



## Original Articles

# Modeling land use change using Cellular Automata and Artificial Neural Network: The case of Chunati Wildlife Sanctuary, Bangladesh

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## ABSTRACT

Land use changes generally affect the integrity of an ecosystem. The effect of this change can be very severe if the conversion disrupts a crucial habitat of major plants and animals. The degraded Chunati Wildlife Sanctuary is one such area of Bangladesh which is facing a serious problem of rapid land use change. In this study, the future trend of land use change of the area was modelled using Artificial Neural Network. Several driver variables were also incorporated to determine their effect on land use change. Binary logistic regression was used to assess the significance of the drivers of land use change for this region. The analysis shows that nearly 76% of the total land area (8258 ha) was covered by vegetation during 2005. After 2005, that was reduced to 61% (6637 ha) in 2015, a 15% decline from 2005. On the other hand, the coverage of vacant land increased from nearly 10% in 2005 to 22% in 2015. This is indeed a matter of real concern. The critical analysis suggests that Cellular Automata is not a good fit to simulate the future land uses as it misdirects the analysis both spatially and numerically. The incorporation of driver variables gives strength to the Artificial Neural Network to predict the future. The chi-square value for the prediction of land use of the area found from the neural network was 7.815 which was greater than the critical value (3.316). The neural network was found to be a good fit for future land use prediction. The kappa index of variation shows that the overall accuracy of the prediction using neural network was above 90%. Elevation, slope, and distance to the road were the three driver variables which were found statistically significant while predicting the probability of forest land use change. The accuracy of the binary logistic regression was about 61% which was quite satisfactory. The simulation result shows that almost 5732 ha of the total land will be in the forest category of land use during 2020 and it will be further decreased to 5128 ha in 2025. The vacant area will increase from 24% to 31% from 2020 to 2025. Based on the findings and simulated land use map of 2020–2025, the study will help the management authority of this critical habitat to take proper action before further degradation occurs.

## 1. Introduction

Information regarding land use and land cover change (LULCC) has been a great interest for environmentalists because of the impact of it on the global environment (Abuelaish and Olmedo, 2016; Subedi et al., 2013). Anthropogenic utilization of land is referred to as ‘land use’ (Islam et al. 2017), while unaltered surfaces are described as having a land cover (Islam et al. 2016). The major causes for LULCC vary depending on the nature and extent of the area (Lambin et al., 2001) but massive deforestation, grassland modification, agricultural intensification and excessive extraction ends the list of LULCC causes (Goldewijk, 2001). Apart from the causes, some researchers (Araya and Cabral, 2010; Dahdoub-guebas, 2002; Gao et al., 2015; Han et al., 2015) opined

that LULCC is happening due to some factors or drivers. Biophysical (López et al., 2001), physical (Rizk Hegazy and Kaloop, 2015), and socio-economic (Megahed et al., 2015) factors are the most influential drivers of LULCC.

With the massive improvement of satellite based technologies, scientists are now continually using Remote Sensing (RS) and Geographic Information System (GIS) in the broader aspect of land use science (Le Hégarat-Masclé et al., 2005; Mallick et al., 2008; Nguyen et al., 2016; Raghuvanshi et al., 2015; Ramachandra et al., 2016). Until 2005, researchers of land use science were confined to figuring out past and present trends of LULCC (Aspinall, 2004). However, with recent improvements and availability of data sources and sophisticated technologies, researchers are now trying to predict the future LULCC

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(Ahmed and Ahmed, 2012; Beaumont and Duursma, 2012; Fang et al., 2006). Modeling LULCC in this aspect is becoming more important (Herold et al., 2002) as there will be time to address anticipated changes at various spatial and temporal scale scenarios (Daye and Healey, 2015). Markov Chain Analysis (MCA) or Markov Model (Sivakumar, 2014), Cellular Automata (Sinha et al., 2015), Cellular Automata-Markov Model (CA-Markov) (Subedi et al., 2013), Artificial Neural Network (ANN) (Schneider and Pontius, 2001), Binary Logistic Regression (Zeng et al., 2008; Zhan et al., 2002) are some of the most commonly used model for the prediction and simulation of future LULCC. The Chunati Wildlife Sanctuary (CWS), located at the southeast corner of Bangladesh, is considered as one of the most important Protected Areas (PA) as it is the habitat of endangered Asian elephants (Islam et al., 2017; Rahman et al., 2016). However, due to excessive extraction of its natural resources, this nature reserve is now in a fragile condition (Islam et al., 2016; Nath et al., 2016a). Rahman et al. (2016) showed that the forested landscape of CWS is highly fragmented, having a tremendous impact on ecosystem functioning. The rich natural forest of the area is now disappearing at an increasing rate (Islam et al., 2017). Nath et al. (2016a) described the background causes of forest loss while Islam (2015) depicted the trend of LULCC for the year 2005, 2010, and 2015. It is evident from these findings that this forested landscape is rapidly degrading. Moreover, the future scenario is still unknown. Some comprehensive studies on the quantitative assessment of vegetation condition can be found from GIZ (2015); Nath et al. (2016a,b); NSP (2003,2004). Most of the studies are performed to find out the impact of co-management (Tamima, 2016), resource extraction from the sanctuary (Miah, 2009), and status of biodiversity (Nath et al., 2016b). However, very little information is available regarding LULCC in CWS and there was no such attempt to assess the future land use change of the area. This research gap must be addressed for the sustainable management of CWS. If such predictions are possible, they will be of great use considering the conservation of this nature reserve. Hence, this study aimed to predict the future LULCC of CWS based on the study of Islam (2015). ANN and binary logistic regression model are found best fitted for this purpose, and are used to simulate the LULCC of CWS for the year 2020 and 2025. These models were also found successful to predict the future LULCC of the forested landscape (Beaumont and Duursma, 2012; Beuchle et al., 2015; Dale et al., 2009). Attempts are also made to determine the drivers of the land use change. The findings from this study will be useful for the conservation planning of this important protected area.

