Shield Ecoregion

Overview

The Shield Ecoregion of southeastern Senegal stands out for its relatively pristine and semi-natural landscapes. It gets its name from the Precambrian shield of ancient rocks that underlie the complex geology of this part of Senegal. It lies mainly within the Kedougou Region, but also spills over into the Tambacounda and Kolda Regions. This region is also considered part of the Mandingue Plateau, spanning the borders of southeastern Senegal, southwestern Mali, and northern Guinea. The ecoregion harbors some of Senegal's most critical and biodiverse habitats. The high degree of biodiversity reflects the diversity of landscapes and ecosystems, and a relatively well-preserved region of low human population. In addition, the region includes a large part of the large Niokolo-Koba National Park, established in 1951 and more recently classified as both a biosphere reserve, and as a World Heritage for Humanity site. The Park and the zones to the east still preserve a relatively abundant diversity of flora and fauna, including Africa's westernmost populations of chimpanzees, and a variety of antelope. Indeed, the Park itself includes 1500 species of plants, of the 2100 species found in Senegal. Yet, over the past 3 decades, the biological resources of this enclave have been hit by drought and human pressure, threatening this fragile ecosystem. The region has been opened up for transportation and exploitation through new road systems. Just beyond its borders, the Eastern Transition Ecoregion (Tambacounda Region) is the nation's primary source of charcoal. Charcoal production is already making inroads into the Shield Ecoregion. Efforts must be continued to map, monitor and assess the rapid changes buffeting this ecoregion, in order to track and mitigate the human impacts from mining and other pressures on Senegal's last remaining large area wilderness.

Geographic Setting

The Shield Ecoregion occupies all of the Kedougou Region, and parts of southern Tambacounda and eastern Kolda Regions. Geology is the primary feature that sets this region apart. Ophiolitic, granitized, and tightly folded volcanic and sedimentary rocks make up a Precambrian shield (Stancioff *et al*. 1986). The surface geomorphology of low plateaus and hills, terraces, and valleys only hints at the complexity of the underlying geology. Figure 1 presents a digital elevation model of Senegal, showing the considerable variations in relief that set this region apart. The soils are generally gravelly and rocky, with laterite occurring near or at the surface over much of the area. These have been notched by a fossilized hydrographic system. The fossil valleys provide bottomlands where the bulk of arable land is located. Until recently, the great distance from Senegal's population centers and the very limited agricultural potential of the region has deterred migration to the region. Population and human pressure has been low (4 people/km^2), with widely scattered villages lining up along the fossil valleys.

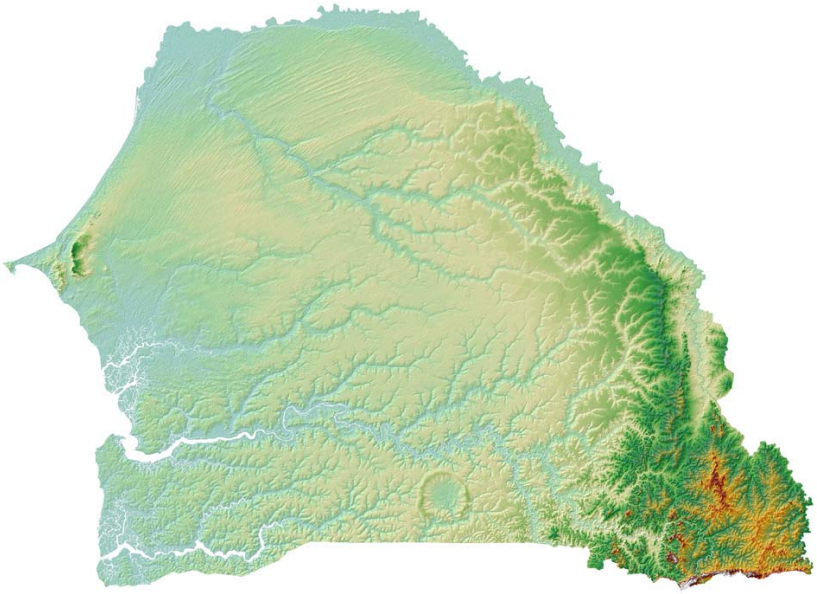


Figure 1. A digital elevation model of Senegal produced from Shuttle Radar Topographic Mission data. Note the complexity in the geomorphology of southeastern Senegal.

