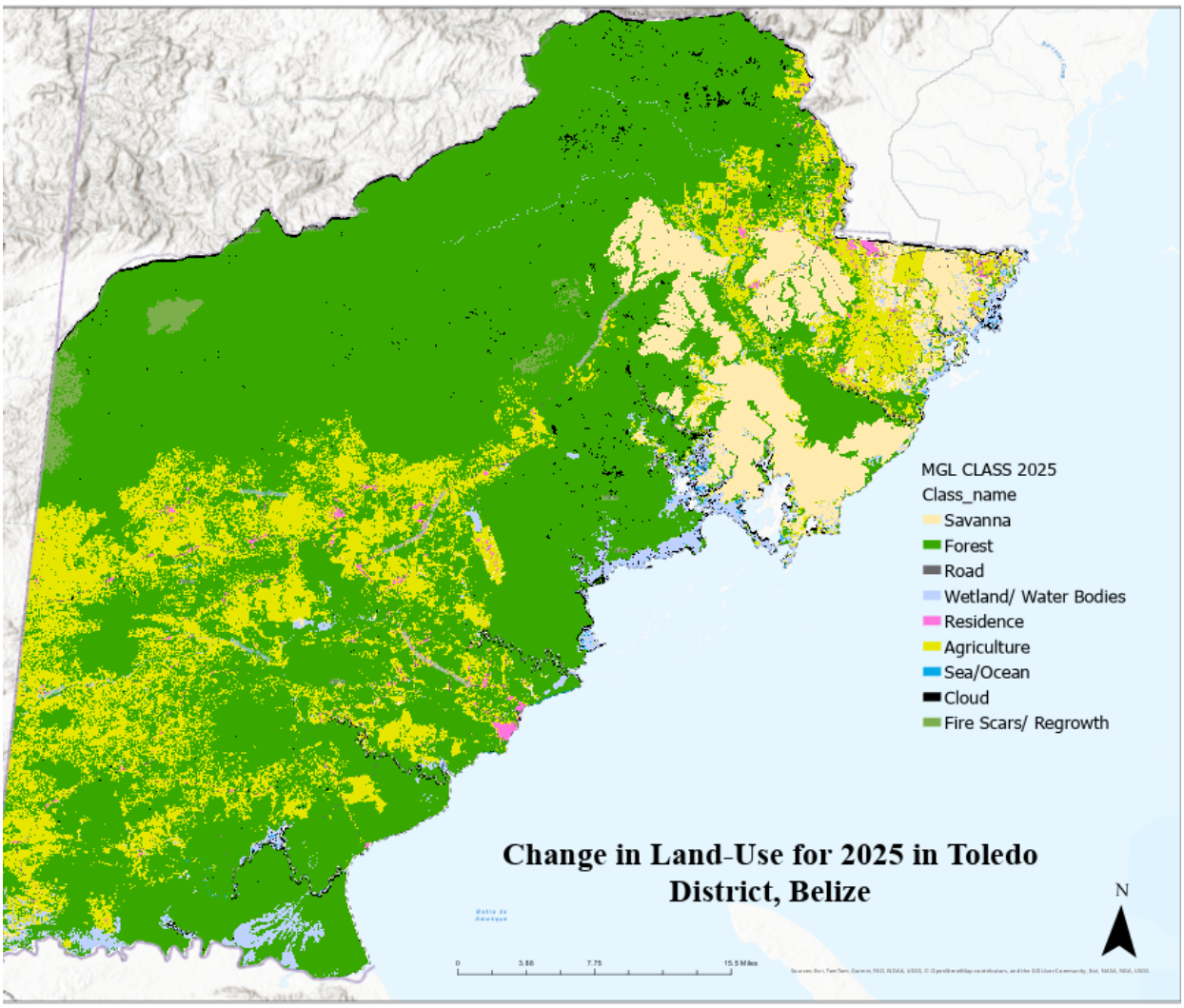

Figure 3B. Change in Land Use/Land Cover classification for the Toledo District, 2025.

Land Use & Land Cover Rate of Change

Toledo

The Toledo District contains a diverse mosaic of forest, savanna, wetlands, aquatic systems, and anthropogenic land uses. For Reporting Year 2025, forest remained the dominant land cover class, covering approximately 760,857 acres (69.24%) of the district (Table 3). Agriculture represented the second largest land cover class, covering approximately 190,391 acres (17.33%), followed by savanna at 82,900 acres (7.54%). Wetlands/waterbodies accounted for 29,832 acres (2.71%), while Fire Scar/Regeneration Areas covered 12,176 acres (1.11%). Residential areas and roads occupied relatively small proportions of the district, accounting for 0.51% and 0.40% of total mapped area, respectively.

Interpretation of year-to-year changes should consider differences in class representation between reporting periods. In Reporting Year 2025, the classification included Cloud Cover and Sea/Ocean as distinct mapped classes, which were not reported separately in the previous assessment. As a result,

the total mapped area for Reporting Year 2025 is larger than that reported for Reporting Year 2024. In addition, the substantial increase observed in the Wetland/waterbodies class may partly reflect differences in the delineation of wetlands and water features, seasonal hydrological conditions, and classification sensitivity associated with satellite imagery. As a result, changes observed in wetland and aquatic classes may not necessarily represent permanent land cover change on the ground.

Compared to the previous reporting period, forest cover increased by approximately 27,931 acres. This reporting period incorporated more detailed pixel level refinement and quality control, reducing miss classification error and improving the delineation of the forest cover which resulted in improved forest classification and overall increase in coverage. While agriculture and savanna decreased slightly by 6,258 acres and 726 acres, respectively. Fire Scar/Regeneration Areas increased marginally by approximately 582 acres. The observed increase in wetland/waterbodies extent can often be due differences in seasonal conditions, water availability, and classification sensitivity may have influenced the delineation of wetland/waterbodies and aquatic features between reporting periods.

Overall, the spatial distribution of land cover classes continues to reflect the mosaic of uses of the Toledo District, with extensive forest cover concentrated within the Maya Mountains and southern portions of the district, while agricultural and other anthropogenic land uses remain associated with transportation corridors, settlements, and areas of historical land conversion Table 4.

Table 3. Land Use/Land Cover classes of the Toledo District with area and corresponding percentage cover per class and Rate of Change. Reporting period 2024 to reporting period 2025.

LULC Class	2024Acreage (ac)	2024 %	2025 Acreage (ac)	2025 %	Acreage Change (ac)	% Change in Coverage	Rate of Change
Forest	732,925.26	69.80%	760,856.74	69.24%	+27,931.48	-0.56%	+3.81%
Agriculture	196,648.97	18.73%	190,390.72	17.33%	-6,258.25	-1.40%	-3.18%
Savanna	83,626.59	7.96%	82,900.37	7.54%	-726.22	-0.42%	-0.87%
Wetland/waterbodies	4,204.44	0.40%	29,832.12	2.71%	+25,627.68	+2.31%	+609.53%*
Waterbodies	14,468.68	1.38%	-	-	-	-	-
Residential	3,395.75	0.32%	5,597.16	0.51%	+2,201.41	+0.19%	+64.83%
Roads	3,175.79	0.30%	4,377.64	0.40%	+1,201.85	+0.10%	+37.84%
Fire Scars/Regrowth	11,593.78	1.10%	12,175.72	1.11%	+581.94	+0.01%	+5.02%
Sea/Ocean	-	-	1,282.95	0.12%	-	-	-
Cloud	-	-	11,410.91	1.04%	-	-	-

*Results from the combination of Wetland and Waterbodies classes during classification.

Table 4. Land Use/Land Cover classes and percent coverage in the Toledo District derived from the Reporting year 2025 classification.

Class	Frequency	Hectares	Acres	Percentage Cover
Savanna	3354859	33548.59	82,900.37	7.54%
Forest	30790780	307907.8	760,856.74	69.24%
Road	177157	1771.57	4,377.64	0.40%
Wetland/waterbodies	1207263	12072.63	29,832.12	2.71%
Residence	226509	2265.09	5,597.16	0.51%
Agriculture	7704839	77048.39	190,390.72	17.33%
Sea/Ocean	51919	519.19	1,282.95	0.12%
Cloud	461783	4617.83	11,410.91	1.04%
Fire Scars/ Regrowth	492734	4927.34	12,175.72	1.11%

Maya Golden Landscape

Within the Maya Golden Landscape (MGL), forest remained the dominant land cover class during Reporting Year 2025, covering 507,868 acres (74.62%) of the total landscape area (Table 6). Although several land-cover classes increased in area in the MGL, their proportional contribution to the landscape varied, reflecting differences in the overall classified extent between reporting periods Figure 4B. The largest relative increases were observed in wetlands\waterbodies and residential areas, while fire scars/regrowth was the only mapped land-cover class to exhibit a decline in both area and rate of change.

Compared to Reporting Year 2024, when forest cover was 492,633 acres (75.81%), the landscape shows a net increase in forest area of 15,234.86 acres in 2025 corresponding to a +3.09% rate of change (Table 5 & 6.). This proportion remains substantially higher than the district wide forest cover of 69.24%, reflecting the concentration of forests in protected areas within the MGL. However, the increase in cover is partially influenced by differences in classification outputs, including the inclusion of cloud cover and minor boundary and methodological refinements (Figure 4B). This result suggests that forest trends should be interpreted as stable high forest persistence rather than absolute gain or loss.

Agriculture accounted for 66,725 acres (9.80%), a modest increase from 2024 by 625.95 acres, corresponding to a 0.95% rate of change. However, its proportional cover decreased from 10.17% to

9.80% a 0.37% decrease from 2024, suggesting that agricultural expansion occurred more slowly than the overall increase in the mapped landscape or that other land-cover classes expanded at a faster rate.

Savannahs covered 68,338 acres (10.04%), corresponding to an increased by 2,324.83 acres, resulting in a 3.52% rate of change (Table 5 & 6.). Nevertheless, its proportional cover declined slightly (-0.12%), indicating that although the area classified as savanna expanded, its contribution to the total landscape changed very little.

Wetlands\waterbodies experienced the most substantial increase of all land-cover classes, expanding by 13,081.27 acres, equivalent to a 1,142.65% rate of change (Table 5 & 6.). The proportional cover also increased markedly from 0.18% to 2.09% (+1.91%). The main factor influencing the drastic increase in coverage is the combination of waterbodies and wetlands\waterbodies into one class. Combining the two reduced noise and allowed for better interpretation of the classification results.

Residential land expanded by 1,195.87 acres, representing an 88.08% rate of change (Table 5 & 6.). This change is attributed to improved classification of settlement areas through data analysis refinement. Although residential areas continued to occupy a relatively small proportion of the landscape (0.38% in 2025), the substantial rate of increase may also suggest ongoing settlement growth and infrastructure development within the Maya Golden Landscape.

Fire Scars/Regrowth covered 10,279 acres (1.51%), indicating existing but localized disturbance, along forest–agriculture and forest–savanna interfaces (Table 5 & 6.). Overall, the MGL continues to function as a predominantly forested landscape with localized zones of disturbance concentrated at its margins, particularly in areas of agricultural expansion and fire activity.

