The Mayas Wetlands of the Dinder and Rahad: Tributaries of the Blue Nile Basin (Sudan)

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Abstract

Mayas wetlands forms an important ecological zone in the arid and semiarid Sodano – Saharan region in Dinder and Rahad basins. They are the most unique feature of the Dinder National Park (DNP) and one of its three major ecosystems. "Mayas" is a local name for floodplain wetlands that are found on both sides along the Dinder and Rahad Rivers. According to DNP authority, there are more than 40 mayas that are part of the rivers Dinder and Rahad ecosystems inside the DNP. They are the main source of food and water for wildlife (herbivores) especially during the dry season which extends from November to June. The mayas support large communities of wildlife and provide a refuge for a large number of migratory birds. Recently, the Dinder River has experienced significant changes of floodplain hydrology (i.e. dryness of some of the major mayas), and the reasons are not fully identified. This has significant negative implications on the mayas ecosystem functions and services. Thus, understanding the climate variability and its hydrological impacts is important for water resources management and sustainable ecosystem conservations.

Keywords

Dinder and Rahad basins · Dinder National Park · Mayas ecosystem

Introduction

"*Mayas*," a local name for riverine wetland, are found along the Dinder and Rahad tributaries of the Blue Nile basin in Sudan. They are the most important features in the Dinder National Park (DNP), as they are the main source of food and water for wildlife during the dry season from November to June (Abdel Hameed et al. 1997). The DNP (10,291 km^2) was proclaimed as a national park in 1935 following the London Convention for the Conservation of African Flora and Fauna (Dasmann 1972). It is located in the Dinder and Rahad river basin in the southeastern part of Sudan next to the Sudan-Ethiopian border, between longitude 34°30′ and 36°00′ east and latitude 11°00′ and 13°00′ North (Fig. 1).

Mayas are formed by the combination of a river with its seasonal inflow pattern flowing into a relatively flat area where the channel flow is restricted by gentle gradient, and the river channel is braided and meandering. A braided river is one of the river types that consist of a network of small channels separated by small and often temporary islands called braid bars. Braided streams occur in rivers with high slope and/or large sediment load (Schumm and Kahn 1972). A meander is a bend in a sinuous watercourse or river, forming when the water flow in a stream erodes sediments from the outer banks (concave configuration) and deposits them on the inner banks (convex). The result is a snaking pattern as the stream meanders back and forth across its down-valley axis (Julien 2002). An oxbow lake forms when a meander bend becomes cut off from the main stream.

Mayas have formed due to the meandering nature of the river on both sides of the present channel of the Dinder River. Their areas vary significantly from 0.16 to 4.5 km^2. Generally, mayas are flat with slight and/or no clear banks (Fig. 2). The

