Comparative Impact Analysis of Cyclone Ana in the Mozambique Channel using Satellite Data – Project Plan

1. Background

Tropical cyclones are some of the most devastating natural disasters with far reaching consequences such as human displacement, economic loss, and environmental damage and changes (Charrua et al., 2021; Ouyang et al., 2022). Tropical cyclones are defined as low pressure systems with organized deep convection that form over warm tropical waters along maximum sustained surface winds ranging from 39-73 mph (NOAA, 2015). As such, the Southwestern Indian Ocean is one of the main tropical cyclone areas in the world and the most active one in the Southern Hemisphere (Charrua et al., 2021).

In the Mozambique Channel, 3 to 12 cyclones form every year. Cyclone season in Madagascar typically occurs between November and March with an average of 1.5 cyclones yearly, the highest number on the African continent, (ACAPS, 2022; OCHA, 2021). In Mozambique, on the other hand, cyclone season spans November to April and is estimated to be hit by 1.16 cyclones every year on average (Matyas, 2014). Since mid-March 2022, it has been estimated that around 960,000 people have been affected by the 5 extreme tropical weather events that occurred in the Mozambique Channel and left displaced people in need of health, water, housing, and alternative livelihoods.

Madagascar harbours a high level of biodiversity and a species endemism of more than 80% (Giri et al., 2008). Described as one of the 'hottest hotspots' (Myers et al., 2000) due to the island's alarming rate of habitat loss and high numbers of endemic species, monitoring forest cover degradation, such as resilience-enhancing mangroves, in the face of tropical cyclones is also of utmost importance. In Mozambique particularly, mangroves occur almost along the entire coast and act as a crucial first barrier for local populations against damaging tropical storms as well as sea level rise (Barbosa et al., 2001). Many studies have investigated the impacts of tropical cyclones on natural habitats such as in the USA (Ouyang et al., 2022) or India and Bangladesh (Bhowmik and Cabral., 2013) through satellite data but very few have offered insights into tropical cyclone impacts in the Mozambique Channel.

Moreover, it is important to offer an integrative approach to cyclone impact analysis whereby population health and infrastructure is analysed within the environmental system. As such, key consequences of tropical cyclones include landslides and flooding, which can cause damages to infrastructure such as health practices. In addition, heavy rainfall, flooding and favourable temperatures can promote the appearance of breeding grounds for mosquitoes that transmit malaria and other vector borne disease (Harp et la., 2021). In the Mozambique Channel, the majority of malaria cases occur through the medium of the group *Anopheles gambiae*, *Anopheles funestus* in Mozambique (de Sousa Pinto et al., 2021) and *A. gambiae*, *A.funestus, A. mascarensis* and *A arabiensis* in Madagascar respectively (Nepomichene et al., 2015).

Both Madagascar and Mozambique are amongst the 15 countries that account for 80% of malaria deaths around the world (UNICEF, 2019). In coastal areas in Madagascar and Mozambique particularly, there is a high endemicity of cases. In Madagascar in 2018 for example, there was an estimated 2.16 million cases leading to more than 5000 deaths (Arambepola et al., 2020). Moreover, after the damaging category 3 cyclone Idai that hit Mozambique and Malawi in March 2019, more than 14,800 cases of malaria were reported in the Sofala Province alone, located in coastal central Mozambique (UNICEF, 2019). As such, monitoring malaria prevalence after tropical cyclones constitutes an important avenue to increase adaptive humanitarian response but also malaria prevention strategies and ecological conservation strategies.

In a context of high dependence on agriculture for economic livelihood, frequent tropical cyclones and high deforestation rates in Madagascar and the Mozambique Channel (Paternostro et al., 2003; Razafindrakoto et al., 2015), monitoring the impact of tropical cyclones and their anthropogenic and climatic amplifiers is primordial. A comparative impact analysis across the Mozambique Channel, in vulnerable coastal regions in eastern Mozambique and Western Madagascar, will also have the potential to improve adaptive local management and humanitarian practices when faced with climatic uncertainties all the while offering a well-rounded data-driven approach to tropical cyclones.

