GIS-Supported Survey of Low-Land Rain Forests in South-Western Nigeria

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Abstract

A survey investigating the capabilities of the remaining natural forest as conservation areas for already threatened wildlife population in South-western Nigeria was conducted using Aster and Landsat imageries. Spatial data acquired during the survey were incorporated into a mobile Geographic Information System (GIS) and analyzed in near real-time. Results of ground-survey revealed that a high natural forest patterns are similar to what was observed on the satellite imageries. The estimated total area of remaining natural forest in the reserves was 1,125 km^2 which is about 40 percent of the reserve area and the largest undisturbed natural forest is the 4.6 km^2 Strict Nature Reserve (SNR) found in western Omo. The forests probably still retain some level of their ecological integrity. Therefore there is an urgent need to produce new and accurate maps of the forest reserves to inform government, local people, and planners and to allow more effective management.

Keywords: GIS, Survey, Low-land Rain Forest, SW Nigeria

Introduction

The lowland rain forests of south-west are of considerable biological and socioeconomic importance in Nigeria. Right from the colonial era the rain forests have provided sustainable supplies of timber through controlled logging and had safeguarded water supplies through protection of the watersheds. Several animal and plant species many of which are now endangered flourished abundantly in the rain forests. At that time the forests were far from human enclaves and as such witnessed less human incursions. The strategic geographic location and services provided by the rich ecological composition these rainforests also made them of high importance in the old western region and the nation at large. But today, the originally ecologically rich and biologically abundant forests have come under intense pressure with population growth and economic expansion since Nigerian independence in 1960. At the moment it faces a severe threat of extinction.

Anadu and Oates (1982) in a broad-area survey of southwestern Nigerian forests in 1982 found huge pressures on the natural vegetation, which was being destroyed and converted at a rapid rate from excessive logging, conversion to plantations, farming and oil extraction, decimation of their wildlife populations through indiscriminate poaching. Ola-Adams, (1999) recalled that people were permitted to remain living within 65 km^2 of "enclaves" of Omo Forest Reserve at its establishment in 1925. Today, settler farmers have moved in to occupy many other parts of the reserve, especially since 1966 when the Gmelina Pulpwood Plantation Project began (WRM, 2007). Tree planting also involved the clearance of natural forest by the taungya farming system. By 1997, Greengrass (2006) estimated that 20,000 people were living in the forest reserves. During the 1970s and 1980s large areas of the Omo and Oluwa reserves were converted to monoculture plantations of the fast-growing exotic tree *Gmelina arborea* in a programme assisted by loans from the World Bank and the African Development Bank (Isichei, 1995). The Gmelina plantations was envisaged to provide material for a paper (pulp) mill in Iwopin Ogun State Nigeria but could not meet up with the goal owing to the premature extraction of the plantations. In addition to the many troubles of the rain forest of the southwest is the expansion of the human enclaves within the forests due to large influx of migrant taungya farmers. The remaining areas of the Nigerian southwestern forests have been identified on a continental scale as of high priority with respect to consideration for conservation (Toham *et al*., 2006).

As these forests continue to degrade in the face of excessive exploratory activities by humans, through large scale industrial, commercial and domestic extraction of timber and non-timber forest products, a deep concern is being expressed in many circles on developing effective conservation options for the remaining but threatened clusters of forests and its biological diversities. Developing a good framework for serious conservation option is the crux of the matter in any meaningful study. The recent anxiety about the precarious status of the forest ecosystem in Nigeria is perhaps one of the most critical aspect of environmental degradation debate. In this paper therefore, an assessment aimed at investigating the extent and condition of the natural forest and the status of their wildlife populations were conducted with the aim of developing the best conservation options and make preliminary recommendations for conservation. The study combined an analysis of remotely-sensed imagery with in-situ data from ground surveys with the aid of mobile Geographic Information System (GIS).

Methodology

Study Area

The rain forests of southwestern Nigeria occupy an intermediate position between the Upper and Lower Guinea forests which is a part of an extensive vegetal cover stretching from Sierra Leone to the Ghana-Togo border and reaching into eastern Nigeria and the Central Africa. This southwestern Nigeria rain forest area comprises clusters of contiguous forest reserves spanning parts of Ogun, Ondo and Osun States. These reserves include the Omo, Oluwa, Shasha, Ife and Ago-Owu Forest Reserves which in this paper is regarded as the Omo-Oluwa-Shasha forest complex. Prior to the creation of the state administration in Nigeria, these five forest reserves were all part of the then Shasha Forest Reserve, established in 1925 (Isichei, 1995).