Table 5. Land Use/Land Cover classes of the MGL with area and corresponding percentage cover per class. Reporting period 2024 to reporting period 2025.

LULC Class	2024 Acreage (ac)	2024 %	2025 Acreage (ac)	2025 %	Acreage Change (ac)	% Change in Coverage	Rate of Change
Forest	492,633.19	75.81	507,868.05	74.62	15,234.86	-1.19%	+3.09%
Agriculture	66,099.10	10.17	66,725.05	9.80	625.95	-0.37%	+0.95%
Savanna	66,012.78	10.16	68,337.61	10.04	2,324.83	-0.12	+3.52%
Wetlands\ waterbodies	1,145.25	0.18	14,226.52	2.09	13,081.27	+1.91	+1142.65%
Waterbodies	10,479.02	1.61	-	-	-	-	-
Residential	1,357.72	0.21	2,553.59	0.38	1,195.87	+0.17%	+88.08%
Roads	1,280.20	0.21	1,616.69	0.24	336.49	+0.03%	+26.28%
Fire Scars/Regrowth	10,754.37	1.65	10,278.52	1.51	−475.85	-0.14%	-4.42%
Sea/Ocean	-	-	575.43	0.08	-	-	
Cloud	-	-	8,396.76	1.23	-	-	

Table 6. Land Use/Land Cover classes of the MGL derived from the 2025 classification.

Class	Frequency	Hectares	Acres	Percentage Cover
Savanna	2765525	27655.25	68337.61	10.04%
Forest	20552691	205526.91	507868.05	74.62%
Road	65425	654.25	1616.69	0.24%
Wetlands/waterbodies	575727	5757.27	14226.52	2.09%
Residence	103340	1033.4	2553.59	0.38%
Agriculture	2700267	27002.67	66725.05	9.80%
Sea/Ocean	23287	232.87	575.43	0.08%
Cloud	339805	3398.05	8396.76	1.23%
Fire Scars/Regrowth	415957	4159.57	10278.52	1.51%

A closer comparison of forest cover between coverage within Ya'axché Protected Areas and outside the protected areas but within the boundaries of the MGL is useful to show the difference in the rate of change and understand the importance of protected areas. Forest cover change was evaluated using the FAO annual rate of change/deforestation formula (FAO, 1996; Puyravaud, 2003) to compare forest extent in the MGL within Ya'axché's Protected Areas and outside of Ya'axché Protected Areas (Table 7). Across the Maya Golden Landscape (MGL), forest cover Increase from 492,633 acres in 2024 to 507,868.05 acres in 2025, representing a net gain of 15234.86 acres and rate of change of +3.09%.

Within the Ya'axché-managed protected areas, forest cover increased by 6,608.08 acres, corresponding to a rate of change of approximately 4.12 %, indicating continued maintenance and recovery of forest ecosystems under protected area management. In contrast, forest cover outside the Ya'axché-managed protected areas Increase by 8,626.78 acres, representing a 2.60 % increase over the reporting period. These contrasting trends suggest recovery of forest areas that may have been disturbed in 2024 by forest fires or may have been affected by anthropogenic activities.

Table .7 Forest cover (acres) and annual rate of forest change within the MGL and Ya'axché-managed Protected Areas, Reporting Years 2024 and 2025.

Area	Reporting Year 2024 Forest Cover (ac)	Reporting Year 2025 Forest Cover (ac)	Change (ac)	Rate of Forest Change (%)
Maya Golden Landscape (Total)	492,633.19	507,868.05	+15,234.86	+3.09%

Within Ya'axché Protected Areas	160,525.43	167,133.08	+ 6,608.08	+ 4.12 %
Outside Ya'axché Protected Areas (MGL)	332,108.19	340,734.97	+ 8,626.78	+ 2.60 %

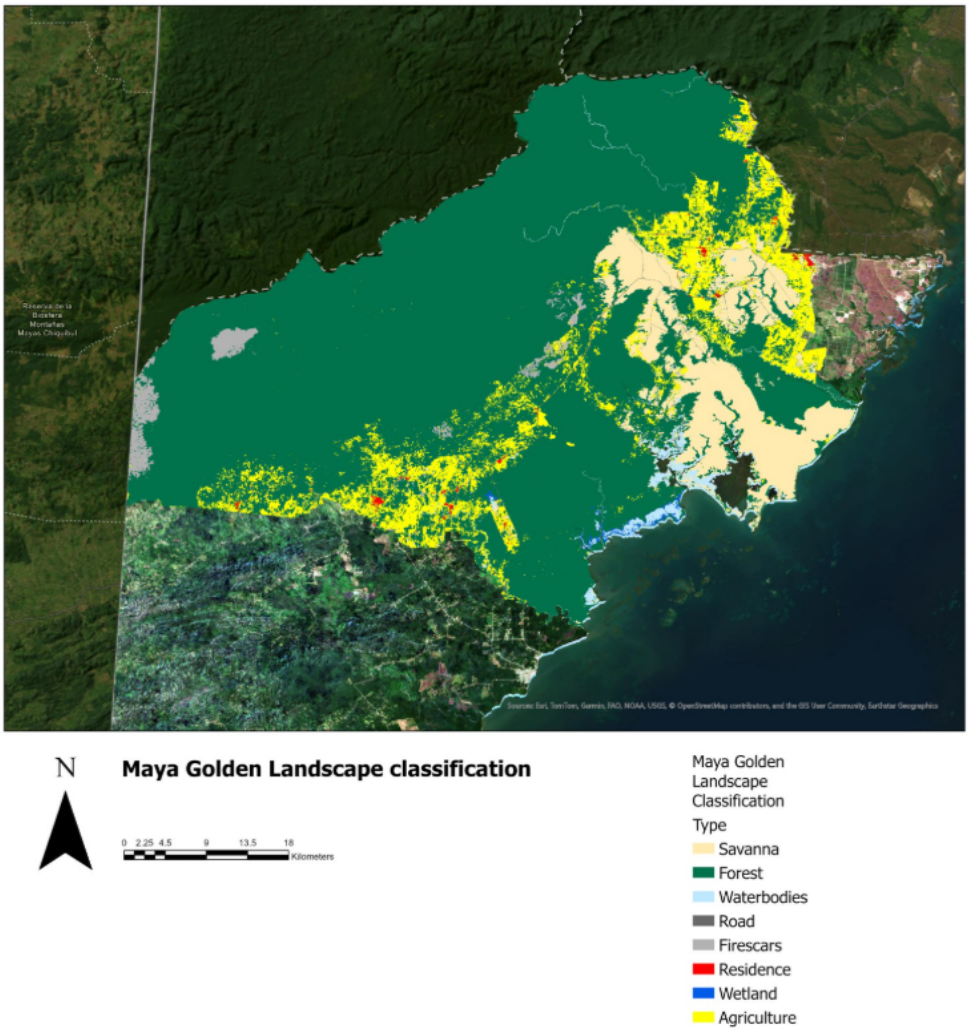

Figure 4A. Land Use/Land Cover classification for the Maya Golden Landscape, Reporting Year 2024.

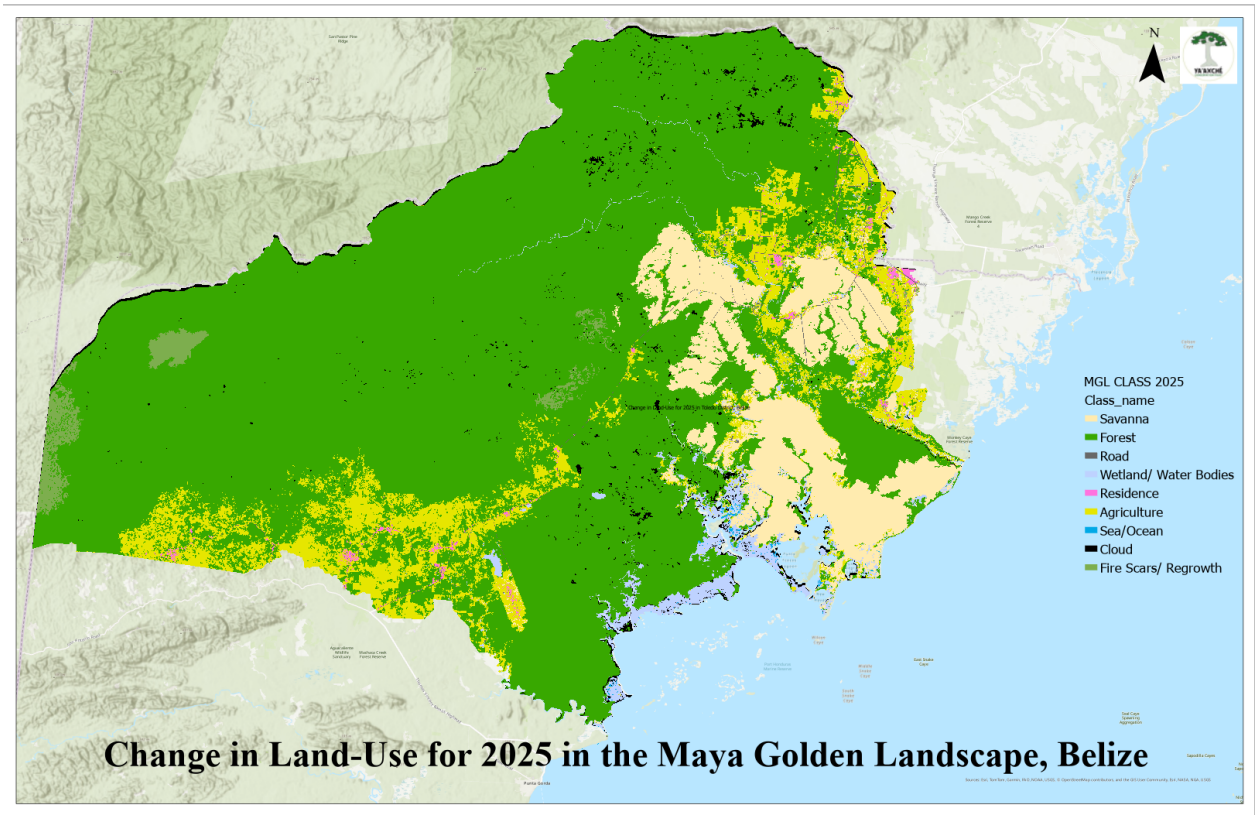

Figure 4B. Change in Land Use/Land Cover classification for the Maya Golden Landscape, 2025.

Ya'axché Managed Protected Areas

Across the four protected areas managed by Ya'axché, forest cover remained overwhelmingly forested in 2025, with forest cover exceeding 89% in every protected area and accounting for 97.14% of the land mass under the four protected areas. Anthropogenic land cover represented only 0.73% of the total protected area coverage, confirming very little in human caused disturbances (Table 8). Combined forest cover across these protected areas totalled 167,133 acres, representing the dominant land cover class within each protected area. Anthropogenic land uses, including agriculture, residential areas, and roads, occupied only a small fraction of the protected areas and were primarily concentrated along reserve boundaries and access points.

Table 8. Forest and anthropogenic land cover within Ya'axché-managed Protected Areas in the Maya Golden Landscape: 2025.