Vegetation Cover and Diversity

A Sudanian deciduous wooded savanna constitutes the main vegetation type of the region. Locally, however, higher vegetation densities occur, forming woodlands and dense forests. Figure 2 presents a portion of the Vegetation Cover Map of Senegal published by Stancioff et al., 1986. The map shows some of the diversity of vegetation types, particularly the abrupt changes from uplands and plains to valleys.

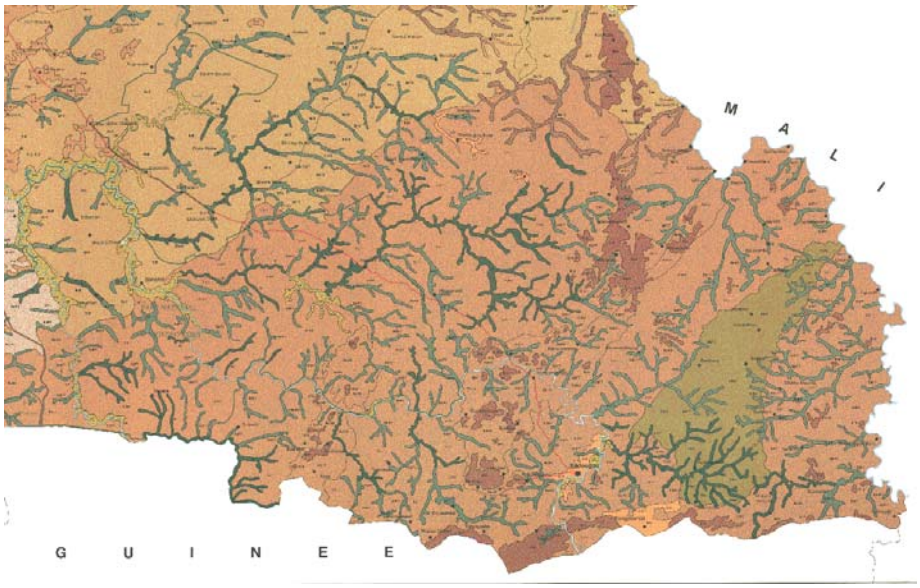


Figure 2. A portion of the Map of Vegetation Cover of Senegal, hinting at the complexity of the vegetation formations in the Shield Region. The map provides a general overview (legend not shown). Riparian vegetation and gallery forests dominate some of the many valleys from an ancient drainage system. Agricultural clearings are still a relatively minor component of the overall land cover of the region, but this is beginning to change. Map source: Carte du Couvert Végétal du Sénégal. Sheet 4, 1:500,000, 1986, Remote Sensing Institute, Brookings, South Dakota.

Based on his detailed field observations the 1930s, Trochain (1940) found that the dry woody formations that cover the region form heterogeneous communities, with no one tree species dominating the floristic composition. The communities are floristically rich. We found over 150 woody species at 57 monitoring sites established in 1984 and revisited in 1994-97 (Stancioff *et al*. 1986). Species that have become rare in the Eastern Transition Ecoregion (Tambacounda) are still common here. To the south, along the Guinea border, the composition takes on a Sudano-Guinean character as plants from the Guinean bioclimatic region become numerous, particularly on the hydromorphic soils in valleys.

The predominant vegetation formations of the hills and plains of much of the Shield Region consist of a complex wooded savannas and open woodlands (figures 4 and 5a and 5b), punctuated throughout the region by open grasslands (locally known as *bowé*) that form on large lateritic outcrops (figure 6). The wooded savannas and woodlands occur on lithosols and regosols of gravelly texture (Stancioff et al., 1986).

Figure 4. View overlooking the canopy of an open woodland typical of much of the land cover of the Shield Region. Wet season aspect taken in October 1994.

Figure 5a and 5b. General aspect of the woodlands that dominate much of the Shield Region. The canopy remains open, with an understory of small trees and tall perennial grasses. Most trees are deciduous. The pair compares the dry season and wet season aspect at the same location.