2. Objectives

This study aims to act as a pilot for further integrative impact analysis assessment in the Mozambique Channel. As such it will focus on cyclone Ana which occurred in January 2022 between the genesis on the 20th January until 25th January over Madagascar, Mozambique and Malawi. As this study aims to be comparative and contrast affected regions in Mozambique and Madagascar only, it attempts to fine tune parameters and socio-climatic impacts related to cyclones in the region.

The main questions to be answered by this study will be the following:

- Are there differences in the climatic and anthropogenic impacts after tropical cyclones in coastal Mozambique and Madagascar?
- Specifically, were mangrove forests degraded after the tropical cyclone? Were there regional differences in the degradation extent and pattern? For example, do areas in the vicinity of the mangrove hit by the tropical cyclone fare better than non-mangrove areas?
- Did the covariates of malaria get amplified, and/or do they exhibit regional trends?

3. Methodology

In this study, open-access databases will be leveraged. This will include the 2020 CGLOPS Copernicus land cover classification published by ESA, which has a 10m resolution with classes such as urban areas, mangrove forests and dry forests. The ESA classification used Sentinel data, both synthetic aperture radar (SAR) and optical data, derived from Sentinel 1 and Sentinel 2 data. SAR has been shown to improve accuracy, particularly as it has cloud-penetrating functionalities, useful in cyclonic conditions, and can better discriminate between surface water cover and aquaculture structures as well as the complexity of mangrove rooting systems (Lucas et al., 2007).

The flooding model will use Sentinel-1 SAR data and use the SRTM mission's digital elevation model for terrain correction and masking of zones of interests.

In the case of sociological data, in order to address the impact of the tropical cyclone on populations, the World Population Hub population density dataset will be used from the latest update in 2020.

To assess the potential health impacts related to cyclones, malaria cases will be investigated following the occurrence of the tropical cyclone from local health surveys. This will be explored along environmental covariates from previously used datasets such as rainfall, population density, surface temperature, health infrastructure damage and distance to water bodies. All these covariates have the potential to increase the likelihood of disease spread as well as promote the breeding of female mosquito of the aforementioned *Anopheles* species in the Mozambique Channel.

A summary of all the datasets used for the purpose of the study can be found in table 1.

Table 1. IRP Dataset overview, sources, resolution and temporal coverage

Data Type	Data Name	Source	Resolution	Dataset Temporal Coverage
Land Cover Classification	CGLOPS Land Cover Classification	Copernicus - ESA- VITO	10m	Static - 2020
Daily Rainfall Data	CHIRPS	UCSB	0.05 degrees	1981-2022
Malaria Prevalence Model (covariates)	CHIRPS	UCSB	0.05 degrees	1981-2022
	CGLOPS for urban areas	VITO/ESA	10m	2020
	Distance to Water bodies (CGLOPS)	VITO/ESA	10m	2020
	Surface Temperature – MODIS Aqua LST	NASA	1 km	Daily, 2002 -2022
	NDVI – Sentinel 2	ESA	~15m	2013-2022
	World Population Density	World Pop Hub	1 km	Static – 2020
NDVI	Sentinel 2	ESA	15m	2013-2022
Flooding Model	Sentinel 1 SAR	ESA	5 x 20m	2017-2022
	NDWI – Sentinel 2	ESA	~15m	2013-2022
	SRTM DEM – void filled (2015)	NASA	30m	Static – 2015
	CGLOPS			Static - 2020

4. Project Schedule

Progress on the IRP so far can be seen in the project schedule and tracker in figure 1. As part of the month of June, phase 1 was finalised which included project planning and data exploration. This was done by setting up the backing-up of data and data storage, setting up the Github repository, but also engaging in a literature review, choosing and discussing the appropriate datasets and writing up the project plan. Initial directions were set for the use of multiple tropical cyclones in the Mozambique Channel; however, it was found that too few cyclones impacted both Mozambique and Madagascar at the same strength and in ecologically comparable regions. The project was therefore amended to focus on a single tropical cyclone event in the Mozambique Channel.

As of the submission of this project plan, the duration of the IRP is of 8 weeks. Figure 1 will be updated throughout the entire IRP process in order to track the progress of the different steps to be taken and continuously reassess those that need more work than others. A consequent amount of time is dedicated to modelling and data processing with an additional emphasis on code sustainability in the process.

