Use of GIS and Remote Sensing in Tourism

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Contents

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Abstract

A geographic information system (GIS) is a computer-based information system using special tools to manage location-based data and their attributes for decision-making. Geospatial functions cut across many fields and support problem solving through geodata design and analysis. GIS have been used, for example, in environmental conservation and wildlife management. Its use in tourism planning, development and management, and marketing of destination products is only a more recent approach. The adoption of the technology affects both the sustainability of environmental resources and the quality of tourists' experience. The purpose of this chapter is, first, to explore the functionalities and usage potentials of GIS in the tourism domain. Second, two studies of Maasai Mara Game Reserve and Nairobi National Park portray how GIS and satellite remote sensing imagery is applied to assess the ecosystem's changes, their causes, and major implications. Examination of Landsat satellite image data for 2000 and 2017 shows that due to conversion of areas to farmlands and settlements, the coverage of Mau Forest Complex, the main catchment area for the Mara ecosystem, had reduced by 30.2% and vegetation by 22.8%. The analysis of Nairobi National Park showed that the Kitengela wildlife migration corridor has been completely encroached by human settlement and mining activities, thus seriously compromising the performance of the ecosystem. Mapping of human development pressure on the ecosystem using GIS technologies can be used to assess and manage the tourism resources potential in conjunction to biodiversity conservation as a critical element in improving wildlife as a tourism destination product.

Keywords

GIS · Geospatial functions · Ecosystem · Satellite remote sensing imagery · Tourism · Wildlife management

Introduction

Geographic information system (GIS) is a computer-based technology that is used to manage and manipulate geographic data (Bennett and Armstrong 2001; Shashi 2008). The functionalities of GIS require inputs from different knowledge fields: computer engineering, network engineering, communication technology, application areas and methods, and end-product use (Burrough et al. 2015; Krumm et al. 2013). In a GIS system, the real-world features are represented using four cartographic data elements (Van Kreveld 2017; Yao and Li 2018) in two data models: vector data model representing Earth features as points, lines, and polygons and raster data model representing grid cell feature classes (Lena 2007; Lwin et al. 2012). The design of such data models supports thematic mapping, map analysis, tabular data processing, and automated cartography (Burrough 2001), all of which are represented in space as a set of features with locational and attribute data. This leads to object-oriented and topological representations of real-world objects (Bian 2007; Kumar 2013) with their attribute data containing spatially referenced alphanumeric statistics as well as descriptions of the location features.

The main value of GIS is in geographical analysis where vector and raster data models are used to perform six main analysis functions: proximity analysis, network analysis, overlay analysis, temporal change analysis, statistical analysis, and three-dimensional visualization (Fotheringham and Rogerson 2005; Kurian 2014). These particular functionalities allow for the study of trends, patterns, and relationships using a combination of different themes in the data, thus enabling its use in studying the Earth and its manifold human-geographical phenomena (Baddeley et al. 2016; Esri 2005). Methodologically, this is achieved through geo-processing: a framework and a set of tools that are used for spatial data conversion, management, and analysis in a geodatabase environment (Fotheringham and Rogerson 2005). According to Rigaux et al. (2002), data conversion is used to change data from its existing format to a format that is suitable for a defined geodatabase. Data management, on the other hand, is used to organize and improve the quality of spatial data through editing existing features and the addition of any new features (Yao and Li 2018). According to Hand (2008) and Lena (2007), spatial analysis is used to query geodata from the real world and any geospatial phenomena therein. Thus, it examines location attributes and relationships of features through a range of spatial modeling procedures leading to diverse application areas using the six functionalities highlighted above.

Geospatial Functions and Major Application Areas

Proximity Analysis

Proximity analysis uses a mapped feature of interest to compute and determine its spatial relationship in distance with its neighbors, thus enabling suitable site or event selection, respectively (Stillwell and Clarke 2006; Wang et al. 2017). Proximity analysis has found major use in the transportation sectors to determine distance to destinations (Wu and Carson 2008). Moreover, Buckland et al. (1991) used the tool to monitor the direction of movements of animals and their proximity to each other and their independence. In calculating influence areas of tourism attractions, sites' proximity analysis has been used to determine location and distance to sites and hospitality facilities, thus facilitating tourism planning and marketing Service and Essays (2019). Proximity analysis has also been used by Jotikapukkana et al. (2010) for optimal distance calculation in biodiversity conservation at Huai Kha Kaeng Wildlife Sanctuary, Thailand.

Network Analysis

In determining flow and in assessing (e.g., linear) network connectivity, network analysis is applied using nodes, links, and any type of geographical region to develop a series of topological measures to characterize the network structure (Brandes and Erlebach 2005; Michael 2013). This analysis type aims at understanding the behavior of networks and of flows within and around a network, and, therefore, in a geographical context, it can be used to provide solutions for routing problems (Evangelos 2013). This analysis type has been used in finding the shortest routes to areas of incidents in health care and emergency services provision as demonstrated by Ahmed et al. (2017) in Greater Cairo metropolis and MacFarlane (2005) for fire and emergency management in London. Moreover, Karadimas and Loumos (2008) and Chalkias and Lasaridi (2011) demonstrate the use of network analysis to optimize routes for waste collection and its disposal to waste dumps. In tourism management, it has been used to determine the best routes to tourism destinations and points of interests (Lau and McKercher 2006) as well as to determine optimal information flows within tourism destinations (Baggio 2014; Baggio and Del Chiappa 2014; Del Chiappa and Baggio 2015; Éber et al. 2018).

Overlay Analysis

Overlay analysis uses a geometric intersection process to superimpose multiple thematic layers in order to update or combine features in a new output dataset (Tiede 2014; Xiao and Boutaba 2014). Stillwell and Clarke (2006) and Adhikari and Li (2013) used this technique to plot the relationship between automated teller machines' location and consumer residences in Leeds and reclassification of settlements for informed urban planning, respectively. In crime mapping, the technique has been applied to map crime hotspots by overlaying spatial data layers of factors that determine crime occurrence (Ferreira et al. 2012). Land cover types within a wildlife habitat have been mapped for conservation and wildlife management using overlay techniques (Salem 2003). The technique has also been used to map risk-prone areas within protected areas through a combination of factors such as population and settlement (Westen 2013).

Temporal Change Analysis

The dynamic changes in the environment are mainly occasioned by hydro-meteorological processes and development activities requiring a temporal change analysis approach (Lütkepohl 2005; Andrienko and Andrienko 2006). The temporal change analysis is useful for detecting location-specific trends and patterns in the real-world geographical features over a period of time and in certain time intervals (Baddeley et al. 2016). Matouq et al. (2013) has used it for weather forecasting and monitoring geographical climate change implications in Jordan. Ebifuro et al. (2016), on the other hand, monitored revenue collection by relating tax-payers location and their incomes over time in Bayelsa State, Nigeria. Swart (2016) applied time series satellite images to map forest cover loss in the Mau Forest Complex, Kenya, over the last 40 years and its implication on the ecosystem performance as a catchment area. This is useful in understanding forest cover change impacts on the ecosystems as demonstrated by Mango et al. (2011) in his study of land use and climate change impacts on the hydrology of the upper Mara River Basin, Kenya. ESRI (2010) demonstrates that temporal change analysis is useful in ecosystem assessment and wildlife management and therefore a critical component in tourism destination attraction development and marketing (Cvetkovi and Jovanovic 2016).

