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Detecting changes in mangrove forests along the Bintang Bolong Estuary, Gambia using Google Earth Engine, Sentinel-2 imagery and Random Forest classification

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ABSTRACT

The changes in mangrove areal distribution can result in significant changes in the coastal ecosystem. In order to curb this, conservation efforts have been adopted especially in developing nations due to the ease of implementation of some of those initiatives. Despite their positive impacts, poor monitoring and evaluation of these initiatives have introduced gaps when it comes to accountability. This majorly results in project failures and economic losses. The Google Earth Engine cloud computing platform was utilized in the analysis of mangrove changes and land cover transitions. The resulting info-graphics illustrated the changes that occurred in the Bintang Bolong estuary in the years 2017 and 2020. This provides scientific evidence on the outcomes of the ongoing restoration projects thus further aiding sustainably driven mangrove restoration efforts.

1. Introduction

Mangrove ecosystems are an essential component of wetland biodiversity. They play a big role in the mitigation of climate change (Rahman, 2010) through carbon sequestration (Alongi, 2002, 2008; EL Gilman, 2008; Giri, 2011). Their diverse benefits are what make them the most vulnerable habitats (Kenduiywo et al., 2020). Conservation of these ecosystems is in line with the United Nations Sustainable Development Goal (SDG) 15 on life on earth (Mondal et al., 2019) through targets 15.1 and 15.2. Mangroves cover a vast stretch in the tropics with approximately 20% in Africa spread unevenly along the east and west coasts (Giri, 2011).

Mangrove forests on the east coast are relatively well-studied compared to those on the west coast (Giri, 2011). The coverage of mangroves in the Gambia is approximately 51,911 Km^2 (Bryan et al., 2020)and they grow farther inland at a stretch of approximately 100 km due to the intrusion of River Gambia (Corcoran et al., 2007; Njisuh Z. & Gordon N., 2011). Despite this vast occurrence of mangroves within the country, their distribution has received little or no attention in the existing literature. The country prior to 1980, had a total of about 68,000 ha of mangrove forest with the main area of die-back being along the Bintang Bolong area, extending into the Cassamance Region of Senegal (Dia Ibrahima, 2012). However, the trend of the loss is not linear. Several initiatives have been introduced by the Gambian government to address the loss of mangrove forests in the country. These intervention measures have not been well documented. Consequently, there is a limited understanding of biological and morphological changes brought about by these interventions. Often it leads to poor scientific input into ecological planning and goal setting. This leads to failures and economic losses in these well-intentioned projects.

This study utilizes multi-spectral and multi-temporal Sentinel-2 imageries to assess changes in mangrove forests, and the relationship with ongoing land cover transitions in the Bintang Bolong estuary in Gambia. The areal extent of the mangroves and other land cover classes were extracted using random forest classification within the Google Earth Engine (GEE) application. The observed changes were quantitatively and qualitatively analyzed and validated with a field survey. This study informs knowledge-based mangrove intervention and restoration efforts, and enables sound decision making.

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2. Methods

This section presents the materials and methods adopted for this study including the data acquisition, processing and analysis stages. Figure 1 shows the methodology workflow diagram.

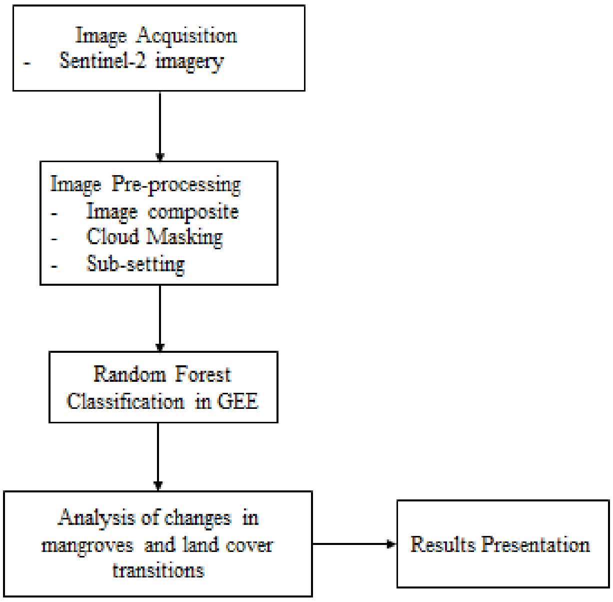

Figure 1. Methodology workflow diagram

2.1. Study area

The study area is the Bintang Bolong estuary in the Kiang West Lower River Region which is part of the Gambia River, centered approximately between latitude 13° and 14° N (Figure 2). It is bordered on the north, south and east by the Republic of Senegal and on the west by the Atlantic Ocean. The climate of Gambia is largely semi-arid with two distinct seasons –wet season (June to October) and dry season (December to May) (Gambia Department of Water Resources, 2018).