Protected Area	Total Area (Ac)	Forest (ac)	Forest (%)	Anthrop. (ac)	Anthrop. (%)
BNR	104,189.66	102,894.51	98.76	5.61	0.01
MMNFR	37,461.20	36,138.49	96.47	79.74	0.21
GSCP	16,469.20	15,595.04	94.69	81.33	0.49
BCEP	13,941.29	12,505.04	89.70	1,093.56	7.84
PAs Combined	172,061.35	167,133.08	97.14	1,260.24	0.73

Bladen Nature Reserve (BNR)

The Reporting Year 2025 LULC classification for BNR confirms that forest overwhelmingly dominates the reserve (Figure 5 and Table 9). Forest covers approximately 98.76% of the total area (102,895 acres; 41,640 ha). The forest cover declined slightly from 99.80% in 2024 to 98.76% in 2025 due to classification limitations including cloud cover which was an issue during data collection. Water bodies account for 0.20% (206 acres; 83 ha), while savanna covers 0.10% (107 acres; 43 ha). Anthropogenic land cover within BNR is negligible, with agriculture accounting for approximately 5.56 acres (2.25 ha), and roads representing a similarly minimal proportion of the landscape.

No significant fire related or anthropogenic disturbance was detected at a scale indicative of forest loss. Comparison between Reporting Years 2024 and 2025 indicates a net increase in forest cover of approximately 4,546.63 acres, suggesting continued forest stability and regeneration within the reserve. Minor variations between reporting periods are likely influenced by differences in cloud cover, classification sensitivity, and improved spectral separability in the Reporting Year 2025 classification.

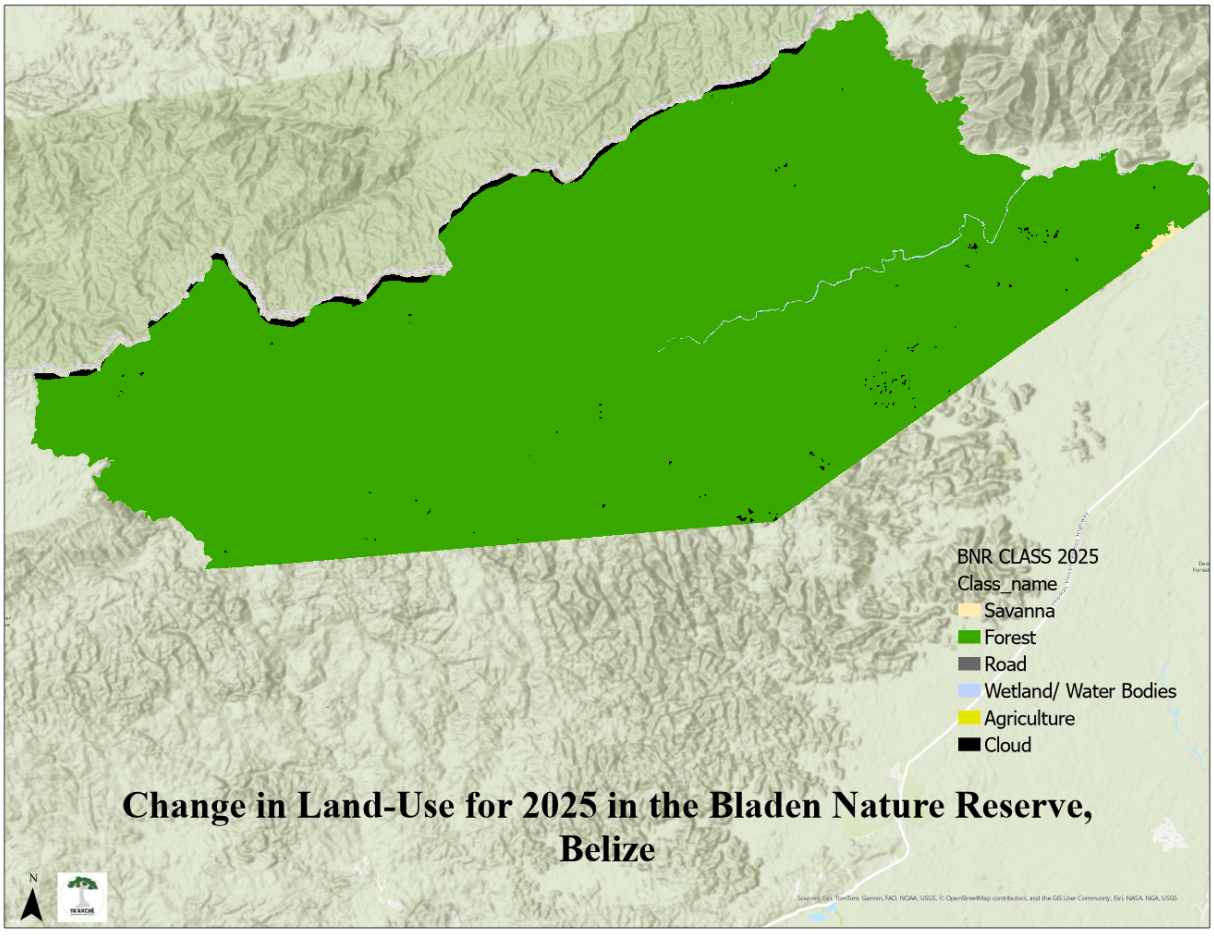

Figure 5. Land Use/Land Cover classification for the Bladen Nature Reserve, 2025.

Table 9. Land Use/Land Cover classes of the Bladen Nature Reserve. 2025 classification.

#	Type	Frequency	Hectares	Acres	Percentage 2024	Percentage 2025
1	Savanna	4312	43.12	106.55	0.07%	0.10%
2	Forest	4163993	41639.93	102894.51	99.80%	98.76%
3	Road	2	0.02	0.05	0.00%	0.00%
4	Fire Scars	0	0.00	0.00	0.00%	0.00%
5	Residence	0	0.00	0.00	0.00%	0.00%
6	Wetland\waterbodies	8331	83.31	205.86	-	0.20%
7	Agriculture	225	2.25	5.56	0.00%	0.0%
8	Cloud	39543	395.43	977.13	-	0.94%

Maya Mountain North Forest Reserve (MMNFR)

The Reporting Year 2025 LULC classification for MMNFR indicates that forest remains the dominant land cover type, covering approximately 96.47% of the reserve (36,138.49 acres; 14,624.73 ha; see Figure 6 and Table 10). Forest cover declined from 99.25% in 2024 to 96.47% in 2025. Wetlands\waterbodies account for 0.35% (130.52 acres; 52.82 ha), while agriculture represents 0.21% (79.74 acres; 32.27 ha). Savanna and roads are negligible within the reserve, each covering less than 0.01% of the total area.

A notable proportion of the 2025 classification is attributed to cloud cover (2.97%), which reflects atmospheric conditions during image acquisition rather than actual land cover change. Agricultural land remains limited and concentrated along established concession boundaries, consistent with historical land use patterns within the reserve. The agroforestry concession established in 2014 continues to support the maintenance of forest cover and landscape stability within MMNFR.

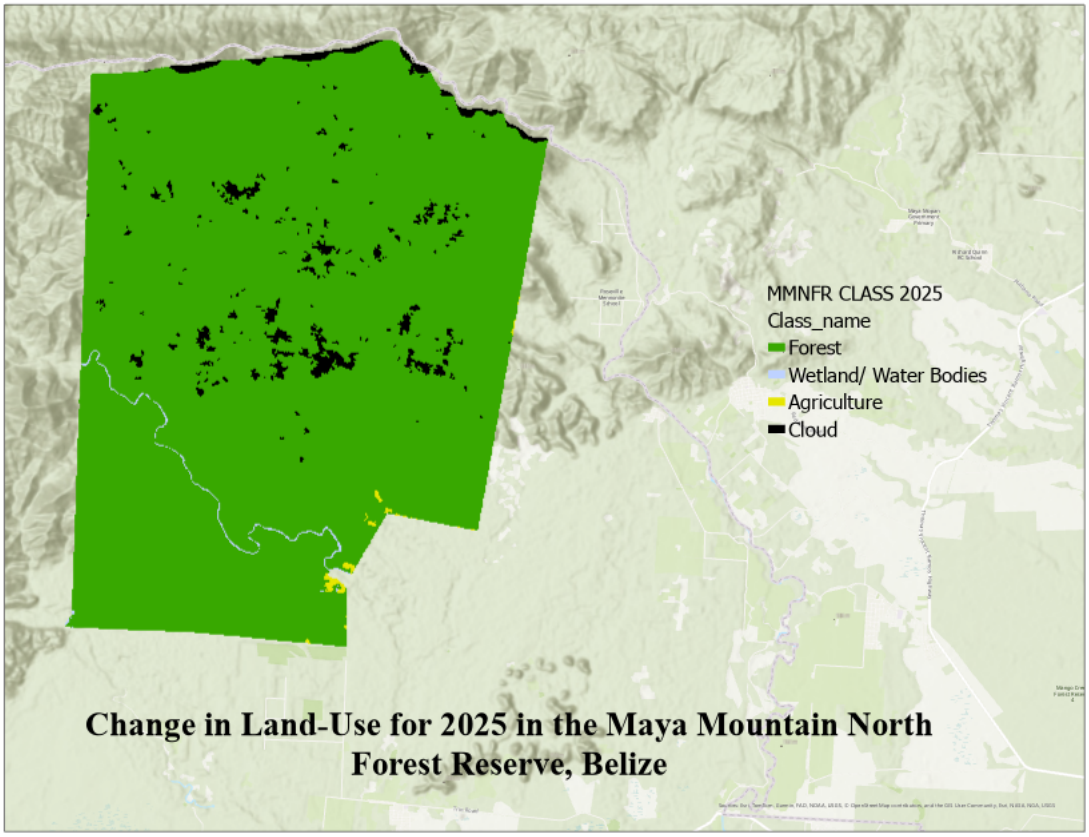

Figure 6. Land Use/Land Cover classification for the Maya Mountain North Forest Reserve, 2025.

Table 10. Land Use/Land Cover classes of the Maya Mountain North Forest Reserve: 2025 classification.

#	Type	Frequency	Hectares	Acres	Percentage 2024	Percentage 2025
1	Savanna	13	0.30	0.75	0.07%	0.00%
2	Forest	1462473	14624.73	36138.49	99.25%	96.47%
3	Cloud	45019	450.19	1112.44	-	2.97%
4	Roads	0	0.00	0.00	0.00%	0.00%
5	Fire Scars	0	0.00	0.00	0.00%	0.00%
6	Residence	0	0.00	0.00	0.00%	0.00%
7	Wetland\waterbodies	5282	52.82	130.52	0.45%	0.35%
8	Agriculture	3227	32.27	79.74	0.29%	0.21%

Golden Stream Corridor Preserve (GSCP)

The Reporting Year 2025 LULC classification for GSCP indicates that forest remains the dominant land cover type, covering approximately 94.69% of the preserve (15,595.04 acres; 6,311.09 ha; see Figure 7 and Table 11). Wetlands\waterbodies account for 2.48% (407.90 acres; 165.07 ha), while fire scars/regeneration areas represent 0.33% (54.39 acres; 22.01 ha), indicating localized and likely temporary disturbance and subsequent vegetation recovery. Water-related features, including wetlands and aquatic systems, remain ecologically important components of the landscape mosaic.