The tree layer is typically composed of *Pterocarpus erinaceus* (rosewood), *Bombax costatum*, *Lannea acida*, and *Combretum glutinosum*. Scattered associates include *Terminalia macroptera*, *Ostryoderris stuhlmannii*, *Combretum nigricans*, *Sterculia setigera*, *Afrormosia laxiflora*, *Cordyla pinnata*, *Acacia dudgeoni*, and *Daniellia oliveri*. *Combretum glutinosum* tends to dominate the otherwise heterogeneous and relatively rich shrub stratum. The most common small tree and shrub species are *Hexalobus monopetalus*, *Vitex madiensis*, *Strychnos spinosa*, *Lannea acida*, *Pterocarpus erinaceus*, *Bombax costatum*, *Combretum nigricans*, *Hymenocarya acida*, *Acacia dudgeoni*, *Combretum micrantum*, *Ostryoderris stuhlmannii*, *Crossopterix febrifuga*, and *Annona senegalensis* (Stancioff et al., 1986).

The herbaceous layer is dominated by coarse perennial grasses that, unlike the overstory, do not occur in heterogeneous communities. Tall *Andropogoneae* grasses are the rule, mainly *Andropogon amplectans*, *Andropogon pseudapricus*, and *Andropogon gayanus*. *Oxytenanthera abyssinica* (bamboo) can form dense stands in local areas. Numerous forbs also make up part of the herbaceous stratum.

The *bowé*, or open grasslands on the lateritic hard cap surfaces, are usually devoid of woody vegetation. Continuous to scattered grasses and forbs can develop with a few centimeters of soil collect on the laterite. One plant – *Lepidagathis capituliformis* – is found exclusively on the *bowé*. The outcrops of impermeable laterite restrict root penetration, resulting in open, often-treeless meadows.

Figure 6. An aerial view of the one of the many naturally occurring open grasslands that punctuate this region, surrounded by wooded savanna and woodland.

A mosaic of several other vegetation formations occur as a function of the geomorphology, soils, rainfall, fire, and to a smaller degree, grazing and shifting cultivation. The plains and rolling hills of this ecoregion are dissected by numerous shallow valleys whose diverse and rich vegetation break the monotony of the dry upland wooded savannas and woodlands. Many of the hydrophytic species found in these valleys are typical of the Guinean bioclimatic region to the south, since favorable soil moisture condition allow them to survive the harsh and long dry season of the Sudanian bioclimatic region.

Evergreen, closed-canopy gallery forests still occur along some valleys, but they are being fragmented and destroyed by agricultural expansion, and recent mining activities. They are also being degraded by lopping and felling by transhumant herders who seek green browse fodder for their livestock in the dry season. Even some of the more remote

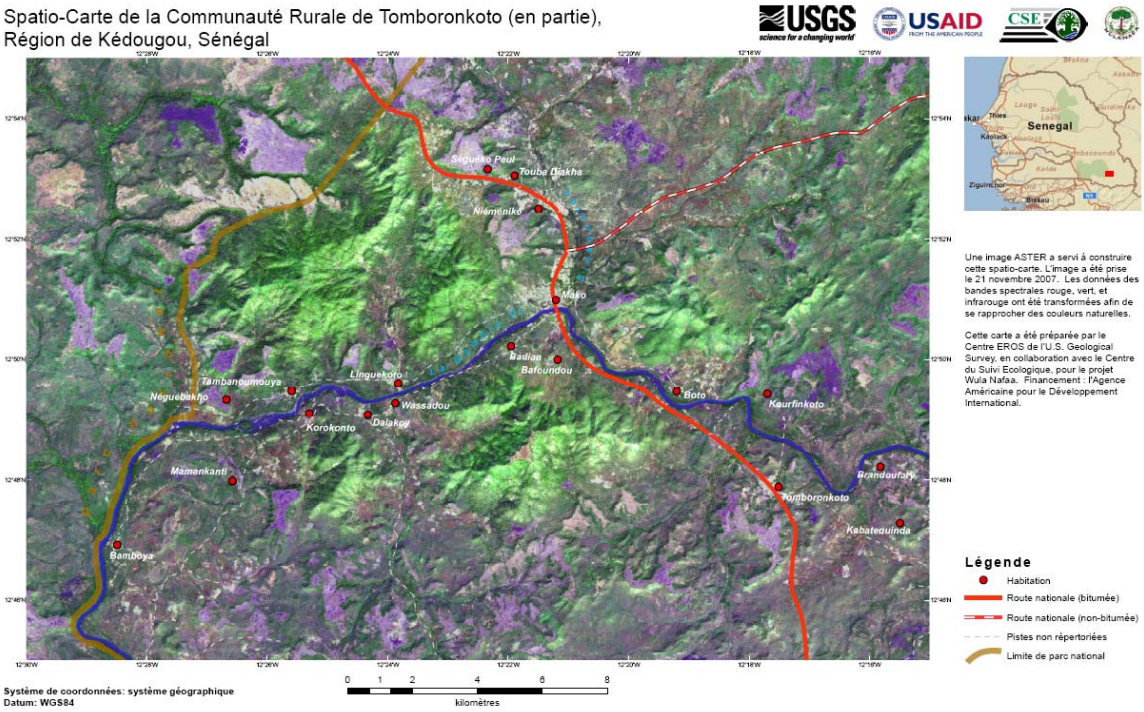
gallery forests are being subjected to the pressure from transhumant migrants. Gallery forests are particularly important habitats for primates. Two species of primates are highly endangered in Senegal – the West Africa colobe bai monkey, and the chimpanzee. The degradation of gallery forests and dense forests caused by illicit mining, bush fires and illicit wood exploitation, which are habitats for these monkeys and apes, are the main threat to these primates.