Statistical Analysis

In understanding use of place and spatial relationship of entities within a particular geographical space, statistical analysis is used (Chatfield 2005; Gras et al. 2008). The applied mathematical computations, such as spatial measures of central tendency (e.g., centroid, Euclidean center, etc.) and spatial measures of dispersion, are used to identify patterns or relationships in the data, which is then used in modeling and statistical interpolations (Bhattacharjee et al. 2019; Hand 2008). The technique has been used in combination with field data and modeling methods by Wulder and Franklin (2007) to monitor landscape change over large areas. Wulder and Franklin (2007) did this with sufficient spatial detail to allow comparison of resulting patterns of different landscape disturbance regimes. In epidemiology, Cleckner and Allen (2014) used statistical analysis to determine malaria high- and low-risk areas by mapping mosquitos' breeding patterns. Geographical statistical analysis has also been used by Norizawati et al. (2013) to analyze tourist demands, behaviors, and distributions in Langkawi Island, Malaysia, for tourism planning and management.

Image Analysis

The technique of image analysis is used to extract meaningful information from satellite imagery, using two approaches: image processing and pattern recognition (Blaschke 2010; Koprowski 2017). In satellite images, real-world objects and features are represented using radiometric signatures that can be classified according to their digital value clusters (Lu and Weng 2007). At high resolution, satellite images present valuable opportunities for analyzing landscape change patterns, such as forest cover change at a structural scale (Wulder et al. 2008). In urban setting, remote sensing image analysis is useful in planning new infrastructure based on current and predicted future land cover and land use change patterns (Mahmoud and Ahmad 2013). Keller and Smith (2014), on the other hand, have applied remote sensing tools to classify landscape component types at an ecological scale relevant for wildlife and tourism management. Finally, Boitt (2016) used the technique to map the ecological impacts of Mau Forest Complex degradation on the rift valley lakes in Kenya.

Three-Dimensional Visualization

A digital elevation model (DEM) represents average terrain altitude values in raster format and is used for three-dimensional visualization of elevation data (Abdul-Rahman and Morakot 2013; Mat et al. 2014). This visualization technique supports slope angle and attitude measurements for inter-visibility and flow direction analysis (Kennedy 2009). The technique has been successfully used for environmental assessments of placement of new developments against the backdrop of the surrounding landscape (Dunbar et al. 2004). The same technique has been used in communications planning by mobile phone services providers where the line of sight between transmitter and receiver is applied in service assessment and planning to avoid transmission obstacles (Tao 2013). Moreover, Birendra and Sagar (2005) have used high-resolution satellite images and 3D visualization to map landslides and flood early warning systems using flood simulations in the Nepal part of the Mount Everest region. In tourism marketing, Knox (2004) has used 3D visualization to create a virtual fly-through that displays existing natural and man-made features, landscape sensitivities, terrain analysis, and conservation assessment for an existing tourism area, in Gold Coast. Finally, Mango et al. (2011) portrays the use of digital elevation models (DEM) of the Mara ecosystem to show the connectivity of the Mau Forest Complex and the Mara plains ecosystem.

GIS Application in Wildlife and Tourism Management

The use and application of GIS technologies in the tourism sector can be divided into three major application areas: tourism development and research, tourism planning, and tourism marketing (Sureshkumar et al. 2017). GIS offers valuable and manifold opportunities for the development of modern tourism. In tourism development and research, GIS has been used to study ecosystems' biodiversity, their value as a tourism product, and the challenges they face from human development (Rahman 2010; Christ et al. 2003). Burrough (2001) presents a use case of GIS-based image analysis and data visualization functionalities for the mapping of object data. Data collection and modeling through use of GIS and remote sensing tools provide valuable information on areas facing environmental degradation and requiring rehabilitation and restoration (Dubovyk 2017). This has been done though wildlife tourism resource inventorying, monitoring, biodiversity conservation, and management, respectively (Bunruamkaew and Murayama 2012; Thilagam and Sivasamy 2013). Understanding specific needs of wildlife populations is key to preventing major anthropogenic threats that in many cases affect the wildlife tourism product (Salem 2003). In fact, wildlife management is central to tourism planning and tourism destination management (Bahaire and Elliott-White 1999; Feng and Morrison 2002; Brown 2006; Jovanovic and Njegus 2008; Chancellor and Cole 2008; Bunruamkaew and Murayama 2012).

In tourism planning, Minagawa and Tanaka (1998) Avdimiotis and Christou (2008) and Abomeh (2017) have successfully used GIS technologies to describe and identify tourism infrastructure elements, such as visitor centers, hotels, trails, and field situation. With location-enabled mobile phones, web-based navigation maps have been successfully used to track vehicle and animal movement, which helps monitor their activities to improve their security and safety Shoval and Isaacson (2007). Through geo-relational data queries, proximity and overlay functions have been used to provide the tourists with updated information about both places to visit and to explore (Christ et al. 2003) and to also get information on particular tourism services (Kim and Graefe 2000), such as hotels, hospitals, security facilities, interesting locations, and costs involved (Jovanovic and Njegus 2008).

Moreover, GIS have been successfully applied to promote, plan, implement, manage, and market tourism resources and to bring their value to the knowledge of tourists (Brenes-Bastos et al. 2014). According to Rahman (2010), modern tourism marketing strategy depends on making analysis on geodemographic characteristics, experiences, cultural heritage, and time space factors, all of which can be performed using GIS and, thus, make it possible to locate and analyze the geodemographic characteristics of actual and potential travelers. In particular with digital elevation model (DEM) and 3D spatial visualization tools, it has been possible to present landscape features on web-based information platforms and complete their profile with traveler data, thus presenting information about travelers' decision-making process and destination choice behavior (Munar 2012). This has changed the understanding about what travelers are willing to pay for and about their experiential patterns of tourism services and landscapes (Pitman et al. 2010; Fan and Liu 2013).

A GIS Application for Maasai Mara Game Reserve Ecosystem Management

The below sub-section illustrates how GIS has been applied in wildlife and tourism resources management and conservation at Maasai Mara Game Reserve.

Maasai Mara Game Reserve (1,510 km^2) is one of the prime game reserves in Kenya, considered globally as the world's 8th wonder because of its wildebeest migration (Serneels and Lambin 2001). The reserve, together with the Serengeti National Park (14,763 km^2), Tanzania, forms the Mara-Serengeti ecosystem that is served and drained by the Mara River Basin. The Kenyan part of the Mara Basin (Fig. 1) covers 8,907 km^2 and has its catchment at Mau Forest Complex within a range of hills forming the western escarpment of the Great Rift Valley.

The Mau Forest Complex has increasingly become vulnerable due to conversion of the forest area to agricultural land, which has reduced the recharge area and, thus, affecting the base flow of the Mara River. Other anthropogenic pressures are observed in the Ngorengore and Mara plains area of the basin within and around the game reserve, mainly due to human settlements, attendant infrastructure development, and large-scale wheat cultivation in the dispersal areas to the north of the reserve (Omondi and Musula 2011). These pressures have brought into focus the connectivity and reliance of Mara-Serengeti ecosystem to the Mau Forest Complex catchment area and the implication of population growth and human development on ecosystem's sustainability, respectively.