Anthropogenic land use remains minimal within GSCP, with roads covering 0.11% (18.21 acres), residences 0.01% (1.98 acres), and agriculture 0.02% (6.75 acres) of the total preserve area. A notable proportion of the 2025 classification is attributed to cloud cover (2.33%), reflecting atmospheric conditions during image acquisition rather than actual land cover change.

Comparison with Reporting Year 2024 indicates no evidence of net permanent deforestation within GSCP. Apparent differences in class proportions between reporting periods are primarily influenced by cloud contamination and classification sensitivity rather than true land cover conversion.

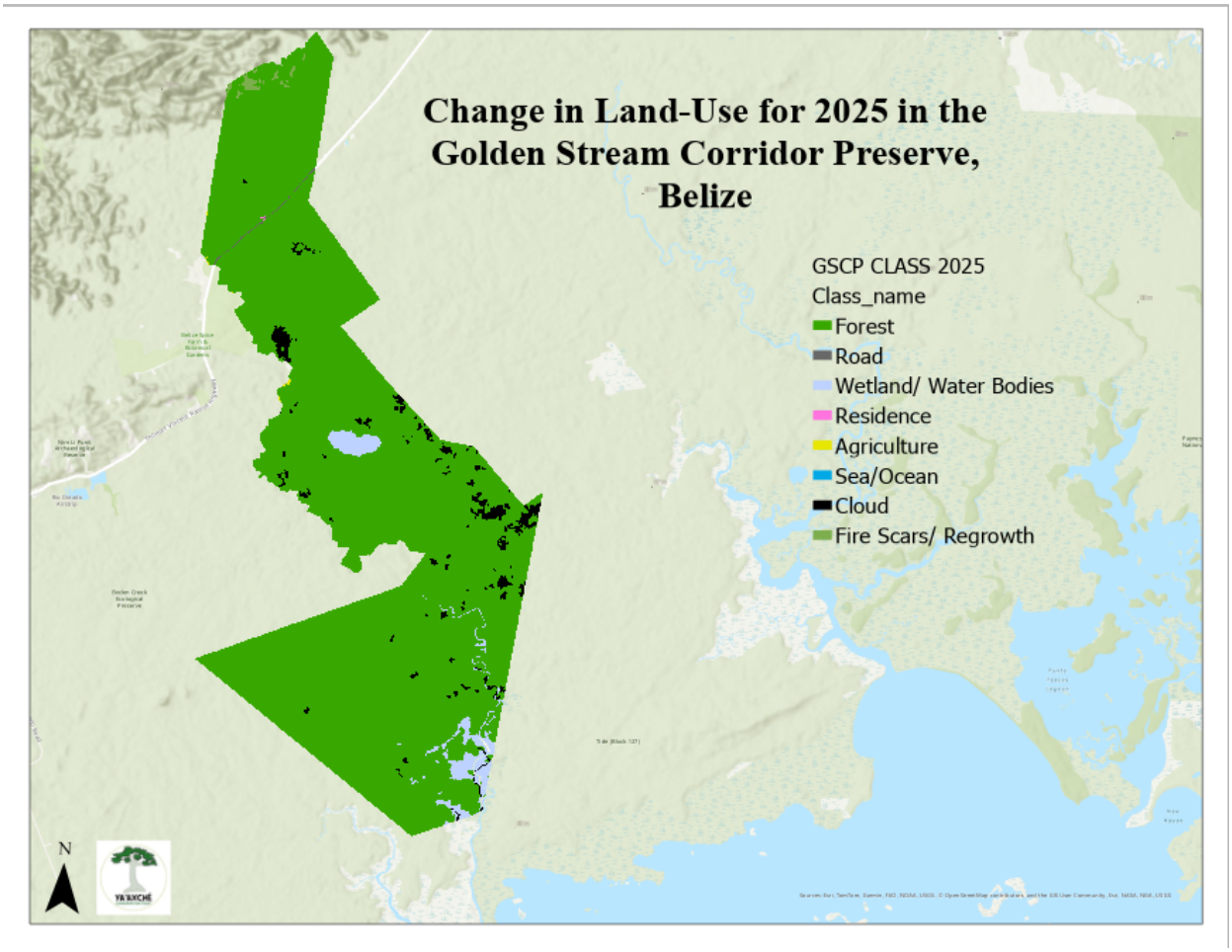

Figure 7. Land Use/Land Cover classification for the Golden Stream Corridor Preserve, 2025.

Table 11. Land Use/Land Cover classes of the Golden Stream Corridor Preserve: 2025 classification.

#	Type	Frequency	Hectares	Acres	Percentage 2024	Percentage 2025
1	Savanna	0	0.00	0.00	0.00%	0.00%
2	Forest	631109	6311.09	15595.04	97.88%	94.69%
3	Cloud	15556	155.56	384.40	-	2.33%
4	Road	737	7.37	18.21	0.21%	0.11%
5	Fire Scars/ Regrowth	2201	22.01	54.39	0.35%	0.33%
6	Residence	80	0.8	1.98	0.01%	0.01%
7	Wetland\waterbodies	16507	165.07	407.90	1.54%	2.48%
8	Agriculture	273	2.73	6.75	0.01%	0.02%

Boden Creek Ecological Preserve (BCEP)

The Reporting Year 2025 LULC classification for BCEP indicates that forest remains the dominant land cover type, comprising approximately 89.70% of the preserve (12,505.04 acres; 5,060.61 ha; see Figure 8 and Table 12). Agriculture accounts for 7.12% (992.50 acres; 401.65 ha), while wetlands represent 2.06% (286.84 acres; 116.08 ha) and water bodies 0.70% (93.84 acres; 37.98 ha). Anthropogenic land cover includes roads (0.39%; 53.89 acres) and residential areas (0.33%; 45.49 acres). Fire scars/regeneration areas were minimal, covering only 1.68 acres, indicating highly localized and short-term disturbance.

A small proportion of the 2025 classification (0.40%) is attributed to cloud cover, reflecting atmospheric conditions during satellite image acquisition rather than actual land cover change. Comparison with Reporting Year 2024 indicates no evidence of net permanent deforestation within BCEP. Observed differences in land cover proportions between reporting periods are likely influenced by classification sensitivity, residual cloud contamination, and the reclassification of transitional vegetation and disturbed areas rather than true land cover conversion.

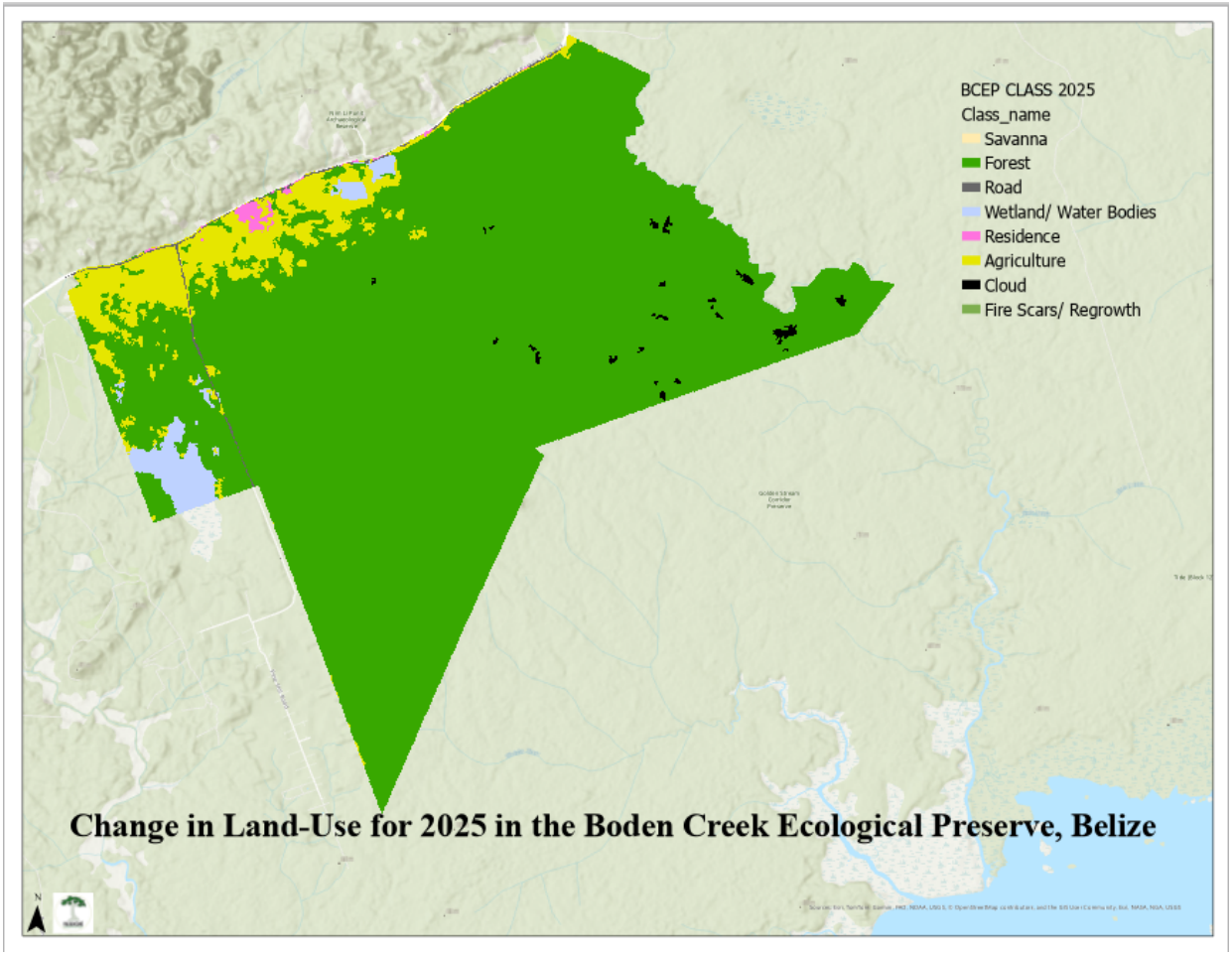

Figure 8. Land Use/Land Cover classification for the Boden Creek Ecological Preserve, 2025.

Table 12. Land Use/Land Cover classes of the Boden Creek Ecological Preserve. 2025 classification.

#	Type	Frequency	Hectares	Acres	Percentage 2024	Percentage 2025
1	Savanna	16	0.16	0.40	0.04%	0.00%
2	Forest	506061	5060.61	12505.04	92.17%	89.70%
3	Cloud	2244	22.44	55.45	-	0.40%
4	Road	2181	21.81	53.89	0.52%	0.39%
5	Fire Scars/ Regrowth	68	0.68	1.68	0.02%	0.01%
6	Residence	1841	18.41	45.49	0.35%	0.33%
7	Wetland\waterbodies	11608	116.08	286.84	1.56%	2.06%
8	Agriculture	40165	401.65	992.50	5.34%	7.12%

Case Studies

Areas of Interest

The following areas of interest are maintained consistently across reporting years to enable longitudinal monitoring and comparison of land use change over time.

