1. Which geographic area of interest (AOI) are you focusing on? This can be the same AOI you selected for written assignment 1, or you can focus on a new AOI.

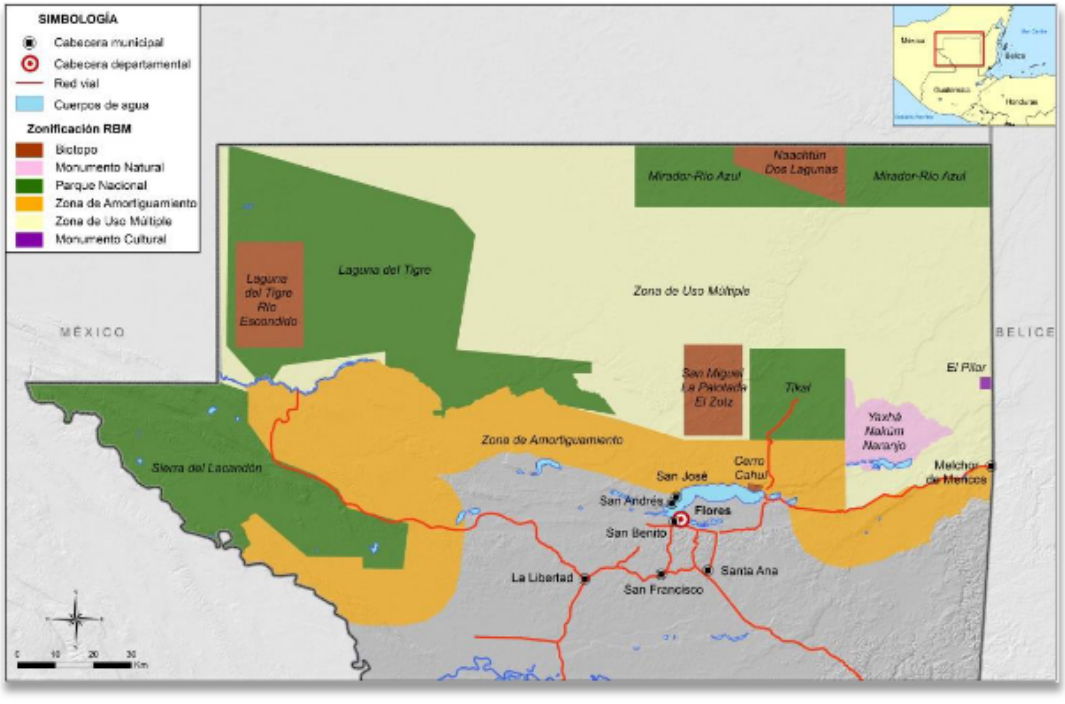
Geographic Area of Interest

The Maya Biosphere Reserve (MBR) is the largest protected ecosystem in Mesoamerica, composed of about 14 percent of the surface of Guatemala (Maya Biosphere Reserve Living Landscape, USAID). The MBR is composed of protected areas, multi-use zones, and buffer zones at the southern edge of the reserve.

In the late 1990s, the Guatemalan government granted concessions to local communities for forest use in multi-use zones. These concessions lasted for 25 years, with concessions being renewed on an ongoing basis by the federal government. Around 36% of the MBR's area prohibits human settlement, logging, or extraction. Established multi-use zones 36% as well as a where silviculture and agroforestry are permitted (Protected Planet, 2024, Preferred by Nature, 2024).

The multi-use zone makes up around 40% of the reserve boundaries and allow communities to utilize silviculture and agroforestry (Protected Planet, 2024, Preferred by Nature, 2024). Lastly, a buffer zone comprising of around 24% of the reserve area permits certain regulated economic activities, such as timber and non-timber forest product extraction (Protected Planet, 2024, Preferred by Nature, 2024).

Figure 1. Mayan Biosphere Zone and Management Areas



Source: Mayan Biosphere Reserve (2020)
National parks—such as the Parque Nacional Tikal and Parque Nacional Laguna del Tigre—are excluded from my area of interest, as these are managed by separate entities.

2. Describe your AOI in terms of its landscape characteristics: what are the dominant LULC categories? Strictly speaking: do these qualify as purely land cover, land use, or combinations of land cover and land use?

