BUSHMEAT HUNTERS DO BETTER

Indigenous Vs Scientific Habitat Evaluation

Michael Abedi-Lartey
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Indigenous Vs Scientific Habitat Evaluation

by

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Dedicated To My Son

Michael Kwasi Tenkorang Abedi-Lartey

May you realise your full potential in life

Abstract

The growing recognition of the importance of indigenous knowledge in the planning and decision making related to the sustainable management of natural resources by resource planners and managers is directly related to the growing realization that scientific knowledge has not contributed to the development of communities and societies, but rather has often resulted in the depletion of their social and natural resources. A typical example is the growing bushmeat crisis in West Africa and elsewhere in the tropics. This has led to the development of programmes, such as the Community Resource Management Programme (CREMA) in Ghana, to devolve resource management rights and responsibilities to local communities. Crucial to this devolution of resource management authority is the need for the local communities to monitor the resource over time and in space to assist them in their decision-making processes. The collection of data on wildlife populations and habitats by conventional approaches are almost invariably constrained by a combination of limited time, space, and funds. Therefore the challenge is to develop habitat evaluation methods that effectively combine the expertise of bushmeat hunters and the utility of the Geographic Information Systems (GIS) and Remote Sensing analytical tools for addressing resource assessment and decision-making. Using a combination of Habitat suitability Index (HSI) and Fuzzy Set analysis in GIS-based habitat modelling, this study looked at whether habitat evaluated by indigenous people (bushmeat hunters) differed from an evaluation at the same time and for the same place by scientists (wildlife ecologists). The Goaso forest agro-ecological was used as a case study, with the Maxwell's Duiker (*Cephalophus maxwelli*) as the evaluation species.

The study findings showed that habitat evaluated by indigenous people (hunters) is in an "Almost Perfect" agreement with scientific evaluation of the same study area. The strength of agreement (Overall Accuracy = 0.93; *Kappa*=0.90) was so significant that there is only a 0.0004 probability that it could have occurred by chance alone ($P < 0.05$). For 94% of the time, hunters classified the *same locations* with the same suitability classes as the wildlife ecologists ($\kappa location$ = 0.94); 96% of the total number of suitability classification by the wildlife ecologist was also assigned the same classes by the hunters ($\kappa histo$ = 0.96). Two major differences of management and research importance were observed between how scientists and indigenous people perceive bushmeat habitats. Firstly, whilst wildlife ecologists would consciously break down the habitat into several components (food, shelter, security, etc.) and attempt to find their individual contribution to the overall habitat suitability, hunters appear to sub-consciously combine the habitat components in a 'single' process, borne of years of personal experience. Secondly, hunters consider not just the diversity and abundance (of food) and density (for refuge) of vegetation cover, but also factor in the *phenology* and *configuration* of the vegetation, factors not captured by the scientific model. From the time perspective, hunters consistently used much less time in evaluating a site, spending between 20% and 25% of the time taken by the wildlife ecologist per site. The financial cost of habitat evaluation by hunters, limited to daily labour cost, is less than a third of the daily food boarding and lodging cost of an ecologist; it is extremely unlikely the gap will ever close up. The conclusion is that hunters could be entrusted with the inventory and monitoring of bushmeat habitat in their communities with a degree of accuracy equalling that of wildlife ecologists, but at a very small fraction of the cost.

The usefulness of this study can be maximized by using long-term participatory GIS methodology, such as long-term village immersion, is used to improve on the understanding of the knowledge acquisition process of hunters. Emphasis should be on identifying the exact inferential system used by the hunters, especially regarding the site conditions (phenology). Furthermore, it would be of considerable research and management interest to apply spatio-temporal scenario development and analysis to assess how hunters' knowledge evolves over time, as well as how the adoption of an integrated agriculture-bushmeat production by local communities would influence their livelihood and the landscape.

Keywords: Bushmeat, Indigenous Knowledge, community resource management, habitat modelling, GIS, HIS, Fuzzy Set, Kappa statistics.

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Abbreviations and Acronyms

ADMADE	Administrative Management Design project.
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer.
BMU	Biodiversity Monitoring Unit.
CAMPFIRE	Communal Areas Management Programme for Indigenous Resources.
CREMA	Community Resource Management Areas programme.
FAO	Food and Agricultural Organisation (UN)
FC	Forestry Commission.
FCC	False Colour Composite.
FSD	Forestry Services Division.
GIS	Geographic Information Systems.
GPS	Geographic Positioning Systems.
HEP	Habitat Evaluation Procedures.
HFZ	High Forest Zone.
HSI	Habitat Suitability Index
IHK	Hunter Knowledge
ILWIS	Integrated Land and Water Information System
ITC	International institute for Geo-Information science and Earth Observation
MLF	Ministry of Lands and Forestry
MoFA	Ministry of Food and Agriculture
NAFGIM	National Framework for Geo-spatial Information Management
NGO	Non-Governmental Organisation
NTFPs	Non-timber forest products
PAMIS	Protected Areas Management Information System
RGB	Red-Green-Blue colour transformation in satellite image processing.
USDI	United States Department of Interior, Fish and Wildlife Service.
WD	Wildlife Division.

