GIS in Modern Zoological Park Management: Case Study of the Federal University of Agriculture, Abeokuta, Nigeria

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ABSTRACT

The paper demonstrates Spatial Decision Support System (SDSS) in Geographical Information System (GIS) for management the zoological park of Federal University of Agriculture, Abeokuta South-western Nigeria. The aim of the study is to produce an effective system for monitoring and managing natural environment of caged animals in any animal preserve. The map of the zoo park was first created through 'on-screen' digitising of geo-referenced Google Earth images. Environmental parameters namely: ambient temperature, humidity, noise, and light intensity were randomly sampled using environmental meters and a hand-held Global Positioning System (GPS) receivers. The data were interpolated in GIS using Inverse Distance Weighted (IDW) method. Results showed noise level as high as 81 decibels and as low as 34 decibels, humidity as high as 99% and as low as 68% and ambient temperature as high as 39oc and as low as 29.1oc. Light intensity (reflected) was as high as 54 at some locations and as low as -0.01 at some others. The interpolated data revealed the variability distribution of environmental parameters across the zoo which can be understood when overlaid with features including animal locations within the zoo park. For instance, the highest humidity was recorded near the river valley while the highest noise level was recorded close to the main road. The study concluded that these maps can serve as a guide when deciding to situate sensitive new animals as well as a guide for maintaining optimum conditions for animal environments.

(Keywords: geographical information systems, GIS, zoological park, environmental data, spatial data modeling)

INTRODUCTION

Throughout the world, animal preserves such as zoological parks, botanical gardens, aquaria, and nature reserves are highly important heritages for recreation, conservation, education, and scientific research (Rodríguez-Guerra and Guillén-Salazar, 2012). For leisure especially, zoos have an important role as hundreds of thousands of people come to relax and see in real life, the animals they have read about or at best only watched in films and documentaries (Frost, 2011 and Perthzoo, 2011). In Africa, zoos are not typically such a thrill especially amongst rural folks to whom game are common sights in the country sides. However, the rate of decimation of animal resources in the wild and the perturbation of thier habitats has made zoos such a crucial heritage to protect worldwide (WAF, 2015). It is therefore great news that many zoological gardens are springing up in Nigerian cities and their suburbs (Vconnect, 2016). While this is quite a welcome development, it is worrisome however, that many of these resources pass through vagaries of stress that makes almost non sense of the concerted effort for them to grow and become sustainable (Sijuade, 2007). One major stressor is the loss of these animals because of their inability to adjust to capivity after extraction from the wild (Henson, 2011). Perhaps this situation is pestering because many managers of modern zoo parks and gardens are either inexperienced in zoo management techniques or have not discovered better management strategies to keep the animals.

The world's leading zoos have been developing strategies for best practices in management techniques since they offer recreation seekers head-on encounters with some of the rarest creatures from the world wilderness (SNZP, 2006). Such experience that very few people will ever be able to pursue even in the wildlife parks. Modern zoos tend to create environment as close to nature as possible in contrast to the cramped cages that housed animals in zoos of the past (Spedding, 2014). The modern zoo parks now imitate nature in reconstructing animals' natural environments and offering them challenging activities to reduce boredom and stress (Shepherdson, Mellen and Hutchins, 2012). The evolution of zoos has also included programs dedicated to protecting endangered species, both in captivity and in the wild (Bove, 2014). Zoos accredited by the Association of Zoos and Aquariums (AZA) participate in Species Survival Plan Programs that involve captive breeding, reintroduction programs, public education, and field conservation to ensure survival for many of the planet's threatened and endangered species (Bove, 2014).

The challenge of keeping animals close to nature stems from the incapacitation of the zoo management to perform the oversight functions with the exactitude and dexterity required (Röhrlich, 2012). Simulating a natural environment for animals reared in captivity is highly tasking for curators; as they cannot decide by mere visual observation whether the animals have the optimum ambient conditions in their immediate milieu for optimum performance. It is only loggical that animals kept as close as possible to nature will perfom better than those completely enstranged from the conditions of their natural environments.