Land Use / Land Cover (LULC)

The Copernicus Global Land Cover Layers Collection 3 dataset was used to identify LULC classes in the MBR (Buchhorn et al., 2020). The "discrete_classification" band was used to obtain the dominant land cover classification for each pixel, while the "forest_type" band was used to classify forest type for pixels with a tree vegetation cover larger than 1%.

The dominant land use / land cover (LULC) classifications of the Maya Biosphere Reserve include closed forest, evergreen broadleaf (60%); cultivated and managed agriculture (27%); open forest, other (7%); herbaceous vegetation (1%); and pockets of urban/built up areas (<1%).

Table 1. Copernicus Global Land Cover Layers LULC classification in Maya Biosphere Reserve

Land Value	LULC Classification	Percentage
112	Closed Forest, Evergreen Broad Leaf	60.38
40	Cultivated and Managed Vegetation/Agriculture	27.2
126	Open Forest, Other	7.14
122	Open Forest, Evergreen Broad Leaf	1.65
30	Herbaceous Vegetation	1.07
90	Herbaceous Wetland	0.86
80	Permanent Water Bodies	0.65
116	Closed Forest, Other	0.6
20	Shrubs	0.36
50	Urban/Built Up	0.08

Figure 1. Copernicus Global Land Cover Layers Discrete Classification (2019)