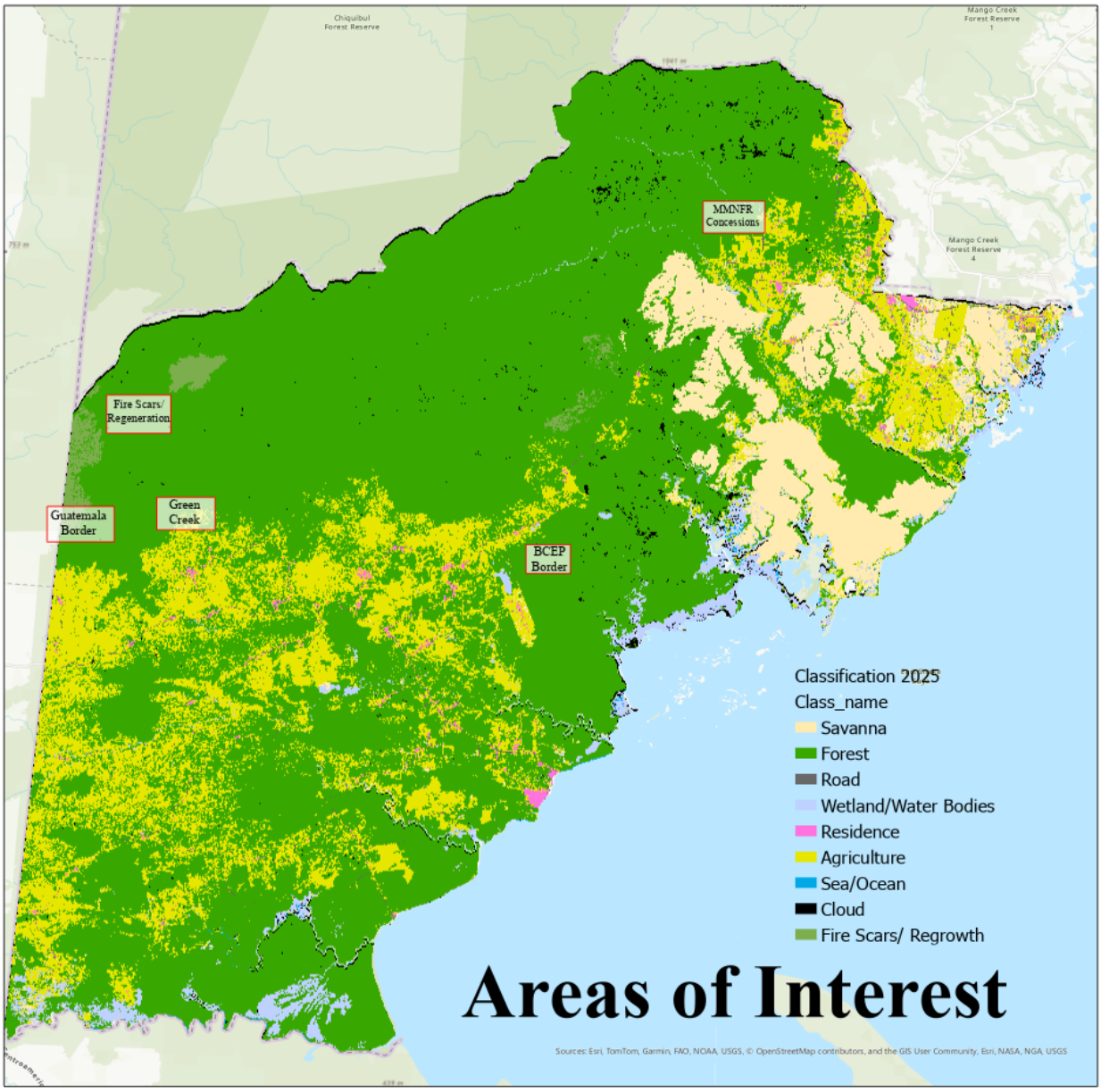

Figure 9. Areas of Interest in Toledo for Case Studies. From left to right: 1, section of the Belize-Guatemala border adjacent to the Columbia River Preserve; 2, Green Creek Farmers' Cooperative in San Jose Village; 3, northern border of BCEP adjacent to Indian Creek Village; 4, southern portion of MMNFR covering the agroforestry concession and de-reserved area; 5, fire disturbance in Columbia River Forest Reserve.

Boden Creek Ecological Preserve

Land cover change within Boden Creek Ecological Preserve (BCEP) remains concentrated along the northern boundary adjacent to Indian Creek Village, in areas historically used for agriculture and now characterized by a mosaic of agricultural land, secondary vegetation, and regenerating forest (Figure 10). Forest remains the dominant land cover type, accounting for approximately 89.70% of the preserve (12,505 acres; 5,061 ha), while agriculture and other anthropogenic land uses occupy a relatively small proportion of the landscape and are concentrated primarily along the northeastern and southeastern boundaries.

The Reporting Year 2025 classification shows continued forest dominance within BCEP, with no evidence of significant new clearing extending into the preserve interior. Along the northern boundary near Indian Creek Village, several areas that appeared as recently cleared or sparsely vegetated land in the previous reporting period exhibit spectral characteristics consistent with early secondary regrowth, suggesting short-cycle cultivation or abandoned agricultural plots rather than sustained agricultural expansion. Agricultural extent along the southeastern boundary remains generally consistent with previous reporting periods, with only minor localized changes associated with the continued management of existing agricultural areas. The transfer of BCEP to Ya'axché management in 2024 is expected to strengthen monitoring, boundary management, and enforcement activities in future reporting periods, supporting the long-term conservation of the preserve and its role within the Southern Biological Corridor.

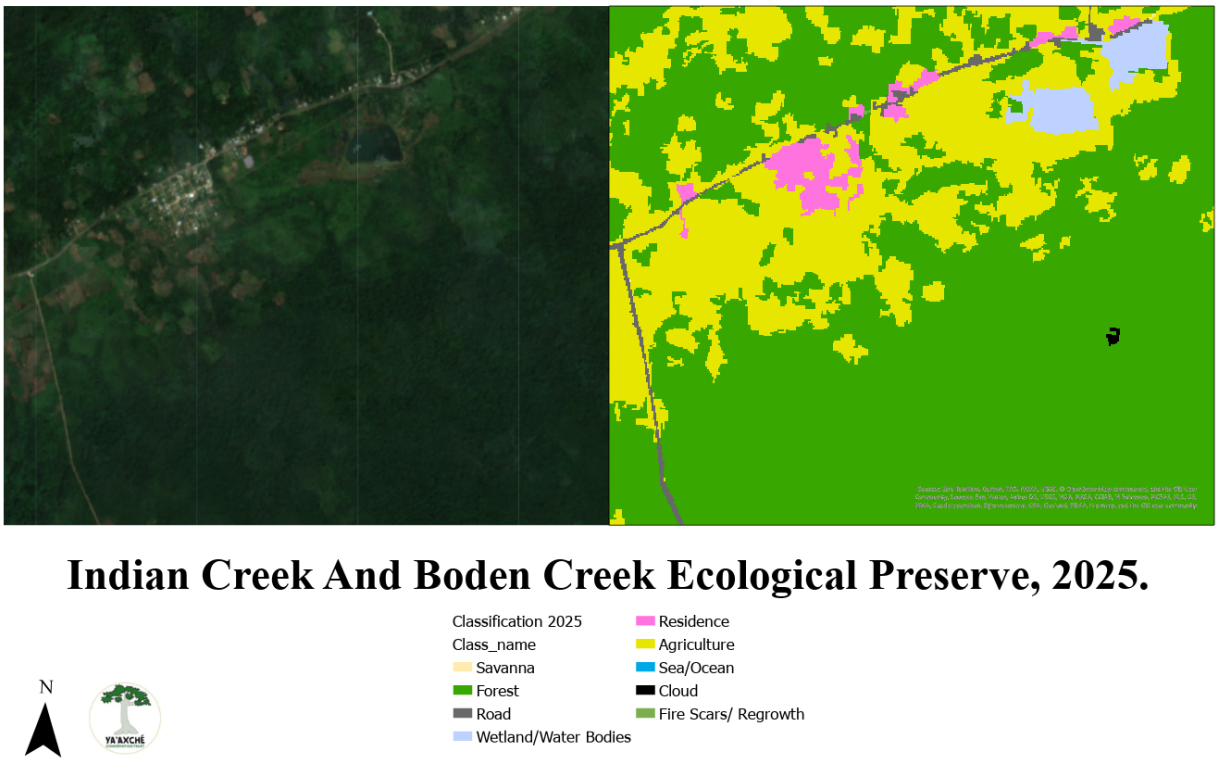

Figure 10. Land use change along the northern boundary of the Boden Creek Ecological Preserve adjacent to Indian Creek Village: 2025.

Maya Mountain North Forest Reserve

Forest cover within MMNFR remains largely intact, with approximately 96.47% of the reserve classified as forest (36,138 acres / 14,625 ha; see Figure 11). Minor localized disturbance was observed during the reporting period, primarily along the southern and eastern boundaries near de-reserved areas and buffering communities. Comparison with the previous reporting period indicates that the agroforestry concession boundary remained stable, with no measurable expansion of agricultural activity beyond previously mapped extents. Small variations observed along the reserve edge are likely attributed to classification sensitivity, cloud cover, and the spectral similarity between agroforestry systems and natural forest rather than new land use conversion.

Within MMNFR, anthropogenic land uses, including agriculture, account for approximately 0.21% of the reserve (80 acres / 32 ha), confirming the reserve's high forest integrity. Wetlands\waterbodies occupy approximately 0.35% (131 acres / 53 ha), while approximately 2.97% of the reserve was obscured by cloud cover during image acquisition. Continued monitoring of concession boundaries is recommended to verify compliance with established land use agreements and to support sustainable forest management within the reserve.