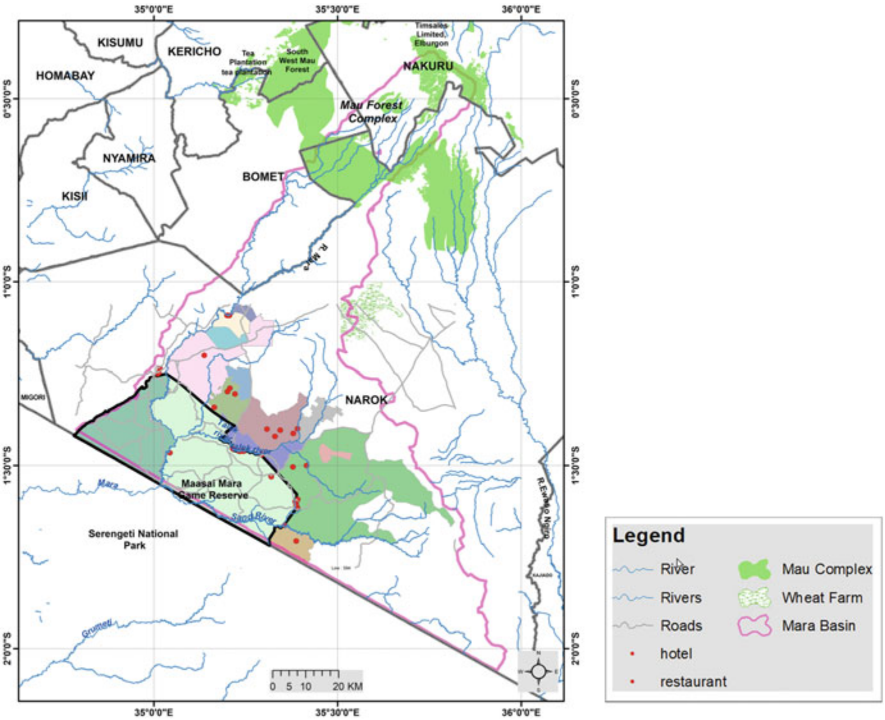

Fig. 1 Mara River Basin catchment area in Kenya, showing its source at Mau Forest Complex

In Kenya, Kenya Wildlife Service (KWS) governs land ownership of national parks and game sanctuaries on behalf of the government. Game reserves are, however, gazetted as community land and have since 2013 been under the management of county local administration in trust for the local communities. In the game reserves, local communities live within and freely use the area for their livestock. The Maasai community, for example, freely grazes their livestock in the plains of the Mara-Serengeti ecosystem. However, over the years, this has posed a challenge as some individuals and groups of individuals have claimed group ranch ownership and converted the areas to wildlife conservancies. This is what retrospectively bore the game conservancies around the Mara Game Reserve and the concept of ecotourism management and conservation across the country (Maasai Mara Wildlife Conservancies Association 2019).

Understanding the Challenge to the Mara Ecosystem and Its Tourism Impact

Wildlife and beach tourism are the most preferred tourism products in Kenya with about 63% of tourists coming for what has come to be known as safari tours. The safari tours have strong linkages with hospitality, transport, food production, retail, and entertainment industries. Sustenance of this type of tourism in Kenya largely depends on the ease of both sighting and accessing the wildlife. The predictable patterns of wildebeest migration to and from the Maasai Mara Game Reserve from July to October offer great opportunities in addition to optimal viewing of predator-prey interactions (Serneels and Lambin 2001). As a tourism destination, the value of Maasai Mara Game Reserve is in its wildlife resources, and its fame is for the Big Five, elephants, buffaloes, rhinos, lions, and cheetahs, the wildebeest migration, and the Maasai cultural heritage (Bhandari 2014). However, an increased number of tourists and their associated travel activities place substantial pressure on the fragile ecosystem through increased traffic and attendant pollution.

Of the 4,098 km^2 of the Maasai Mara ecosystem conservation area, only 36.8% is gazetted as the Mara Game Reserve and is under the jurisdiction of the County Government of Narok. KWS personnel collects the revenue on behalf of the county government (Bhandari 2014). The remaining 63.2% of the land is under the jurisdiction of 14 private conservancies (Maasai Mara Wildlife Conservancies Association 2019) which boasted up to 35 hotels compared to only 4 within the Maasai Mara Game Reserve. The distribution, concentration, and density of the hotels within the surrounding conservancies as illustrated in the heat map (Fig. 2) have implications on Mara ecosystem integrity. More precisely, these ecological pressures stem from both vehicular and human traffic, often deficient waste management, and unregulated off-road traffic to access game, especially within the riparian areas. In the recent past, the concentration of visitors has also been within the conservancy areas.

Negative impacts from tourism activities particularly occur when the number of visitors using the facility is greater than the environment's ability to cope with