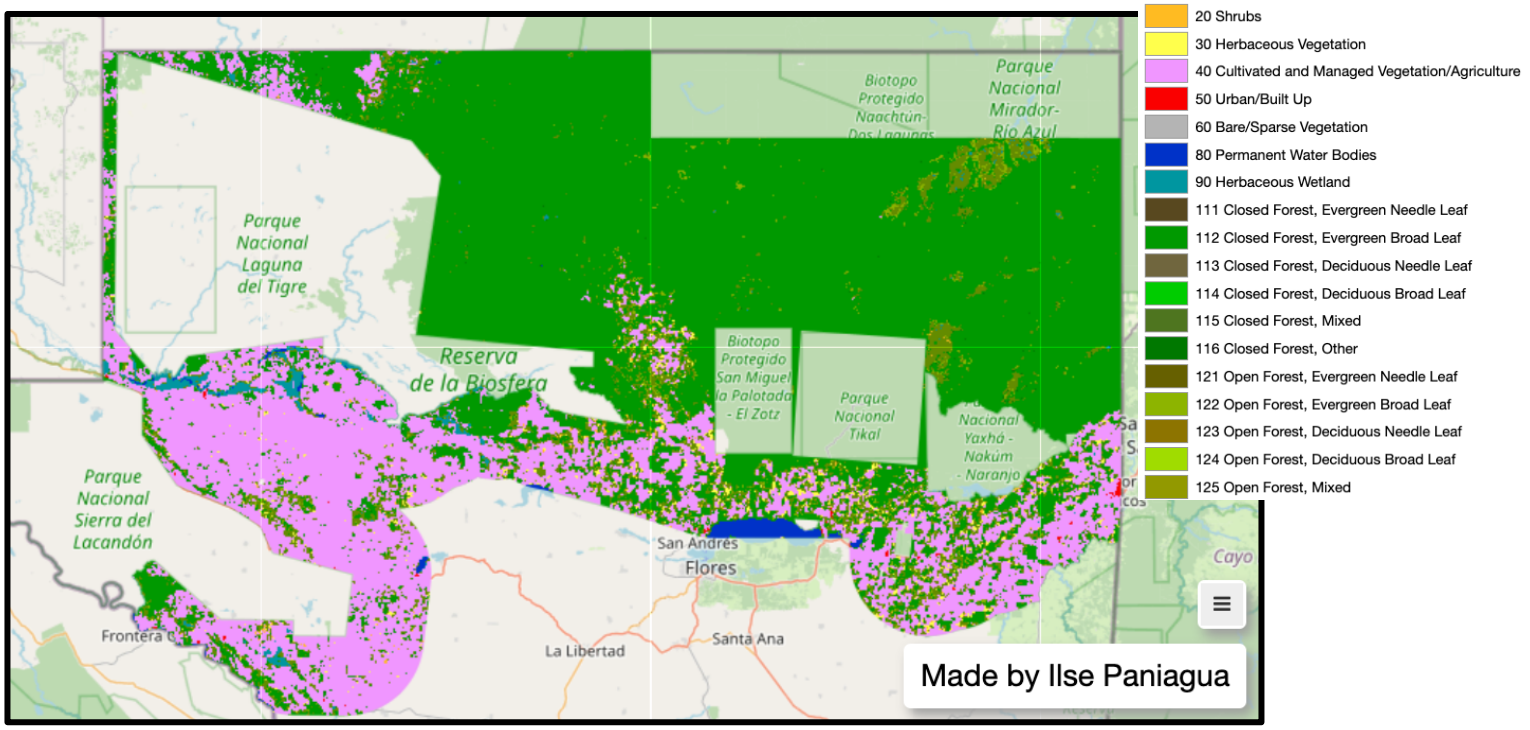
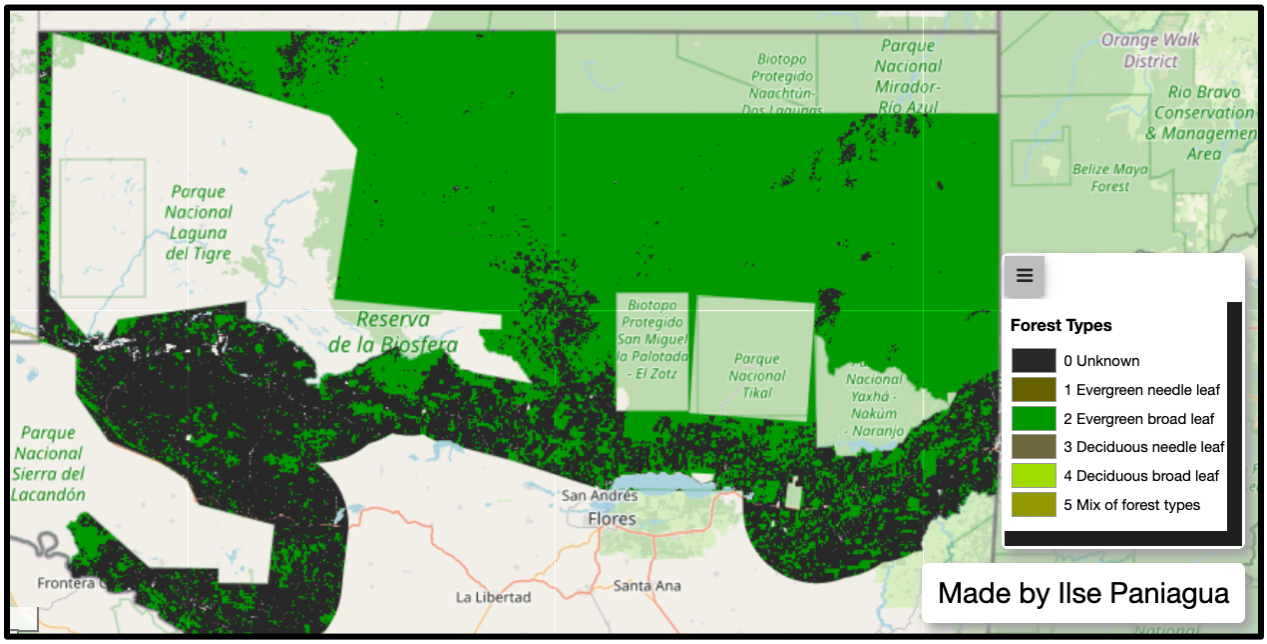