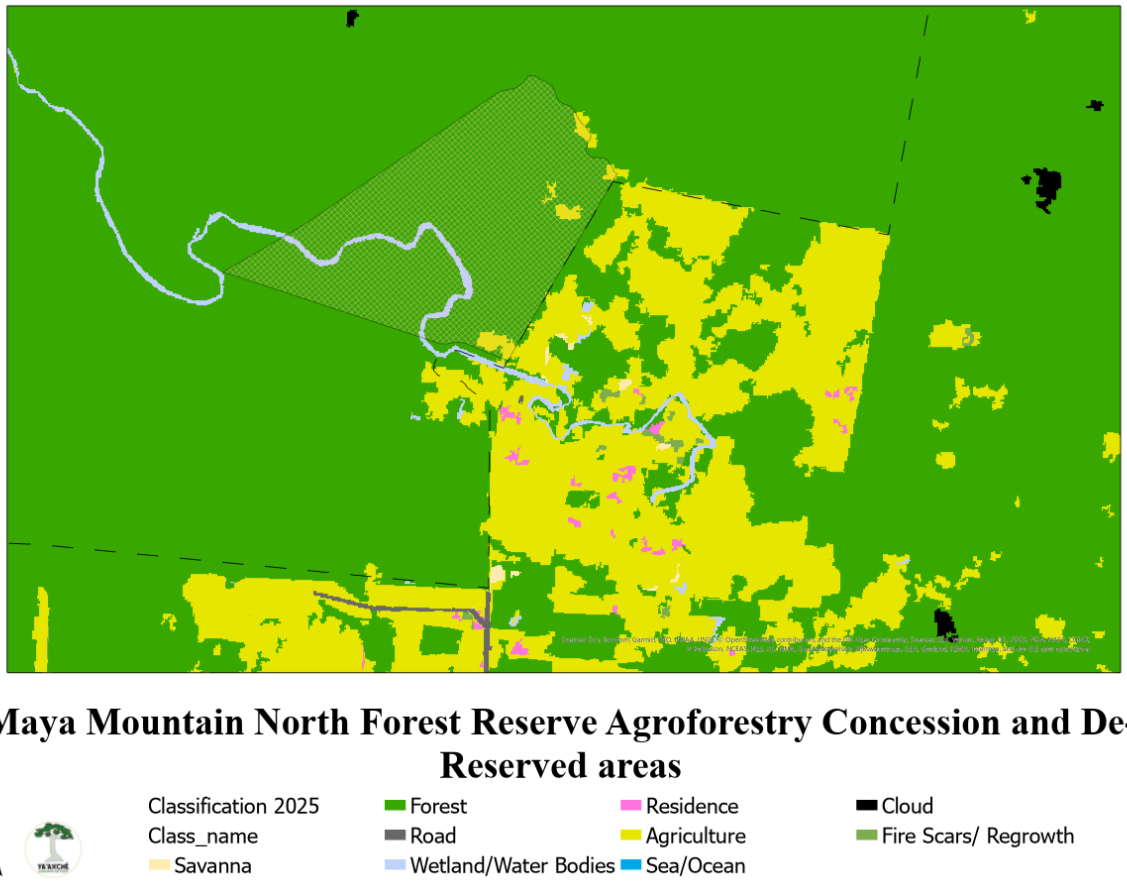

Figure 11. Land use patterns within the Maya Mountain North Forest Reserve agroforestry concession and de-reserved areas: 2025.

Ya'ax Ha Livelihood Area at San Jose Village

The Ya'ax Ha (Green Creek) Livelihood Area is a locally recognized Indigenous Community Conserved Area (ICCA) managed by the Green Creek Farmers' Cooperative (GCFC) under traditional land use systems, including cacao agroforestry and subsistence agriculture. The Reporting Year 2025 classification indicates that forest remains the dominant land cover type, covering approximately 1,219 acres (493 ha; 82.66%), while agriculture occupies approximately 256 acres (103 ha; 17.34%, see Figure 12). Agricultural activity remains concentrated within established cultivation areas and is consistent with traditional community-based land use practices.

Comparison with Reporting Year 2024 indicates a reduction in the proportion of mapped forest cover from 1,873 acres and a corresponding increase in agricultural land from 302 acres. When assessing the classification outputs, they indicate that agricultural activity remains spatially concentrated within historically cultivated areas, and no evidence of large scale clearing or unmanaged encroachment into surrounding forest especially the conservation zone. Overall, land cover patterns remain consistent with a community managed landscape.

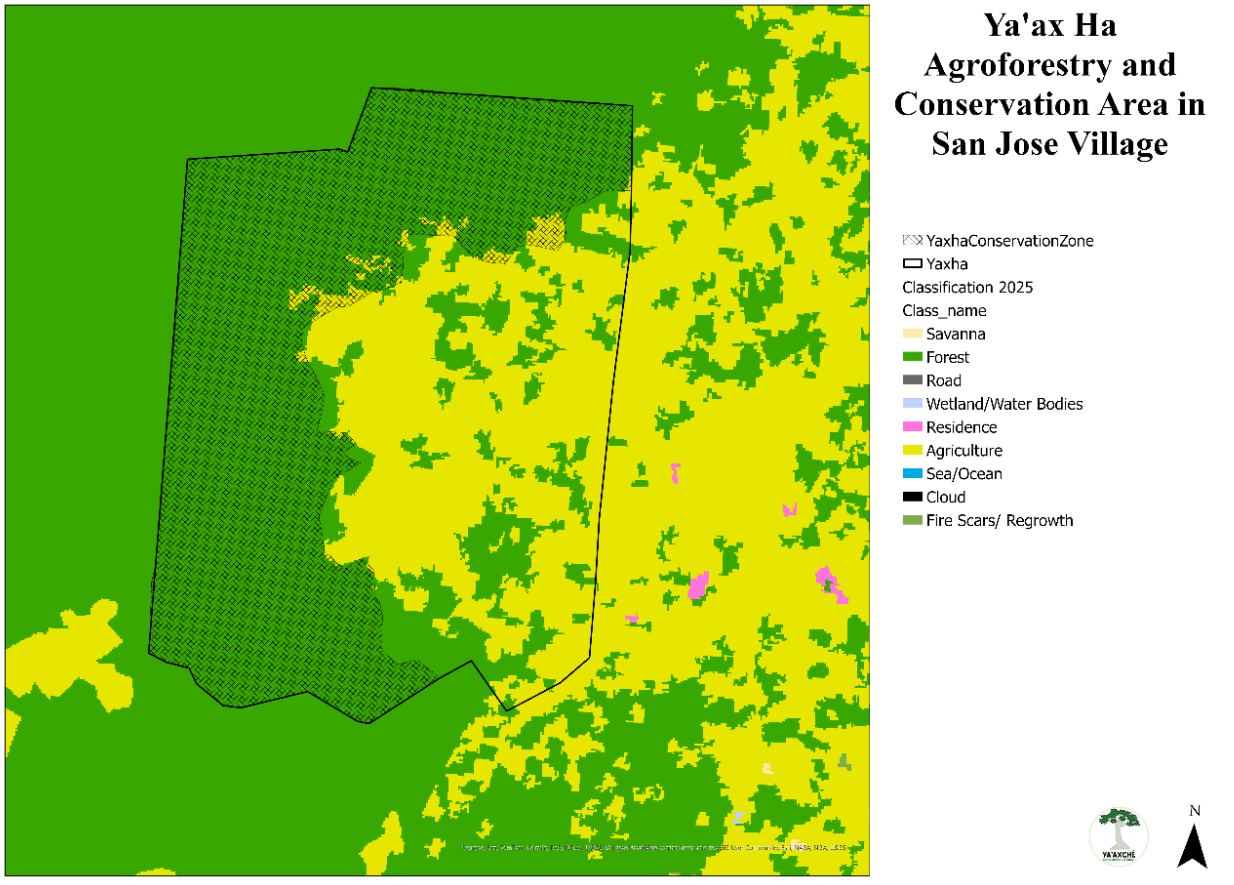

Figure 12. Land use patterns within the Ya'ax Ha Livelihood Area (Green Creek), San Jose Village: 2025.

Columbia River Forest Reserve (CRFR – Agricultural Incursions)

CRFR continues to experience anthropogenic pressure along its western and southern boundaries, where illegal agricultural expansion, cattle grazing, and resource extraction associated with cross-border access from Guatemala remain ongoing concerns. Multiple informal access routes into the reserve facilitate human access and continue to require targeted monitoring and enforcement. Agricultural activity remains concentrated along the southern boundary of CRFR and continues to be the primary source of anthropogenic pressure on the reserve (Figure 13). Agricultural land increased from 1,663.82 acres (1.20%) in the previous reporting period to 1,849.16 acres (1.26%) in Reporting Year 2025, representing an increase of approximately 185 acres. Existing agricultural plots have become more consolidated, and localized expansion was observed adjacent to previously cultivated areas, indicating continued land use pressure near the reserve edge. These impacts remain concentrated along established access routes and boundary zones rather than within the interior of the reserve. Forest remained the dominant land cover type within CRFR, accounting for 135,325.26 acres (92.57%) in Reporting Year 2025. While mapped forest cover increased relative to the previous reporting period, this is due to differences in classification conditions and the presence of 931.86 acres (0.64%) of cloud cover in the Reporting Year 2025 imagery.

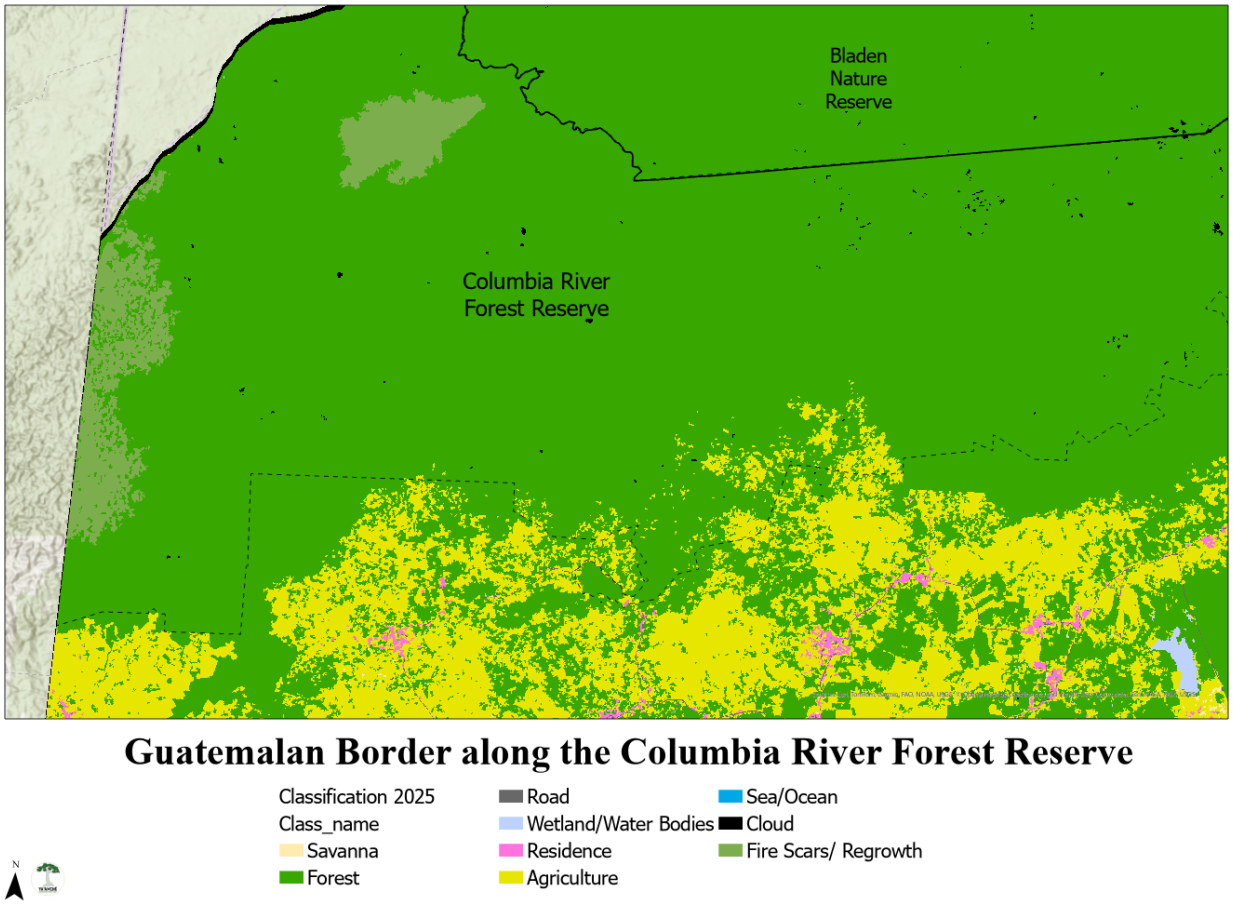

Figure 13. Land use change along the Belize–Guatemala border within the Columbia River Forest Reserve highlighting agricultural incursions, 2025.