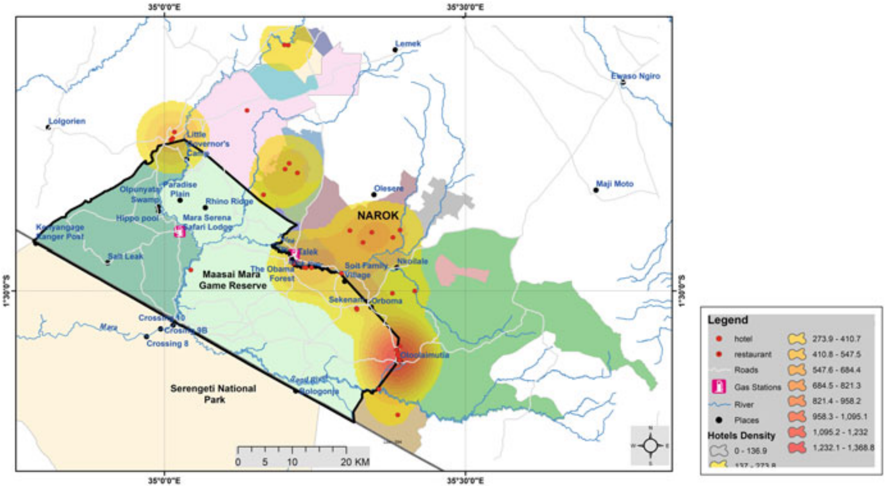

Fig. 2 Hotels' density heat map of Mara Game Reserve and conservancy's area

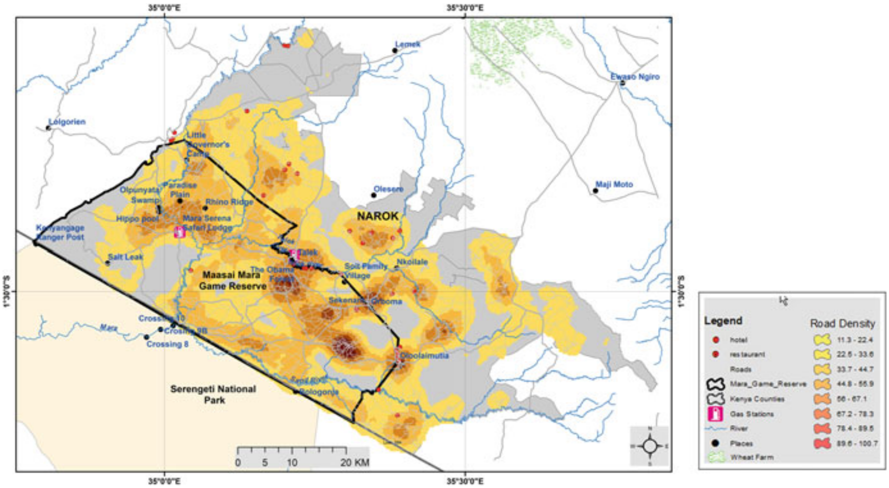

Fig. 3 Roads density heat map of Mara Game Reserve and conservancies' area

the use (Ayiemba et al. 2015). Geospatial tools were applied in order to conduct a road density analysis of the Mara Game Reserve and the conservancy area. The result (Fig. 3) show six hotspot areas of high road density within the game reserve area associated with convergence of access routes to the hotels. More precisely, within the conservancy's area, there are six such hotspots, whereas three such areas are located along the boundary of the conservancies and the game reserve. Uncontrolled conventional tourism activities using vehicular transport to access wildlife and attraction sites lead to increased traffic that put enormous pressure on the fragile ecosystem. The concentration of movements leads to significant stress on the vegetation and, therefore, its ability to support herbivorous wildlife as well as the Maasai livestock (Bhandari 2014). There are additional impacts, such as natural habitat loss through vegetation degradation, soil erosion, increased pollution, and heightened vulnerability to fires (Fig. 4) and flood hazards (Boitt 2016). Such impacts often put a strain on water resources with poor runoff retention, which translates to short-term elevated river discharge and, therefore, flooding or long-term low-level discharge and base flow and, finally, water scarcity especially during the dry season.

Tourism can also create great pressure on local resources, such as energy, food, and other raw materials (Bhandari 2014). More precisely, a substantial amount of energy used in the local hotels is in the form of charcoal, most of which is sourced from the forests in the Mau escarpment area. Moreover, timber for construction of the hotels is derived from these forests as well (Ayiemba et al. 2015). In addition, conversion of land from forest to agricultural land in the escarpment area is contributing to the degradation of the catchment area, as seen from a comparison of Landsat images of 2000 and 2017, respectively, for the January dry season (Fig. 5). The Landsat images were downloaded from the US Geological Survey (USGS) data

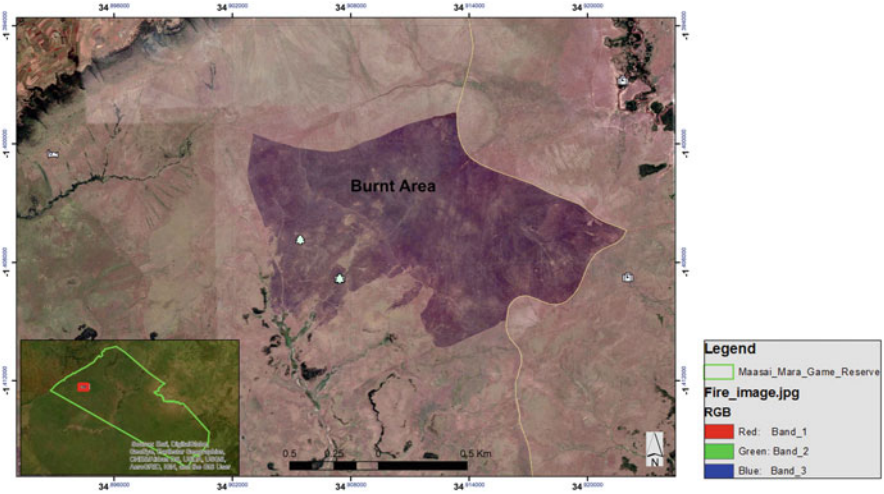

Fig. 4 Image map extracted from Google Earth web image as of February 8, 2018 showing burned area within a section of the game reserve

portal pre-processed and a classification carried out on them based on supervised classification of signatures using Impact Tool Box (Simonetti et al. 2015) that classifies land coverage based on digital numbers. The output was segmented to produce shape files that enabled computation of areas of each land cover class. The results are presented in Fig. 5 and Table 1.

First, Fig. 5 illustrates the level and extent of forest change within the Mau Forest Complex, the main catchment area of the Mara River Basin. Second, Table 1 shows that there are significant changes in the six land cover classes with the combined forest and vegetation area decreasing by 53%, whereas the farmland areas increased by 26% demonstrating increased human encroachment and impacts. In fact, the land cover change and land use in the area show increased bareness of the area over time, a consequence of physical impacts associated with resource use and land degradation. This is bound to affect the ecology of the area from increased run-off and its impacts on riverbank erosion and, therefore, significantly reduced wildlife biodiversity (Boitt 2016). Moreover, this degradation is contributing to pollution of the Mara River from soil erosion in the deforested area (Omondi and Musula 2011). This is further exacerbated by the construction of the Itare Dam in Kuresoi area of Molo Division to transfer water from the 250 km^2 upper catchment area of Mara River to Nakuru municipality. This will affect the Mara River discharge levels due to water abstraction. In fact, there is evidence of water abstraction for irrigation downstream (Boitt 2016)

Digital elevation models (DEM) and 3D modeling of the topography of the Mara ecosystem in Kenya (Fig. 6) show the connectivity of the ecosystems and the dependence of the Mara plains on the water supply from the Mau catchment area. Forest cover degradation and pressure on vegetation is likely to increase flood

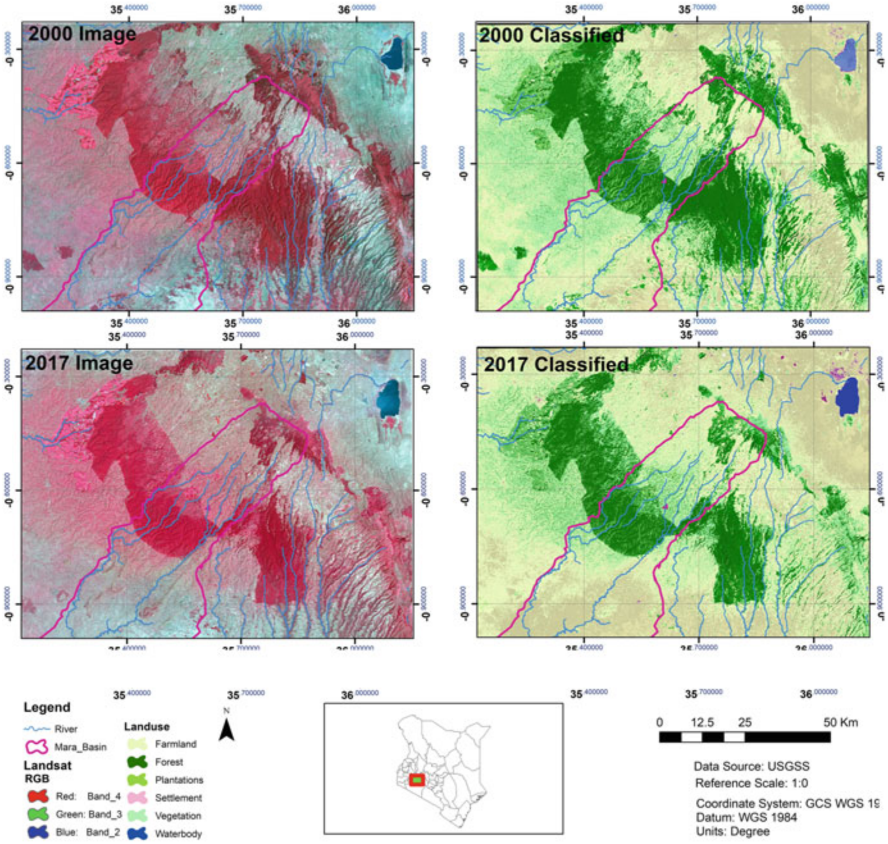

Fig. 5 Landsat image classification maps showing extent of forest cover change in the Mau Forest Complex area between 2000 and 2017

