Chapter 28

Adapting to anomalous floods in Kaziranga National Park: ecosystem-based disaster risk reduction linking climate change to conservation strategies

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28.1 Introduction

There are 43 World Heritage properties in India of which 35 are cultural and rest eight are natural. The natural heritage properties include Kaziranga National Park (1985), Manas Biosphere Reserve (1985), Keoladeo National Park (1985), Sundarbans Biosphere Reserve (1987), Nanda Devi Biosphere Reserve and Valley of Flowers National Parks (1988, 2005), Western Ghats (2012), Great Himalayan National Park Conservation Area (2014), Khangchendzonga Biosphere Reserve (2016), and (UNESCO 2024). The UNESCO heritage sites in India are affected by anthropogenic pressures, global warming, and natural hazards (Padma, 2018) including various mining and oil-gas exploration activities in the Western Ghats (Padma, 2018), and unsustainable harnessing natural resources in Sundarbans Biosphere Reserve (Danda et al., 2017). The Kaziranga National Park (KNP), situated in the floodplain of the Brahmaputra River, is one of the finest wildlife refuges and home to the world's largest population of one-horned rhinoceroses (*Rhinoceros unicornis*) (Fig. 28.1). In the present chapter, the precipitation and surface runoff anomaly in the Brahmaputra basin was analyzed to deduce its possible relation with the recurrent flood in the region. Also, the implementation of ecosystem-based disaster risk reduction (EbDRR) was explored to mitigate the flood vulnerability in KNP. Climate change mainly affects ecosystems due to physical and anthropogenic activities (Bengtsson et al., 2000; Kumar et al., 2020). Over the past several decades, developmental activities have led to increased deforestation, landscape alterations (Kumar et al., 2019), and climate-induced natural hazards that exacerbated a significant toll on assets, human lives, livelihoods, animals, and their habitats (Lal et al., 2020a, 2020b). Forests provide important ecological services and help sustain humankind by stabilizing soils, providing livelihood security, and regulating climate and water flows (Daily, 1997). Nearly 50% of the total 17,500 species of flowering plants in the country are growing in the northeastern region of India (Rao, 1994), and about 40% of them are endemic (Mao et al., 2009). The Himalayan forests are considered one of the most depleted and fragile ecosystems of the World (Schickhoff, 1995; Tucker, 1987) and the increasing human population in the Himalayan region exerted tremendous pressure on it (Eckholm, 1975; Myers, 1986). Large-scale commercial harvesting (Ali & Benjaminsen, 2004) and overutilization of forest resources for fuelwood and other household activities have led to enormous forest cover loss, more than 30% deforestation since the 1990s (Kumar & Saikia, 2020). Approximately 9.3% loss of natural forest is evident in the Eastern Himalayan region from 2007 to 2017 (Lal et al., 2019) leading to a significant change in local to regional climate (Das, 2016) and increased frequency of flooding in Northeastern India (Ali et al., 2019).

Forests for Inclusive and Sustainable Economic Growth. DOI: https://doi.org/10.1016/B978-0-443-31406-3.00028-X

