Mapping mangrove forest land cover change in Jaro Floodway, Iloilo City using Google Earth imagery

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Abstract

The construction of the Jaro Floodway was completed in 2011 to divert the floodwater from the Jaro River towards the Iloilo Strait. Its construction may pose a threat to the nearby mangrove forest due to its large-scale anthropogenic disturbance. This study aims to determine the effect of the floodway to the nearby mangrove forest in terms of its areal change. Google Earth imagery was downloaded for the years 2005, 2009, 2012, 2014, 2016, and 2018. The images were digitized in Quantum Geographic Information System (QGIS) and classified into four thematic classes, namely, mangrove, non-mangrove, fishpond, and water. Mangrove cover increased throughout the years measuring 8.98 (2005), 9.35 (2009), 11.39 (2012), 16.60 (2014), 26.82 (2016), and 42.98 ha (2018). The general increase in mangroves is attributed to a combination of factors such as sedimentation rate and mangrove planting efforts. Its construction led to the formation of a new delta which the mangroves currently thrive in.

Keywords: *mangrove colonization; sedimentation; remote sensing; mapping; satellite imagery*

Introduction. Mangroves in the Philippines have significantly decreased by 51% throughout the years, where it amounted to approximately 500, 000 hectares in 1918 and about 256, 000 hectares in 2010 [1,2,3,4]. Anthropogenic disturbances, illegal logging, urban development, agriculture, aquaculture, and natural disasters (e.g. storm surges, tsunamis, flooding) are the primary causes which have been attributed to the degradation of mangroves in the Philippines [4,5]. However, environmental factors such as wave action, duration and depth of tidal inundation, salinity, sediment accretion, and ground subsidence might have also influenced the colonization of the mangroves [2]. Studies such as those of Albano [2], Long et al. [3,4], Dan et al. [6], Fromard et al. [7], Heumann [8], and Nascimento et al. [9] have used remote sensing to measure the mangrove cover in the study area.

The construction of the Jaro Floodway was completed in 2011 with the goal to minimize the flooding in Iloilo City by diverting the floodwater from the Jaro River to the Iloilo Strait. It is 4.8 km long and 82 m wide and designed to protect the city against a 20-year flood return period [10]. However, its construction may pose a threat to the nearby mangrove forest due to its large-scale anthropogenic disturbance, which may lead to an overall change in ecological processes in the area such as water current movements, sedimentation, and salinity shifts. Possible causes that can be attributed to the change in mangrove cover will be determined by examining the large-scale environmental change as seen from the series of satellite images. Results of the study can contribute in providing insights on how mangroves adapt to environmental changes.

Types of remote sensing data may vary, each having a significant purpose to analyze an area from a distance. There are numerous ways that remote sensing technology has been applied in the different fields of sciences, which include: applications in land use/land cover mapping, geologic and soil mapping, agriculture, forestry, rangeland, water resources, snow and ice mapping, urban and regional planning, wetland mapping, wildlife ecology, archaeology, environmental assessment, disaster assessment, and landform identification and evaluation [11,12].

As stated by Kuenzer et al. [13], remote sensing (RS) has been widely proven to be essential in monitoring and mapping threatened mangrove ecosystems. Examples of remote sensing systems that have been utilized for mangrove forest studies include the use of aerial photography, or satellite images provided by Landsat, SPOT, MODIS, ASTER, etc. [8]. Landsat images were used by Long et al. [4] to estimate the mangrove cover for the entire Philippine archipelago during 1990, 2000 and 2010 to be approximately 269, 256, and 241 kilohectare, respectively.

This research determined the change in area covered by mangrove for the years 2005, 2009, 2012, 2014, 2016, and 2018 in Brgy. Bito-on, Jaro, Iloilo City before and after the construction of the Jaro Floodway using freely available high-resolution satellite images from Google Earth. It specifically aimed to:

(i) determine the area of the mangrove forest in the Jaro Floodway in Brgy. Bito-on, Jaro, Iloilo City using Quantum Geographic Information System (QGIS); and

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(ii) determine the rate of mangrove colonization in the Jaro Floodway in Brgy. Bito-on, Jaro, Iloilo City by adapting the formula used by Albano [2].