It implies then that environmnetal parameters around the animal cages in the zoo park should be regularly monitored and kept within tolerable range for the animals. If it is not possible to create a completely naturalhabitat for them natural conditions could be simulated by planting trees around the pens creating right humidity, light intensity and temperature. To achieve this, installation of analyzers of ambient conditions might be required in the zoo. Ideally, analyzers that measures air quality (gases) and physical conditions, (temperature and humidity) should be permanently installed in all animal pens and the readings recorded or data logged in an archival system, but this is still not sufficient for effective management. Even with full automation of environmental quality analysers in place, special computer-based tools will still be needed for graphical presentation of the variability distribution of measured physico-chemical parameters in and around the animal pens for near real-time decision making.

Under a good management scheme, a zoo should keep daily records of animal performance, including fecundity, feed conversion, and health status (Fidgett *et al.,* 2008). Where this is so, the zoo will have enormous quantity of data to handle. This is where computer-based tools such as the Geographical Information Systems (GIS) becomes inevitable. Incidentally, GIS has been designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data (Mignard and Nicolle, 2015). GIS, according to ESRI (2008) is a special type of ICT that integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information for comprehending geography and making intelligent decisions. In other words, GIS is a computer-based systems used for storing, retrieving, analysing, and displaying spatial data in a problem solving environment.

Several authors have variation of definition for GIS but all the definitions coalesce around a number of terms which forms the main components. The broad definition regards GIS as a computerised system comprising hardware, software, data and applications for managing spatial data and solving spatial problems. By implication therefore, a GIS must comprise of five components namely: computer hard ware, computer (applications) software, spatially reference data, spatial data analysis technics and the spatial data analysts.

GIS presents its outputs in the form of maps, digital images, and tables of geocoded data elements. GISs therefore have the unique capability of storing up spatial data of different units of measurements and sources from the real world in layers, thereby presenting them seamlessly, thus representing the real world in a virtual environment. This attribute of GIS has evolved as a means of assembling and analysing diverse data pertaining to specific geographical areas, with spatial locations of the data serving as the organizational basis for the information systems (IAIA, 2015).

From the explanations above, GISs over the last five to six decades have been developed as tools for management of natural resources and for spatial decision support of facilities. It has been heavily utilised in natural resources management and research (Longley *et al.,* 2011). As a computer-based tool for mapping and analysing spatially referenced data, GIS can be used for automated mapping and facility management of resources as zoological gardens and parks.

GIS is therefore quite relevant in environmental resources management since it is capable of integrating environmnetal data from different sources and measurement units seamlessly such that the real world is presented on a virtual platform (Gesch and Wilson, 2002). This capability has endeared GIS as a versatile tool to resource managers who requires Automated mapping and facility Management as part of the aid to successful implementation of their dutes (Rich and Davis, 2010). The manager can know which facility to replace, which pen is getting overcrowded and requires expansion, which animal pen requires urgent intervention. GIS will provide near real-time decision support for the zoo manager even at the comfort of his office. Information such as the environmental and physical conditions of facilities at the animal pens can be recorded daily and translated to maps of biosecurity and facility of the entire zoo park. In Nigeria, application of GIS technology for facility management is rather new and as such this paper presents illustrates this using the example of zoological park of Federal University of Agriculture Abeokuta Nigeria.

METHODOLOGY

Study Area: The research was undertaken at the Zoological Park of the Federal University of Agriculture, Abeokuta, Nigeria (Figure 1). The park which lies geographically within latitudes 7^{o} 12’ to 7^{o} 20’ and longitudes 3^{o} 18’ to 3^{o} 27’ was established in year 2010 by the institution for the purpose of fund generation and as a recreation, teaching, and learning resource. The study area is located in the derived Savanah zone of south west Nigeria, a few kilometers north of Abeokuta city. It has different animal groups such as the primates, duckers, cats, birds and reptiles which are just representative of the games found in the wild in this part of Nigeria (IFSERAR, 2010). The forty-hectare zoo has now become a haven to several free ranging wildlife including, monkeys, antelopes and birds of all types because its near to nature (FUNAAB Zoopark, 2016).

Figure 1: Satellite Imagery of the University Zoo Park.