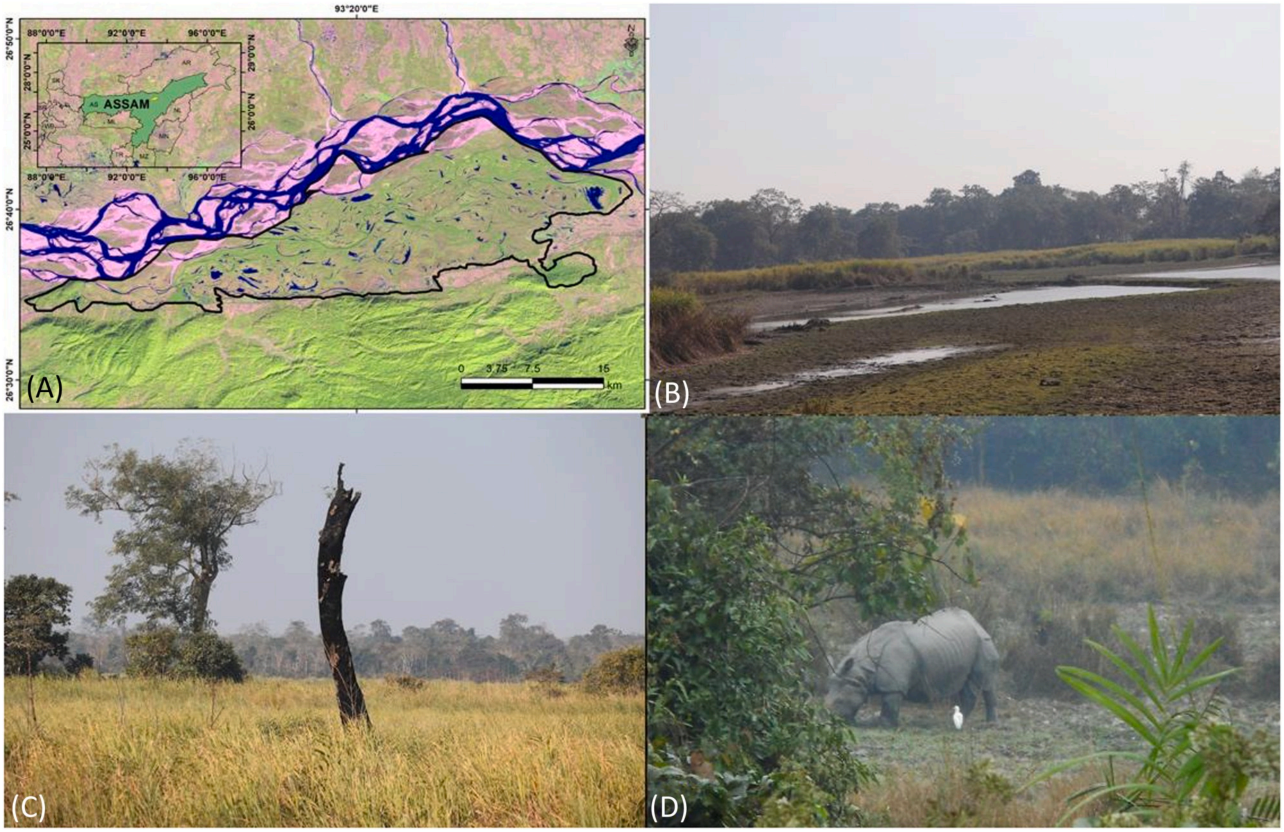

FIGURE 28.1 (A) Satellite view of a UNESCO heritage site Kaziranga National Park (true color composite BGR: 432 of Sentinel 2A), (B) field photograph of Kaziranga National Park representing a synoptic view of the wetland, (C) grassland, and (D) one-horned rhino in the grassland of Kaziranga National Park.

KNP is one of the oldest protected areas in the world notified as a game reserve in 1905 and as a forest reserve in 1908 (Mathur et al., 2005). The status of Kaziranga was upgraded to Wildlife Sanctuary in 1950, to National Park in 1974 (Das, 2017), and designated as a Natural World Heritage site in 1985 due to its unique natural environment, rich biodiversity, and outstanding universal value. The park is presently a protected area of global significance and was declared a Tiger Reserve in 2007 (https://whc.unesco.org/en/list/337/). The diverse ecological habitats of KNP including grasslands, floodplains, and wetlands host a wide range of flora and fauna. The provisions of the Indian Wildlife (Protection) Act 1972, the Indian Forest Act 1927, and Assam Forest Regulation 1891 provide KNP with the highest legal protection and a strong legislative framework (UNESCO, 2020). It is facing constant poaching pressure, along with the seasonal monsoon flood. Although floods are considered socio-economic disasters due to their enormous impact on humans and wildlife, annual flooding in KNP improves soil fertility, replenishes the wetlands, and flourishes the grasslands (Choudhury, 2004), thus it is important to maintain the wildlife habitats within the KNP (Mathur et al., 2005). Annual floods in KNP force the wild animals to move southern highlands (Karbi Anglong hills), and it used to cause significant animal deaths every year due to the lack of habitat, food, and vehicle hits while crossing National Highway-37 (NH-37; Asian Highway-1 [AH-1]), and high exposure to poaching (Bonal & Chowdhury, 2004). Poachers killed 110 rhinos in KNP from 2009 to 2019 (https://bit.ly/32XEa6P) and the number of poaching has reduced due to the strict management by the authorities around the clock. The rhinos are more susceptible to poaching during flood periods when they try to move southward highlands to escape the raging Brahmaputra river in the north (https://bit.ly/2QXAKvm).