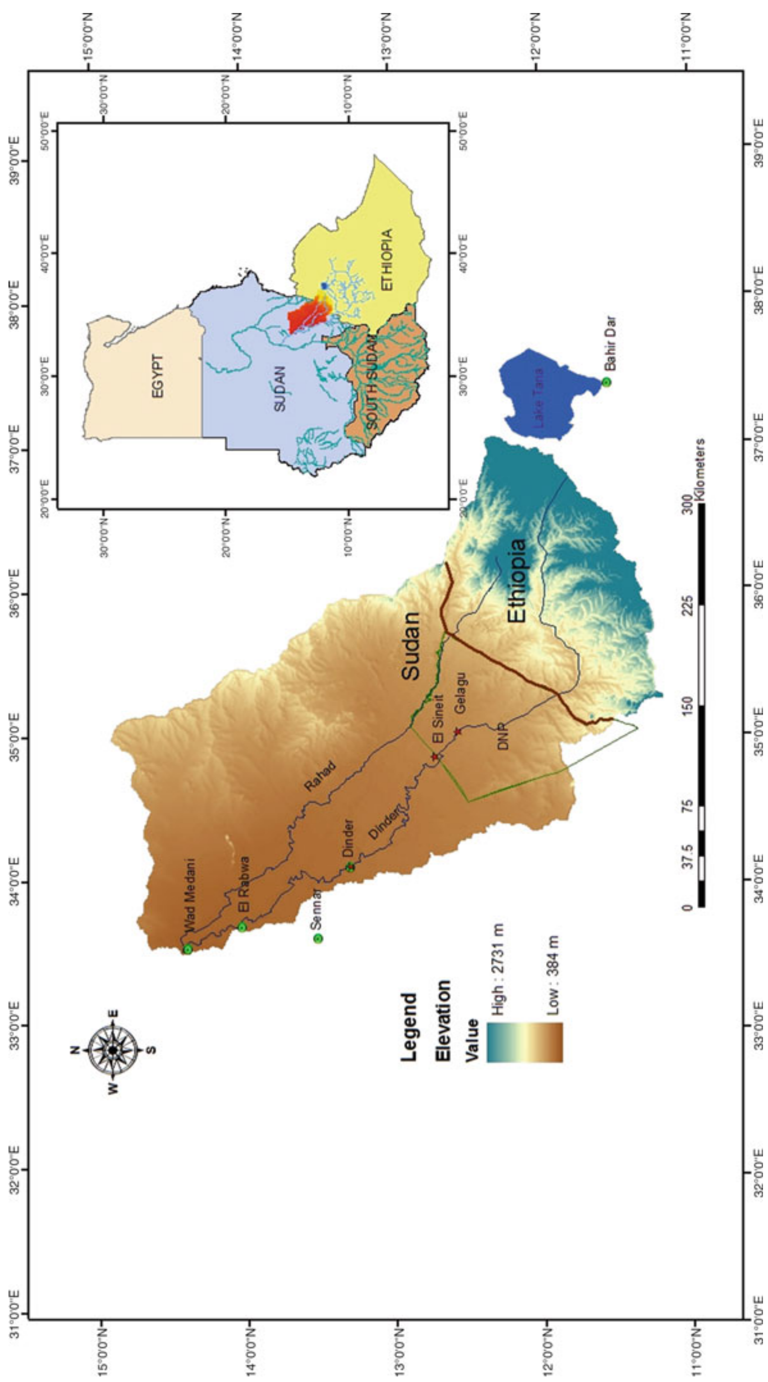

Fig. 1 Dinder National Park location and topography map (legend shows maximum and minimum elevation)

Fig. 2 Mayas – the main source of water and food for wildlife during the dry season in the DNP (Photographs by K. Hassaballah © Rights remain with the author)

feeder channel connecting the river with the mayas is also not well defined in many cases. Some mayas dry up soon after the end of the rainy season, and others remain wet throughout the dry season. Recently, the DNP authority started to manage the mayas water levels with the objective of supporting wildlife, and some of the dry mayas are kept artificially wet by pumping from groundwater.

This chapter aims to highlight the ecological importance of the mayas of the DNP and to describe the mayas ecosystem services, biodiversity and threats, with more emphasis on the hydrological threats, as well as ongoing research to improve planning for mayas ecosystem conservation.

Hydrology of the Mayas

The Dinder and Rahad River basins have a complex hydrology, with varying climate, topography, soil, vegetation, and geology as well as human interventions. The Dinder catchment area is about 37,600 km^2 and its effective catchment in Ethiopia is about 14,000 km^2. The Dinder River average flow is about 3.0×10^9 m^3/a with monthly precipitation records indicating a summer rainy season, with highest totals in the months of June–September (Block and Rajagopalan 2006). The rains during this season account for nearly 90% of total annual precipitation in the lower part near Sennar town, while in the Ethiopian highlands, approximately 75% of the annual precipitation falls during the long rainy season June-September (Shahin 1985).