Gallery forests are the most biologically diverse and rich habitats in the entire ecoregion. They occur in the deeper valleys where the water table is at or near the surface, or where a local spring provides a permanent water source. Gallery formations are dense, usually closed canopy forests. They often transition into somewhat open forest formations where soil moisture lessens, or where they are being degraded by human pressure. Gallery forests create their own microclimate, providing permanent shade, cooler temperatures, and increased humidity. The hydrophytic trees may attain heights of 30m. They are further distinguished by the presence of numerous evergreen Guinean species. While no one species dominates, characteristic tree species include *Ficus capensis, Ficus gnaphalocarpa, Erythrophlaeum guineense, Piliostigma thonningii, Syzygium guineense, Elaeis guineensis, Khaya senegalensis, Parkia biglobosa, Ceiba pentandra*, and *Cola cordifolia*. Shrub and liana species include *Saba senegalensis, Mitragyna inermis, Baissea multiflora, Nauclea latifolia*, and *Raphia sudanica*. Grasses are relatively scarce under the dense overstory. Figure 7 presents an aerial view of a gallery forest.

Figure 7. Vertical aerial view of a dense gallery forest in the Assirik region of the Niokolo Koba Nationa Park. Note the closed canopy, evergreen aspect. Gallery forests

harbor many species from the Sudano-Guinean and Guinean bioclimatic regions, and are key habitats for primates, including a small population of chimpanzees.

Wooded savannas, woodlands, and gallery forests represent three of numerous land cover types found in this complex region. The land cover of the Shield Region has only been mapped at a general scale (figure 2), notably by Stancioff, Staljanssens, and Tappan (1986), and more recently by the Centre de Suivi Ecologique (unpublished and very generalized map). Land cover trends at the national scale were also derived from general land cover maps from 1975 and 2000 by the EROS and AGRHYMET collaborative project, as presented in the West Africa Land Use and Land Cover Trends Project. Detailed land cover maps are needed for many applications, including wildlife conservation, park management, establishment of new reserves and hunting ranches,



community forest management, and monitoring rapid changes occurring as a result of increased human activity. In 2009 we started an ambitious effort with support from USAID/Senegal to map the land cover of the region in unprecedented detail. The effort is ongoing, but early examples of the detailed land cover are presented in figures 8 and 9. Map compilation is being done at 1:50,000 using ASTER and high resolution imagery, and final maps will be published at 1:200,000.

Figure 8. Image-Map based on ASTER satellite imagery showing some of the complex land cover and pronounced local relief in part of the Rural Community of Tomboronkoto.

The Gambia River passes through this area. A portion of the Niokolo Koba National Park can be seen at left. This image was used to produce the land cover map shown in Figure 9.