The increased natural hazards have created a loss of ~130 billion US$ worldwide (2016), which is likely to increase to 415 billion US$ by 2030 (Desai et al., 2015). Climate change-induced variations in mean temperature and precipitation patterns may lead to more frequent, and extreme events of floods and droughts (Lehner et al., 2006). Rising temperatures with the increasing number of days with the high temperatures accelerate species loss and change in cropping seasons, which ultimately affects food as well as livelihood security (Lal et al., 2021, 2022; Saikia et al., 2016). It is essential to develop more effective strategies, methods, and tools based on the local socio-economic, and agro-ecological conditions to mitigate flood hazards and their impacts on wildlife and the most vulnerable societies in and around KNP. Water-related disasters including floods and drought are mainly developed due to the conflict between humans with their environment, which has significant ecological and socio-economic consequences (Dadson et al., 2017; Diksha et al., 2022; Lehner et al., 2006). Ecosystems have an inbuilt ability to reduce disaster risks, mitigate the increasing impacts of climate change, and protect communities (Lo, 2016). Ecosystem-based adaptation (EbA) strategies can be a more cost-effective strategy as compared to hard infrastructure and traditional engineering solutions, as produce multiple benefits. It is considerably more accessible to rural poor communities and they are able to integrate local traditional knowledge, and cultural values in their risk reduction efforts (SCBD, 2010). EbA has profoundly been used to adapt to the adverse impacts of climate change through natural capital (Munang et al., 2013; Saikia et al., 2020). Investment in ecosystem management and restoration is essential to help disaster-ridden societies and for sustainable socio-economic growth (Masundire et al., 2006). Having the ability to spatially integrate multiple biophysical conditions, EbA facilitates collaboration between social and natural sciences with policy in finding nature-based solutions (NbS) for global challenges, man-environment interactions, and efficient flood-drought risk reduction (Goldenberg et al., 2017). NbS uses natural functions of ecosystems including natural attenuation processes for addressing a range of global environmental and socio-economic challenges, including meteorological vulnerabilities (Cohen-Shacham et al., 2016), and facilitates sustainable utilization of natural resources for human well-being with the least impacts on the environment (Dhyani et al., 2020). It also clarifies the potential need for additional ecological engineering approaches to achieve the targets of disaster risk reduction (DRR) (Nesshöver et al., 2017). EbDRR helps in solving environmental and disaster-related issues and improving sustainability by increasing livelihood resilience through community participation (Saalismaa, 2013).

28.2 Flood impacts in Kaziranga National Park

KNP is affected by floods every year, which primarily influence the wildlife and local inhabitants of the region. KNP is located in the floodplains of the river Brahmaputra, which is passing through its northern parts. KNP covers ~567.5 km^2 area and is dominated by grassland and tree cover developing a suitable habitat for *R. unicornis*. The temporal Sentinel-1A SAR-based study demonstrated that Kaziranga National Park has been highly affected by floods almost every year during 2015–19 due to the anomalous precipitation and spillover flow of the Brahmaputra River during the summer monsoon. The annual observation indicated that the flood in Brahmaputra river has severely affected by inundated ~47.69% (270.62 km^2) area of KNP during August 2015, followed by 2018 (37.73%; 214.11 km^2), 2016 (36.34%; 206.21 km^2), 2019 (29.18%; 165.60 km^2), and least in 2017 (27.5%; 155.99 km^2) (Fig. 28.2). The major cause of flood in the region is attributed to the overflow of water mainly due to either discharge of water in the river or extreme precipitation. Precipitation, evapotranspiration, and storage factors are major contributing factors related to river discharge (Bhattachaiyya & Bora, 1997; Kumar et al., 2022; Mirza et al., 2001).