***In-Situ* Data Measurements:** Environmental parameters such as noise levels, ambient temperature, humidity, and luminous intensity were measured directly with a portable 4-in-1 environmental meter which consists of a noise meter, thermometer, hygrometer, and light meter. The measurement of environmental parameters was done at diffenrent locations with the support of a hand-held GPS reciever. Readings recorded at various location around the animal pens were developed into a spatial data base using coordinates of the sample locations.

Sampling Intervals: The sampling was done mostly along existing tracks and around the animal individual pens. The sampling resolution of 10 to 15 meters was adhered to in order to forestall data redundancy on one hand and over-generalization on the other. The closer the sampling interval the better for spatial interpolation of continuous datasets.

Basemap and database creation: The base map was created from the google earth image of the area. The high resolution image was downloaded and visually inspected to ensure recent acquisition. The image was georeferenced using coordinates of known points obtained extracted from the Google earth image of the park. Hand-held Global Positioning Systand hand held GPS. The GPS recievers were useful in tracking roads and paths within and around the park.

The basemap for the zoopark was created "On-screen" digitizing at a scale of 1:5000, with geographic projection in ArcGIS 9.3. Features such as roads and other infrastructure were captured while the GPS locations of the animal pens were added as point layers. Geo-coded environmental parameters were captured using 5 in 1 environmental meter; a special equipment calibrated for parameters such as noise, humidity, luminous intensity and noxious gas concentration. These parameters were tabulated against the respective coordinates of the locations where measurement of the parameters were taken. For example, the noise level around each pen, ambient temperature, luminous intensity, humidity and noxious gas concentrations were tabulated against the geographic coordinates of the respective areas. The figure below is the generalized base map with the location of the animals in captivity.

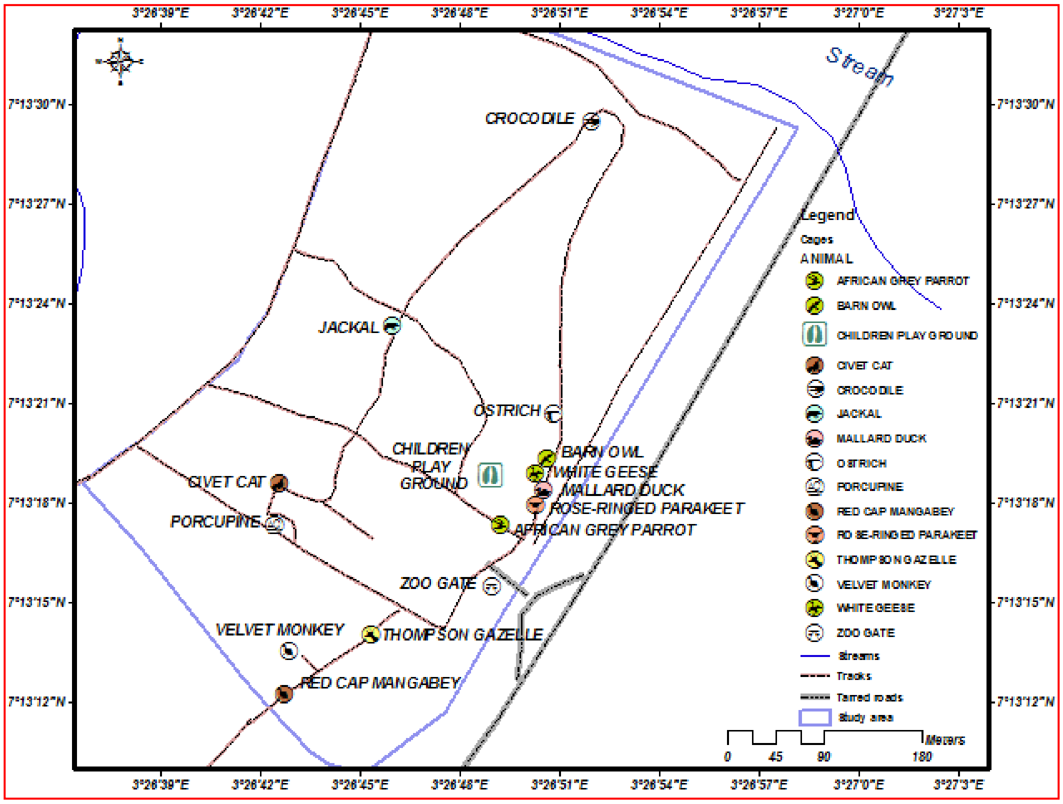

Figure 2: Map of the University Zoo Park showing Location of Animal Pens.