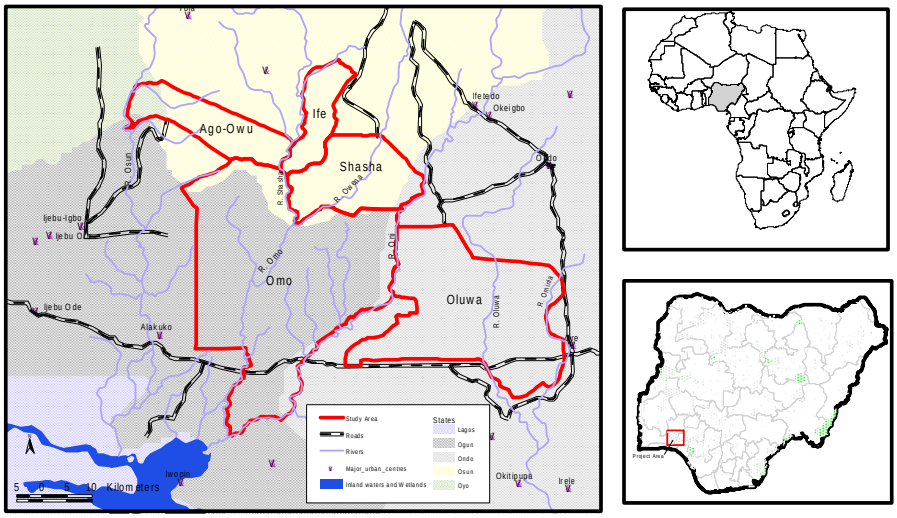


Fig. 1: Map of the forest reserves, showing major rivers and roads (Inset is Map of Nigeria and Africa showing location of the rain forests)

Data Types and Equipment for Survey

Geographic data used were obtained from different sources. The data included ASTER satellite imagery of the forest area acquired for January 2007, Landsat image of the same scene acquired for 2003, topographic map sheets and forest reserve boundary maps were assembled for the study.

A couple of hardware considered essential for the study were also acquired these include: ruggedized computer notebooks (Panasonic Toughbook) and a GPS-enabled pocket computer (Trimble GeoXM) for use in the field for mobile data capture. A customized data collection system for the project was developed with the aid of ArcPad GIS software on GPS-Pocket PC. In addition to these other field equipments necessary for the project were procured these include sleeping bags, backpacks, standard GPS units (Garmin Map60-CSx), binoculars, digital camera traps, waterproof cases, and other items.

Preliminary Survey and Establishment of Geographic Information System

Prior to the commencement of the field work a reconnaissance survey was conducted for the purpose of 'ground truthing' and developing the strategy for the actual survey. Next, a Geographic Information System (GIS) was established to support the survey. In order to guide field operations and data collection the ASTER imagery was geo-referenced, and subjected to a supervised classification based on the information obtained from 'ground truthing' during the reconnaissance survey. Maps of the project area were produced from 'on-screen digitizing' of scanned analogue maps of forest reserve boundaries and topographic map sheets. All Geographic features such as rivers and roads were captured from the scanned and geo-referenced map at a scale of 1:20,000. Information gathered from the field ground truthing exercise during the preliminary field works were utilized for database development of the maps produced.

Field Transects and Data Collection Methods

A grid of 5 km x 5 km designed to extend over the entire project area was superimposed on the geo-referenced satellite image. Within any grid cell where the satellite imagery suggests the presence of large areas of natural forest, a 5 km-length transect walks was conducted. Each walk began at the cell boundary which is easily located by means of ArcPad installed on the GPS aided pocket PC for 5 km towards the cell centre. Across the Omo-Oluwa-Shasha complex, a total of twenty-seven 5 km x 5 km cells were selected for the surveys. Of the twenty-seven 5 km x 5 km cells selected for transect surveys on the ground, 9 were located in Omo, 7 in Oluwa, 5 in Shasha, 2 in Ago-Owu, 2 in Ife, and 2 were shared between Omo and Shasha (Fig. 2).