28.3 Precipitation and runoff in Kaziranga National Park

The standardized anomaly (SA) of precipitation (IMD) and surface runoff (ERA-5) for the years 2013–18 were estimated using the long-term mean (1981–2018) to understand the implications of precipitation and runoff in the region in recent years (Fig. 28.3). The study exhibited increased SA of precipitation (0.4–1.2) in the lower parts of northeastern India (Assam) during 2013 and 2016–18, in contrast, a decreased SA of precipitation (−0.8 to −2) in the upper part during 2014–18 barring 2013. An increased SA of surface runoff (1–2.6) was observed in the lower part of northeastern India except in 2018 and 2014, while a severely decreased surface runoff (−0.6 to −1.4) was observed in the upper part. A decreasing trend in river discharge was evident from the upper catchments to the lower catchments along the Brahmaputra River over the observation period of 1979–2019 (Harrigan et al., 2020). The increase in surface runoff, in contrast to the decrease in cumulative precipitation primarily during 2013, 2017, and 2018 may be attributed to the increased snow melting in the Eastern Himalayas. The highly negative mass balance (i.e., an increase in snow ablation and a decrease in snow accumulation) and a decrease in snow cover lead to decreased water discharge (Kumar et al., 2019). The flood was observed almost every year in KNP despite a decreasing trend in precipitation, runoff, and discharge. The rise in precipitation intensity has led to increasing flood incidents in the region (Ali et al., 2019). The increasing sediment load over the years contributed to the increased severity of flooding in the region (Fischer et al., 2017). Despite the flood has positive implications as it washes away invasive weeds, revitalizes the wetlands, and replenishes the grasslands and a proper EbDRR is required to reduce the flood risk in KNP. The varying pattern in the standardized anomaly of surface runoff and precipitation exhibited no significant correlation between the surface runoff and precipitation in KNP.