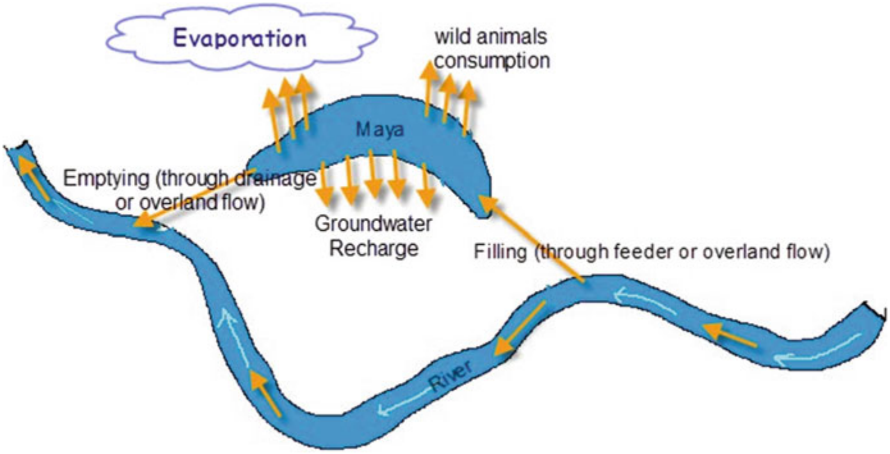

Fig. 3 Schematization of the functioning of the mayas hydrological system

Although the flow of the Dinder River is seasonal, large areas of mayas used to be inundated each year and then become dry as the spill drains or evaporates, or due to wildlife consumption, or through infiltration to recharge groundwater (Fig. 3). The ability of mayas to store significant amounts of runoff depends on the hydrology and storage capacity of individual mayas and the permeability of the subsurface. Man-made channelization of feeders to enhance the filling of mayas also complicates their hydrology.

The hydrology of mayas can be very complex. Some mayas have relatively well-defined channels while others do not. Some retain water throughout the year, while others may be dry for part of the year. Depending on the type and condition of vegetation and the amount of open water, evaporation rates will vary greatly. The mayas are also affected by surface drainage and groundwater recharge. Antecedent conditions of soil moisture and the amount of water already stored in the wetland will affect how much storage is available for runoff.

During recent years, the hydrology of the mayas has experienced significant changes. This has large implications on the ecosystem of the Dinder National Park. In particular, engineering solutions that have been undertaken in order to support wetland conservation in DNP such as channelization of the mayas feeders and excavation of mayas for removing sediment need to take account of land use and land cover changes and their impacts on runoff.

An overview of the hydrological characteristics of the Dinder and Rahad basin follows. Little baseline data has been obtained for the catchment near the border in and outside of the Sudan; therefore the climate data presented in this section has been obtained from the following sources:

http://entroportal.nilebasin.org/OSIKit/Pages/subBasin.aspx?bid=2
http://www.climate-charts.com/World-Climate-Maps.html#rain

Rainfall

The rainfall counts for 1,200 mm in the Ethiopian highlands near Lake Tana and reduces to 900 mm at the highland plateaus at the upper part of Dinder and Rahad catchment. In the middle course as in Gelagu station (inside the DNP) mean annual rainfall is reduced to less than 600 mm and further in the lower course (in Sudan) it is reduced to less than 400 mm at the village El Rabwa at the mouth of the Dinder sub-basin.

Figure 4 shows the variations in the monthly mean rainfall at the Dinder station downstream of the Dinder catchment, the Gelagu station within the mayas area inside the DNP and at Bahir Dar station further upstream of the catchment (Lake Tana). Bahir Dar is the nearest rainfall station to the upper catchment of the Dinder and Rahad with long historic records. The mean annual rainfall varied from 470 mm/a at Dinder station to 600 mm/a at Gelagu and up to 1,000 mm/a at Bahir Dar. Figure 5 shows the annual flow of Dinder River at Dinder station.