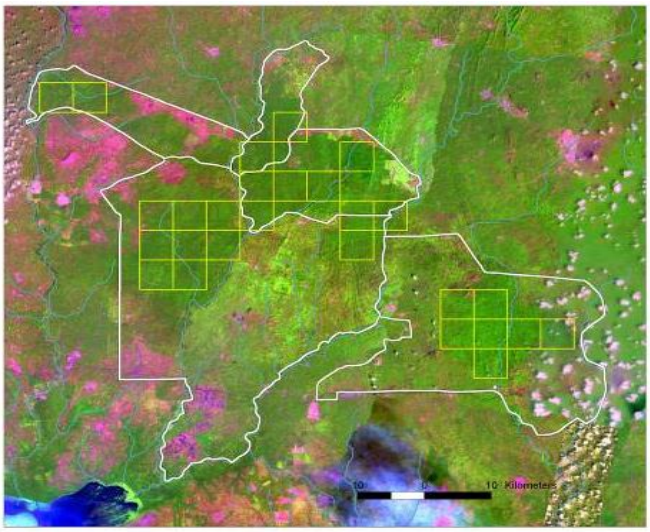


Fig. 2: 5 x 5 km cells selected for reconnaissance surveys

The number of transects created were based on the proportion of natural forest remaining in the reserves, the level of fragmentation observed and evidence of wildlife presence during the reconnaissance survey. Accordingly therefore, data collection along transects were done across three sampling zones: (1) western Oluwa Forest Reserve (west of the Omo River) (9 transects); (2) Ife, Shasha and northeastern Omo Forest Reserves (between the Omo-Shasha River and the Oni River) (6 transects); and (3) Oluwa Forest Reserve (7 transects). Since the remaining natural forest in Ago-Owu is highly fragmented, only one transect census was there, in the far west of the reserve, providing inadequate data for meaningful analysis.

The survey walks followed a path of least resistance on a compass bearing towards the approximate cell centre (along old logging roads, trails, and through the forest undergrowth with light vegetation clearing). Distances travelled were measured with a hip chain. Evidence of larger mammals, large birds and human activity encountered were recorded as a series of way-points on the GPS receiver, and information on land-use/land cover types were recorded at 200 m intervals. In addition to recording major categories of vegetation (e.g., natural forest, farmland, *Gmelina* plantation), the density of undergrowth and density of large trees (as low,

medium or high) were also recorded within 25 m of the waypoint. "Large trees" were defined as those with a stem diameter of at least 30 cm at breast height.

Experimental wildlife samplings were done with four Stealth Cam V450 digital camera traps strapped to trees. The passive Infared Sensor (PIR) of the cameras senses movement and triggers the camera to photograph the moving object object. With this technique a total 24 trapping days in each of Omo, Oluwa and Shasha Forest Reserve were done and the images bushbuck, a side-striped squirrel, small mongooses were recorded.

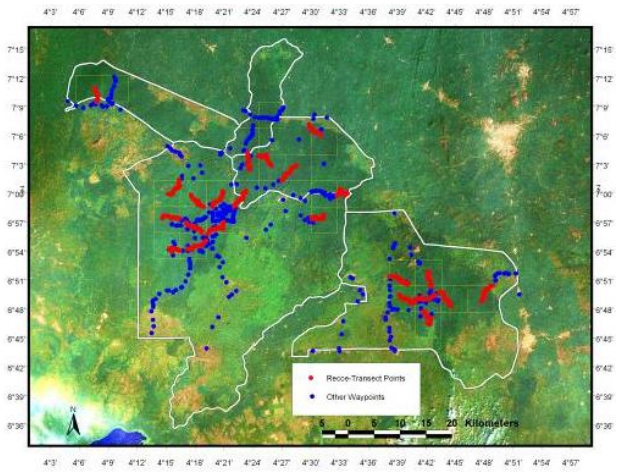


Fig.3: Waypoints: Survey transect walks (red) and other ground-truthing positions (blue)

Results and Discussion

General Observations on Status of Habitat and Wildlife

Gross successions had taken place in large portions of the natural forests ecosystem; natural vegetation have been replaced by other land cover types, and within areas that were predominantly natural forest, there were abundant signs of human activity: footpaths, roads, logging, farming, hunting, and the gathering of non-timber forest products (NTFPs). The observations were in agreement with the reports from previous studies (Ikemeh, 2007) on the conditions of the forest reserves around this area.