The country is host to some of the sub-regions tallest mangroves (+20m)The Bintang Bolong estuary has experienced more of the mangrove die-back with the level of degradation estimated at approximately 90% (Dia Ibrahima, 2012). The majority of the dieback is believed to have been caused by a severe drought in the 1970s, the Sahel drought, leading to deeper tidal penetration, and higher soil and water salinity and also its proximity to the Cassamance region in Senegal (Rivera-Monroy et al., 2017).

This situation has led to community involvement in the restoration and rehabilitation of mangroves especially in the Kiang West District along the estuary. Communities such as Sankandi, Keneba, Jiffarong, Bajana etc are very such involved in these efforts coupled with their strategic locations as shown in Figure 4.

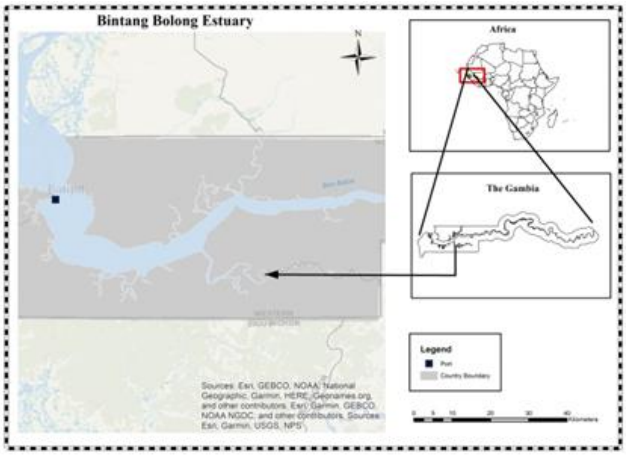

Figure 2. Map of the Bintang Bolong Estuary

2.2. Sentinel-2 imagery

The main datasets used for this study are Sentinel-2 multi-spectral imageries acquired at the following dry season periods- January 11 2017 and May 14 2020. Sentinel-2 is a Copernicus mission launched in 2015 comprising of twin (Sentinel 2A/B) polar-orbiting satellites with a high revisit time dependent on the latitude. Sentineel-2 contributes to the Copernicus themes: atmosphere, marine, land, climate, emergency and security. Several researchers have adopted Sentinel-2 imageries for mapping and monitoring of changes in mangroves (e.g., Cissell et al.,, 2021; Ghorbanian et al., 2021; Jamali, 2020; Tieng et al., 2019; Wu et al., 2020). The Sentinel-2 Multi-spectral Instrument (MSI) has 13 spectral bands with different spatial resolutions.

2.3 Image classification

The Random Forest (RF) classifier was used in the extraction of mangroves and other land cover classes within the Google Earth Engine (GEE) platform (See Figure 3). The Sentinel-2 imageries were imported into GEE and sub-set to the area of interest (AOI). Image composites were generated with spectral bands in the following order- band 4 (red), band 3 (green) and band 2 (blue). Interpretation of the composite revealed 4 main land cover classes- mangroves, water bodies, bare lands and mixed forests. Training data were created at selected points on the imageries to represent the land cover classes. The classification was executed with the RF classifier and the results were converted to GeoTIFF format for further analysis in ArcGIS.

