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GIS AND REMOTE SENSING TECHNIQUES AS TOOLS FOR SURVEYING PRIMATES

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Abstract. Status and distribution of species are essential data for wildlife research and conservation. GIS (Geographical Information System) and Remote Sensing Techniques are increasingly applied in monitoring habitats. We tested the suitability of these methods as a preparatory step for a survey of hamadryas baboons (*Papio hamadryas*) in Eritrea. In order to detect potential hamadryas habitats, we used information on the distribution of four main habitat factors for hamadryas baboons: year-round water supply, steep sleeping cliffs, food resources and an altitude below 2500 m. Sites with a combination of these factors were considered potential hamadryas habitats. Information on surface water, cliffs and altitude was digitized from topographical maps and Landsat MSS data. Distribution of the main food plants of hamadryas baboons was taken from Landsat MSS. An evaluation of the techniques was conducted by comparing the detected habitats with historical data on hamadryas distribution (data from 1835 through 1970) and a short survey in 1995. Potential habitats, as classified in our study, corresponded strongly with the historical and recent distribution. We conclude that the method would also be appropriate for working with present data and would provide an excellent map of current habitats. A field survey in Eritrea will focus on these areas. *Accepted 27 August 1996.*

Key words: *GIS, remote sensing*, Papio hamadryas, *survey, Eritrea, habitat classification, suitability for other taxa.*

INTRODUCTION

After 30 years of civil war in Eritrea, current information on the status and distribution of wildlife is very fragmentary or non-existent. Such knowledge, however, is essential for wildlife management and conservation. Hamadryas baboons (*Papio hamadryas*) were an important part of autochthonous Eritrean wildlife (Yalden *et al.* 1977) and, in contrast to many other species, it seems that they are still relatively abundant (pers. observ.). Yet, even for this species, data on recent status and distribution do not exist. IUCN classifies *Papio hamadryas* as 'rare' (Lee *et al.* 1988), probably because of its comparatively limited distribution. This does not necessarily reflect the current degree of threat within its range. In other parts of their range, for example in Saudi Arabia, hamadryas baboons have become scavengers at garbage dumps and they cause problems for villages (Biquand *et al.* 1994).

The results of a study of status and distribution of hamadryas baboons in Eritrea will serve two aims. First, it will provide data on recent status and distribution to facilitate conservation management plans. Second, we can rely on these data to make surveys and monitoring more efficient by detecting and mapping potential hamadryas habitats before doing the actual survey. The methods we will use are remote sensing techniques and geographical information systems (GIS). These methods have been successfully used in similar contexts in recent years (Haslett 1990, Sample 1994, Edwards *et al.* 1994, Maehr & Cox 1995). Before investing in expensive satellite data, a test of usefulness and reliability of these applications was appropriate. In this paper, we test for the first time the utilization of remote sensing techniques and GIS in surveying primates.

METHODS

Rationale of the test

We used remote sensing techniques and GIS to locate potential hamadryas habitats, digitize the information and map them. We extracted the data from a relatively old (1972) and inexpensive Landsat MSS image and topographical maps. We tested how our potential hamadryas habitats corresponded with historical data (1835 through 1970) on hamadryas distribution in the same area. Because there were only 13 locations of historical sightings documented within the test area we had to include all of them, even the very old ones. Additionally, we tested the correspondence with recent (1995) hamadryas sightings in the same area.

If potential hamadryas habitats detected by our analysis coincided with the actual distribution of the baboons, we would expect a reliable correspondence between recent satellite data and their distribution. We would then concentrate the subsequent survey effort on areas that were classified as recent potential hamadryas habitats.

Procedure

As a starting point for the detection of suitable habitats, we used four ecological and geophysical factors which Kummer (1968) described as the most important habitat requirements of hamadryas baboons. These are: (1) year-round surface water as water supply, (2) steep cliffs as safe sleeping sites, (3) a certain type of vegetation as main food resource and (4) an altitude below 2500 m. The mean daily range of hamadryas baboons is about 6 km (Sigg & Stolba 1981). Given these factors, it was possible to identify suitable areas and to map them as potential hamadryas habitats, encircled by a 3 km buffer according to the mean daily range.

Data sources: Landsat 1 MSS - WRS 182/49, 180 km x 180 km, 3 Nov., 1972; Topographical maps 1:250000, Ethiopian Mapping Agency 1979; Historical distribution 1835 - 1970, Yalden *et al.* (1977); Preliminary ground survey, Zinner & Torkler, June 1995.