Land-use/land-cover types on the ground corresponded quite closely to patterns observed on the satellite imagery. Although several farms were discovered right inside the reserves, areas such as southern Shasha are still predominantly forested. Comparison between the Landsat imagery acquired for 2003and ASTER imagery acquired for 2007 did not reveal any outstanding changes in land cover.

In this study, areas that have not been converted into tree plantations, farms or settlements are regarded as natural forest being the original vegetation of the reserves when they were established, although they might have been modified by many years of logging but not yet totally transformed. In table 1 the area and percent cover of natural forest in each of the reserves are presented.

Table1: Areas of surveyed reserves, and areas of natural forest in the reserves

Forest Reserve	*Total protection area (km^2)*	*Area of forest reserve still natural (km^2)*	*Percent of forest reserve still natural*
Omo	1,325	381.2	28.8
Oluwa	827	347.9	42.1
Shasha	309	240.8	77.8
Ago-Owu	240	79.4	33.1
Ife	142	75.8	53.2

Omo forest reserve with over 1,300km^2 is largest in terms of area demarcated for protection and forest area (381km^2) still remaining natural. It is followed by Oluwa forest with over 800km^2 reserve area and 347km^2 of it still natural. However in terms of effective conservation, Shaha forest retains the largest percentage of the protected areas as natural forest. This trend might be related with the size of the reserve which makes smaller reserves easy to monitor. For instance, Ife forest is the smallest but it is next to Shaha in terms of effective protected area; about 53% of its original coverage, unlike Omo which retained less than 30% of its original land area. The inclination in these survey finding is further clearly depicted by the chart in figure 4.

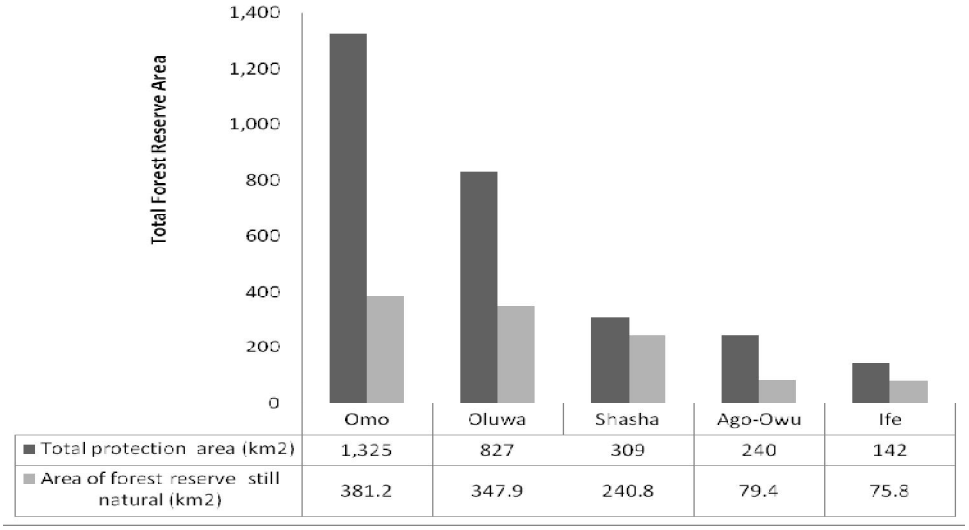


Fig. 4: Chart showing the proportion of natural forest vegetation to total protected area

Most of the forest reserves have been fragmented through human anthropogenic activities. The areas of mostly contiguous natural vegetation (although highly disturbed) are in western Omo, Oluwa, Shasha and parts of southern Ife. Spatial analysis of land cover types suggested that more than 50% of Ago-Owu reserve is still forested. Figure 5 reveals its level of fragmentation.