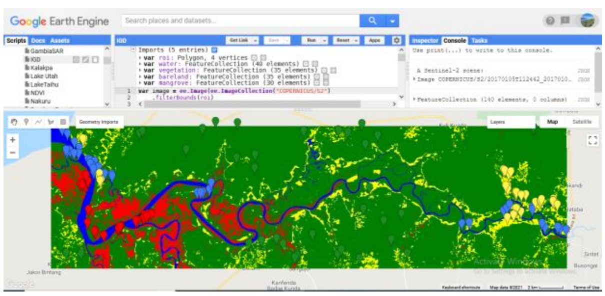

Figure 3. Image showing the 2017 classified image in the Google Earth Engine GUI. The points (Red, Blue,

Green and Yellow) are training data sampled for classification

3. Results

Figure 6 presents the land cover maps for 2017 and 2020. Results show an increase in mangroves, bare land and water body land cover at 38.6 Km^2 in 2017to 41.5 km^2 in 2020; 23.8 km^2 in 2017to 29.4 km^2 in 2020 and 36.8 km^2 in 2017to 79.0 km^2 in 2020 respectively. In the contrary, there was a dramatic decrease in in mixed vegetation at 410.7 Km^2 in 2017to 360.1 km^2 in 2020 as illustrated in Figure 7. A total of 0.3618 km^2 and 9.9783 km^2 of water bodies and bare lands land covers in 2017 were converted into mangroves land cover in 2020. These results are supported by field survey exercise carried out in Sankandi village during a tree planting exercise (Figures 4 and 5).

Figure 4. Mangroves in a rehabilitated bare land at Sankandi 2-Feb. Source: Field survey, 2021

Figure 5. Sections of bareland and planted mangrove trees at Sankandi 2-Feb. Source: Field survey, 2021