Table 1 Land use and land cover change in the Mau Forest Complex (2000 to 2017)

Land use name	2000 area (km^2)	2017 area (km^2)	Change (km^2)	% Change
Farmland	4641	5836	1195	25.75%
Forest	3126	2181	−945	−30.23%
Vegetation	1608	1242	−366	−22.76%
Plantations	269	365	96	35.69%
Waterbody	44	58	14	31.82%
Settlement	4	10	6	150.00%
Sum area in km^2	**9692**	**9692**		

occurrence in the Mara Basin within the reserve where its morphology covers a wide U-shaped valley with the river meanders indicating increased riverbank erosion. The elevation maps are particularly useful in giving a clear idea about habitat suitability for animal species and wildlife corridors.

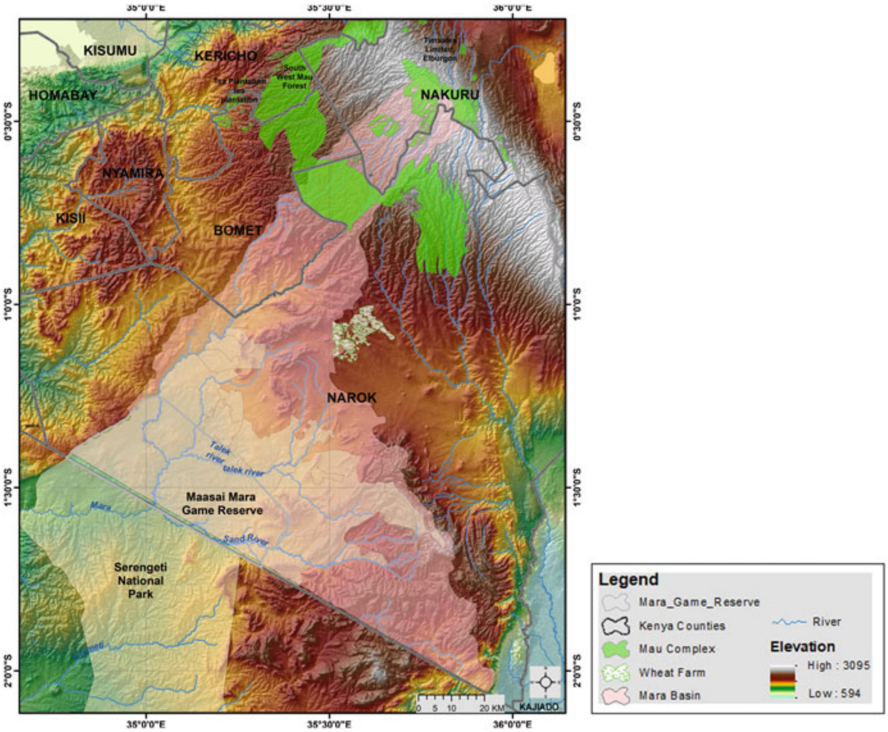

Fig. 6 DEM of the Mara ecosystem area showing the position of the Mara River Basin

In the Mara plains, there are increased settlements with a large part of the area within Ololunga sub-county area taken up for arable farming and large-scale wheat production (Fig. 7). Land cover change between the images of 2000 and 2017 shows that the area is scantly covered by grass and therefore considered as bare. This trend has increased by area from 394 km^2 in 2000 to 2449 km^2 in 2017, a change of 521% (Fig. 8 and Table 2). Moreover, there is a significant decrease in the thicket area from 1464 km^2 (2000) to 285 km^2 (2017), equivalent to a decrease of 80.5%

The increasingly reduced vegetation cover is a clear indication of biodiversity loss that will affect the abundance of biomass in the grazing area. This will in the long run affect the wildebeest migration patterns with a longer residence of the wildebeest in much larger neighboring Serengeti plains of Tanzania (Serneels and Lambin 2001) with implications on the number of tourists visiting Maasai Mara Game Reserve and therefore, also affect the economy of Narok County. With GIS technology, there is an opportunity to use, for example, the Landsat images to monitor human and animal activities in the catchment area with a view for its sustainable management. Geospatial tools can effectively be used to indicate degradation trends and to demonstrate areas of intervention for sustainable wildlife tourism management.

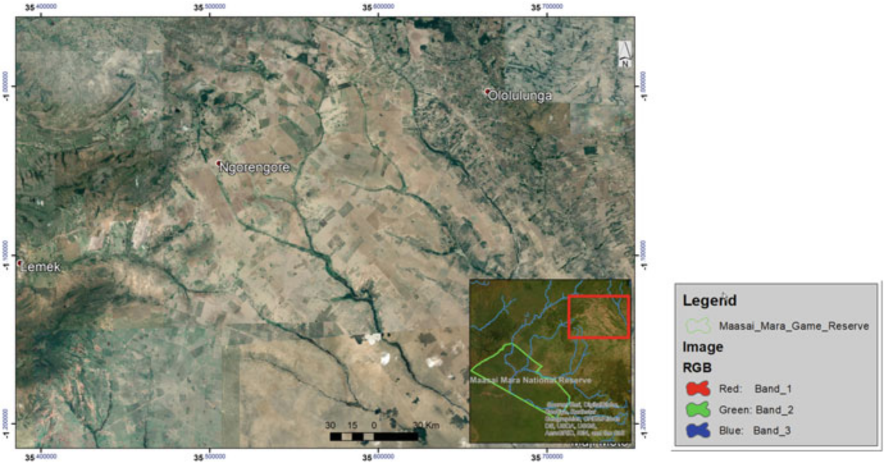

Fig. 7 Wheat fields in the dispersal area of Ngorengore to the North-West of the Maasai Game Reserve