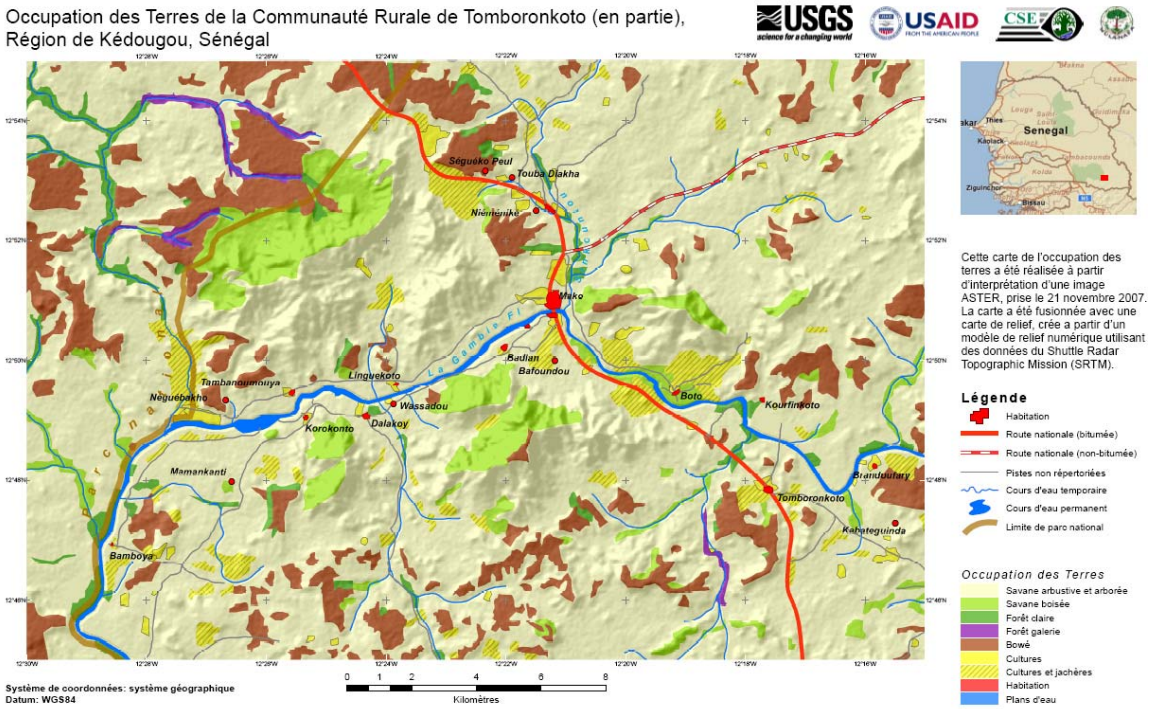


Figure 9. Land Cover map of part of the Rural Community of Tomboronkoto. Note the scattered presence of human activity, seen though settlements and cropland (yellow patches). Critical, high biodiversity habitats include gallery forests (purple) and forests on steep slopes and along valleys. Agricultural encroachment into the Niokolo Koba National Park is visible, left side of map. The map is an example of a detailed land cover map currently being produced for the entire Kédougou Region, including the Park.

Land Cover Trends

Results from the land-use and land-cover trends analysis published by Tappan et al. (2004) showed a relatively stable situation for the period 1965 to 2000. In 2000, 98 percent of the region was still blanketed by diverse natural vegetation types. The agricultural area had only increased from 1.6 to 2.0 percent in 35 years. A 1994 airborne video survey showed little pressure on the natural vegetation, including virtually no charcoal production. Woody cover generally ranged from 10 to 30 percent. In the Niokolo-Koba National Park, the percent cover range was generally higher than other areas, occasionally reaching 40 percent. Field surveys in 1984 and 1994-1997 confirmed the physical and biological stability of the woody vegetation throughout the region. Exceptions to this are found around the fast-growing mining towns, and in areas of expansion where gallery forest is being converted to agriculture (0.9 percent in 1965, 0.4 percent in 2000). These riches bring vulnerabilities that will need to be carefully managed in the near future.

Niokolo Koba National Park

A large part of this ecoregion falls under the protection of the Niokolo-Koba National Park. The Park covers some 913,000 hectares, and contains some of the most pristine Sudanian type flora and fauna left in Africa. The floristic diversity remains high, preserving many of the genetic resources that are being lost in other parts of Senegal. It is among the last Sudanian areas with legislated protection in Africa. In 1990, a project began to create a transnational park, joining Niokolo Koba to the Badiar Park in northern Guinea. This was officially achieved, resulting in the Niokolo Badiar Transnational Park. The objective between the two countries was to help protect and preserve the some of the last remaining populations of large mammals in West Africa.

The Park represents less than 5 percent of the land area of Senegal, yet is home to 1500 species of plants (Adam, 1971; Schneider and Sambou, 1982), or over 62 percent of the flowering plants of Senegal. The diversity of this flora is determined by environmental factors including soil type, moisture, and topographic position. Soil type and presence of water varies with geomorphology. These variations in terrain create development conditions for different vegetation formations characterized by their density, structure, and floristic composition. Figure 10 shows the diverse landscapes of the Park.