Table 1: Environmental Parameters Recorded at different Locations in the Zoo Park.

S/N	Latitude	Longitude	Sampling points	Noise (dB) [Day 1]	Noise (dB) Day 2	Ambient Temp. (ºC)	Ambient Temp. (ºC)	Lux (up)	Lux (down)	Rel Humid (%)
1	7.2205639	3.4459306	Thompson Gazelle	45	35	33.3	39	94.3	1.8	68.4
2	7.2200611	3.4452083	Red cap Mangabey	51	41	33.5	38	456	54	80.5
3	7.2204222	3.4452417	Velvet monkey cage	43	33	31.8	37	1295	83	94.3
4	7.2212694	3.4452000	Primate Junction	61	51	30.7	36	-2	-0.03	95.4
5	7.2214889	3.4450000	Porcupine Junction	58	48	31	36.3	648	-0.02	92.4
6	7.2214778	3.4451222	Porcupine cage	48	38	31	36.5	541	33	97.5
7	7.2218250	3.4451639	Civet cat cage	49	39	30.8	36.2	647	37	92.3
8	7.2217222	3.4453361	Jackal road pt1	45	35	30.5	35	167.5	24.3	96.3
9	7.2216306	3.4455556	Jackal road pt2	44	34	30.1	35.1	126.7	-0.01	97.2
10	7.2224028	3.4459306	Jackal road pt3	47	37	30.5	35.5	238	6	97.4
11	7.2226611	3.4460639	Jackal road pt4	45	35	30.3	35.3	141.5	8.4	97.9
12	7.2231444	3.4461028	Jackal cage	48	38	30	34	55.8	0.9	97.4
13	7.2234361	3.4462861	Crocodile road 1	51	41	29.7	34.5	17.13	0.1	98.8
14	7.2240444	3.4469028	Bronze manikin nest	70	60	29.6	35.3	0.24	0.13	99.8
15	7.2233930	3.4446700	crocodile road 2	32	42	30.5	35.5	11.5	1.5	95.9
16	7.2248556	3.4477639	Crocodile cage	44	34	29.5	34.7	0.34	0.05	97.5
17	7.2248139	3.4479778	Ostrich road pt1	48	38	29.5	33.5	0.24	0.16	96.2
18	7.2244000	3.4478222	Ostrich road pt2	50	40	29.7	35.2	0.33	0.15	93.5
19	7.2237278	3.4474694	Ostrich road pt3	45	35	29.3	34.3	7.67	0.65	98.8
20	7.2232278	3.4474472	Ostrich road pt4	44	34	29.1	33.1	0.33	0.35	95.8
21	7.2226194	3.4474278	Ostrich road pt5	44	34	28.9	34.9	0.35	0.17	97.8
22	7.2224139	3.4474528	Ostrich cage	45	35	29.1	34.1	0.35	0.22	97.5
23	7.2219111	3.4473056	White Geese	86	76	30.5	35.5	0.35	0.13	98.3
24	7.2220389	3.4473944	Barn Owl	68	58	30.3	36.3	0.31	0.13	98.2
25	7.2217750	3.4473694	Mallard duck cage	48	38	30.4	34.4	0.33	0.22	99.5
26	7.2216472	3.4473028	Parakeet cage	67	57	30.4	33.4	0.28	0.1	97.5
27	7.2215972	3.4470861	Play ground	51	41	30.6	33.6	0.23	0.14	98.1
28	7.2214750	3.4460056	African grey Parrot	54	44	30.5	35.5	0.34	0.21	97.3
29	7.2209667	3.4469417	Zoo gate	91	81	30.7	36.7	0.23	0.1	94.8

Spatial Analysis and Derivative Decision Support Maps: Table 1 above is the database created for the environmentalparameters around the animal pens. The spread sheet containing the spatial data of the sampling points, animal pen location and attributes of each sampled position were saved into a directory in the computer as a database (DBF) file format. The DBF was then imported into the GIS as an event theme.