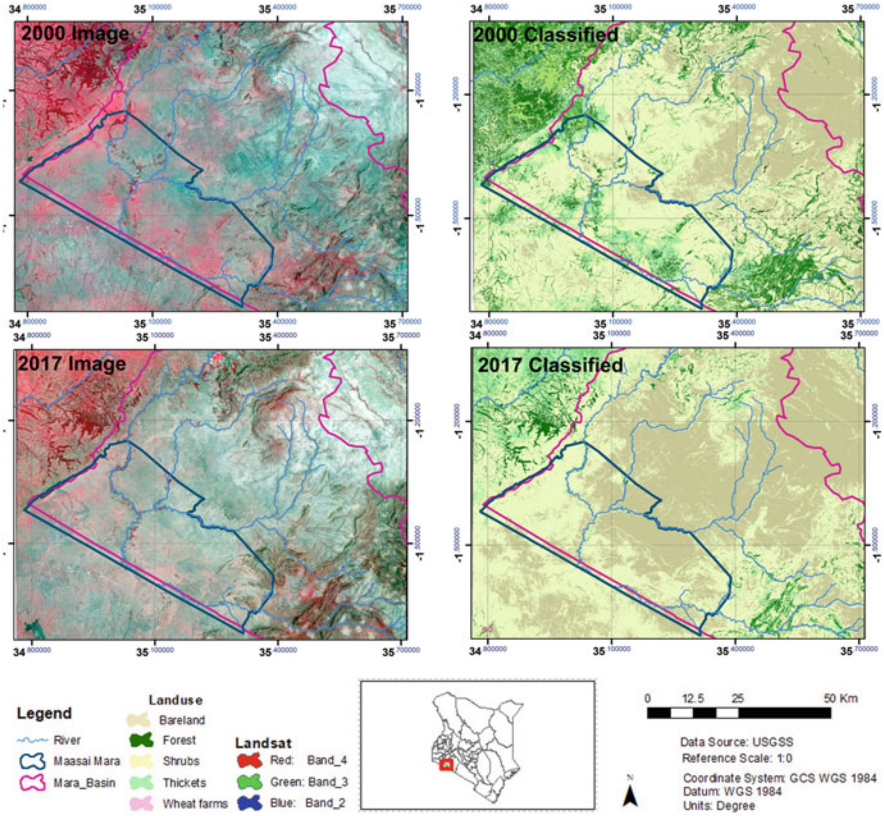

Fig. 8 Landsat image classification maps showing the Maasai Mara Game Reserve and the environs between 2000 and 2017

Table 2 Land use and land cover change in the Maasai Mara Game Reserve area (2000 to 2017)

Name	2000 area (km^2)	2017 area (km^2)	Change (km^2)	% Change
Shrubs and grassland	4256	3618	−638	−14.99%
Barelands	394	2449	2055	521.57%
Wheat farms	1441	1813	372	25.82%
Forest	1478	868	−610	−41.27%
Thickets	1464	285	−1179	−80.53%
Sum area in (km^2)	9033	9033		

Wildlife Location Suitability and Tourism Pressure on the Maasai Mara Game Reserve

Moreover, high-resolution images, when available, have the potential to provide closer analysis of the pressure of the tourist traffic, their movement in the game reserve, and the impact of the wildlife on the vegetation biomass. In addition, real-time wildlife tracking systems mounted on selected animals enable easy monitoring of their location at any time. A similar process is used in mobile tracking of vehicles to prevent off-track traffic that highly compromise the integrity of game reserve ecosystems. This plays an important role in movement and behavioral analysis for animals and tour tracks across a landscape through positional analysis to track the animals' location in relation to dynamic features, such as livestock herds and stationary geographical features such as roads, paths, fences, and houses. This can support to direct tourists to a location with optimal proximity for wildlife viewing. The date, time, latitude, and longitude data in the global positioning system (GPS) tracker is utilized to calculate the distance between locations, travel speed, paths, direction, and analysis of spatial and temporal variations in behavior of the object being tracked. GPS data helps monitor movement patterns and support re-directing traffic to reduce pressure from degradation hotspots and is, thus, vital for tourism planning and infrastructure development (Bhandari 2014).

A GIS Application for Ecosystem Management in the Nairobi National Park

In the course of a second case study, the below sub-section illustrates how GIS technology has been applied in wildlife and tourism resources management and conservation at the Nairobi National Park.

Nairobi National Park (NNP) was established in 1946 to safeguard the wildlife that roamed the Athi-Kaputei plains to the east and south of Nairobi Railways Station. It lies between latitude 1°19'47.68" and 1°26'59.99"S, and longitude 36°45'36.27" and 36°58'12.38"E, and occupies an area of 117 km^2 or about 16.8% of the Nairobi county city area (i.e., 649 km^2). Worldwide, NNP is the only open game park within a city and is one of the largest green areas in a city, making it a key place identity for Nairobi as a city with a carbon sink. The National Park boasts a large and varied wildlife population making it of high heritage and biodiversity value to the city. The park is home to two of Kenya's Big Five: the lion and the buffalo. Other wildlife species evident in the park include giraffes, elands, zebras, antelopes, gazelles, ostrich, as well as over 400 bird species (Kenya Wildlife Service, 2018). The park's significance played out in April 2016, when it was used to destroy 105 tons of elephant ivory and 1.35 tons of rhino horns, which translated to 6,500 poached elephants and 450 killed rhinos, respectively (Kahumbu 2019). The site is presently a monument, frequently visited by tourists. Other attractions are the Nairobi Safari Walk and the animal orphanage.

Regrettably, the NNP is threatened by unplanned urban sprawl around the park, increased infrastructure development within the park, rock mining, as well as settlements at the Kitengela migration corridor and increasing industrial pollution from the industries within the proximity of the park's boundaries. The urban sprawl and settlement have encroached into the Kaputei plains as evidenced by the development of the peri-urban areas of Kitengela, Ongata Rongai, Kiserian, and Isinya (Lafforgue 2018). This has greatly affected the non-gazetted and unsecured wildlife dispersal area of Kitengela. This area is now highly fragmented, leading to unintended confinement of the wildlife within the 40 km fenced part of the park and the unfenced 24 km part of the park along the Mbagathi River. These developments will, by no doubt, lead to destroy the value of the park as a wildlife area within a city (Kahumbu 2016; Mutanu 2019; Mangat 2020).

Geospatial tools have been deployed to collect data and for monitoring these destructive development trends, the impacts of these developments, as well as the integrity of the ecosystem as a habitat and its support to the biodiversity of the area (Rahman 2010). For example, a subset of the time series Landsat satellite imagery data from 1998, 2008, and 2018 for the NPP park area shows densification of settlement around the park (Figs. 9 and 10). More precisely, the built-up area increased by 91 km^2 from 11 km^2 in 1988 to 102 km^2 in 2018 (Table 3), and the dense grassland decreased by 140 km^2 from 284 km^2 in 1988 to 144 km^2 in 2018, thus indicating an increased ecological pressure on, and fragmentation of, the National Park. Over the years, there has evidently been an increase in human development activities, such as the settlements, construction of roads, and mining activities.

The evidenced changes taking place have adversely affected the wildlife ecosystem from four fronts. Pollution from the industrial area and the settlement area as the entire area along the northern 40 km border to the park drains through the park into Mbagathi River. The pressure on the dispersal area is due to fencing and subdivision of the land from group ranch ownership to individual ownership. Building stone extractions along the tributaries is draining from the southern plains into the Mbagathi River, thereby disrupting wildlife movement. Finally, infrastructure developments through the park, i.e., an oil pipeline, a high transmission power line, and the standard gauge railway (SGR) line, have all used part of the parkland as an easy and cheap alternative despite the obvious impact this will bring to the sustainability of the park through increased fragmentation and pollution (Kahumbu 2016; Mutanu 2019; Mangat 2020).