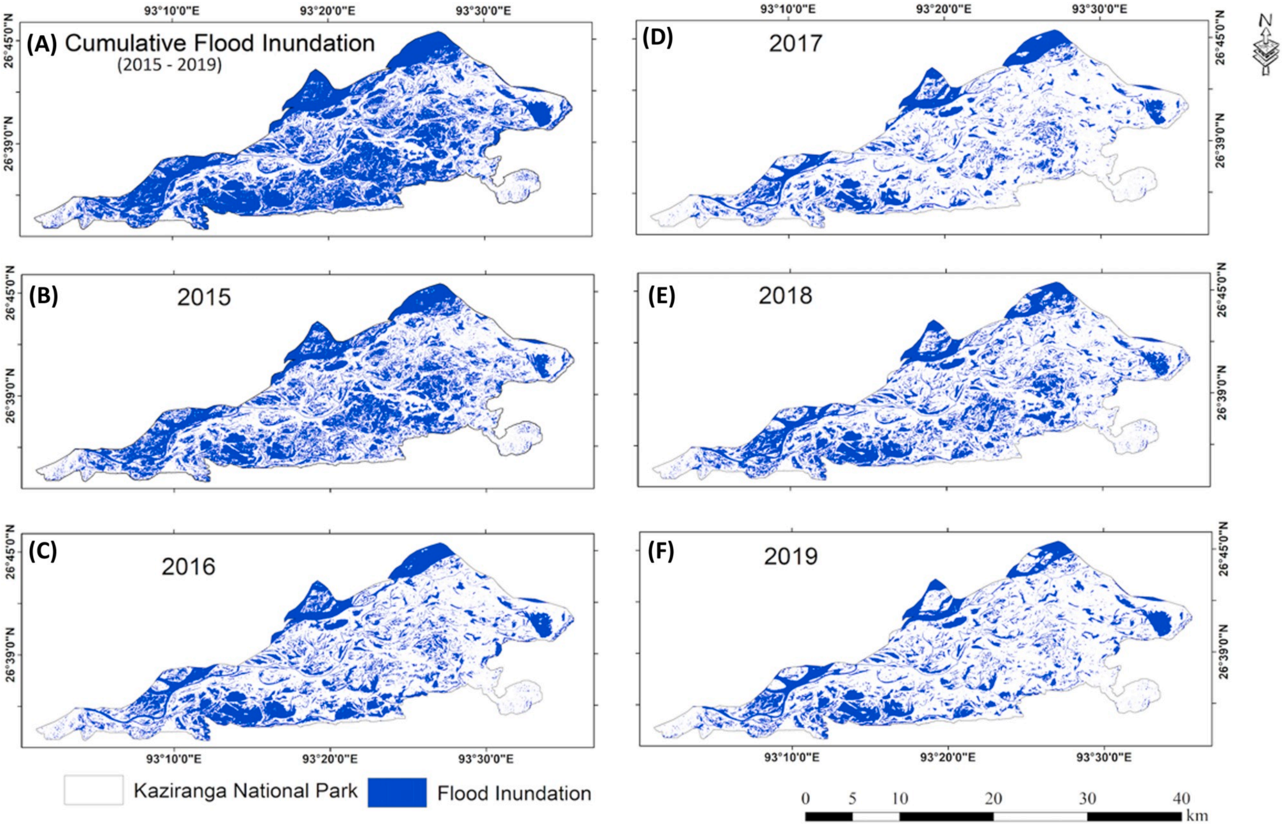

FIGURE 28.2 Sentinel-1A synthetic aperture radar-based assessment of (A) cumulative flood inundation (2015–19), and temporal flood inundation during the years (B) 2015, (C) 2016, (D) 2017, (E) 2018, and (F) 2019 in Kaziranga National Park.

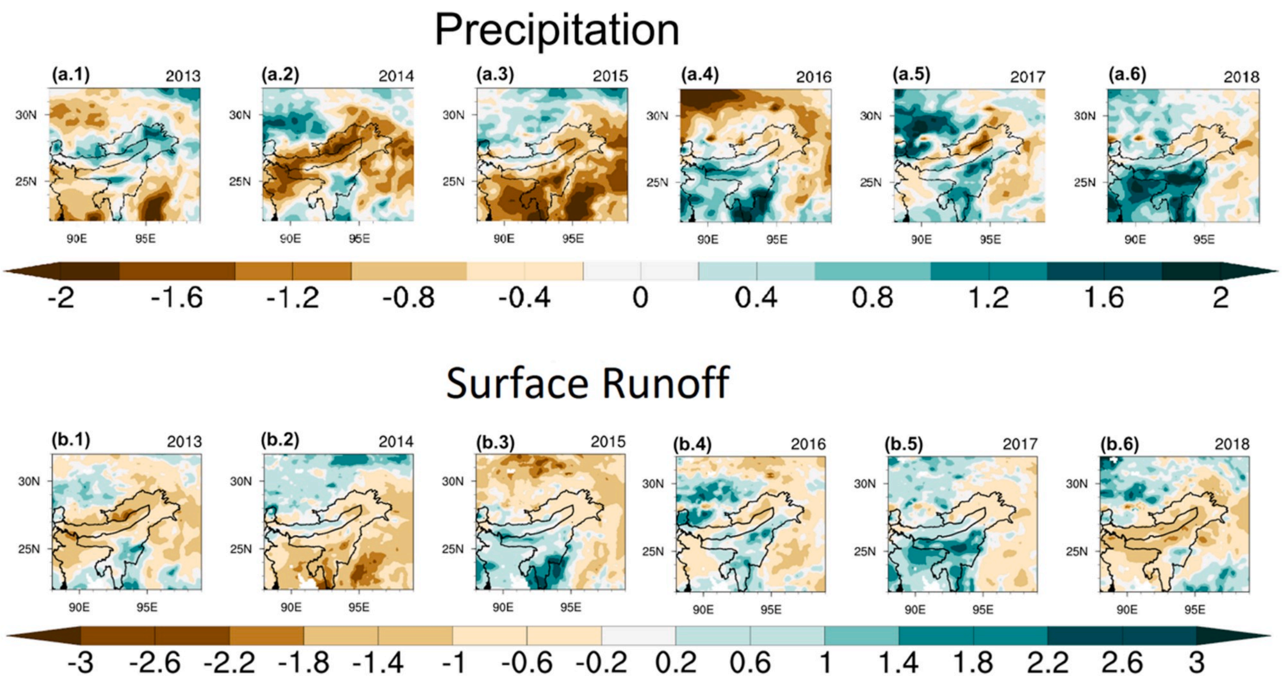

FIGURE 28.3 (a.1–a.6) IMD-based standardized anomaly of precipitation, and (b.1–b.6) ERA-5-based standardized anomaly of surface runoff during 2013–18.