Methods. The methods was divided into three steps: (1) georeferencing of satellite images from the years 2005, 2009, 2012, 2014, 2016, (2) digitization of each georeferenced satellite image and image classification into four thematic classes, namely, mangrove, water, non-water, and fishpond areas and, (3) calculation for the rate of mangrove colonization.

Study area. The study area included the mangrove cover area at the mouth of the Jaro Floodway in Brgy. Bito-on, Jaro, Iloilo City as in Figure 1. A grid with a 200 m spacing bounded by geographic coordinates 122.5836°E, 10.7487°N and 122.5982°E, 10.7361°N was created in QGIS software, version 3.4.6. The grid served as a guide in downloading high resolution images from Google Earth for the years 2005, 2009, 2012, 2014, 2016 and 2018.

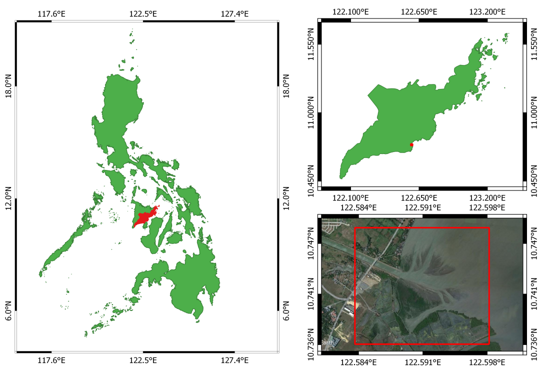

Figure 1. Study area.

Satellite image georeferencing. Satellite images as of December 2018 were georeferenced using Google Earth Pro, version 7.3.2 and Smart Geographic Information System (SmartGIS) 2019, version 19.11. Images were available for the years 2005, 2009, 2012, 2014, 2016, and 2018. The georeferenced images were saved as a Geospatial Tagged Image File Format (GeoTIFF), then imported as a raster layer to QGIS for digitization.

Digitization and image classification. The georeferenced images for each year were then classified into four (4) thematic classes using visual interpretation namely water, fishpond, mangrove, and non-mangrove areas. Water was identifiable as a dark blue color in the satellite image. Fishpond areas were rectangular shaped with a well-planned distribution, as seen through the satellite image. Mangroves were identifiable in the satellite images as green regions along the coast. These are the only plant species which could thrive on the salinity of the brackish water. Other areas which do not fit the criteria for the other three thematic classes were classified into a non-mangrove area. Every thematic class was then manually traced over using QGIS and saved as a shapefile layer. After the digitization process, the area of each thematic class, which was measured in hectares, was automatically determined by the software. An ocular inspection was also conducted in order to verify the classified areas.

Mangrove colonization rate. The rate of mangrove colonization for the years 2005-2009, 2012-2014, 2014-2016, and 2016-2018 was calculated using the formula used by Albano [2]:

$$CR_X = \frac{MC_b - MC_a}{b - a}$$

where CR_X is the average rate of mangrove areal cover change (ha/yr) or colonization rate of x, MC_a is the mangrove areal cover for the earliest year a, and MC_b is the mangrove areal cover for the most recent year b.

Results and Discussion. The construction of the Jaro Floodway began in 2008 and was completed in 2011. After its construction, mangrove cover steadily increased throughout the years as in Figure 2. In 2005, mangrove cover was measured to be 8.98 ha, this increased by 34.00 ha by 2018 to 42.98 ha.

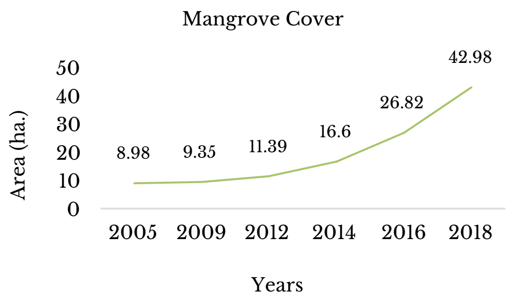

Figure 2. Area of mangrove cover in the Jaro Floodway from 2005 to 2018.