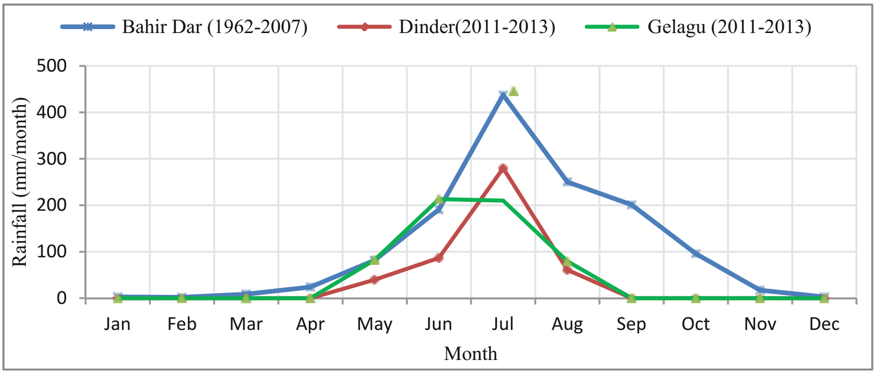

Fig. 4 The monthly mean rainfall at three different locations within the catchment

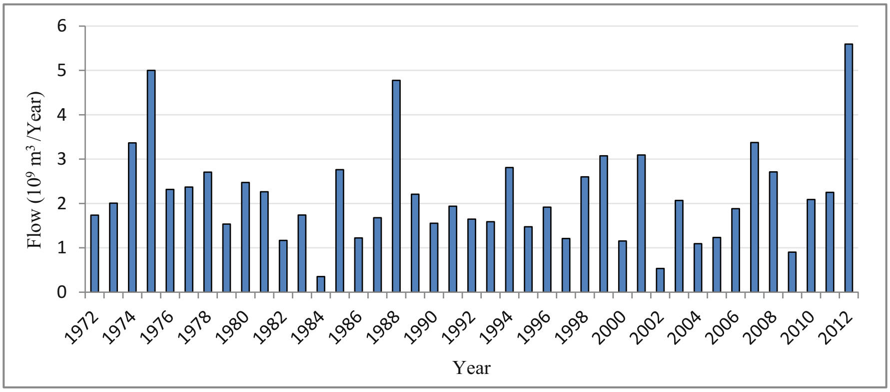

Fig. 5 Annual flow of Dinder River at Dinder station

Evaporation

Mean annual evaporation follows similar trend as that of temperature. In the highland plateau of the sub-basin, the evaporation rate is observed to be 1,150 mm/a. The low-lying area (below 1,500 masl) located at the foot of the highland plateaus, up until the border and a little beyond, experiences mean annual evaporation that ranges from 1,600 to 1,935 mm and covers some 30% of the sub-basin. Further in the Sudan lowland area at Gelagu station, evaporation is some 2,300 mm and further downstream at Dinder is observed to exceed 2,500 mm (Block 2007).

Temperature

Temperature in the highland plateau of the sub-basin is pleasant when the mean annual temperature does not exceed 20 °C. Large proportions of this highland exhibit mean annual temperatures of 18 °C. In the western low-lying area of the sub-basin, around the border, mean annual temperature is in the order of 25 °C. Further in the downstream portion of the sub-basin, around the Gelagu station, mean annual temperature is estimated to be 27 °C. In the lower course, at the mouth of the sub-basin, temperature exceeds 30 °C.

Humidity

Most likely it could be resulted from severe land and environmental degradations; nearly 80% of the sub-basin is identified to have a mean annual relative humidity of less than 55%. It is only 20% of the sub-basin with relative humidity exceeding 55%. This portion of the sub-basin is confined in the Ethiopian Plateau.

Biodiversity

The drainage system of the park includes both the Dinder and Rahad rivers and their tributaries and mayas. Dasmann (1972) classified the vegetation of DNP into four categories: wooded grassland, open grassland, woodland, and riverine forest. While, the vegetation assessments by Hakim et al. (1978) and Abdel Hameed et al. (1996) recognized three types of ecosystems, namely, the *Acacia seyal – Balanites aegyptiaca* ecosystem, the riverine ecosystem, and the mayas ecosystem. These assessments show that all three ecosystems are composed of diverse communities with relatively few species.