28.4 Ecosystem-based approach for Kaziranga National Park

The temporal land use/land cover (LULC) assessment exhibited an increase in the grassland by transforming forest cover in KNP during 2001–19 (Fig. 28.4). Temporal normalized differential vegetation index (NDVI) assessment also exhibited a reduction in greenness in and around KNP over the periods. The landscape of the region encompasses the Brahmaputra River in the north, KNP (dominated by grassland) in the center, and Karbi Anglong hills in the south. The geography of KNP and its surroundings can be used to develop the EbDRR approach for wildlife during extreme flood incidents in the Brahmaputra River. The KNP area will be linked with southern Karbi Anglong hills through overhead wildlife corridors for the safe movement of animals (Fig. 28.5). These wildlife corridors will be developed with natural cover (vegetation) at a few locations in KNP and reach the southern highlands with a gentle slope, which is primarily unaffected by the flood due to the topographical advantages. The machinery of forest departments will have to extend their excessive protective regime in these regions to conceal the wildlife migration especially *R. unicornis, Elephas maximus*, and *Rucervus*

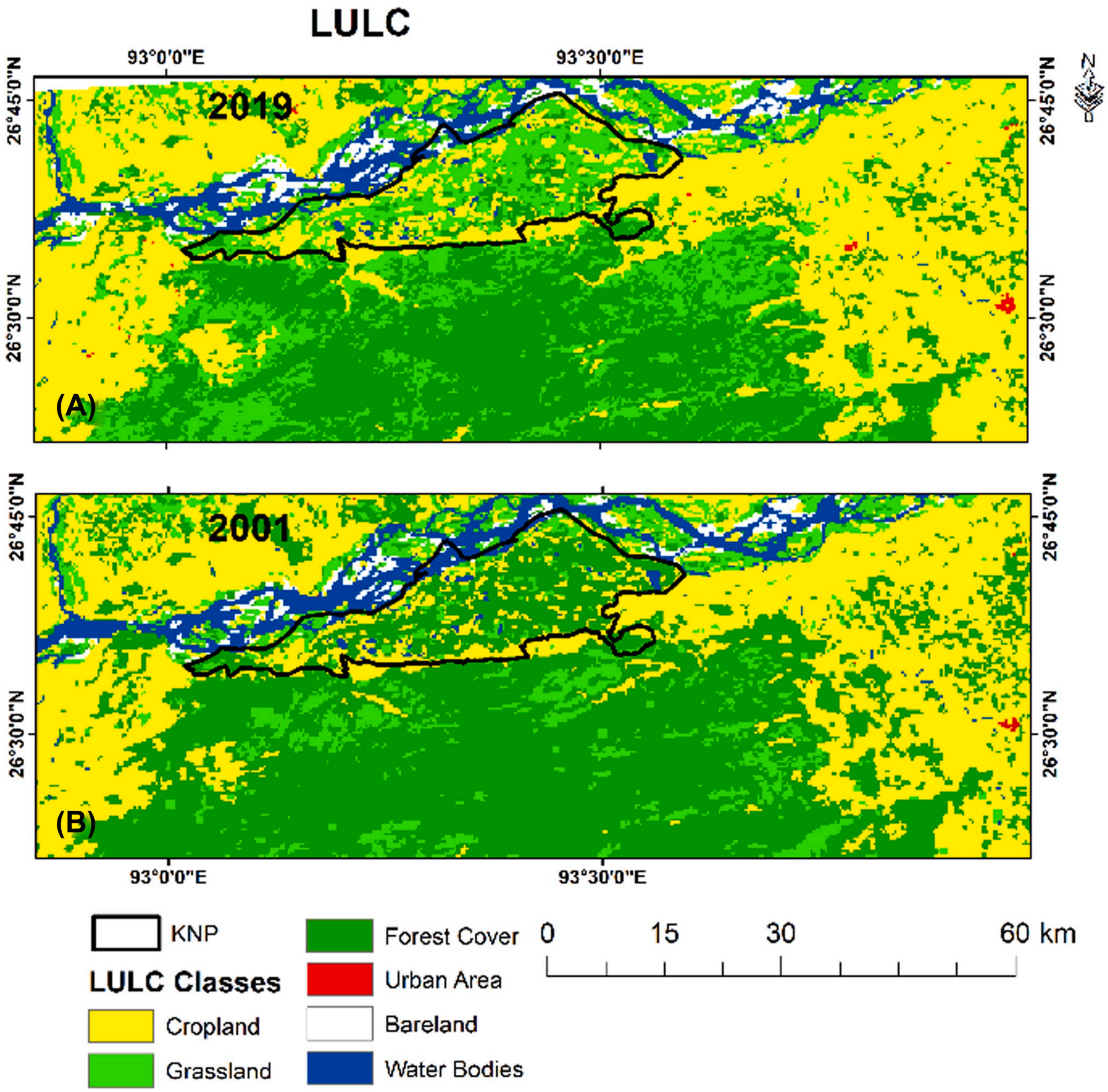

FIGURE 28.4 Land use/land cover of Kaziranga National Park and its surroundings as mapped for the year (A) 2019, and (B) 2001.