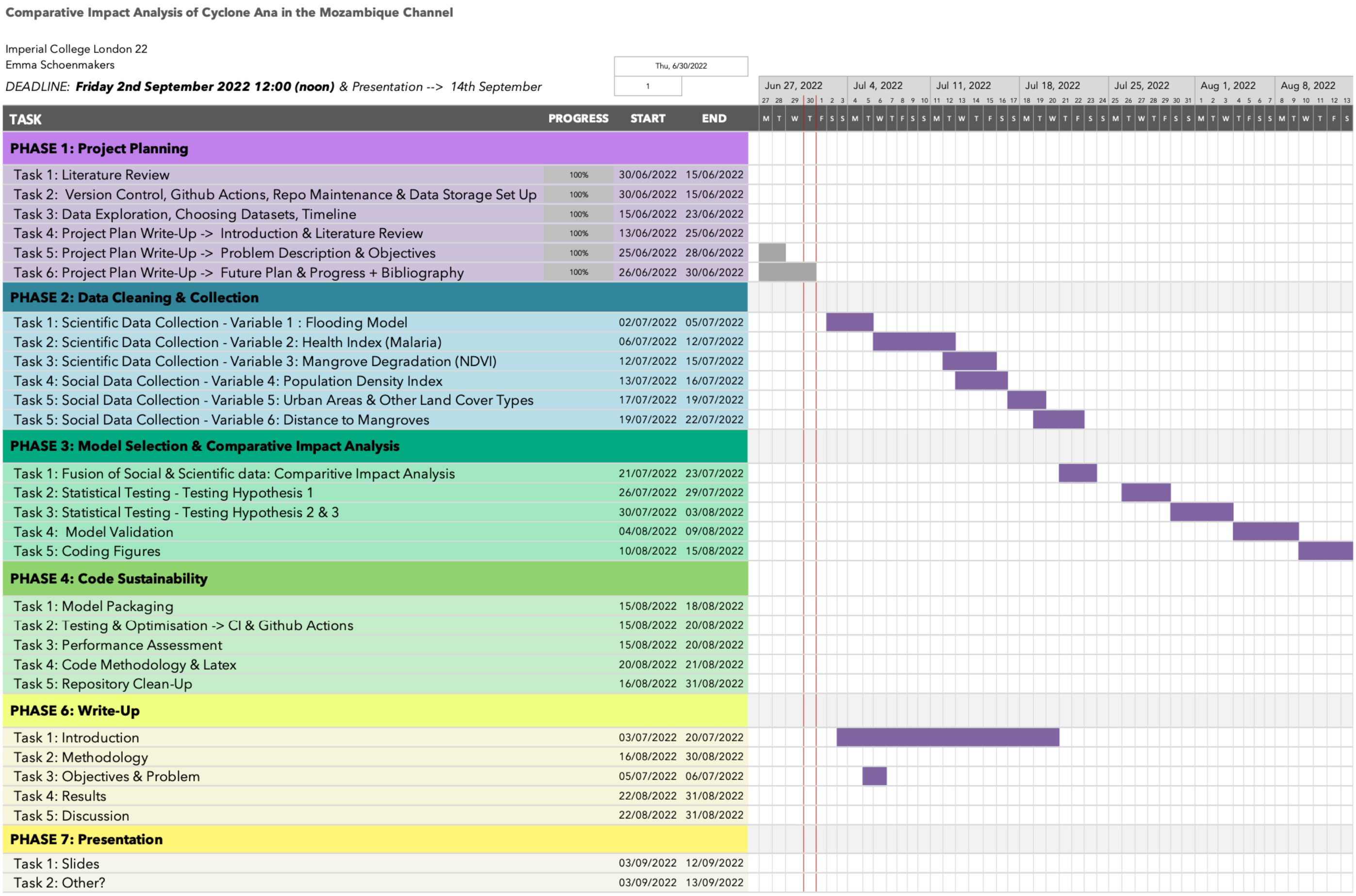

Figure 1. Gantt Chart of the Project Phases & Progress Tracker

5. References

ACAPS. 2022. *Madagascar Tropical Cyclones Season in 2022 | ACAPS*. [online] Available at: <https://www.acaps.org/country/madagascar/crisis/tropical-cyclones-season-in-2022> [Accessed 30 June 2022].