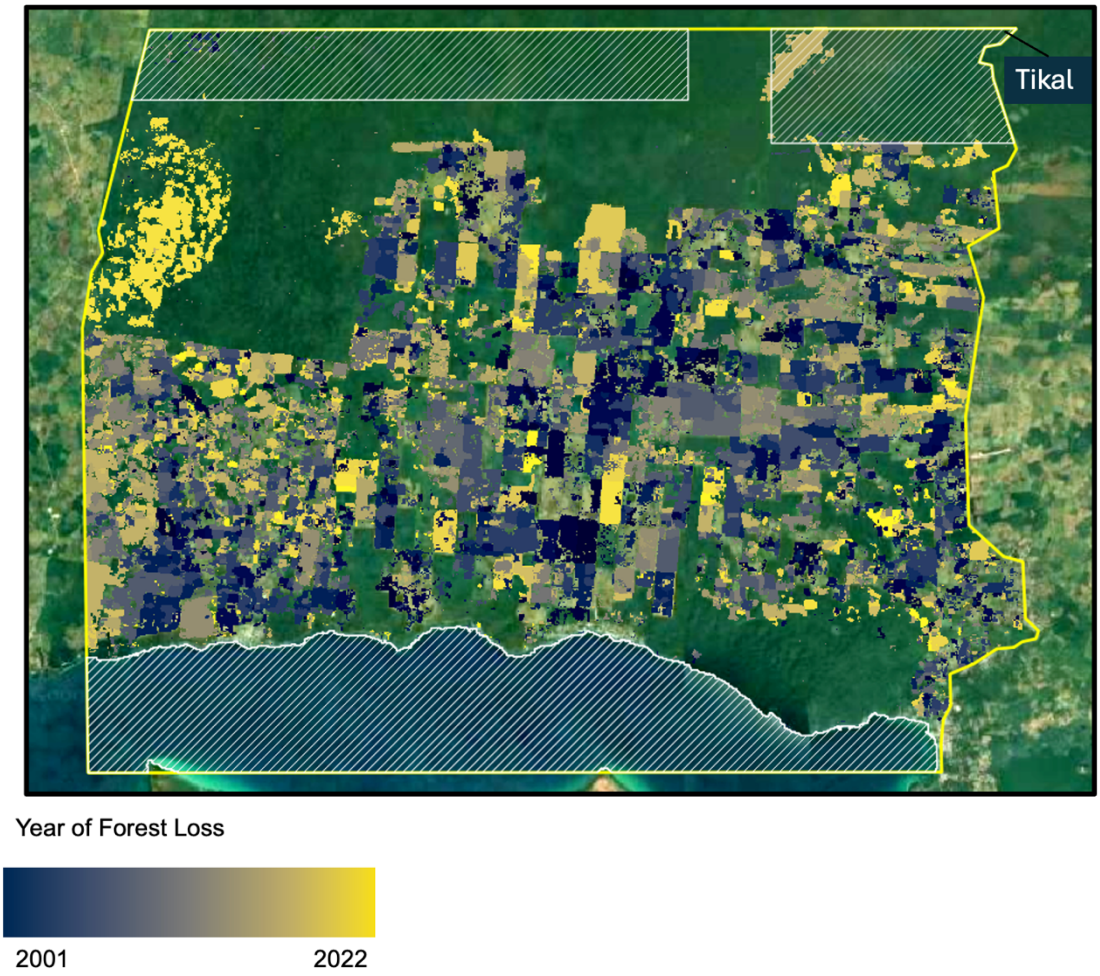