Columbia River Forest Reserve (CRFR – Fire Disturbance)

The Reporting Year 2025 classification indicates that Fire Scars/Regrowth covered approximately 8,053.24 acres (3,259.03 ha), representing 5.51% of the Columbia River Forest Reserve (Figure 14). Forest remained the dominant land cover type within the reserve, accounting for 135,325.26 acres (54,764.19 ha) or 92.57% of the total area. Approximately 931.86 acres (377.11 ha), or 0.64% of the reserve, were obscured by cloud cover during image acquisition. Comparison with the previous reporting period indicates a reduction in the extent of the Fire Scars/Regrowth class, from 8,478.59 acres (3,431.16 ha) to 8,053.24 acres (3,259.03 ha). This decrease of approximately 425 acres (172 ha), together with observed increases in vegetative cover within portions of the affected area, suggests ongoing natural regeneration following the 2024 dry-season fire. Regeneration appears strongest along sections of the western boundary, where previously disturbed areas now exhibit denser vegetation cover and spectral signatures consistent with early secondary succession.

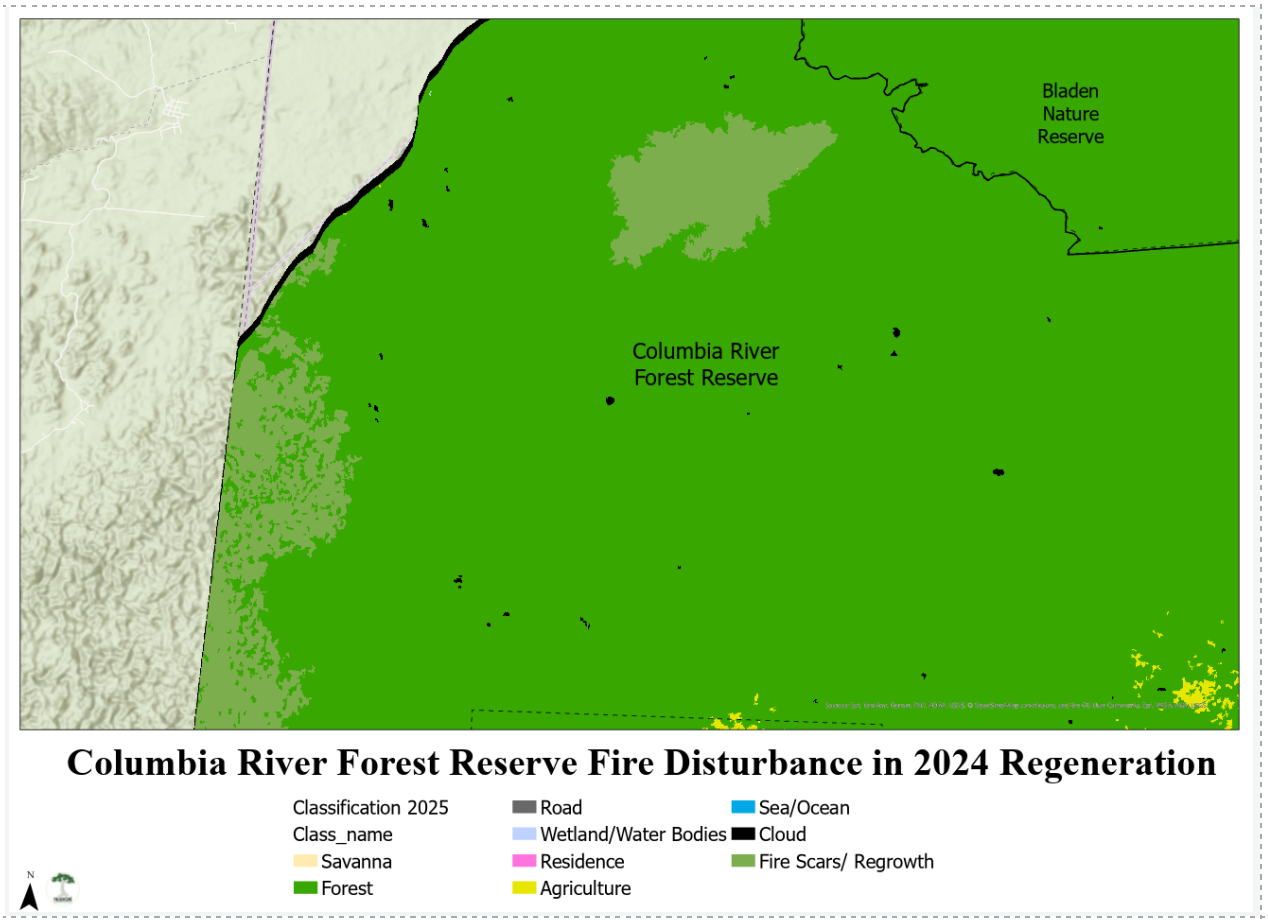

Figure 14. Fire-affected area within the Columbia River Forest Reserve: 2025.

Discussion

Toledo

The Toledo District remains one of the most forested districts in Belize, with approximately 760,857 acres (69.24%) of its land area classified as forest in Reporting Year 2025. The second largest land cover class is agriculture (190,391 acres; 17.33%) followed by savanna (82,900 acres; 7.54%). The spatial distribution of these classes reflects the mosaic of land uses of the district, with extensive forest cover concentrated within the Maya Mountains and protected areas, while agricultural and settlement activities remain concentrated along transportation corridors and community boundaries. Compared with the previous reporting year, Forest cover increased by approximately 27,931 acres, this apparent increase is mainly attributed to refinement in the classification rather than forest cover gain. During this reporting year 2025, more detailed pixel level refinement was applied. The Forest cover presented in this report represents a more accurate depiction of the existing land cover. Additionally, some areas that had been severely impacted by fires in 2024 have been in recovery since and likely influence the increase in forest cover in this reporting period. This, coupled with refinement resulted in a rate of change of +3.81% representing forest gain across the district, a result of method of assessment rather than actual forest gain.

Agricultural land cover decreased between 2024 and 2025, declining from 196,648.97 acres to 190,390.72 acres a rate of change of 3.18%. This reduction suggests a contraction in the extent of agricultural land within the Toledo District during the study period. This observed decrease may reflect the conversion of agricultural areas to other land-cover classes, such as regenerating fallow lands or wetlands, although confirmation of the specific transitions would require further analysis of the land-cover transition matrix. It may also be a reflection of seasonal farming practices by communities in the district that align farming with climate and weather forecasts and patterns. Overall, the results indicate a slight decline in agricultural land cover over the study period.

Wetlands\waterbodies extent increased from 4,204 acres (0.40%) in the previous reporting period to 29,832 acres (2.71%) in Reporting Year 2025. However, this increase is largely explained by the incorporation of areas previously classified as Water Bodies (14,469 acres; 1.38%) into the Wetland class. As a result, the observed increase should not be interpreted as a substantial gain in wetland habitat, but rather because of revised class grouping and differences in classification representation between reporting periods. Separating the two often causes inconsistencies in classification and at times introduces too much noise into the analysis that increases inaccuracies in identifying where both wetlands and water bodies occur. In this case, it provided a cleaner classification raster to work with in determining area coverage.

Differences in cloud cover, seasonal conditions, image acquisition dates, and classification sensitivity can influence the representation of certain land cover classes. In Reporting Year 2025, approximately 11,411 acres (1.04%) of the district were classified as cloud cover, while changes in wetlands\waterbodies extent likely reflect a combination of seasonal hydrological variation and improved class discrimination in addition to classification changes. Consequently, apparent changes in some classes may not necessarily represent permanent land cover conversion. Despite these limitations, the results continue to highlight the importance of sustained monitoring across the Toledo

District and the MGL. Agricultural expansion, fire disturbance, and land use change along forest margins remain important pressures on natural systems, while the persistence of extensive forest cover within protected and community-managed areas demonstrates the critical role of conservation management in maintaining landscape connectivity and ecological integrity (Ya'axché, 2024; Bruner et al., 2001; Gaveau et al., 2009).

Maya Golden Landscape

The Maya Golden Landscape (MGL) remains predominantly forested, with approximately 507,868 acres (74.62%) classified as forest in Reporting Year 2025. Forest continues to be the dominant land cover type across the landscape, followed by savanna (68,338 acres; 10.04%) and agriculture (66,725 acres; 9.80%). Together, these classes account for more than 94% of the MGL and reflect the landscape's continued importance as a conservation stronghold within southern Belize.

Agriculture and other anthropogenic land uses remain concentrated along transportation corridors, community boundaries, and areas adjacent to reserve margins. Although agricultural activity occupies less than 10% of the landscape, its spatial distribution continues to place pressure on forest edges and near protected areas. Fire Scars/Regrowth covered approximately 10,279 acres (1.51%) of the MGL in Reporting Year 2025, highlighting the impact of fire on landscape dynamics, particularly within and around the Columbia River Forest Reserve and other forest–agriculture transition zones. There was slight decrease in fire scars which is an encouraging trend that indicates that areas affected by fires in 2024 are now starting to show signs of recovery. It will be important to monitor this trend in the years to come to understand the recovery process of fire affected forests.

Wetlands\waterbodies accounted for 14,227 acres (2.09%) of the MGL in Reporting Year 2025. Areas previously classified as Water Bodies were incorporated into the Wetland class during the current assessment. Consequently, part of the apparent increase in wetlands\waterbodies extent reflects revised class grouping rather than actual landscape-scale wetlands\waterbodies expansion. There is also the influence of seasonal hydrological conditions the influence the extent of water bodies and wetlands. These conditions would fluctuate between the dry and wet seasons showing contractions during drought conditions and expansions during the rainy season and during flood conditions.

Approximately 8,397 acres (1.23%) of the MGL were obscured by cloud cover during image acquisition. As a result, direct comparison of individual class areas between reporting periods should is difficult particularly where cloud cover, seasonal conditions, and classification sensitivity may influence mapped land cover extents. While forest remains the dominant land cover class throughout the MGL, continued monitoring of agricultural expansion, fire disturbance, and land use change along reserve boundaries remains essential to maintaining landscape connectivity and ecological integrity (Ya'axché, 2024; Bruner et al., 2001; Gaveau et al., 2009).