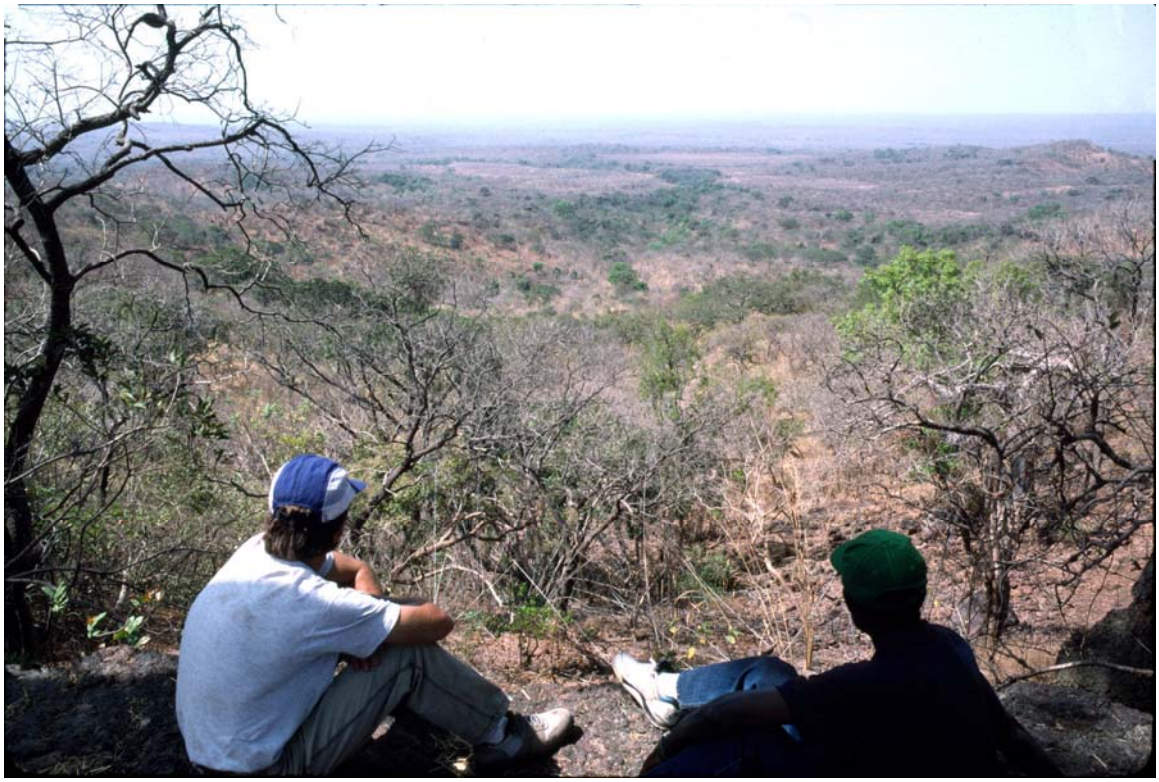


Figure 10. A view of the diverse landscapes of the Park from its highest peak – the Mont Assirik. Note the evergreen gallery forests in the distance.

The Park can serve as a benchmark for evaluating climate change affects on the vegetation, since human pressure on the vegetation resources is relatively minor (some illegal logging does occur, particularly the Borassus palm).

Working with local botanist, we established ground monitoring sites in the park in 1984 in support of the vegetation mapping efforts published by Stancioff et al., 1986. In 1994, 1996, and 2007, we revisited some of the sites in order to assess changes in vegetation cover and composition. Overall, we found that the upland wooded savannas and woodlands were in excellent condition, maintaining a high level of biodiversity. Figures 11a and 11b show the stability and diversity of a typical woodland on a lateritic plateau in the Park. The photographs present a 23-year interval for comparison. The natural growth, mortality and regeneration is evident. However, the photographs indicate that tree growth is quite slow in these dry upland environments. The effect of drought from the 1980s is minimal compared to landscapes in northern Senegal. Figures 12a and 12b show the slow change in woody vegetation growth at a 12-year interval at another site in the Park, with the open *bowé* formation in the foreground.

Figures 11a and 11b. Left: April 1984; right: January 2007. A 23-year comparison of a site in a Sudanian wooded savanna on a lateritic plateau in the heart of the Niokolo-Koba National Park. This site is typical of the stability and good condition of plateau woodlands, maintaining a high level of biodiversity. Dry conditions of the 1980s and 1990s have had a slight impact on the woody cover, slowing tree growth. Human activity is limited to managed annual burning of the grassy understory. This is carried out in the early dry season to minimize impact on the woody vegetation.