Spatial interpolation of the data was run for all the parameters collected with the 4 in 1 environmental meter including noise level, temperature, light intensity, and humidity. These present the tranquility, temperature, luminant intensity, and humidity maps of the zoo park, respectively.

RESULTS AND DISCUSSION

The table above is the environmental parameters measured at different position within the zoo park. The table consists of all parameters considered paramount to animal welfare. This paper is constrained by space and as such can not present all parameters measured. However, since it is a demonstration of zoo management using GIS, four parameters presented would suffice as illustration. In the table, noise level and temperature were recorded into two columns because they were observed at different times a particular quiet afternoon and in the evening time of the other day. Environmental parameters should be taken routinely and plotted in GIS in a near real-time for prompt decision support.

The ambient temperature was taken towards the evening time when the sun was already going down. The sixth column however shows the temperature on a hot and sunny day. Temperature pattern could determine productivity of animals. Feed conversion, growth egg, laying and other physiological processes in animals could be influenced by excessive ambient temperature. Animal welfare can therefore be incorporated into management plan through such data.

Spatial Interpolation: The values of environmental parameters as shown in Table 1 is better presented in graphical format. The variability distribution of the parameters is better in map form. The hidden trends and patterns can be easily visualized. An example is the spatial interpolation of ambient temperature as shown in Figure 3 below.

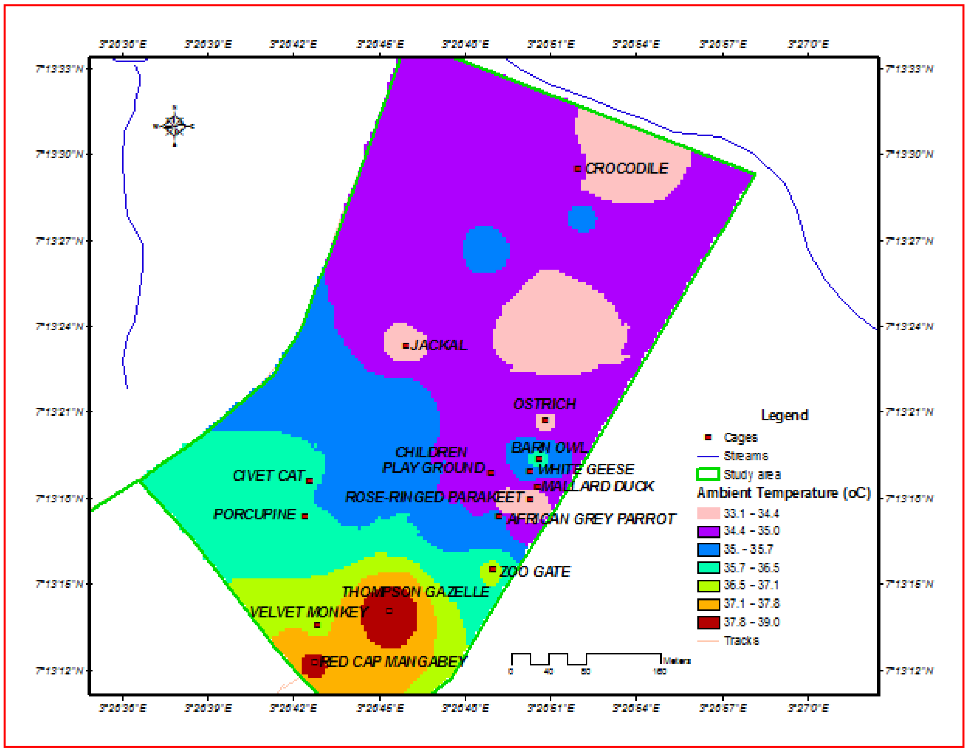

Figure 3: Temperature Distribution of the Zoo Park.

Reclassifying the map of temperature in Figure 3 above into low risk moderate risk and high risk presents the risk map of temperature as shown in Figure 4.