Fig. 1 shows the location of the test area and the position of the rectified satellite image within the borders of Eritrea. The test area included Asmara, the capital of Eritrea, parts of the 'green belt' in the eastern slopes of the central highlands, and the coastal lowlands. Our test area covered a total of 18,679 km^2.

The approach is illustrated in Fig. 2. We digitized data on cliffs, surface water and altitude directly from topographical maps 1:250000 with PC ARC/INFO. Additionally, we used a second method

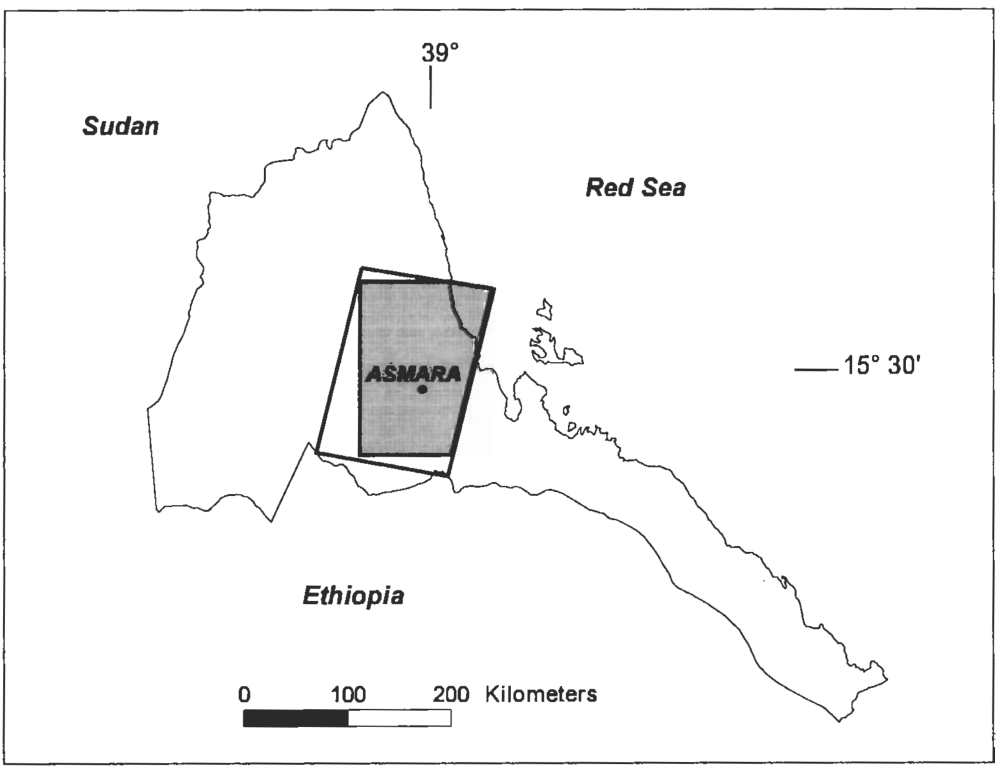

FIG. 1. Position of test area (stippled) in Eritrea. The frame indicates the position of the rectified satellite image.