Figure 12a and 12b. Left: April 1984; Right: February 1996. A 12-year comparison showing the very stable environment of naturally occurring open *bowé* formations, and the upland trees that surround it. Note that many of the scattered laterite blocks in the foreground have shifted their positions in random directions. This is a result of antelope and warthogs that nudge them to expose the tender grass shoots underneath the rocks.

Despite the relative stability of the uplands, the park's ecology is changing. Nowhere is this more evident than the invasion of the seasonal wetlands (*bas-fonds*) by *Mimosa*

pigra, a thorny bush that forms an impenetrable thicket. Its spread in recent years is probably related to the dramatic decrease in numbers of mammals, particularly antelope, elephant, and buffalo. The infestation of *M. pigra* in the seasonal wetlands around Simenti is very significant, rendering them useless as dry season grazing lands. We are tracking the spread of *M. pigra* using high resolution satellite images. Mapping *M. pigra* invasions is park of the ongoing land cover mapping effort. Park ecologists are considering the options for controlling this species.

Wildlife

The variety and richness of vegetation cover in the Shield Ecoregion has long been a refuge for wildlife in Senegal, particularly for big mammals found in Niokolo Koba National Park, the last significant sanctuary that has been reserved for them. Animal species diversity remains relatively high, and the protection of the natural vegetation allows for conservation of a large part of the genetic resources threatened by extinction in Senegal. Protected areas of this zone are part of the last ecosystems pertaining to the Sudanese zone that are legally protected in Africa (Gallegos et al., 2008).

Despite the full protection offered by the Niokolo Koba National Park, nearly all large mammal populations are down, and many are threatened with extinction. Poaching is the main factor within the park, driven by poverty or inequitable access to economic opportunity. The national park service has fairly limited human, financial and material resources available to maintain and patrol the very large area covered by the Park. Many of the mammal species are threatened with extinction, at least within the region. Among the species at risk in southeastern Senegal (and many of these occur nowhere else in the country) are the chimpanzee, the West Africa colobe bai monkey, the Dama gazelle, the Derby eland, and the lycaon or wild dog. The elephant may now be completely extinct from the region, and the Derby eland has not been spotted since 2006. Numbers of other medium and large sized mammals are also at very low levels, including the hartebeest, Cape buffalo, roan antelope, waterbuck, oribi, bushbuck (figure 13), duiker, Defassa kob, Buffon's kob, reedbuck, and lion.

Figure 13. A bushbuck, still somewhat common in the core area of the Niokolo Koba National Park. They frequent a variety of habitats, and are found near water.

Outside the Park, in the vast area extending east to the Falémé River (Mali border), the diverse vegetation types and biodiversity is subject to growing pressure from human population, and a rapid increase in mining. The main causes of biodiversity and forest degradation linked to human activities are extensive agriculture (peanut and cotton cultivation), bush fires, logging and charcoal production, transhumance, poaching, wildlife habitat degradation by mining (Zone Intérêt Cynégétique (ZIC), or "Zones of Hunting Interest", in the Falémé), construction of roads (Gallegos et al., 2008). They conducted numerous interviews in villages in the region and found that many people viewed mining in protected areas as a potentially significant factor for degradation of forests and biodiversity. The ZIC Falémé in particular, as well as the Niokolo Koba National Park, appear to be under threat of invasion by mining interests according to the interviewees.

One of the particular wildlife concerns is the decline in primate populations. West African chimpanzees (*Pan troglodytes verus*) are no exception (figure 14), with population numbers in drastic decline over the past thirty years. Having already gone extinct in Benin, Togo, and Burkina Faso, this subspecies is now at risk of extinction in Senegal, Guinea-Bissau, and Ghana, where their numbers are in the hundreds (Kormos et al., 2003). The savanna chimpanzees of Senegal exhibit unique cultural behaviors not seen in other chimpanzee populations. For example, at the Fongoli field site, the chimpanzees have been observed using caves, soaking in pools of water, and hunting mammals with tools (Pruetz et al., 2002; Pruetz and Bertolani, 2007). Chimpanzees are very sensitive to conflicts with humans around water sources, to disturbance by poachers, or even by unregulated tourism. Populations of chimps in Senegal, which rely on remnant patches of gallery forest, have been observed to move long distances between bedding, feeding, and watering areas (Gallegos et al., 2008).