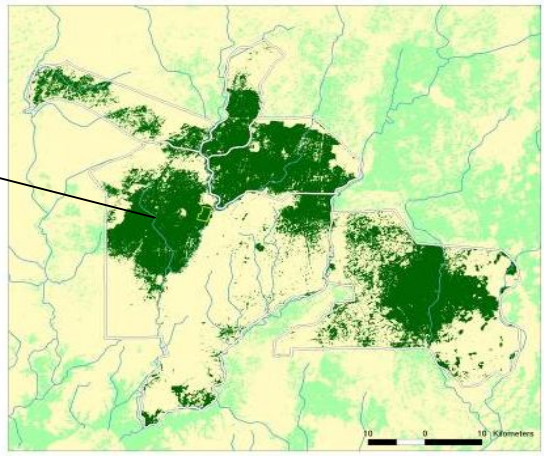


Fig.5: Distribution of remaining natural forest (dark green) in the target reserves, based on ASTER imagery and ground truthing.

In several places, logging has been so intensive that only few stands of timbers remain. The density of large trees varies considerably from place-to-place. Figure 3 indicates that there is a gap of more than 10 km between the remaining area of continuous forest in Oluwa, and the nearest remaining such forest area in northeastern Omo. Ground surveys revealed much of the area has been converted to teak plantation and cocoa farms, with only a few patches of forest left. Forest still fringes the Oni River that marks the boundary between Oluwa F.R. and Omo F.R., but this forest is under pressure from logging and farming.

Estimates of tree density and thickness of undergrowth made at 200 m intervals along transects is another measure of human impact on the forest reserve. This is presented in Table 2.

Table 2: Percent undergrowth and tree density in each class by survey zone

	Western Omo	**Shasha Reserve – Oni Reserve**	**Oluwa Forest Reserve**
Density of undergrowths			
High	47.0	66.7	46.6
Medium	40.5	23.0	38.8
Low	12.5	10.3	14.6
Tree Density			
High	32.7	27.6	19.4
Medium	42.9	36.8	52.4
Low	24.4	35.6	28.2

Intensive logging that occurred over the years in all the forest reserves has given rise to vegetal transformation producing dense undergrowth and low density of larger trees. Western portion of Omo forest reserve had the most dense timber population while Oluwa forest had the lowest

density of timber. Western part of Omo forest appears to have been less damaged by logging than the other areas.

Wildlife Distribution Status

The wildlife population distribution in the lowland rain forest in south western Nigeria is influenced by the pattern of its vegetal cover. Table 3 displays records of mammals obtained during the survey. Again western part of Omo had evidence of presence of more mammal than the other forest areas. For instance, signs of elephant's presence were more in western Omo they were not encountered elsewhere. This is because it is only in western, but primates were also much more often encountered in western Omo than in the other areas, and primate evidence was very sparse in the Shasha-Oni zone.

Table 3: Mammal records from transect walks

	Western Omo			**Shasha River - Oni River**			**Oluwa F.R.**		
	No.	*No. per walk*	*No. per km*	*No.*	*No. per walk*	*No. per km*	*No.*	*No. per walk*	*No. per km*
All mammals	105	11.7	2.33	10	1.67	0.33	33	4.71	0.94
Elephants	35	3.9	0.78	-	-	-	-	-	-
Ungulates	20	2.22	0.44	8	1.33	0.27	13	1.86	0.37
Primates	31	3.44	0.69	2	0.33	0.07	13	1.86	0.37

Although signs of elephants are still relatively frequent in western Omo, generally mammals are scarce throughout the survey area, as judged by the relatively sparse evidence of their presence acquired during the survey. Large birds, including large hornbill species, remain relatively abundant, however.

Olmos and Turshak (2007) noted that Omo forest harbours a significant number of birds some of which are endemic to the area and or endangered. For example the globally near-threatened, grey parrot species (*Psittacus erythacus*) and yellow-casqued hornbill (*Ceratogymna elata*).

Figure 6 shows the presence of mammals in the five forest reserves as recorded both on and off transects during the survey. The map shows that western Omo is the richest in animal biodiversity.