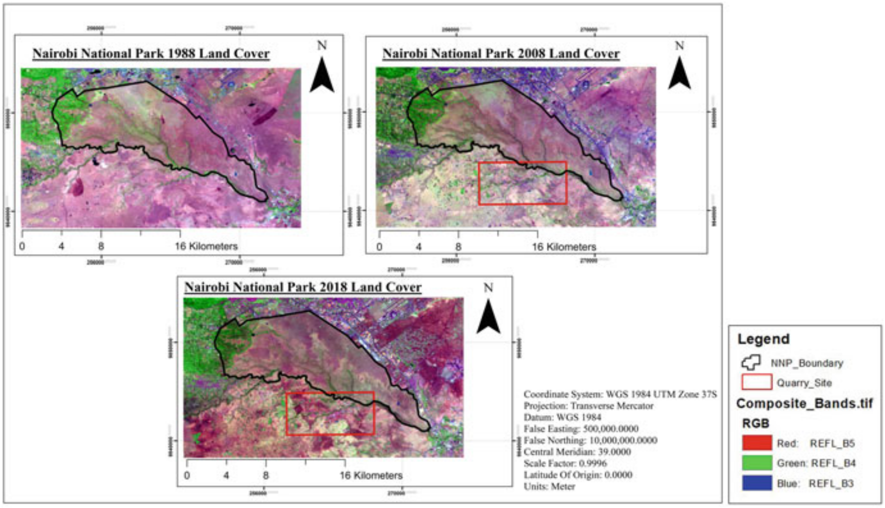

Fig. 9 Landsat composite image extracts for 1988, 2008, and 2019 showing the NNP area and its environs

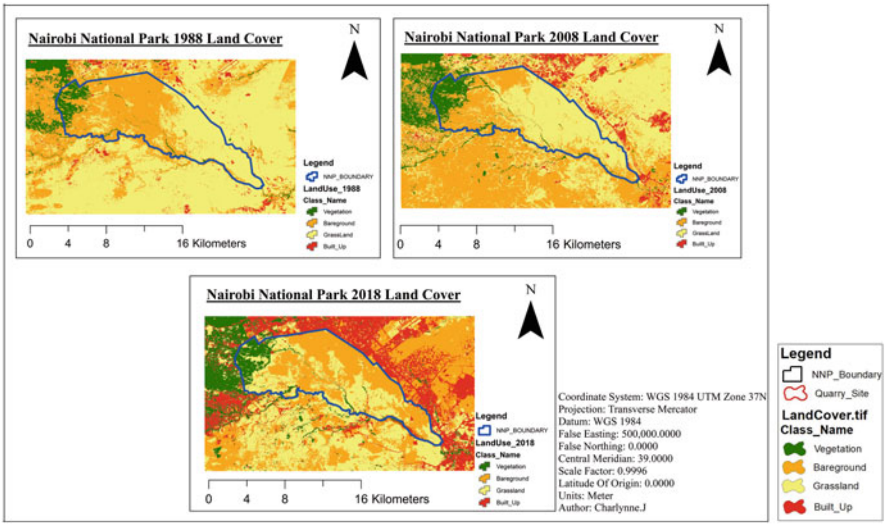

Fig. 10 Classification result of Landsat image extracts for 1988, 2008, and 2019 showing NNP area and its environs. The location of the quarry site is indicated

Table 3 Land cover change as computed from classification of 1988, 2008, and 2018 Landsat images

Land cover	1988 (km^2)	2008 (km^2)	2018 (km^2)	Change 1998–2018 (km^2)
Degraded grassland	142	196	164	22
Built-up area	11	27	102	91
Dense grassland	284	197	144	−140
Vegetation	24	41	51	27
Total	461	461	461	

Infrastructural Development and Habitat Fragmentation

In fact, habitat fragmentation is a major contributor to biodiversity decline, which occurs when natural habitats and ecosystems are split into smaller and isolated patches (Dubovyk 2017). During the portrayed case study, satellite image analysis and classification are used to identify, evaluate, and map such changes for knowledge enhancement and informed decision-making. As expected, the principal cause of habitat fragmentation was infrastructure developments. High-resolution satellite images show a park encroached by a highway, railway line within parkland, and an increased construction intensity of residential housing blocks and industrial buildings close to the park boundary. Such developments release pollutants, which have an adverse effect on the park's ecosystem and its wildlife. The SGR's current re-aligned route encroaches on 87.29 ha of NNP land, which, in fact, is a significant portion of the wildlife habitat. Phase IIA part of the line further cuts across the park along a 6 km stretch. Although the line is constructed using pillars, it occupies and affects a park area of 2,992 m^2, thus heavily interfering with the wildlife ecosystem.

Human Settlement and Mining Activities

The growth in human population and the accompanying need for land due to urbanization has cut off and threatened the traditional migration routes of migrating animals, especially during the dry season. While the wildlife is transiting in search for pasture, they tend to reach the southern pastures by traveling through the Athi plains of Kitengela. However, human settlement and quarrying activities which in the long run have affected the fauna and the landscape, are now hindering the wildlife freedom of movement (Peña et al. 2015). The quarry activities taking place to the south of NNP (Fig. 11), for example, created deep and high walls that prevent wildlife movement across them.

Quarrying and mining activities carry the potential of destroying habitats and the species within the environment around it. It results in environmental impacts, such as changes of ground water levels, or surface water, that cause some area to dry out and others to be flooded. Moreover, air pollution, especially dust from cement processing in Athi River, is responsible for stress on and loss of vegetation in the

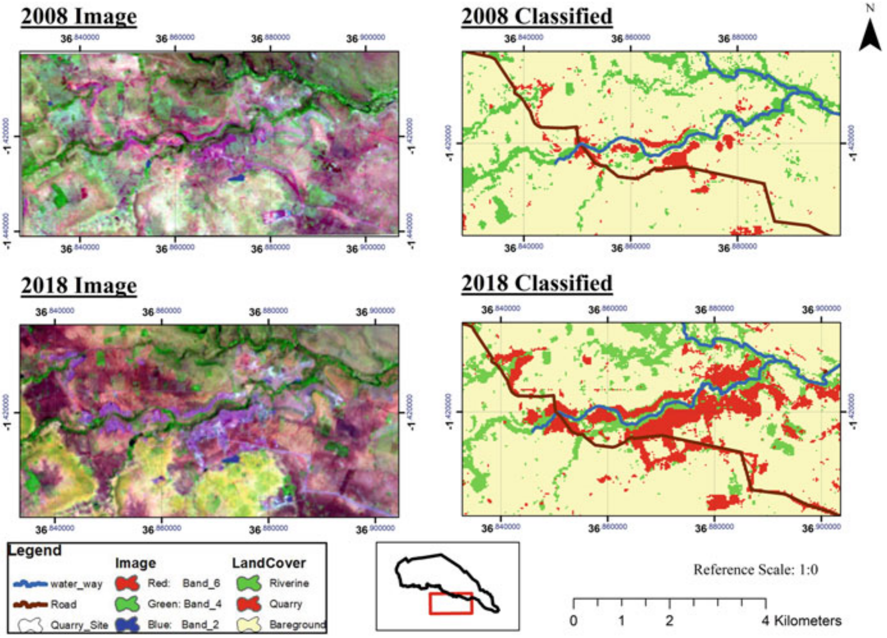

Fig. 11 Extensive mining in the area immediate to the south of the NNP

Table 4 Land cover change within the mining area presented in Fig. 13

Land cover	2008 (km^2)	2018 (km^2)	Change (km^2)
Grassland	33	28	−5
Quarry site	1	5	4
Riverine vegetation	4	5	1
Area (km^2)	38	38	

area. The computed size of the loss of the Riparian area from the current image analysis between 2008 and 2018 shows an increase of the quarry area by 4 km^2 (Table 4).