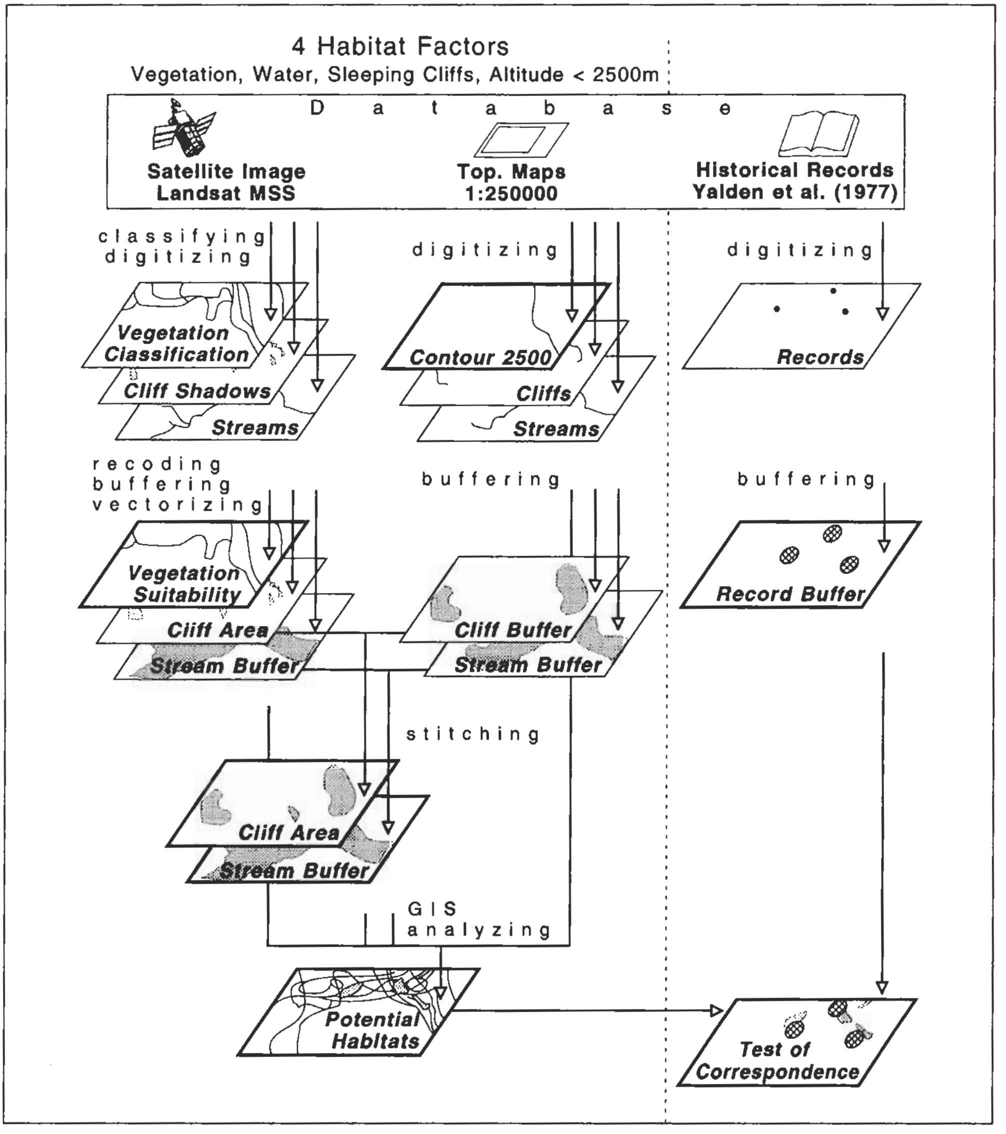

FIG. 2. Flowchart of the test procedure.

to find cliffs. The satellite image, taken at 9:25 a.m. on 3 November, shows pronounced sun shadows on the northwestern side of mountains whose inclination exceeds 41°. We computed a 1 km buffer around observed shadows on the satellite image to include all sides of a particular mountain and considered these areas as being areas with a high probability of cliffs. The reliability of this method was confirmed by comparing areas of high relief interpreted from shadows on the satellite image with known cliffs as indicated on published maps. The distribution of riparian vegetation was used as an additional method of detecting areas with a high probability of small-scale surface water. A classification of vegetation was made from Landsat MSS data by the ERDAS image-processing system. A supervised classification al-

TABLE 1. Vegetation classes and suitability. Source: Landsat MSS image Nov. 1972, topographical maps. Definitions of classes following preliminary ground survey from June 1995.

class	suitability	score
Water bodies (sea and fresh)	no	0
Bare soil 1	no	0
Bare soil 2	no	0
Dunes 1	no	0
Dunes 2	no	0
Coastal wetland	no	0
Agriculture 1	no	0
Agriculture 2	no	0
Agriculture 3	no	0
Agriculture 4	no	0
Agriculture 5	no	0
Pasture	no	0
Plantation	no	0
Eucalyptus plantation	no	0
Agriculture - Acacia mix	low	1
Dry forest	low	1
Acacia bare soil	low	1
Acacia low-density 1	low	1
Shadow	mid	2
Eucalyptus dispersed	mid	2
Acacia low-density 2	mid	2
Acacia low-density 3	mid	2
Acacia mid-density	mid	2
Semi-dry forest	mid	2
Moist evergreen forest	mid	2
Riparian vegetation	high	3
Olea slope vegetation	high	3
Opuntia mixed slope vegetation	high	3
Opuntia dense	high	3

gorithm was employed using 29 training areas checked on a field trip in June 1995 (Table 1). Classified areas were then vectorized and imported as polygons into PC ARC/INFO where we performed a GIS analysis incorporating all four factors.