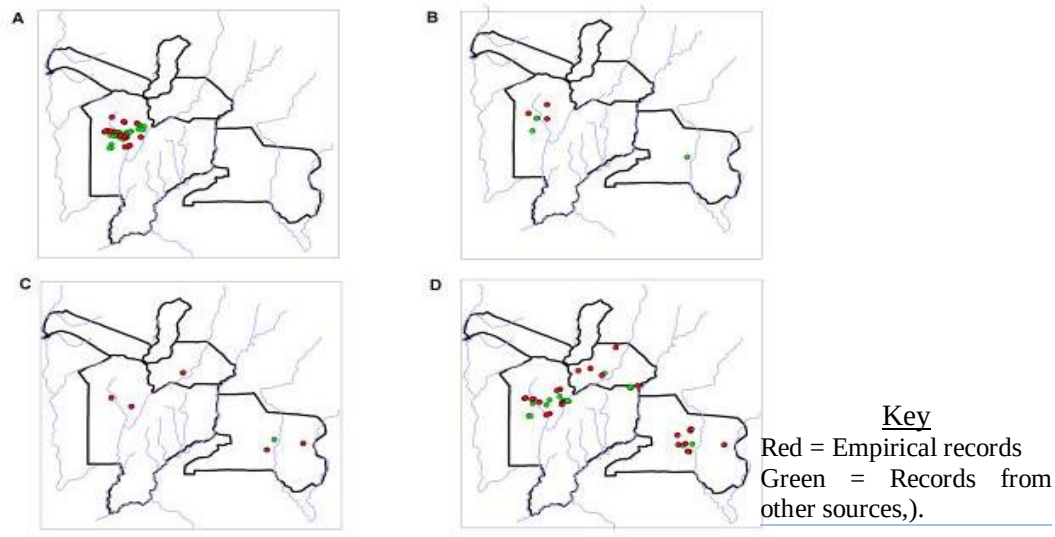


Fig. 6: Map of distribution of large mammal records
(A: Elephant; B: Buffalo; C: Red river hog; D: antelopes)

This trend remains otherwise hidden without the aid of spatial technology. Elephants are present only in western Omo this is obviously due to the density of the vegetation here. Antelopes are common to Omo, Oluwa and Shaha.

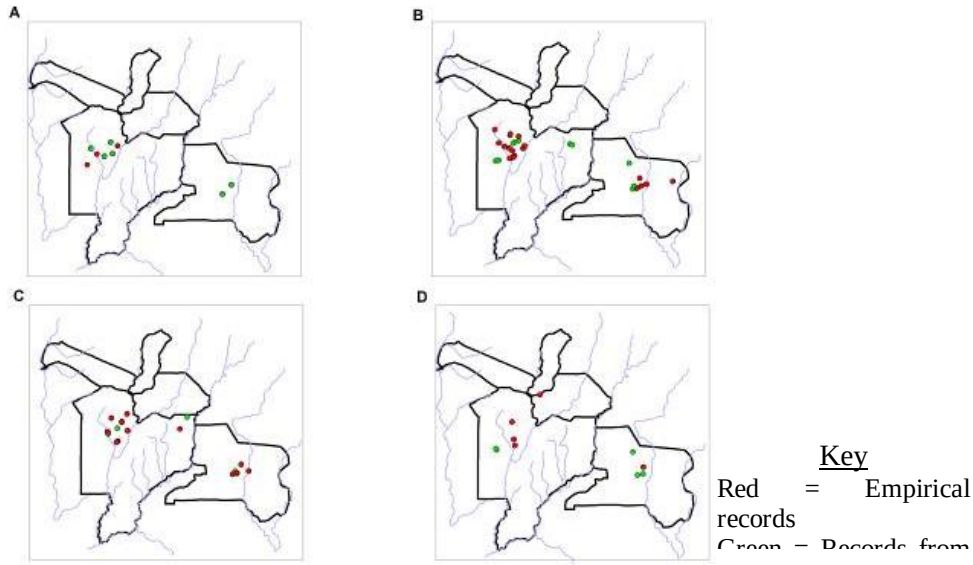


Fig. 7: Distribution of primate records

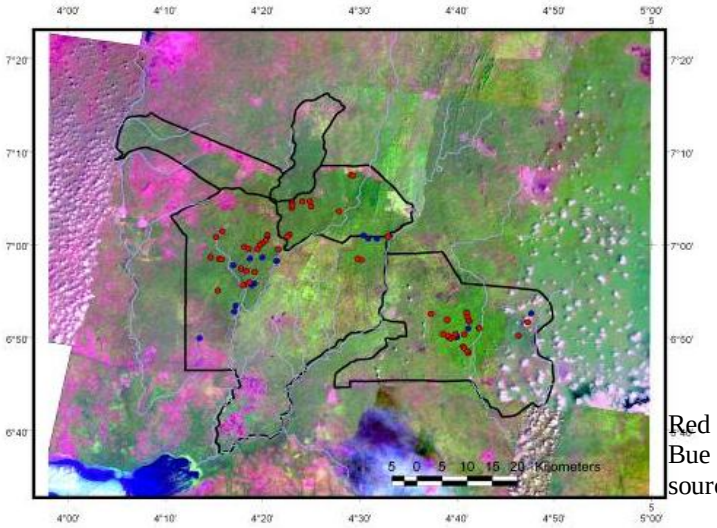
(A, red-capped mangabey; B, mona monkey; C, putty-nosed monkey; D, white-throatedmonkey)