Mangrove colonization rate has also increased from 2005 to 2018, as observed in Figure 3, wherein the slope of the line steadily increases. It can also be observed that from 2009 to 2012 and 2016 to 2018 there is a notable increase in mangrove colonization in the area. Overall, the colonization rate of mangroves in the Jaro Floodway increased by 7.99 ha/yr from 2005-2009 and 2016-2018.

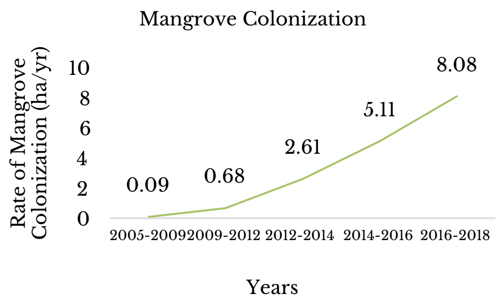

Figure 3. Rate of mangrove colonization in the Jaro Floodway from 2005 to 2018.

The extent of mangrove colonization depends on various environmental factors such as availability of propagule or seedling source, wave action, duration and depth of tidal inundation, and salinity [1]. In this study, the rate of mangrove colonization after the construction of the Jaro Floodway is mainly attributed to sedimentation [2,14]. Bathymetric charts available from the National Mapping and Resource Information Authority show that the water depth at the river mouth section of the Jaro Floodway before it was constructed is approximately 1 m, which is too deep for the propagules to grow. Thus, sedimentation played a major role by reducing the water depth to the optimal depth needed for mangroves to grow, which resulted in an increase in mangrove cover from 9.35 ha in 2005 to 42.98 in 2018. This study does not imply that an abrupt change in sediment accumulation is beneficial for the environment but rather emphasizes that mangroves increased from this environmental change.

There have been mangrove planting efforts in the study site that were initiated by the government. The Department of Public Works and Highways reported that a total of 13,000 seedlings were planted along the coasts of Barangay Bito-on. Personal communication with the Department of Environment and Natural Resources also reported that there are annual mangrove planting efforts after the Jaro Floodway was constructed. However, there are no reports on the survival of the planted seedlings. Despite this data gap, it is still likely that natural colonization took place because mangroves are known to colonize unutilized areas at a fast rate. Albano [2] reported that unutilized fishponds in selected barangays of Guimaras and Sorsogon, were naturally colonized by mangroves at a rate of 2,305 $^{m^2}/_{yr}$ in 2006-2012 and 1,890 $^{m^2}/_{yr}$ in 2000-2015, respectively. Nascimento et al. [9] also reported that mud deposition at the mouth of the Amazon River lead to an increase in mangrove cover by more than 700 km^2 in 12 years. Although the results of this study indicate that there was an increase in the mangrove cover, the contribution of mangrove planting efforts and natural colonization could not be quantified because of the lack of field data. However, in the case of natural colonization, the most likely propagule and seedling source is the nearby mangrove forest located at the mouth of the Jaro River.

Limitations. The study determined the area of mangrove cover and rate of mangrove colonization in the Jaro Floodway; thus, the species of the mangroves present in the area were not identified. Calculation for the rate of sediment accumulation could not be quantified with the methods used.

Conclusion. Mangrove cover increased after the Jaro Floodway was constructed. Sedimentation from the Jaro Floodway led to the formation of a new delta lobe that increased the area covered by mangroves from 9.35 (2005) to 42.98 ha (2018). Results of the study can contribute in providing insights on how mangroves adapt to environmental changes. Government offices can also use the results in the study in future decision making and aid in the development of rehabilitation projects.

Recommendations. Further studies regarding the survey of the presence of mangroves in the area and comparative studies between the number of naturally colonized mangroves and planted mangroves could be conducted. Quantifying sedimentation in the area may also be investigated.

Other sources of satellite imagery data and georeferencing software can also be used for the conduct of the study. When using a different source for the satellite imagery data, it is advised that the earliest and most recent available satellite image of the study site should be downloaded. There should also be a specific time interval for every acquired satellite image for the computation of the mangrove colonization rate.

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