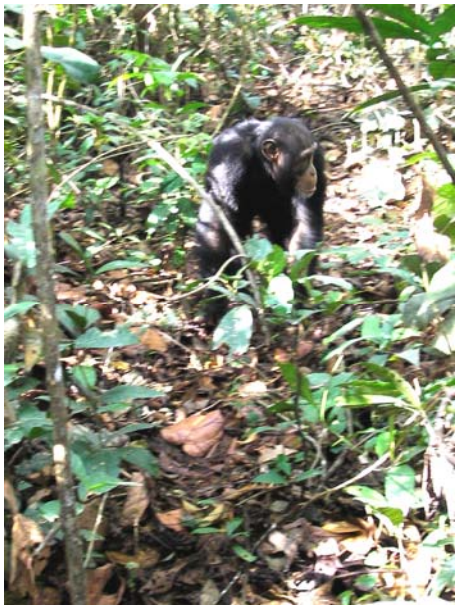


Figure 14. The Shield Region contains approximately 5 separate populations of chimpanzees, four of which live outside the National Park. They are classified as a subspecies of savanna chimpanzees, known for their unique cultural behaviors.

Agriculture

Agriculture in the Shield Ecoregion enjoys relatively high rainfall and farmers grow responsive crops such as maize, sorghum, peanuts, cotton and even rice. Bush fallows of up to five years are still practiced. When the fragile soils are laid bare by cultivation, however, they are quite vulnerable to water erosion. The vast areas of non-tillable terraces and plateaus assure the availability of extensive rangelands for cattle and a corresponding potential for internal transport of nutrients to fields (Grosenick *et al*. 1990).

Agricultural expansion, driven by rapid population growth, is recently becoming a significant force of change. It is beginning to nibble away at the wooded savannas, woodlands and gallery forests. Cotton and peanuts have become significant cash crops. Farmers carve new fields out of the wooded savannas and systematically clear stumps, shrubs, and trees to facilitate animal traction. The authors have revisited many sites since 1983 and have documented the process of agricultural expansion. Figure 15 shows recently cleared woodland northeast of Kedougou and the resulting transformation.

Figure 15. Cropland recently cleared from woodland northeast of Kedougou.

Mining

The Shield Ecoregion has the greatest potential of any for exploiting mineral resources. Numerous metallic and non-metallic minerals have been found, including gold, iron, marble, diamonds, copper, uranium, and manganese (Stancioff *et al*. 1986). Mining, particularly for gold, is mobilizing an increasingly large sector of the local population and several new mining towns have appeared. It is also drawing migrants from other regions. Newly paved roads, including the Tambacounda-Kedougou highway, are opening the region to exploitation. These developments place new pressures on the vegetation and fauna.

As metal mining increases in this ecoregion, habitats are increasingly affected and diminishing (figure 16). Mining operations can have wide ranging environmental effects, at times causing water, air, and noise pollution, deforestation and the production of toxic waste. Habitat loss, due to the open pit mining system characteristic of iron mines, is marked by overall loss of vegetation and changes in landscape. Water pollution may occur in both ground and surface water in mining areas, causing water sources to be highly vulnerable to heavy metal contamination. New service roads and systematic survey routes are having a negative impact on the vegetation cover, and by extension, on animal habitat. Presently, at least 12 companies with at least 18 mining permits are present in the eastern part of the region.

Gallegos et al. (2008) interviewed village people near the mining areas. Many people stated they thought mining and the exploitation of recently-discovered mineral deposits of gold, iron and zirconium (e.g., the Zone d'Intérêt Cynégétique (ZIC) near Niokolo Koba National Park and within the Park itself) constituted the most serious potential threat to biodiversity and tropical forests. The reason given for this is that mining interests tend to be given authority and priority over the conservation of natural resources occurring in protected areas.

When we complete the detailed land cover map of the region, we will also overlay it with existing and planned mining concessions to gain a much clearer picture of the impacts of mining on all habitats, including the most critical ones.

Figure 16. The hills near the Falémé River east of Saraya are rich in iron ore, and are attracting the attention of major mining companies. One of the world's largest global steel companies, ArcelorMittal, has signed an agreement with the government of Senegal to develop an iron ore mine in this area. This area is also known for one of several populations of chimpanzees in the region.

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