The distribution of these large bird records across survey zones is shown in Table 4. The most readily recognized large birds were large hornbills, of which four species have been recorded in these forests: the black-and-white casqued hornbill (*Bycanistes subcylindricus*), the white-thighed hornbill (*Bycanistes albotibialis*), and the black-casqued hornbill (*Ceratogymna atrata*), in addition to the yellow-casqued hornbill (Olmos & Turshak, 2007).

Table 4: Large bird records from recce transects

	Western Omo			**Shasha River - Oni River**			**Oluwa F.R.**		
	No.	*No. per recce*	*No. per km*	*No.*	*No. per recce*	*No. per km*	*No.*	*No. per recce*	*No. per km*
All large birds	23	2.6	0.51	14	2.33	0.47	21	3.0	0.60
Large hornbills	18	2.0	0.40	13	2.17	0.43	19	2.7	0.54

In some parts of West Africa it is now unusual to encounter any large hornbills. The relative frequency with which these birds were encountered on our survey (0.4-0.5 encounters per km on transects), is an indication that these forests still retain a significant amount of their biodiversity and ecological integrity, despite the abuses they have suffered. The distribution of the birds is presented on the satellite image in Figure 8.



Key
Red = Empirical records
Bue = Records from other sources).

Fig.6: Distribution of large bird

Their niches can be seen to coincide with the less disturbed patches of the forest area. The pink patches are human dominated ecological systems.

Evidence of human impact

Human activities in these forest reserves were widespread and recurrent. No ecosystem can be regarded as pristine. Table 5 presents the records of human activities in the forest reserves.

Contrary to expectations, the largest number of human activity per km was found on the western Omo where species richness of biota was highest.

Table 5. Human Activities Records from Recce Transects

	Western Omo			**Shasha R. - Oni R.**			**Oluwa F.R.**		
	No.	*No. per recce*	*No. per km*	*No.*	*No. per recce*	*No. per km*	*No.*	*No. per recce*	*No. per km*
Farming	10	1.11	0.22	2	0.33	0.07	9	1.29	0.26
Hunting	15	1.67	0.33	3	0.50	0.10	17	2.43	0.49
Logging	33	3.67	0.73	13	2.17	0.43	19	2.71	0.54
NTFP	6	0.67	0.13	1	0.17	0.03	3	0.43	0.09
Gathering Camps	7	0.78	0.16	2	0.33	0.07	2	0.29	0.06
TOTAL SIGNS	**71**	**7.89**	**1.58**	**21**	**3.50**	**0.70**	**50**	**7.14**	**1.43**

This perhaps can be explained by the size of the forest relative to the fragmentation. Beyond this is the presence of the Strict Nature reserve (SNR) located on eastern edge of the natural forest area in northwestern Omo; which serves as sanctuary for most wildlife in the area. This pattern again is depicted in Figure 9.