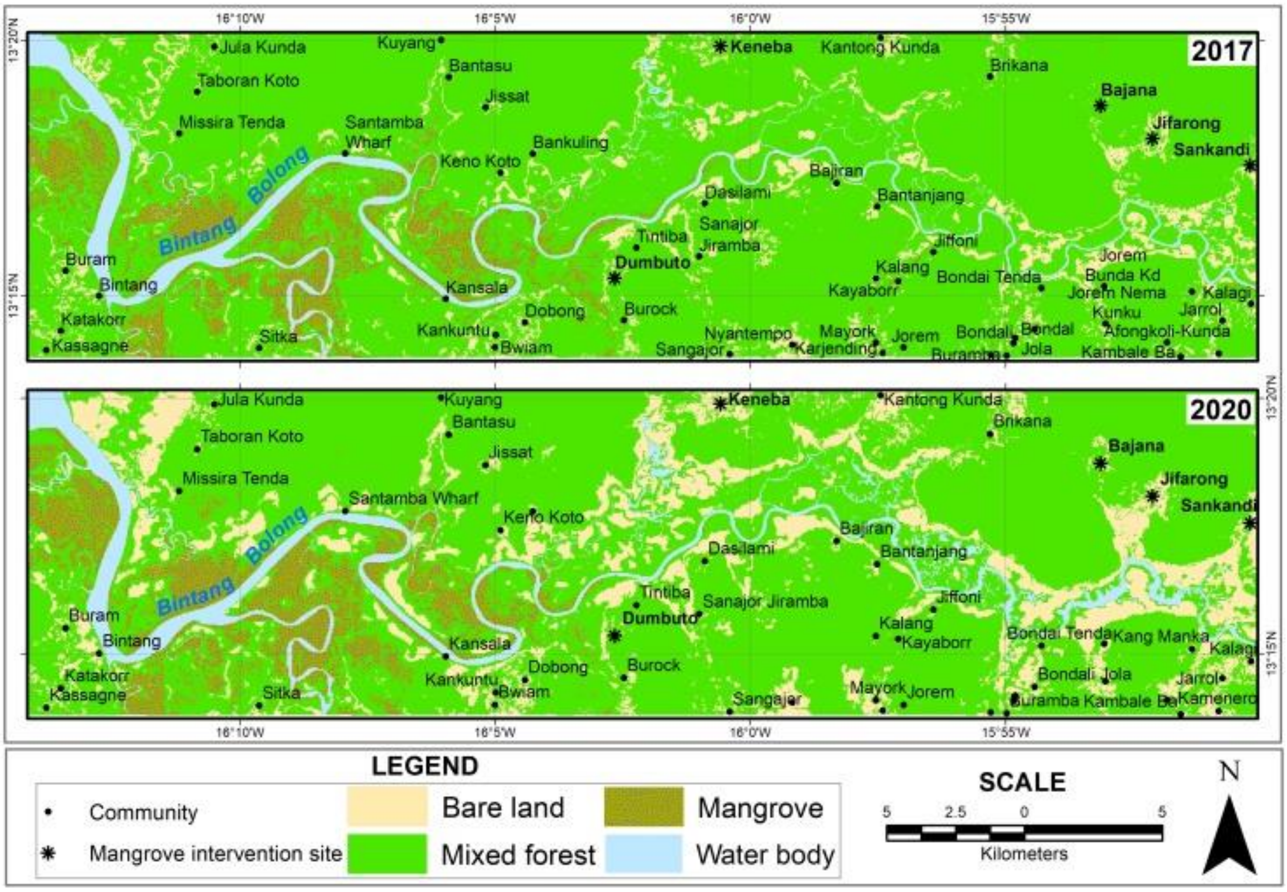

Figure 6. Land cover map of Bintang Bolong river

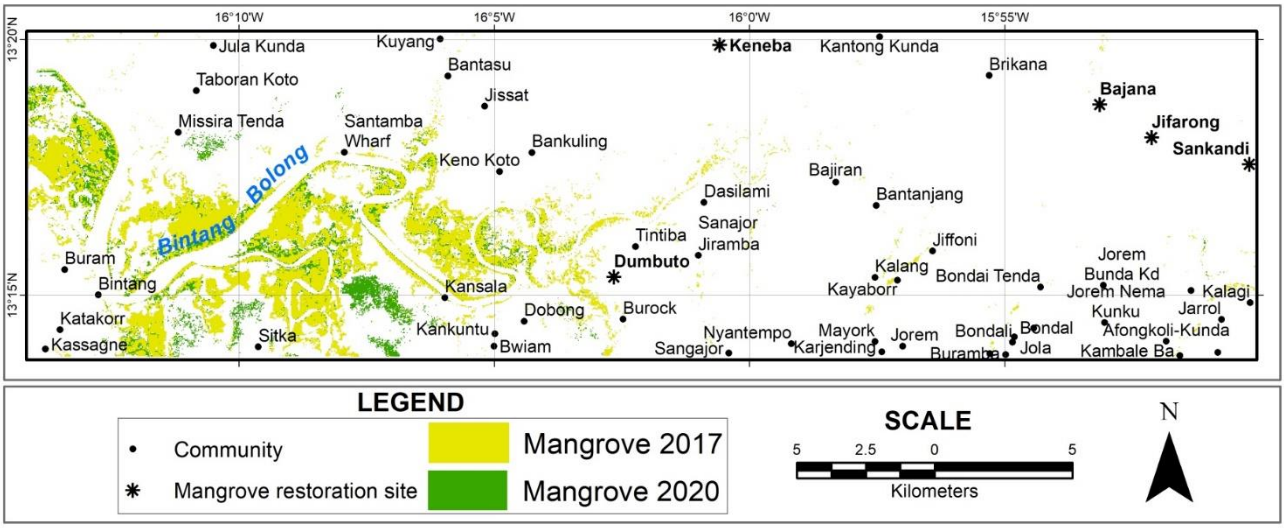

Figure 7. Overlay of the mangrove change at Bintang Bolong

Table 1. Land cover change statistics

Land Cover	2017 (Km²)	2017 (%)	2020 (Km²)	2020 (%)	Change (Km²)
Water bodies	23.8	4.7	29.4	5.8	5.5
Mangroves	38.6	7.6	41.5	8.1	2.9
Mixed forests	410.7	80.5	360.1	70.6	-50.6
Bare lands	36.8	7.2	79.0	15.5	42.2

4. Discussion

Despite the decline of mangroves globally, mangroves in Bintang Bolong estuary appear to have rapidly increased from 2017 to 2020. This could be attributed to the mangrove planting activities spearheaded by some communities within the Kiang West District. These findings align with those of (Elmahdy et al., 2020) who conducted a spatiotemporal mapping and monitoring of mangrove forest change in the United Arab Emirates. Consequently implying that mangrove loss trend in the Gambia is non-linear that keeps fluctuating for different years.

5. Conclusion

The study presented an approach in monitoring the effects that mangrove related interventions could bring to an area thus enabling accountability.

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