RESULTS

Areas with a high probability of year-round surface water covered 50.7 % of the test area, including a 3 km buffer. Areas with a high probability of steep cliffs covered 53.8 % of the test area. This included a 3 km buffer for cliffs that were found on topographical maps and a 1 km buffer for cliffs that were detected by slope shading. We used different buffers for cliffs because the two methods of detecting cliffs differ in accuracy. By using shadows to detect cliffs it is likely that we overestimated cliff area and, therefore, reduced the buffer to 1 km. Only a very small parr of the test area was located above the 2500 m contour (0.2 %). This factor was of minor importance in the present analysis. We classified different vegetation and bare soil types according to their suitability as feeding areas for hamadryas baboons, following Kummer (1968), Al-Safadi (1994), and our own experience from fieldwork in Eritrea. Areas bare of vegetation or with very low-density vegetation, salt marshes, and areas with intensive agriculture were scored as not suitable. In general, the suitability of vegetation types increased according to the abundance of the main food species of hamadryas baboons (Table 1).

Assessment of habitats

Following the detection and localization of areas with surface water, steep cliffs, food resources and an altitude below 2500 m, we combined these four factors by a GIS overlay. We scored the areas where we detected one or more factors according to the list given in Table 2.

The factors were weighted subjectively according to their presumed relative importance for hamadryas baboons. Areas with no surface water, no cliffs, no food resources and an altitude above 2500 m scored a suitability of 0. The minimum score for potential hamadryas habitats is 9, because the baboons need water (score 5), cliffs (at least score 2), food (at least score 1) and an altitude below 2500 m (score 1).

TABLE 2. Suitability scores of habitat factors. Areas were scored as potential hamadryas baboon habitats.

areas without any of the 4 factors	factor 1 surface water	factor 2 cliff shadow cliff	factor 3 vegetation suitability	factor 4 contour 2500 m
0	5	2 3	1 2 3	1

Vegetation: 3 suitability classes: 1 low, 2 mid, 3 high
Cliff: 3 - cliff, directly from topographical maps, 2 - indirectly from shadows of steep slope