The mayas support large numbers of wildlife during the dry season and a smaller number during the wet season (Dasmann 1972). Yousif and Mohamed (2012) reported that waterbuck *Kobus defassa harnieri*, reedbuck *Redunca bohor cottoni*, tiang *Damaliscus korrigum tiang*, buffalo *Syncerus caffer aequinoctialis*, oribi *Ourebia ourebia montana*, roan antelope *Hippotragus equinus bakeri*, warthog *Phacochoerus* *aethiopicus aelinani*, and bushbuck *Tragelaphus scriptus bor* are the major herbivores that inhabit the DNP, while other animals such as baboon *Papio anubis* and red bussar monkey *Erythrocebus patas* are numerous. The major predators are lion *Panthera leo leo*, striped hyena *Hyaena hyaena dubbah*, spotted hyena *Crocuta crocuta fortis*, and black-backed jackal *Canis mesomelas*. The mayas also provide habitat for various birds such as ostrich, storks, herons, pelicans, starlings, and others.

Hakim et al. (1978) showed that the ecosystems are composed of different plant communities with relatively few species. The dominant trees in the clay plains are *Acacia seyal* and *Balanites aegyptiaca. Acacia fistula* is associated with *A. seyal* in areas of heavy clay which are slightly wetter than the general plain. *Combretum* sp. and *Intada sudanica* are found in drained silty soils. *Combretum hartmannianum* and *Anogeissus schimperii* are the most abundant trees along the border of Ethiopia. *Hyphaene thebaica* and *Acacia siberiana* occur along the Dinder River in the light-colored soils with varying amount of silt. *Sorghum sudanense*, *Becheropsis uniseta*, *Hyparrhenia* spp. and *Aristida plumosa* represent the dominant grasses in the park. Shrubs are limited to a few species, the most common being *Dichrostachys cinerea*.

Ecosystem Services

The DNP ecosystems provide a huge range of ecosystem services to the communities living around the park, as illustrated in Fig. 6 below. These services include purification of air and water, regulation of rainwater runoff and drought, soil formation, seed dispersal and nutrient cycling, opportunity for formal and informal education and research, climate stabilization through carbon sequestration, and moderating extremes of temperature and wind. In addition, the DNP has large potential for tourism.

The provided services can be grouped as (a) provisioning services (e.g., foods such as fish and honey, fuel wood, and medicines that used to be extracted from biota) for wildlife conservation staff and for the local communities living in the area around the DNP; (b) regulating services (e.g., flood, climate, and groundwater recharge); (c) high potential opportunity for tourism and educational services (e.g., an attractive place for local people and foreign visitors and opportunities for research and training); and (d) supporting services that maintain the conditions for life on Earth (e.g., nutrient cycling and habitat for wildlife).

Conservation Status

Wildlife management and biodiversity conservation in the DNP are challenging (Thomas et al. 2003). Yousif and Mohamed (2012) studied trends of poaching, livestock trespassing, fishing, and resource collection from 1986 to 2010 inside the DNP. This study showed that the DNP is confronted with problems such as surface water shortage during the dry season, trespassing livestock, poaching and increased