Protected Areas

Across the four Protected Areas managed by Ya'axché within the MGL, forest cover remained exceptionally high, exceeding 96% of total PA area as of reporting year 2025. Forest cover increased by 6,608.08 acres, corresponding to an annual rate of change of approximately 4.12 %, indicating continued maintenance and recovery of forest particularly from areas affected by fires and in some

cases by agriculture activities. The substantially lower deforestation rates within Protected Areas compared to unprotected lands reinforce evidence that protected area management is effective in reducing large scale forest conversion (FAO, 2020).

There is a clear contrast among the protected areas. BNR, MMNFR, and GSCP all have more than 94% forest cover and less than 0.5% anthropogenic land cover, indicating very high ecological integrity. In contrast, BCEP has noticeably lower forest cover and a higher proportion of anthropogenic activity. This does not necessarily indicate poor management, but it does reflect differences in historical land use and surrounding landscape context. There is no current management plan for the reserve, which is essential in guiding activities as is the case with the other protected areas. Once a plan is developed and implemented, there will be changes that will be reflected in future LULC assessments.

Bladen Nature Reserve (BNR)

BNR remained overwhelmingly forested during Reporting Year 2025, maintaining the highest level of forest integrity among the Ya'axché managed Protected Areas. Forest cover increased from 98,347.88 acres (99.80%) in the previous reporting period to 102,894.51 acres (98.76%) in Reporting Year 2025. Although the proportional forest cover decreased slightly due to the inclusion of cloud cover (977.13 acres; 0.94%) and expanded wetland\waterbodies classification (205.86 acres; 0.20%), there is no evidence of meaningful forest loss or anthropogenic encroachment within the reserve.

Other cover classes are non-existent owing in large part to the strict protection status and remoteness of the reserve. The appearance of wetland\waterbodies areas in the Reporting Year 2025 classification is likely due to improved class discrimination and seasonal environmental conditions rather than new land cover conversion. Overall, the results confirm the continued ecological integrity of BNR and reinforce its role as the core conservation area within the Maya Golden Landscape.

Maya Mountain North Forest Reserve (MMNFR)

Forest remained the dominant land cover type within MMNFR, increasing from 35,156.47 acres (99.25%) in the previous reporting period to 36,138.49 acres (96.47%) in Reporting Year 2025. The lower proportional forest cover in 2025 is primarily due to the inclusion of 1,112.44 acres (2.97%) classified as cloud cover rather than a substantial decline in forest extent. Cloud cover was extensive over the MMNFR excessive mosaicking of satellite images would introduce undesired noise that could affect the classification process.

Agricultural land decreased from 104.49 acres (0.29%) to 79.74 acres (0.21%), while wetlands\waterbodies increased from negligible levels to 130.52 acres (0.35%). The agroforestry concession boundary remained stable throughout the reporting period, with no evidence of agricultural expansion beyond established management areas. These findings suggest that MMNFR continues to maintain high forest integrity while supporting sustainable community-based agroforestry activities. The active logging concession could be contributing to less agricultural incursions by suppressing access due to logging activities.

Golden Stream Corridor Preserve (GSCP)

GSCP maintained a high level of forest cover during Reporting Year 2025, with forest increasing from 15,388.94 acres (97.88%) to 15,595.04 acres (94.69%). Some of the fire affected forest appear to be

recovering and contributing to the increase in forest area. As with other protected areas, the reduction in percentage cover is largely due to the inclusion of 384.40 acres (2.33%) of cloud cover and an increase in mapped wetlands\waterbodies extent.

Wetlands\waterbodies increased from 144.23 acres (0.92%) to 407.90 acres (2.48%) this is due the fact that wetland and waterbodies are classified as one for this reporting year 2025. There is one wetland within the reserve that contracts and expands between seasons and the extent fluctuates year to year adding to inter annual variation in coverage. Agricultural land remained extremely limited, increasing slightly from 1.96 acres to 6.75 acres (0.04%). These areas are boundary edge effects where miniscule changes are seen reflected in the assessment. Fire Scars/Regrowth remained low at 54.39 acres (0.33%). Considering the large areas that were affected by fire it is important to note that while only 54.39 acres appear as scars there are larger areas that are currently in recovery with pioneer vegetation that more resembles fallow land than it does forest. The classification was too broad to single out these areas and perhaps a closer look at only the fire affected areas is warranted in future assessments. The absence of significant agricultural expansion and the persistence of extensive forest cover continue to support GSCP's role as a critical ecological corridor connecting the Maya Mountain Massif with the coastal lowlands.

Boden Creek Ecological Preserve (BCEP)

BCEP exhibited the greatest level of land cover change among the four Ya'axché-managed Protected Areas. Forest cover increased from 12,270.14 acres (92.17%) in the previous reporting period to 12,505.04 acres (89.70%) in Reporting Year 2025. While the proportion of forest cover declined, there was an increase in total forest cover compared to 2024 due to classification refinement, wetland reclassification and the contraction of other classes. There is no apparent significant forest loss and remains predominantly forested.

Agricultural land increased from 710.83 acres (5.34%) to 992.50 acres (7.12%), representing the most substantial agricultural footprint among the protected areas. The proximity to the community of Indian Creek and the land use by the community contributes significantly to the increase in agriculture land use. Wetlands\waterbodies increased from 113.95 acres (0.86%) to 286.84 acres (2.06%) this is due the fact that wetland and waterbodies are classified as one for this reporting year 2025. Fire Scars/Regrowth remained negligible at only 1.68 acres (0.01%). The observed changes are concentrated along the preserve boundaries and are consistent with BCEP's historical multiple use prior to its transition to conservation management. The Reporting Year 2025 classification provides an important baseline for evaluating future management effectiveness and ecological change.

Conclusion

The Reporting Year 2025 Land Use/Land Cover (LULC) assessment builds upon the foundation established in previous monitoring cycles and provides an updated picture of landscape dynamics across the Toledo District, the Maya Golden Landscape (MGL), and Ya'axché managed Protected Areas. By maintaining methodological consistency while incorporating improved classification procedures and quality control measures, this assessment strengthens Ya'axché's capacity to monitor long-term land cover trends and support evidence-based conservation management. There is much room for improvement in the classification process and improvements in methodologies should be considered before the next iteration of this assessment.

The results of the analysis confirm that forest remains the dominant land cover class across all spatial scales assessed. Within the Toledo District, forest covered approximately 760,857 acres (69.24%) in Reporting Year 2025, while the Maya Golden Landscape retained approximately 507,868 acres (74.62%) of forest cover. There are continued pressures associated with agriculture, fire disturbance, and land use activities along forest margins, but these are significantly smaller in comparison to the extensive forest cover that persists across much of southern Belize, particularly within protected and community-managed landscapes.

The assessment highlights the important role of protected area management in maintaining forest integrity. Across the four Ya'axché managed Protected Areas, Bladen Nature Reserve (BNR), Maya Mountain North Forest Reserve (MMNFR), Golden Stream Corridor Preserve (GSCP), and Boden Creek Ecological Preserve (BCEP) forest remained the dominant land cover class, accounting for approximately 98.76%, 96.47%, 94.69%, and 89.70% of each protected area, respectively. Together, these findings demonstrate the continued effectiveness of active conservation management, community engagement, and long-term stewardship in maintaining ecological connectivity and forest cover within the Maya Golden Landscape.

The assessment also identified several important land cover dynamics requiring attention. Agricultural expansion remains evident along portions of the Columbia River Forest Reserve boundary, while fire disturbance continues to influence landscape conditions in localized areas. Similar impacts are seen in the Boden Creek Ecological Preserve where unregulated agriculture and other uses may be contributing to some forest degradation. Fortunately, there is evidence of natural regeneration observed within previously fire-affected zones as in the case of the Golden Stream Corridor Preserve highlighting the resilience of these ecosystems when disturbance pressures are reduced. It is evident that continued remote sensing assessments as presented in this report are becoming essential tools in determining where conservation and livelihood efforts should be focused.

Recommendations

Based on the findings of the 2025 LULCC assessment and the experience gained through its production, the following recommendations are offered to improve the methodological rigour, interpretive depth, and operational efficiency of future reporting cycles:

- Standardise the monitoring framework to a single annual reporting window using consistent end-of-year satellite imagery to improve temporal comparability and ensure that land cover changes are clearly detectable and not influenced by seasonal variation or intra-annual fluctuations.
- Confirm that a 30% cloud probability threshold was applied for the 2024 analysis, while a 40% threshold was used for the 2025 analysis to increase the availability of usable imagery during periods of persistent cloud cover. We acknowledge that using different thresholds between years may affect consistency. To improve comparability across annual analyses, we intend to standardise the cloud masking threshold at 30% for future assessments, unless exceptional data availability requires an alternative threshold. Any deviation from the standard threshold will be clearly documented and justified in the methodology.
- Expand ground truthing efforts. The absence of systematic field-based validation remains a key limitation. Future assessments should integrate GPS referenced field observations to strengthen the accuracy assessment framework.
- Formalise training sample protocols. Consistent documentation of training sample counts, spatial distribution, and selection criteria per class across years and analysts is essential for reproducibility.
- Consider integrating Sentinel-1 SAR imagery to supplement optical data during periods of persistent cloud cover, a recognised limitation in southern Belize.
- Develop a near real time deforestation alert workflow for high-risk areas such as the CRFR boundary, using tools such as Global Forest Watch GLAD alerts or NASA FIRMS fire detection to complement the annual LULC assessment.
- Standardise coordinate reference systems to NAD 1983 UTM Zone 16N for all spatial analyses and area calculations to ensure accuracy of acreage and hectare estimates.
- Maintain the consistent areas of interest framework for case studies to maximise longitudinal comparability. New areas of concern may be added as supplementary case studies without displacing core monitoring sites.

Limitations

- The LULC classification methodology was consistent with previous reporting periods, supporting year-to-year comparability; however, inherent uncertainty remains in all remote sensing-based analyses.
- Natural ecosystem dynamics in Toledo are highly variable, and transitions between forest, savanna, agriculture, and wetlands are often gradual rather than sharply defined, which can lead to spectral overlap and classification uncertainty.
- Seasonal variation in rainfall and vegetation phenology influences spectral reflectance, affecting class separation and contributing to uncertainty in land cover assignment.
- Cloud cover in Sentinel-2 imagery remains a major constraint:
    - Obtaining clear, cloud-free imagery during the reporting year was often difficult, and in some cases nearly impossible.
    - Despite cloud masking, compositing, and careful image selection, residual clouds and shadow effects persisted in some areas.
    - This introduced uncertainty, particularly in forest–wetland and forest–agriculture transition zones.
- Time constraints, limited access to previously classified raster datasets, and lack of field-based ground truthing further contribute to classification uncertainty.
- Limited availability of previous raster datasets constrained pixel level change detection, requiring reliance on area-based comparisons between independently generated classifications. This introduces additional uncertainty in change estimates, particularly for highly dynamic classes such as wetlands and fire scars.
- The transition of BCEP to Ya'axché management during the reporting period required the creation of new boundary datasets and reference areas, which may introduce minor inconsistencies with previous representations.
- Analyst driven variation in training sample selection between reporting years may also contribute to differences in classification outputs that do not reflect actual land cover change.

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