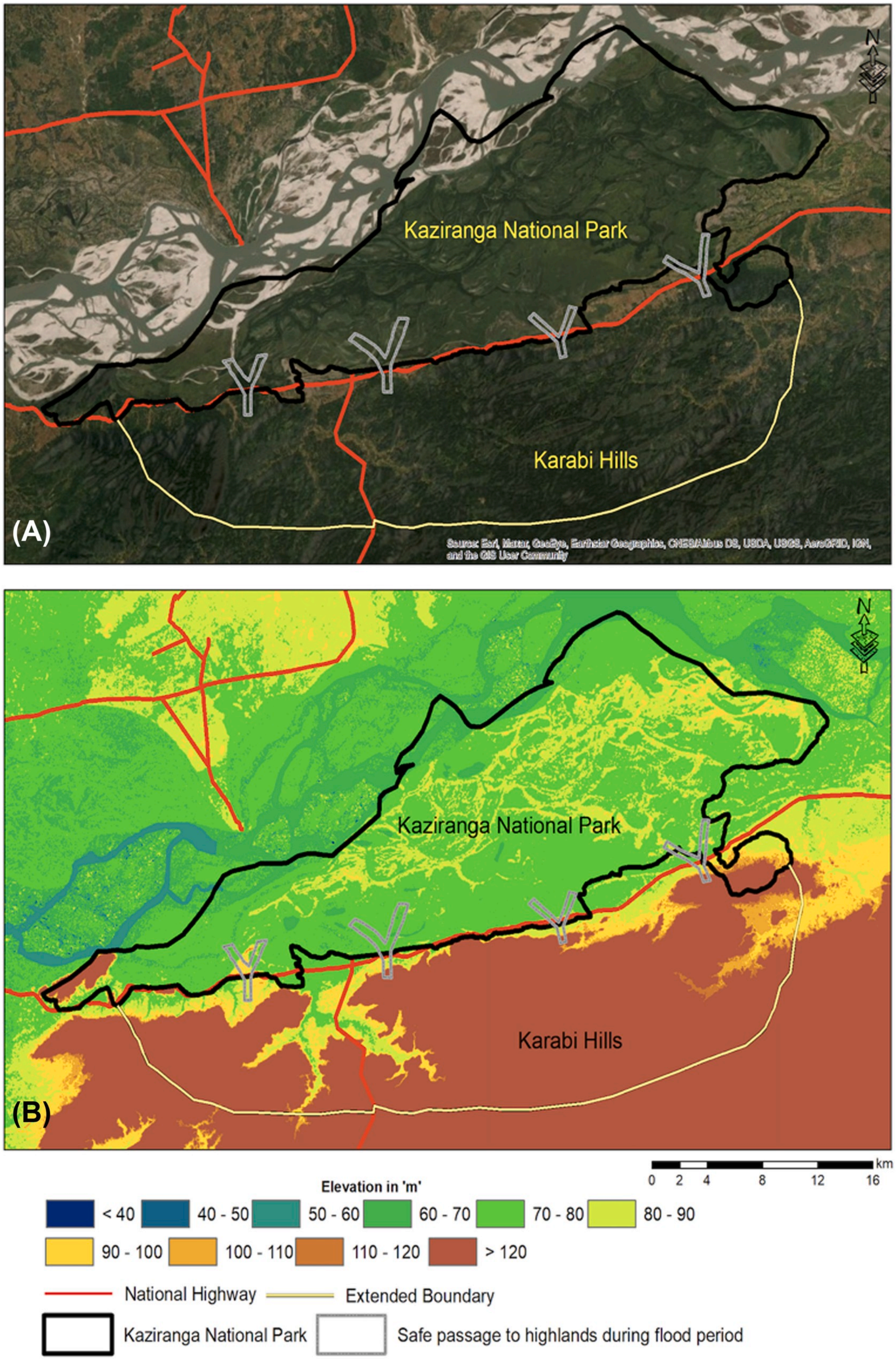

FIGURE 28.5 Recommended wildlife corridors for the safe movement of animals in Kaziranga National Park to Karbi Anglong Hills as represented through (A) satellite imagery, and (B) ALOS PALSAR digital elevation model. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

duvaucelii to prevent their poaching. It is suggested to conceal the AH-1 to safeguard the wildlife during their movement to the southern highlands during the flood period to prevent road accidents while crossing the AH. Also, the habitat for *R. unicornis* may be developed in the northern parts of Karbi Anglong Hill to support their population enhancement and management during the migration period. The northern and northeastern parts of KNP should be developed with dense tree cover without disturbing the grassland as a flood protective measure that will restrict soil erosion and minimize the washing away of wildlife. The poaching activities should be prohibited through the installation of surveillance systems (cameras and sensors), and the effective implications of a hefty fine and strict punishment. Considering the regional environmental condition and its sustainability, a buffer area comprising a large periphery of KNP should be protected and restricted for any further significant land transformation and anthropogenic disturbances to reduce human-animal conflict (Choudhury, 2004). In the present study, the regional topography, LULC transformation, proximity to the existing highway, frequency of flood inundation in the previous years, and area under frequent inundation, were considered to recommend a wildlife corridor in the region.

28.5 Conclusions

Flooding in the Brahmaputra Valley, particularly in KNP, is a long-standing natural phenomenon that poses significant challenges to wildlife conservation and ecosystem health. While altering the natural landscape to mitigate flooding risks may seem appealing, such interventions could lead to long-term negative ecological impacts. Instead, an EbDRR approach, grounded in the principles