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, 2020; USAID, 2005). 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 contracts being renewed on an ongoing basis by the federal government. Around 36% of the MBR's area is a protected zone that prohibits human settlement, logging, or extraction. 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

2. Which of the suggested tools and platforms are the most relevant to your likely applications? And why?

Data/Product Availability

For this analysis, I explored the use of multiple Earth observation products that would meet definitions by the Intergovernmental Panel on Climate Change (IPCC) and have sufficient data availability for a change over time analysis.

IPCC has the following Land Use / Land Cover (LULC) definitions (IPCC 2006):

- Forest land
- Cropland
- Grassland
- Wetlands
- Settlements
- Other land

To select a LULC product, the following considerations were used:

- Data availability going back at least 20 years

- Data availability on a yearly basis
- Land use categories that are as close to the IPCC definitions as possible, with the possibility of collapsing more granular categories into more general groupings

The following products were explored for this analysis:

- The European Space Agency (ESA) WorldCover product had categories that were closest to the IPCC definition, but are only available for the years 2020 and 2021
- GlobCover: Global Land Cover Map provides granular categories that could be aggregated to IPCC definitions. However, data is only available for the years 2009 and 2010
- Copernicus Global Land Cover Layers are available from 2015-2019 and have more granular categories than IPCC. These categories have been externally mapped to IPCC for conversion.
- Dynamic World V1 has data from 2015-2024 with categories that align with IPCC
- The European Space Agency Climate Change Initiative Land Cover product (ESA-CCI LC) has LULC categories that align with the IPCC. Data is also available from 1992-2022. However, this author is unable to find these processed images readily available on Google Earth Engine.

As a Data Scientist, I am most interested in code-based tools that would allow me to automate the generation of reports and analyses beyond what is offered by GUI tools. The Google Earth Engine (GEE) Python API is most relevant to me, since it allows me to link GEE analyses with other workflows.

The Open Floris Earth Map was also a fantastic resource to identify and visualize images quickly without having to explore the Earth Engine Catalog and plot them using the `geemap` Python library. Open Floris Earth Map also included some products that I did not find readily available in the Earth Engine Catalogue, including the European Space Agency-Climate Change Initiative Land Cover (ESA-CCI LC) products. GEE hosts the European Space Agency's Global Product for the years 2020 and 2021 but does not yet offer the processed 1992-2022 images. However, the ESA-CCI LC product is available Open Floris Earth Map globally on a yearly basis.

This analysis uses data from Open Floris Earth Map to calculate land use change between the period of 1992 and 2022. Earth Map also allow users to upload their own boundaries to conduct analyses such as zonal statistics within polygons.

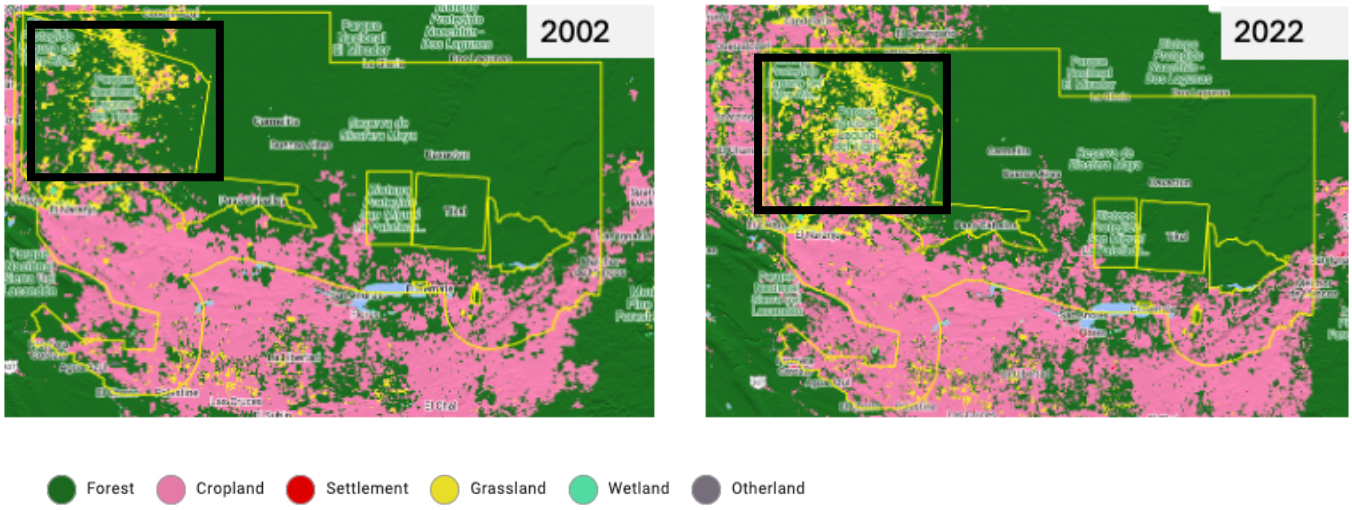
3. Using your own tools or tools described in the class - can you assess how forests in your AOI changed over the last 20 years? Has there been a net gain or loss in forests? Can you determine what is responsible for this change? (Hint: Two tools that allow for AOI level analysis without coding are Global Forest Watch and Open Foris Earth Map).