Figure 2. Copernicus Global Land Cover Layers Forest Type (2019)



Cultivated and managed agriculture is concentrated in the southern portions of the MBR, aligning with the buffer zone concession area. The cleared sections of the Lake Petén are dominated by small-holder farmer plots. Most of these plots were cleared for agricultural use in the 2010s (Hansen et al, 2013).

Figure 2: Deforestation in Lake Petén region of Maya Biosphere Reserve, 2001-2022



3. Does the forest in your AOI have what you believe to be spectrally and ecologically distinct sub-types? If so, what are they? And what spectral and / or ecological characteristics allow differentiation?

Forest Strata

Distinct LULC types and forest strata can be identified by Copernicus Global Land Cover Layers, meaning that sections of the MBR are spectrally distinguishable by satellite imagery. Desktop documents also distinguish between ecological sub-types within the

MBR. The literature distinguishes between the upper forest region; the low forest region; and wetlands that can be found inside of MBR.

Landscape-level ecosystems include forests, valleys, grasslands, and wetlands.
The hills and valleys in the northern forest areas host dense forests with the species Ceiba (Ceiba pentandra), Mahogany (Swietenia macrophyla), Ramón (Brosimum alicastrum), Chicozapote (Manilkara zapota). Less frequent species include Allspice (Pimenta dioica), Chacah (Bursera simaruba), Cedrillo (Guarea sp.) and Manchiche (Lonchocarpus castilloi)(USAID, 2005, Protected Planet, 2024).

Grasslands include species like Escobo (Cryosophila argentea), Tinto (Haematoxylum campechianum), Chechen Negro (Metopium brownei), Guarumo (Cecropia peltata), Cericote (Cordia dodecandra), Pucté (Bucida buceras), Roble (Cordia diversifolia), Cedro (Cedrela mexicana) and Nance (Byrsonima crassifolia)(USAID, 2005, Protected Planet, 2024).

Wetlands in the Mayan Bisophere include the plant species Indian plume (Aphelandra scabra), Annona (Annona glabra), Bayal (Desmoncus spp.), Huano (Sabal morrisiana), Zapote bobo (Pachira aquatica) and Navajuela (Cladium jamaicense), among others (USAID, 2005, Protected Planet, 2024).

Some populations of native fauna in the area include jaguars, pumas, ocelots, anteaters, macaws, spider monkeys, among others (Ruano et al., 2010).

4. How accessible is information representing LULC for your area of interest? What about data relating to socio-cultural and socio-economic attributes, governance, and land-use rights? And biodiversity?

Data Sources and Data Accessibility

Governance and Land Use Rights

The owners of multi-use zone concessions are in the public domain, including the areas and materials each user is permitted to harvest (Cortave). Monterroso (2006) details several land use arrangements within MBR, including a system to return land to those immigrating back to their ancestral communities (“retornados”), land managed by indigenous cooperatives, and informal appropriation mechanisms for agricultural use (“agarradas”). The governance and land-use rights of the MBR, specifically areas in the Lake Petén region, are critical knowledge for afforestation, reforestation, and revegetation projects that wish to operate in this area.

Socio-cultural and Socio-Economic Attributes

Several research papers shed light on the socio-cultural and socio-economic attributes of the population surrounding the MBR and populations around Lake Petén, including the city of Flores and El Remate (Monterroso, 2006, Carroso et al., 2000). In addition to being a biodiversity hotspot, the MBR has the highest concentration of archeological ruins in the country (Mayan Biological Reserve, 2020). The area was a Mayan stronghold between 200 and 900 AD and boasts of over 188 Mayan ruins in the surrounding area (Carrera et al., 2000, Maya Biosphere Reserve, 2020). Over 40 linguistic and indigenous cultures make up the area surrounding the MBR (Monterroso, 2006).

Until the 1960s, the area around Lake Petén was sparsely populated. The 1970s and 1980s saw a marked increase in internal migration by landless peasants seeking agricultural land (Carroso et al., 2000). This population increase can be correlated with forest loss observed using satellite imagery (Hansen et al., 2013).

Today, around 60% of residents in the area live below the poverty line and the illiteracy rate stands at 25% (Maya Biosphere Reserve, 2020). The region is a hotspot for internal migration due to its proximity to the Mexican border (Monterroso, 2006). Ecotourism focused on the MBR is offered by several providers to offer wildlife tours to visitors (Protected Planet, 2024). In 2002, around 300,000 visitors were registered in 16 archeological sites in the area (Maya Biosphere Reserve, 2020).

Biodiversity

As a hub of flora and fauna, the biodiversity of the MBR is well-studied in the literature. According to government sources, over 2,800 plant species 513 bird species, 122 mammal species, 95 reptile species, 60 fish species, and 62 amphibian species can be found in the reserve (Maya Biosphere Reserve, 2020). Specific research studies include a monitoring of jaguar populations and macaw nesting sites (Ruano et al., 2010, Anieu et al., 2006).

5. Who are the primary stakeholders associated with the forests in your AOI?

Project Stakeholders

Primary stakeholders associated with the MBR include users of the multiple-use zone; community and indigenous-based organizations; and indigenous and non-indigenous users of cleared farmland (Monterroso, 2006, Carroso et al., 2000, Mollinedo et al., 2001).