of landscape ecology and NbS utilizing state-art tools comprising geospatial modeling, artificial intelligence, and machine learning, offers a sustainable pathway to adapt to these challenges under changing climatic conditions. Key EbDRR strategies include the development of elevated habitats in the southern highlands, connected to KNP through strategically placed overhead corridors to facilitate safe wildlife movement during flood events. The extension of buffer zones around KNP, with minimal anthropogenic interference, is crucial to reducing human-wildlife conflict and maintaining ecological integrity. Additionally, afforestation efforts, particularly in the northern and northeastern parts of KNP, can enhance the park's resilience to flooding by stabilizing soil and improving water retention capacity. Temporal satellite-based earth observation and GIS tools enable precise mapping of flood-prone areas, identification of wildlife corridors, and assessment of habitat suitability over time, ensuring that conservation efforts are both targeted and adaptive. For example, the Government of Assam's proposed 35.82-km flyover along NH-37 presents an opportunity to integrate wildlife corridors into its design, ensuring safe passage for animals during floods (https://tinyurl.com/4ad4wyey). We recommend constructing a wildlife corridor on the proposed highway for the safe movement of animals during floods as the lower part of the road is still open. This integration can leverage geographical insights to optimize corridor placement and design for maximum ecological benefit. Embracing an EbDRR approach through the lens of landscape ecology and geographical science can help KNP adapt to increasing flood risks, supporting both the protection of biodiversity and the well-being of the communities that rely on the park's ecosystem services. By adopting these nature-based solutions, we can ensure the long-term resilience and sustainability of this UNESCO World Heritage site in the face of a changing climate.

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