Forest Change (Gains/Losses)

In the past 20 years (2002-2022), the primary LULC category is the transition from forest to cropland and grassland. The transition to grassland can be observed particularly in the Parque Nacional Laguna del Tigre in the northwest of the MBR. This area is part of a National Park where logging, settlements, and human disturbances are prohibited.

The transition from forest to cropland can be seen in the MBR's southern buffer zone, which allow the sale of land by federal authorities to individuals for the purpose of sustainable farming. Because the MBR is located at the border of Guatemala and Mexico, it receives migrant populations that have been known to burn land and illegally use forest resources (Carroso et al., 2000).

Figure X. IPCC Land Use Classification (2002-2022) (Source: Open Floris EarthMap)



4. Based on IPCC land use land cover (LULC) categories, which specific IPCC categorical transitions do you think are occurring in relation to the forests in your AOI? (Hint: For a quantitative analysis, check out Open Foris Earth Map has an IPCC focused change analysis "IPCC categories based on ESA CCI 1992/2020")

LULC Transitions

Since 2002, cropland has expanded by over 55 thousand hectares and grassland has expanded by about 5,500 hectares. Both transitions were achieved at the expense of the forest class, which decreased by about 61 thousand hectares from 2002 to 2022. Overall,

the settlement class had the largest percentage point increase, rising from 33 hectares to over 230 hectares, a 615 percent increase. The percentage point decrease in the forest class is 6.84 percent, while grassland grew by about 25% and cropland by about 16%.

Table 1. Summary of LULC category changes (2002-2022) (Source: Open Floris Earth Map)

	Total area 2002 (ha)	Total area 2022 (ha)	Change in area (ha)	Change in area (%)
Forest	898,721	837,215	-61,506	**-6.84%**
Grassland	21,598	27,174	+5,576	**+25.82%**
Cropland	340,516	395,797	+55,281	**+16.23%**
Wetland	216	333	+117	**+54.17%**
Settlement	33	236	+203	**+615.15%**
Otherland	354	549	+195	**+55.08%**
Water Bodies/No Data	9,627	9,761	+134	**+1.39%**

5. What do you imagine the impacts of this historical change (over the last 20 years) have been on human and wildlife populations?

LULC Change on Human and Wildlife Populations

Over the past 20 years, the MBR has been a refuge for wildlife populations in an area that might otherwise have increased forest degradation and deforestation. While forest decreased by about 6% since 2002, the loss of about 61,000 hectares is damaging to the area's biodiversity and conservation efforts. Biodiversity estimates from 2019 support the idea of the MBR continued importance for wildlife. The average biome vulnerability score for the area, ranging from 0 to 1, with 1 being high vulnerability, is 35.15 (World Bank Terrestrial Biodiversity Indicators).

At the same time, the MBR has affected human populations by providing guardrails against forest degradation and deforestation. This was achieved through the legal management of community resources through government concessions, as well as the establishment of multi-use and buffer zones that lay out land tenure rights in the MBR. Indigenous communities are permitted to practice silviculture and agroforestry in the multi-use zone,

while non-indigenous populations have access to land in the buffer zone of the MBR. While recent surveys show that poverty and illiteracy remain high (60% and 25%, respectively), there is limited evidence that the MBR has harmed the interests of the local population since its establishment in the 1990s (Monterroso, 2006).

6. How and why do people use the forests in your AOI?

Population Forest Use

Forest use is dictated by government concessions granted to communities, private companies, and individuals for a period of 25 years. The use of forest resources is further managed within the forest. The multi-use zone allows community-based organizations and two private companies the right to harvest and log wood within the multi-use zone. Indigenous farmers have been granted access to cropland in the buffer zone by Lake Petén, where they pay taxes to the government for the use of this land. Finally, non-indigenous migrants to the area have been known to travel to the MBR on their way to Mexico and the United States. These populations do not pay taxes and are not legally allowed to clear and burn land for agricultural use (Monterroso, 2006).

7. Have carbon emissions reductions and / or removals already been modelled for the forests in your AOI? If yes: how? If no: how would you approach the situation?

Emissions Reductions / Removals

Emissions reductions have been modeled through an estimation of the carbon stored in the MBR. Santoro and Cartus (2023) provide a global estimate of aboveground biomass (AGB) from a combination of Earth observation data, depending on the year, obtained from the Copernicus Sentinel-1 mission, Envisat's ASAR instrument, and JAXA's Advanced Land Observing Satellite (ALOS-1 and ALOS-2). Using the Earth Map analysis tool, I calculated zonal statistics of AGB in the MBR. ABG remained stable from 2010-2020, fluctuating by an estimated 2.6% between this time period.

Table 2. Estimates of Above Ground Biomass in MBR (Source: Santoro and Cartus, 2023)

Year	Mg/ha
2010	78,452,273
2017	74,974,959
2018	74,894,871
2019	76,347,800
2020	76,455,049

Several projects have been established in the MBR in the areas of improved forest management and avoided forest conversion. The Guatecarbon Project was established in 2012 in most of the multi-use zone within the MBR (about 721,000 ha). The project aims to capture over 55.7 million tons of carbon dioxide equivalents in the fight against climate change (CONAP, 2012; Guatecarbon, 2017).

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