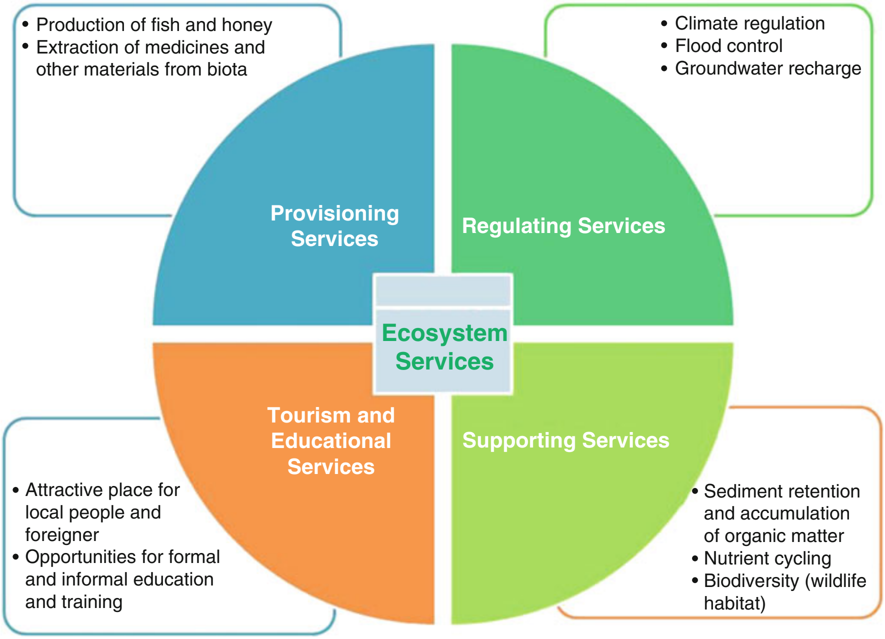

Fig. 6 Ecosystem services provided by the mayas

human settlements in surrounding areas, and consequently serious deterioration in the densities of wild animals and their related habitats. Bashir and Tong (2004) studied the protected areas in Sudan. They reported that the government of the Sudan had shown strong commitment to wildlife conservation reflected by national membership of international and regional agreements such as the African Convention, the World Heritage Convention, and the Convention on Biological Diversity. In response to the requirements of such international commitments, some efforts have been undertaken to assess the status of biodiversity and to develop an action plan by the Government of Sudan, its environmental agencies and NGOs with donor support from the United Nations Development Programme (UNDP), the World Conservation Union (IUCN), and the Global Environment Facility (GEF).

Thomas et al. (2003) studied the environmental threats and opportunities in Sudan and reported that from 2000 to 2004, the Higher Council for Environment and Natural Resources (HCENR), as part of its early efforts to accomplish its mandate, collaborated in the Sudan Country Study on Biodiversity as part of the National Biodiversity Strategy and Action Plan Project (SUD/97/G31) and with technical assistance from the IUCN and funding from the GEF implemented the Dinder National Park Project (DNPP). The main objectives of the DNPP were the conservation of biodiversity of the park and encouraging the positive interaction of the surrounding communities in the conservation and sustainable use of biodiversity in the park through the application of Biosphere Reserve concepts. The project was implemented jointly with the Wildlife Conservation General Administration (WCGA) and the Sudanese Environmental Conservation Society (SECS) and succeeded in developing a management plan for DNP involving all stakeholders adopting Biosphere Reserve concepts (Ramzy et al. 2012). In contrast, Thomas et al. (2003) reported that the outcome of this project, despite its length, was rather shallow in its treatment of wildlife, offering little more than academic or anecdotal discussions on the topic although providing considerable narrative insights into the forest, insect, agricultural, and fisheries aspects of biodiversity. Consequently, wildlife and biodiversity conservation remains an open issue until more reliable data and information can be compiled.

The Government of the Sudan, through the Ministry of Water Resources and Electricity (MoWRE), and the Eastern Nile Technical Regional Office (ENTRO) have been implementing a number of natural resource management projects financed by the World Bank and other donors. These include the Sudan Community Watershed Management Project (SCWMP) to ensure efficient water management and optimal use of resources. The SCWMP 2009–2015 sought to strengthen relevant local institutions, stakeholders, and systems in order to achieve integrated and sustainable management of watersheds in the project sites. In the Dinder area, the project aimed to reduce pressure on DNP and its biodiversity by providing alternative livelihoods to target groups encroaching on the park and by improving park management. The project's development activities were focused on promoting sustainable utilization and management of natural resources and enhancing livelihoods through the community-based project in selected target villages and communities inside and outside the park. Socioeconomic and biophysical surveys were undertaken, as well as environmental awareness campaigns which led to the election of Village Development Committees (VDCs) in 36 villages in three states (Blue Nile, Sennar, and Gedarif). The project succeeded in the rehabilitation of two mayas. To reduce the pressure on DNP and its biodiversity, the project provided alternative livelihoods to the target communities such as implementing the demarcation and plantation of animal routes within the area surrounding the park, establishment of community forest, reforestation of reserved forest, rehabilitation of range land with range seeds, and rehabilitation and construction of new hafirs (water ponds) within the animal routes to ensure enough drinking water for livestock outside the park.