Arambepola, R., Keddie, S., Collins, E., Twohig, K., Amratia, P., Bertozzi-Villa, A., Chestnutt, E., Harris, J., Millar, J., Rozier, J., Rumisha, S., Symons, T., Vargas-Ruiz, C., Andriamananjara, M., Rabeherisoa, S., Ratsimbasoa, A., Howes, R., Weiss, D., Gething, P. and Cameron, E., 2020. Spatiotemporal mapping of malaria prevalence in Madagascar using routine surveillance and health survey data. *Scientific Reports*, 10(1).

Barbosa, F., Cuambe, C. and Bandeira, S., 2001. Status and distribution of mangroves in Mozambique. *South African Journal of Botany*, 67(3), pp.393-398.

Bhowmik, A. and Cabral, P., 2013. Cyclone Sidr Impacts on the Sundarbans Floristic Diversity. *Earth Science Research*, 2(2).

Charrua, A., Padmanaban, R., Cabral, P., Bandeira, S. and Romeiras, M., 2021. Impacts of the Tropical Cyclone Idai in Mozambique: A Multi-Temporal Landsat Satellite Imagery Analysis. *Remote Sensing*, 13(2), p.201.

de Sousa Pinto, L., Arroz, J., Martins, M., Hartz, Z., Negrao, N., Muchanga, V., Cossa, A. and Zulliger, R., 2021. Malaria prevention knowledge, attitudes, and practices in Zambezia Province, Mozambique. *Malaria Journal*, 20(1).

Giri, C. and Muhlhausen, J. (2008). Mangrove Forest Distributions and Dynamics in Madagascar (1975–2005). *Sensors*, 8 (4), pp.2104–2117.

Harp, R., Colborn, J., Candrinho, B., Colborn, K., Zhang, L. and Karnauskas, K., 2021. Interannual Climate Variability and Malaria in Mozambique. *GeoHealth*, 5(2).

Lucas, R., Mitchell, A., Rosenqvist, A., Proisy, C., Melius, A. and Ticehurst, C., 2007. The potential of L-band SAR for quantifying mangrove characteristics and change: case studies from the tropics. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 17(3), pp.245-264.

Matyas, C., 2014. Tropical cyclone formation and motion in the Mozambique Channel. *International Journal of Climatology*, 35(3), pp.375-390.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403 (6772), pp.853–858.

Nepomichene, T., Tata, E. and Boyer, S., 2015. Malaria case in Madagascar, probable implication of a new vector, Anopheles coustani. *Malaria Journal*, 14(1).

NOAA, 2015. *Tropical Definitions*. [online] weather.gov. Available at: <https://www.weather.gov/mob/tropical_definitions> [Accessed 20 June 2022].

Ouyang, Y., Grace, J., Parajuli, P. and Caldwell, P., 2022. Impacts of Multiple Hurricanes and Tropical Storms on Watershed Hydrological Processes in the Florida Panhandle. *Climate*, 10(3), p.42.

Paternostro, S., Razafindravonona, J. and Stifel, D. C. (2003). Changes in Poverty in Madagascar: 1993-1999. *SSRN Electronic Journal*.

Rakotomanana, H., Jenkins, R. K. B. and Ratsimbazafy, J. (2013). Conservation Challenges for Madagascar in the Next Decade. In: Raven, P. H., Sodhi, N. S. and Gibson, L. (Eds). *Conservation Biology*. Oxford, UK : John Wiley & Sons, Ltd. pp.33–39.

Razafindrakoto, M., Roubaud, F. and Wachsberger, J.-M. (2015). L'île mystérieuse : une approche d'économie politique de la trajectoire longue de Madagascar. *Canadian Journal of Development Studies / Revue canadienne d'études du développement*, 36 (3), pp.397–415.

UNICEF. 2022. *Nearly 15,000 cases of malaria reported in areas of Mozambique affected by Cyclone Idai – UNICEF*. [online] Available at: <https://www.unicef.org/press-releases/nearly-15000-cases-malaria-reported-areas-mozambique-affected-cyclone-idai-unicef> [Accessed 20 June 2022].

UNOCHA. 2021. *Madagascar*. [online] Available at: <https://www.unocha.org/southern-and-eastern-africa-rosea/madagascar> [Accessed 20 June 2022].