### 1.1. Objectives of the study and research questions

This study will answer some of the important research questions regarding the trend of LULCC of the CWS. The research questions are (a) what is the current spatial trend of LULCC? (b) what is the rate of this change? (c) where is the location of this change? (d) what are the drivers of this change? (e) which models are useful to simulate and predict this change with good accuracy? and (f) what will be the future scenarios regarding LULCC?

The overall objectives of the study are:

1. To predict the land use and land cover (LULC) scenario of CWS for the year 2020 and 2025.
2. To find out the influence of drivers of land use and land cover change (LULCC) of CWS.

## 2. Materials and methods

### 2.1. Study area

The CWS is a tropical semi-evergreen forest in south-eastern Bangladesh that lies between 21° 40'N latitude and 92° 07'E longitude (Fig. 2.1). It was officially established as a wildlife sanctuary through a

gazette notification in 1986 under the provision of Bangladesh Wildlife (Preservation) (Amendment) Act, 1974 (Act No. XVII of 1974). It is divided into 7 beats (beat is the smallest administrative unit of a large forest area) namely Chunati, Aziznagar, Harbang, Jaldi, Chambal, Napura, and Puichari. It is one of the most vital protected areas of Bangladesh because it is an important habitat of the globally threatened Asian Elephant (*Elephas maximus*). This sanctuary is also rich with diversified flora and fauna, but due to over-exploitation of natural resources, it is now in a poor condition (Islam et al., 2016; Nath et al., 2016b).

The physiography of CWS is hilly to mountainous with shallow to deep gullies spreading over the entire area. The average elevation of the area is 30–90 m above mean sea level. The area is also crisscrossed with creeks, which offers good drainage and supply clean water to both people and wildlife and are also used for irrigation for roughly 3–4 months in a year (Nath et al., 2016b).

### 2.2. Data processing

This study uses both the remotely sensed satellite data provided by National Aeronautics and Space Administration (NASA) and some other ancillary data. The classified images of 2005, 2010 and 2015 of CWS (Islam, 2015) are used as the main input data and again reclassified into four broad categories i.e. Vegetation, Agricultural land, Vacant land and Others (Table S1). Several preprocessings steps were taken to use these classified imageries. The 16 land use classes of Islam (2015) are reclassified to 4 major classes to narrow down the focus of the study.

The input classified images came from two different sensors Landsat TM (Thematic Mapper) and Landsat OLI/TIRS (Operational Land Imager/Thermal Infrared Sensor). As the sensors are different, it could affect the DN (Digital Number) value of pixels. So, the three imageries are resampled to 30 m resolution each having the same extent and same data type (8 bit unsigned) based on the study of Ghebregabher et al. (2016). The imageries are then reprojected to UTM (Universal Transverse Mercator) 46 N coordinate system.

Some studies (Ghebregabher et al., 2016; Kantakumar and Neelamsetti, 2015; Lin et al., 2015) suggested that the satellite data should be passed through atmospheric correction process. Although Song et al. (2001) described that it would not affect the result substantially. So, atmospheric correction is not applied. Beuchle et al. (2015) deciphered that if images (whether classified or raw) from different satellites are used for the study, it should be co-registered to keep the extent of the imageries same. The same method is also applied to this research to co-register all the used imageries keeping the 2005 classified image as a master image and the rest two (2010 and 2015) as slave images (Beuchle et al., 2015).

Apart from the classified imageries, this study also takes some other ancillary data as input for future land use simulation and modeling purpose. Land use change modeling experts showed that some variables like elevation, slope, population, economic proxy indicators, distance from roads, distance from urban centers and so on are the major drivers for change in land use (Han et al., 2015; Kim et al., 2014; Lin et al., 2008; Millington et al., 2007; Raghuvanshi et al., 2015; Schneider and Pontius, 2001; Zeng et al., 2008; Al-sharif and Pradhan, 2013). The driver variables used in this study are slope, elevation, distance to brick field, distance to highways, distance to local roads, distance to locality, and distance to natural water sources (Table S2 and Fig. S1). SRTM DEM (Shuttle Radar Topography Mission; Digital Elevation Model) of 1 arc second from NASA are extracted based on the extent of the study area and processed. The raw DEM are resampled to 30 m resolution along with UTM 46 N re-projection. The elevation and slope images are then prepared using ArcGIS 10.2.2. The unit used for elevation is meter (m) and for slope is percentage (%). These two driver variables are used in the modeling without any further processing operation. Due to unavailability of the valid database for roads, highways, brick fields, localities, water sources, this study uses Google Earth to create the

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