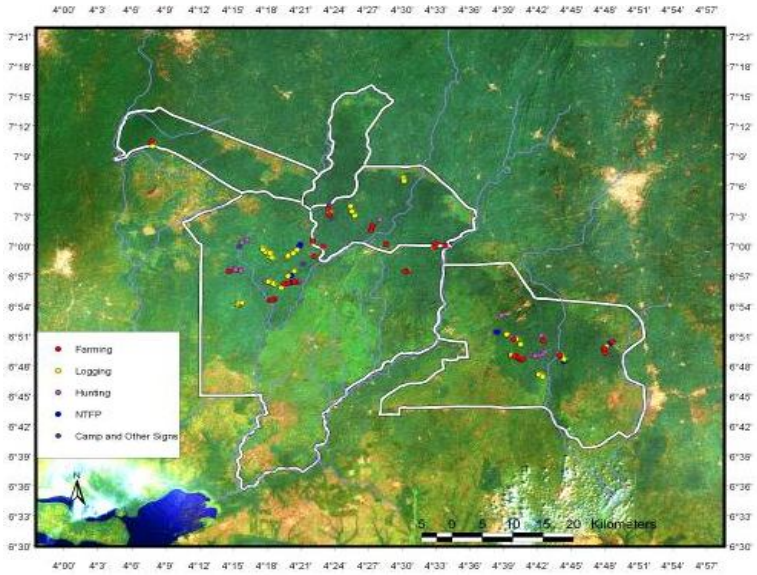


Fig. 9: Records of human activity in the target forest reserves

Around the boundaries of the SNR as shown on the image and ground measurements (Fig. 10) there were no signs of recent human interference with the vegetation during this study.

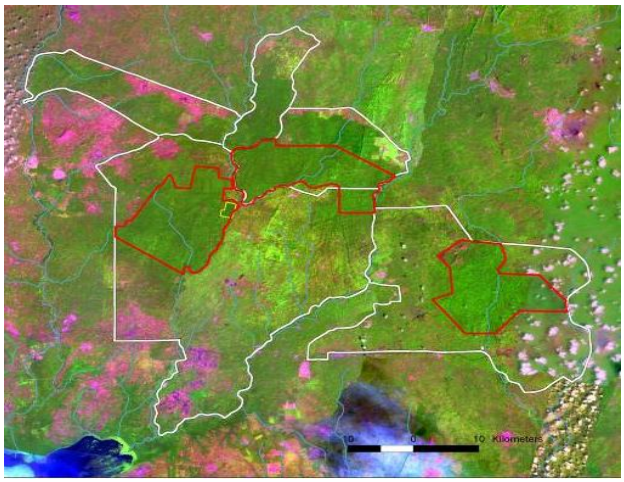


Fig. 10: Suggested areas for protection (within red lines) in Omo, Oluwa and Shasha Forest Reserves.

Conclusion

The Omo-Oluwa-Shasha complex of forest reserves is grossly degraded due to human anthropogenic activities. They are probably the last major rain-forest areas remaining in southwestern Nigeria contain several wildlife species regarded as Endangered or Vulnerable by the World Conservation Union. However, there are still natural forest areas worthy of conservation in Omo, Oluwa, Shasa and Ife Forest Reserves. Pending further biodiversity studies, these areas appear to be of particular national significance, notably because of animal species such as the African elephant (VU), chimpanzee (EN), red-capped mangabey (VU), and white-throated guenon they preserve. Omo Forest Reserve alone houses close to 242 bird species. Although several areas of the rain forest have been heavily degraded, the natural forest ecosystem including its wildlife population could recover, if it is adequately protected even if it should take several decades. The use of GIS will enhance proper management of the forest reserve. Omo, Shasha and Ife reserves are still fairly contiguous though very tenuously, across the Shasha River, forming a block of about 600 km^2 which, if well-managed, could constitute a more viable ecosystem. Although at the moment no area of contiguous natural forest in any single reserve in the complex exceeds 250 km^2.

Recommendations

More Strict Nature Reserves should be established in the areas indicated by the map in figure 10. One protection option would be to gazette Wildlife Sanctuaries similar to the ones created in 1985 within Okomu Forest Reserve of Edo State which subsequently became a national park. In terms of creating protected areas, it is probably helpful that Omo is already formally listed as one of 26 Important Bird Areas in Nigeria by Birdlife International.

Particular attention must be given to reducing human impact in areas of tenuous connection between remaining natural forest areas. This may require relocating people form area demarcated for SNR or wildlife sanctuaries. A particular situation is the Etemi Village, located north of the Strict Natural Reserve.

There is an urgent need to produce new and accurate maps to inform government, local people, and planners. At the moment there are no up-to-date maps to educate people at all levels on the need for protection of natural forests and where to protect. Several people are unaware of the details of reserve names and boundaries. Maps on forest ecology should be widely circulated and made easy to interpret and readily available to local communities.

Funding for the forest maintenance could come from ecotourism. Weeks (1998) noted the tourism possibilities in Omo forest reserve. Another funding possibility that could be explored is the carbon-credit market. The states may be eligible directly (or indirectly through an NGO or the federal government) for carbon credits simply by setting aside areas of natural rain forest for protection.

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