Figure 5 is a map produced from spatial interpolation of relative humidity. It is reveals the most humid portion of the zoo as the northern part; which incidentally is an inland river valley. In the case of FUNAAB Zoo park reptiles such as water loving tortoise, crocodiles, and monitor lizards are positioned here. This provides a good spatial decision support for locating non-water loving animals away from humid zones has no effect on the animals here

Noise disturbance could be an important factor in the performance of animal raised in captivity. The Figure 7 below shows the tranquility map of the zoo park in the afternoon of a particular busy day. The noise maps at different periods will help to know whether the zoo is tranquil and when it is least disturbed, apart from the night hour by noise from the surroundings and within the park itself.

Another parameter that can be interpolated in map form is the luminous intensity (Lux) of the environmnet.

The Figures 7 and 8 shows the intensity of light from the surrounding (up) and the and the fraction of incident light reflected from the ground (down).

Discussion

Continous surface of variability distribution of environmnetal conditions produced from spatial interpolation parameters are very useful in in spatial decision support. For example the temperature map tranformed to temperature risk map could be good for monitoring and managing heat stress in the zoo. Since the map presents the spatial variability distribution of ambient temperature across the zoo park, it is possible to determine areas that require interventions such as more shades or ventilation. Such maps can also aid the the zoo manager in taking prompt decision on where to deploy his limited resources to save the animals from heat stress. The example in the risk map above shows that animals that cannot withstand heat stress should not be placed at the southern portion especially close to the Thompson Gazelle's pen.

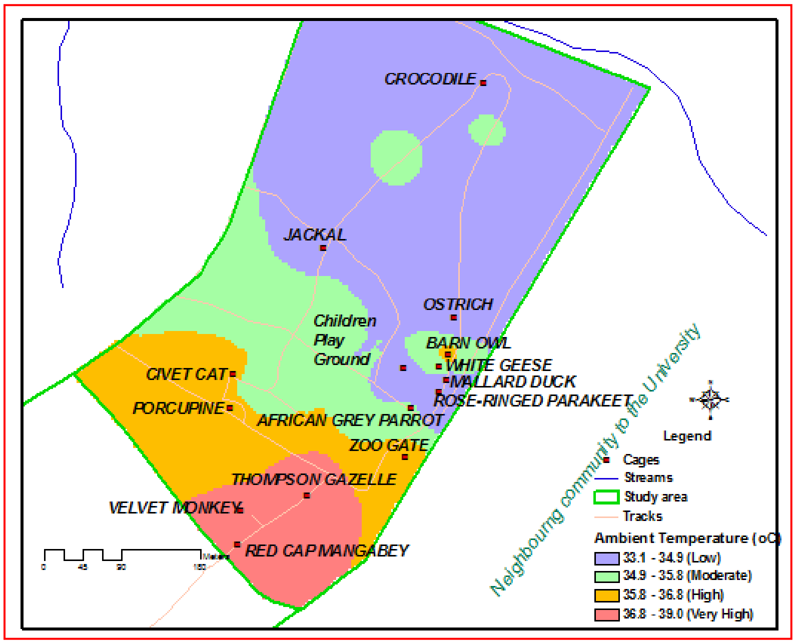

Figure 4: Temperature Risk Map of the Zoo Park.