Threats and Future Challenges

Although the area is relatively rich with a variety of natural resources, it is being impacted by damaging human activities such as intensive grazing, deforestation, poaching, and improper farming practices on steep slopes. These practices have posed a great threat to the sustainable management of the area as well as to its ecosystem integrity and have influenced the wildlife and plant species in the DNP and in downstream areas. The main threats facing the Dinder National Park can be summarized as the absence of proper land use practices surrounding the park, continually increasing size of human population in the Dinder area, and the trespassing of pastoralists (Ali and Nimir 2006).

During the past two decades the area of mayas inside the DNP has significantly decreased due to the temporal and spatial variations in quantities of rainfall, river discharges, and sediment deposition processes, causing many mayas to be subjected to dryness (Abdel Hameed et al. 1997). To sustain the ecosystem, some mayas are artificially watered from boreholes drilled near the mayas, and some are watered during the wet season from the Dinder River using artificial feeders. In many situations this engineering approach has led to over-engineering of the environment (through canalization and impoundment), which seriously reduces the role of the ecological processes in moderating the water cycle. Moreover, it has driven these ecological processes toward further reduction of water quality, e.g., sediment transport, or increase in secondary pollution, e.g., eutrophication (Robarts 1998). As a result, the entire ecosystem of the DNP has become threatened because it largely depends on the mayas. In addition, unlicensed mechanized rain-fed agricultural farms have been established in the areas surrounding the park within the wet season habitats of the wild animals (Abdel Hameed et al. 1999).

Areas around the park have been degraded as a result of mechanized farming and removal of the tree cover. Expansion of mechanized rain-fed agricultural farms around the park has also diminished the natural grazing area available for domestic livestock in the Dinder region (Yousif and Mohamed 2012). Large numbers of sheep and camels used to move from the Butana grasslands to the north of the park in the rainy season each year, while they returned to the banks of the Dinder and Rahad rivers and the Blue Nile during the dry season. Previously, the nomads and pastoralists used to move with their livestock over the extensive areas that are now occupied by mechanized farms or Rahad irrigation schemes bordering the northwest side of the park (Maghraby 1982). Accordingly, they are forced to forage elsewhere, and this has led to increasing invasion of the park by their livestock. Although it is prohibited, such livestock grazing within the park causes competition with wildlife for food and water.

Much of the population of wild animals migrates to habitats outside the park boundaries during the rainy season. However, many of the rainy season habitats near the borders of the park have been destroyed by agricultural activities, and the migrant wild animals are subject to increasing poaching outside the park. Animal poaching in the park during the dry season and other activities greatly affects the ecology of the area, for instance, both poachers and honey gatherers light fires throughout the park.

Recently, the DNP has experienced a serious shortage problem of surface water and green food during the dry seasons. The problem of surface water availability can be considered as a watershed management problem in which the sources of the rivers need to be studied to quantify the impacts of upstream land use on downstream areas. In addition, repeated fires within the area surrounding the mayas inside the DNP have increased the rate of soil erosion in the form of sheet flow, runoff, and silt deposition on the beds of the mayas.

Therefore, an in-depth hydrological study of the basin is crucial for planning and management of water resources as well as wider environmental management. Current research by the authors aims to contribute toward this need by assessing and understanding the interactions between the hydrology, morphology, and ecosystem of the mayas to fill a key knowledge gap for more effective ecosystem management in this important national park. It uses an ensemble of techniques tracing water and sediment fluxes from the source in the upper catchment to the sink at the mayas. This includes long-term trend analysis of hydroclimatology, field measurements, rainfall-runoff modeling, GIS and remote sensing data analysis, floodplain modeling, land-use land-cover changes, and morphological modeling of the river Dinder and its floodplain, with more focus on the mayas within the DNP.

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