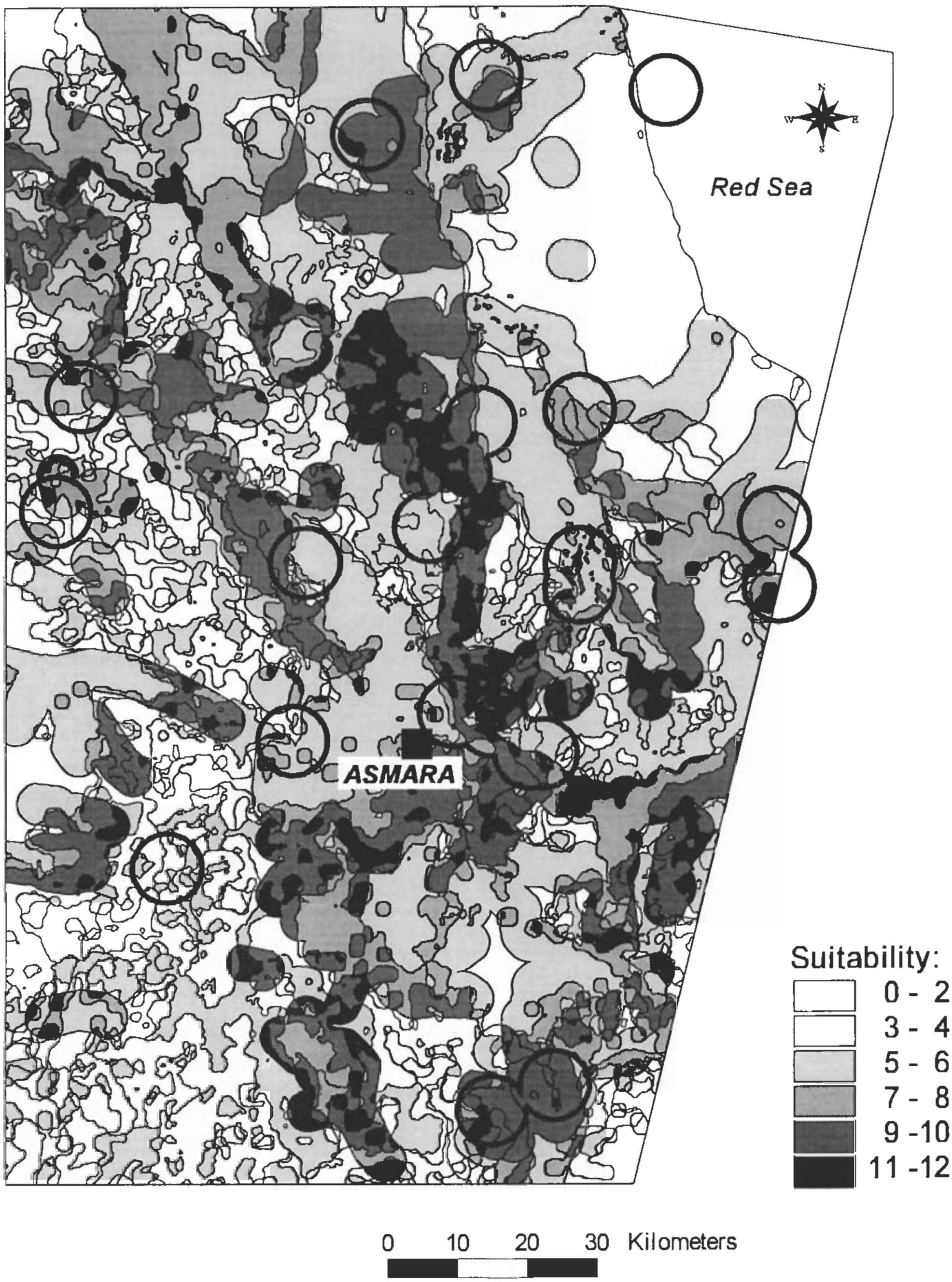

FIG. 3. Distribution of hamadryas habitats. Suitability classes 0-12 and correspondence with historical distribution. Areas with a suitability ≥ 9 are potential hamadryas habitats. Circles indicate actual sightings surrounded with a 5 km buffer.

Maximum score is 12, indicating areas of highest suitability. Fig. 3 shows the distribution of habitats within the test area according to their suitability. Potential hamadryas habitats (≥ 9) cover an area of 3854.9 km^2 (20.6 % of the test area). Areas with high suitability (≥ 11) cover only 883.1 km^2 (4.7 %).

Test of correspondence

We combined the historical data on hamadryas distribution (n=13) with records of hamadryas sightings during the 1995 ground survey (n=7) and measured the distance between each distribution site and the closest suitable area (suitability ≥ 9). The same was done for 20 randomly selected sites. We tested the hypothesis that locations of actual sightings are closer to suitable areas than randomly selected sites.

TABLE 3. Mean distance (km) between locations of hamadryas sightings and nearest suitable area (score 9-12). Comparison of sites of actual sightings and randomly selected sites within the test area.

sites	N	mean	SD
random	20	3.9	4.1
historical	13	1.8	2.3
1995	7	0.4	1.1

Locations of actual sightings tended to be closer to potential hamadryas habitats than randomly selected sites (Table 3; historical records, $t = -1.69$, $P < 0.10$). The highest correspondence, however, was found between sightings made in 1995 and suitable habitats. The mean distance between sightings from 1995 and potential habitats was far less than expected by chance (only 400 m, $t = -2.18$, $P < 0.04$).

DISCUSSION

Considering the time lapse between the historical sightings, the satellite data, and the ground survey, it is not surprising that the correspondence of potential hamadryas habitats with 1995 sightings is better than with historical records. Soil degradation in Eritrea, particularly in the highlands, is a severe problem and has drastically altered the environment during recent decades (Abate 1994). This certainly must have had an impact on hamadryas distribution. Consequently, some of the older records may no longer correspond to a suitable habitat. We also discovered some inaccuracies in the geo-coding of the historical sightings. One sighting from the 19th century, for example, would have been 5 km offshore (Fig. 3).

However, we found a high correspondence between historical hamadryas distribution and areas that were detected by our analysis as potential hamadryas habitats. GIS and remote sensing techniques, therefore, seem to produce reliable results, and it should be possible to use these techniques with recent data to detect current hamadryas habitats. The areas that are classified as potential hamadryas habitats could be the focus of a subsequent ground survey. A concentration on these potential habitats would make the survey more efficient. This method offers other advantages too, including the production of a map of the area under study, and facilitating environmental monitoring by the comparison of old and future data. This allows one to detect changes such as the conversion of hamadryas habitats into farmland, or progressive degradation.

Hamadryas baboon habitats are only sparsely covered with vegetation, and small-scale vegetation diversity is low compared with other primate habitats. This makes remote sensing relatively easy and a very promising method for surveying and monitoring species living in similar habitat types. Recent studies have shown that it is also possible to define and map vegetation types by means of remote sensing and GIS even in tropical forests (Condit 1996). We therefore conclude that the application of these methods could be potentially useful for surveys of primates and other taxa living in dense tropical forests.

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