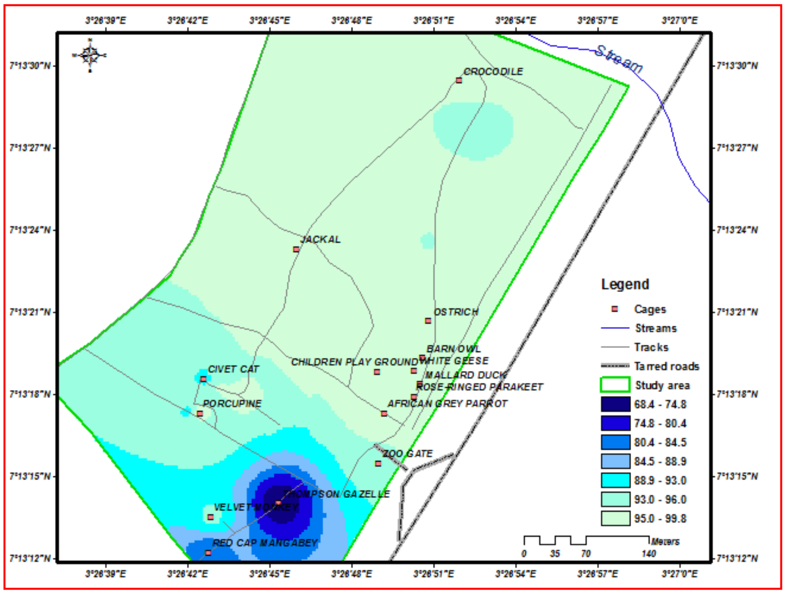

Figure 5: Map of Relative Humidity Across the Zoo Park.

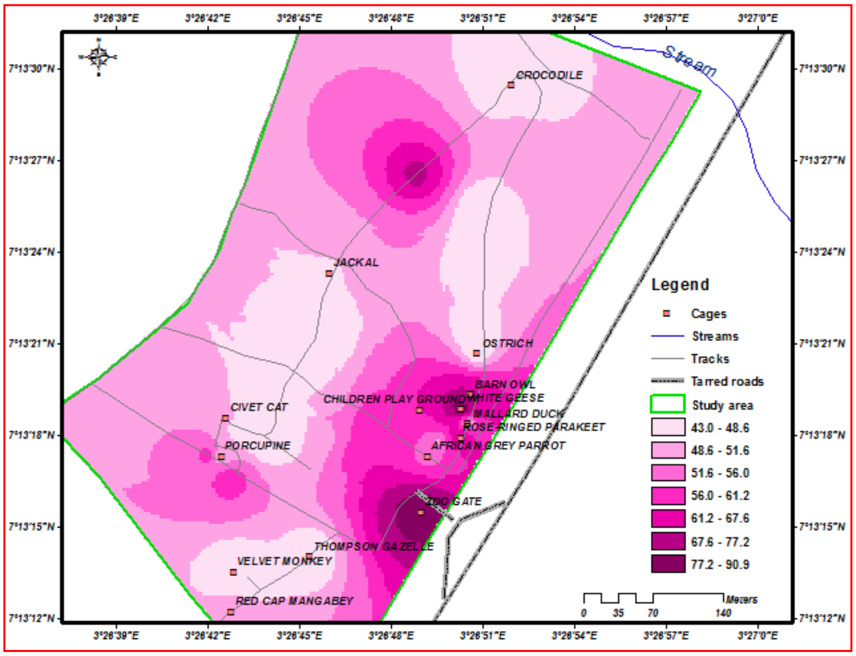

Figure 6: Tranquility of the Zoo Park.

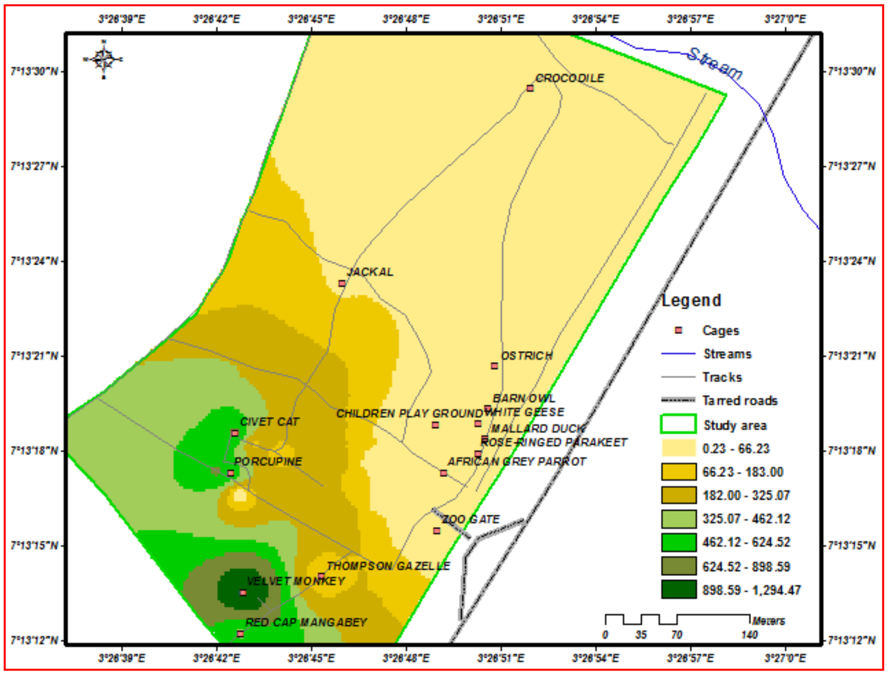

Figure 7: Intensity of Light from the Surroundings (up)