Wildlife corridors are critical components for ecological integrity and the long-term survival of the NNP ecosystem (Dubovyk 2017). Mining creates an environmental disaster, with concerns on the hydrological alteration that is crucial to sustainability of river base flow and as a source of water supply to the local communities, their livestock, as well as the animal wildlife. More precisely, unstable stream channels occasioned by mining and excavating activities are inhospitable to most aquatic species and lead to habitat disruptions and overall decline in biological diversity and productivity. Quarrying effects are long lasting and irreversibly affect land use in an area as seen in Fig. 12. Thus, appropriate rehabilitation recovery efforts of the ecosystem to an acceptable facsimile are a crucial task.

Fig. 12 Impact of quarrying on the landscape, the ecology, and grazing potential of the land

As shown in this chapter, GIS and satellite remote sensing technologies can effectively be used to map and analyze the extent and magnitude of habitat degradation and fragmentations in order to provide information vital for new policy formulation and implementation concerning the natural environment. By doing so, these technologies will positively affect the wildlife ecosystem as vital and unique components of Africa's tourist attractions (Bhandari 2014; Ayiemba et al. 2015; Boitt 2016; Maasai Mara Wildlife Conservancies Association 2019).

Conclusions

This chapter discussed the general functionalities and application principles of GIS in different usage scenarios. GIS and remote sensing applications are increasingly influencing positive change, especially in complex triple-bottom problem solving (ESRI 2010), including tourism management and planning. A similar conclusion is drawn by Avdimiotis and Christou (2008), namely, that GIS is a strong and effective tool for tourism planning and decision-making. In fact, GIS brings significant value to tourism-related decision-making through data analysis, modeling, and forecasting. Nevertheless, a literature review focusing on GIS applications in tourism management, planning, and marketing suggests a limited use of the technology due to limited awareness of its functionality and perceived cost of the technology. Mcadam (1999) and Sureshkumar et al. (2017) concur with this indication in their studies on the scope and value of GIS in tourism.

In tourism development and research, GIS has been used to study ecosystem biodiversity, their value as a tourism product, and the challenge they face from human development (Feng and Morrison 2002; Christ et al. 2003; Rahman 2010; Norizawati et al. 2013; Abomeh 2017; Cvetkovi and Jovanovic 2016). In tourism planning, GIS has been used to describe and identify tourism infrastructure elements, such as visitor centers, hotels, trails, and field situation using interactive digital maps that informs decision-making (Jovanovic and Njegus 2008). The technologies have been used to promote, plan, implement, manage, and market tourism resources and to bring their value to the knowledge of the tourists. This makes it possible to locate and analyze the characteristics of potential customers (Brenes-Bastos et al. 2014).

The discussed two case studies of the Maasai Mara Game Reserve and Nairobi National Park in Kenya demonstrate the use of GIS and satellite-based remote sensing technologies. Findings clearly indicate a large amount of habitat loss triggered by human disruptions, such as deforestation, ecosystem fragmentation, and environmental pollution. These impacts on ecosystem are particularly threatening wildlife biodiversity but also show negative effects to the local tourism industry, which strongly depends on wildlife reserves and national parks. A research on Mau Forest Complex by Swart (2016) concluded that the main land use changes in the period 1973–2013 were loss of forest and rangeland, while small-holder agriculture expanded to the detriment of the Mara ecosystem. In his research on Nairobi National Park Situation Analysis, Lafforgue (2018) showed that the continuous expansion of urban centers in the peri-urban areas of Nairobi and the various land use changes throughout this dispersal area is negatively affecting the stability of wildlife populations. This is certainly putting the future of NNP as a wildlife reserve and a significant tourist attraction in serious jeopardy. In addressing the challenges the two ecosystems under study are facing, GIS technology turned out to be highly effective in managing, analyzing, and visualizing disruptive ecological dynamics that, in the end, not only are negatively affecting wildlife biodiversity but also will destroy the attraction basis of typical African tourism destinations. Nairobi's Tourism Research Institute (2018), in its report on tourism sector performance in 2018 stated that the travel motive of wildlife accounts to 73% of all tourists visiting Kenya.

Moreover, in his research on Mara ecosystem, Ayiemba et al. (2015) concluded that climate change and occupation of the Mau Forest Complex is negatively affecting wild animals, thus causing further changes in the breeding grounds, animal populations, and migration routes and patterns. Behind this background, land fragmentation, human settlement, and poorly planned urban developments around wildlife dispersal areas are posing a major threat to wildlife population (Kiboro et al. 2016). With a forest cover change and vegetation cover reduction by 30.2% and 22.8%, respectively, between 2000 and 2017 due to conversion to farmlands and settlements, the impact on the ecosystem is real and dramatic. In addition, the anthropogenic pressure on the Maasai Mara Game Reserve in the same period has provoked a loss of grassland biomass from 2449 km^2 to 394 km^2 aerial coverage. The analysis of Nairobi National Park on the other hand showed that the Kitengela wildlife migration corridor has completely been encroached by human settlement and compromised by mining activities. Thus, we can highly recommend applying GIS and remote sensing applications for mapping the pressures of human development on ecological systems. These tools serve as valuable resource to continuously monitor and critically assess the environmental health as a sine qua non condition of tourism in Africa. Thus, if GIS and remote sensing applications are used more frequently for monitoring the health of ecosystems, they support the sustainable management and planning of local tourism (Bahaire and Elliott-White 1999; Bunruamkaew and Murayama 2012; Cvetkovi and Jovanovic 2016).

More recently introduced technologies, such as cloud-based storage, big data, Internet of things, as well as machine learning and their integration with social media platforms and GIS, will greatly improve tourism management, marketing, and planning (Zanker et al. 2009; Fuchs and Höpken 2011; Fuchs et al. 2013; Höpken et al. 2015; Werthner et al. 2015; Höpken et al. 2018). However, the need for resilience in tourism in the face of global risks from economic turn downs, environmental hazards, terrorism, and pandemics, as witnessed by the new Corona virus Covid-19, requires a new type of transformative e-tourism research (Werthner 2019; Gretzel et al. 2020). GIS offers a valuable supportive role in mapping areas of adverse impacts, auditing conditions and the suitability of geographical areas, and identifying conflicting interests and problematic relationships in the human-geographical complex (Ioannides and Gyimóthy 2020). With consistent spatial data on tourism locations and their characteristics and tourist flows, GIS applications will continue to grow on importance in supporting tourism planners and marketers alike in developing, implementing, and managing sustainable tourism strategies in the future.

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