1. Community-based organizations (users of the multiple-use zone)
    a. Local communities have concession rights in the multi-use zone. These rights are documented by the federal government and have a term of 25 years

2. Private companies (users of the multiple-use zone)(Carroso et al., 2000, Mollinedo et al., 2001).
    a. Like community-based organizations, two (2) private companies also have rights to log and harvest products within the multi-use zone of the MBR. However, the interests of private companies may not align with those of local communities in areas of sustainability and expansion of buffer zones. They are therefore treated as separate stakeholders for this analysis)(Carroso et al., 2000).
3. Association of Forest Communities of Petén, itself composed of 24 community and indigenous organizations (ACOFOP)
    a. This association has been managing forest resources in Petén for over 20 years. They manage over half a million hectares of forests located in the multiple-use zone of the MBR. These users are advocates for the responsible use of the MBR and carry out trainings related to fire prevention (Cortave).
4. Indigenous farmers practicing agriculture in government-owned land
    a. In the border of Lake Petén and the MBR, indigenous groups have low-impact farms in land owned by the federal government. These individuals live outside of the multi-zone area and pay taxes to the government for the use of this land.
5. Non-indigenous migrants
    a. The area bordering National Parks has been known to host non-indigenous migrants that illegally occupy land without formal rights or tenure. In this system of “agarradas”, land is cleared and burnt for agricultural use.

6. How would you describe the biodiversity associated with the forests in your AOI?

Adjacent to the Mayan Biosphere, Lake Petén is considered a High Conservation Value (HCV) ecosystem. It includes high levels of species diversity, viable populations of naturally occurring species (landscape-level ecosystems and mosaics), and rare and threatened ecosystems (Maya Biosphere Reserve, 2020). .

7. Does carbon stock data exist specifically for the forests in your AOI (i.e., based on the results of a relevant forest inventory)? If yes, did this inventory include forest stratification? Which inventory methodology was used? And which carbon pools were assessed? What about non-forest carbon stock values (e.g., deforested areas)?

Previous Aboveground Biomass Estimates

A study within the multi-use zone of the MBR estimated an aboveground biomass (AGB) value of 209.64 t/ha using a combination of destructive sampling and allometric equations (Arreaga, 2002). The following species were observed: *Terminalia Amazonia, Swietennia*

marcophylla, Cedrela odorata, Lysiloma spp., Lonchocarpus castilloi, Vochysia hondurensis, and Calophyllum barasilense.

Sampling was stratified by two concession areas within the multi-use zone which were said to be representative of the multi-use zone (Uaxactun and Rio Chanchich). The methodology by Segura and Kannien (2001) was used for field sampling, while methodologies by Nelson and Sommer (1975) and Eduarte and Segura (199) were used for carbon estimation from destructive sampling. No samples were taken from deforested areas or soil in the study area.

At the time of the study, the *Swietennia marcophylla* species was the only tree with commercial value. This analysis did not show variability among species and management units (Arreaga, 2002).

8. Are there allometric equations that were developed based on the forests in your AOI? If yes, who developed them? If not, what are the closest/most appropriate allometric equations for you AOI? (find a regional, national, or international source)

Allometric Equations

Arreaga (2002) developed allometric equations for tree species found within the multi-use zone of the MBR using destructive sampling.

No species-specific allometric models were found for the following species in the R `allometric` package: *Swietennia marcophylla* (Mahogany), *Cedrela odorata* (Spanish cedar), *Vochysia hondurensis,* and *Calophyllum barasilense* within the R `allometric` package. However, a meta-analysis conducted by the UN-REDD Programme (2015) notes models that may not have yet been programmed into the `allometric` package (see: https://github.com/ilsep93/forest-carbon-management/blob/main/notebooks/allometric_equations.Rmd).

9. Is there growth and yield data available that's applicable to the forests in your AOI? If yes, what is the source?

Growth and Yield Data

Growth and yield estimates are available for *Swietennia marcophylla* (Azevedo and Marenco, 2012); *Cedrela odorata* (Glogiewicz et al., 1998); and *Calophyllum barasilense* (Rosa et al., 2017).

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