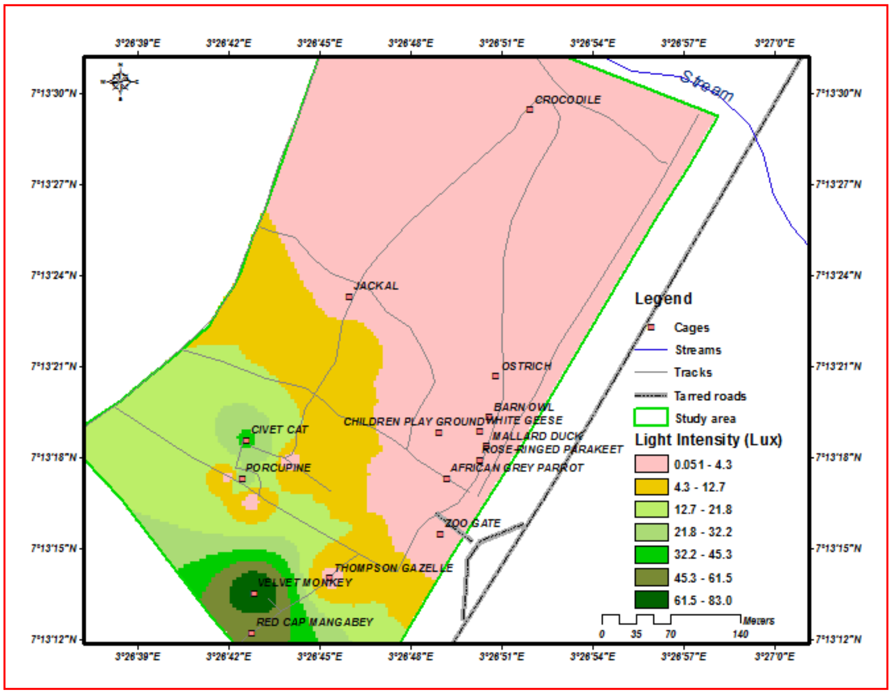

Figure 8: Distibution of the Fraction of Incident Light Reflected from the Ground (down).

Similarly, humidity, tranquility and light intensity maps can also be useful in situating animals at the appropriate locations within the zoo par. Where these maps have been produced as part of strategic baseline documents for a new zoo, it makes planning near accurate. For example, light intensity map is good for situating nocturnal animals like *Galago senegalensis*, while animals that do not like noisy or turbulent environment can be located in areas identified as the most tranquil in the garden.

It is particularly important for nocturnal animals to be placed in areas with minimum albedo; otherwise they are subjected to unnecessary environmental stress that will not make them perform well. When considering biosecurity of the zoo park with respect to weather related contagious animal diseases such as control of causal microbes that thrive under very humid conditions, it is possible to create scenarios for the microbe maps to show areas of the zoo that could be highly vulnerable and the risk is reduced. Since GIS has algebraic functionality it is possible to combine two or more maps to produce another map for spatial decision support.

CONCLUSION

GIS technology has grown over the years as an environmental tool that is flexible for use by any envieonmental resource managers in decision making. This is because of it capability to capture environmental data of diverse source and different measurement units in a seamless manager. Thus GIS presents the real world on a virtual platform. Zoo management decision could be a lot easier if all necessary data are captured into a data base which can be updated in near real-time.

Equipment for analyzing environmental conditions should be position at different location in the zoo and connected to a central data logging system where the data can be collected automatically and imported into a GIS environment. The architecture of the spatial infrastructure in the zoo park should also include a central database system as server with several client.

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