1. General Introduction

1.1. Background

1.1.1. The Bushmeat Crises in Sub-Saharan Africa

Throughout most of Africa's history, people have exploited wildlife and plants to meet their dietary, material, and spiritual needs. Bushmeat (the generic name for all meat obtained from the wild) is a major contributor to food security, and represents a vital dietary item for rural people in particular. Within the West and Central African sub-region, bushmeat is eaten by all classes of people and is often preferred to meat from livestock. The total animal protein consumption *per capita* in rural West and Central Africa that is derived from bushmeat has been estimated at between 20% and 90% (Olatunbosum, 1972; Prescott-Allen, 1982); Asibey, 1990; Tutu, 1996; Ntiamoa-Baidu, 1997; Fa, 2003). Ghana has a clear advantage with bushmeat, in that it is a highly valued and readily accepted food resource. The annual bushmeat production from hunters' harvests in 1997 was estimated at 384,991,820 kg (then worth US$ 350 million) while total local consumption was 225,287,000 kg (US$ 205 million). This was nearly 10 times the reported combined production from cattle, sheep, goats, and pigs totalling 36,101,642 kg (US$ 26.5 million) in 1996 (Ntiamoh-Baidu, 1998). Therefore, it is more important than livestock in terms of its contribution to the Ghanaian national economy, through income generation and animal protein production.

However, there is a rapid depletion of wildlife populations as a result of an unregulated exploitation of bushmeat. This situation is assuming crises proportions, making it currently one of the major conservation challenges in the tropical forest region of West and Central Africa. This situation poses a sever threats to the region's biodiversity and the people dependent on them (Bakarr, 2001). In a recent study of five countries in the Congo Basin, Fa *et al* (2003) estimated that only one (Gabon) would be capable of meeting its animal protein needs if bushmeat exploitation is reduced to sustainable levels. A similar crises situation has emerged in Ghana, where the populations of the key species exploited as bushmeat has declined consistently over the past few decades (Ntiamoah-Baidu, 1998; Holbech, 2001).

Fuelling the bushmeat crises in Ghana is wildlife habitat loss. (Murphree, 2001) suggested that even though over-exploitation by hunting is very significant, the greatest threat to wildlife outside protected areas in Ghana is actually through the extensive and accelerating conversion of habitat used by wildlife into other land uses, notably agriculture. Wildlife and environmental integrity is threatened as people clear land and convert habitat for agricultural activities, sometimes just to secure tenure over land for some future use (Amanor, 1996). Thus, the few forest pockets as may be found are highly fragmented, with small, irregular shapes, and are very widely scattered. However, the diverse habitats in this complex, fragmented landscape is ideal for wildlife species adapted to edge-habitat forest and open bush, such as the Maxwell's duiker (*Cephalophus maxwelli*), Bushbuck (*Tragelaphus scriptus*) and the Grasscutter (*Thryonomis swinderianus*), which feature prominently in the bushmeat production and consumption.

Outside protected areas, the farmer is essentially the *de facto* manager of wildlife, as he bears the presence of wildlife and any resulting crop damage; but any hunter (often another farmer) can hunt any wildlife for bushmeat without recompense to the farmer on whose land it is killed. The result is that most farmers consider wildlife a pest that in many cases is directly competing with their agricultural activities. Thus, there has been no incentive on the part of local farmers to invest in the sustainable development of bushmeat resources, either as a business or for subsistence, by allocating habitat suitable for wildlife as a form of land use.

1.1.2. Ghana's Community Resource Management Area (CREMA) Programme.

In recognition of the present and potential contribution of bushmeat and other forms of non-timber forest products (NTFPs) to the national economy, and to help stem the rapid ecosystem degradation, the Ghana government has produced a new Forest and Wildlife Policy (1994). The Policy strongly emphasizes the participation of rural communities and the private sector in the sustainable development of forest and wildlife resources in the country. Presently, plans are far advanced to enact enabling legislations to support the policy. The Wildlife Division (WD) of the Forestry Commission (FC), Ministry of Lands and Forestry (MLF), is developing a community-based wildlife management programme designed to dramatically change the status of wildlife and other resources outside of protected areas. The Community Resource Management Areas (CREMA) programme, as it is known, aims at the sustainable development of wildlife and plant resources in rural communities through pragmatic community participation, thereby addressing nutritional and economic needs of both rural and urban communities. It is modelled on the experiences of mostly southern African countries, especially the CAMPFIRE and ADMADE programmes of Zimbabwe and Zambia respectively (Murphree, 1995; Murphree, 1996; Child, 2000; Prins and Groothenhuis, 2000).

By using wildlife as an economic resource, these programmes typify the utilitarian approach to conservation, with the aim not only to contribute to rural development, but to change attitudes towards wildlife and therefore to the conservation of the resource (Olthof, 1995). Whilst it focuses on wildlife resources and their habitats, the CREMA programme is designed to achieve long-term positive impacts on a wide range of resources other than wildlife. Management rights and responsibilities are devolved directly to the local communities, and the expectation is that it will lead to sustainable resource development in rural landscapes (Murphree, 2001).

The potential for sustainable production and utilization of bushmeat in Ghana has been strongly advocated by several studies over the past four decades. Rural communities, including the proposed project area, Goaso, fully acknowledge the fact that bushmeat contributes significantly to their nutritional status and household income generation (e.g. Ntiamoah-Baidu, 1998; Falconer, 1993; and Holbech, 1996, 1998). A recent study in one of the newly created CREMAs in south-western Ghana estimated potential bushmeat production at US$140,000 *per annum* for an area of only 30 km^2 (Holbech, 1998). Despite the higher cost of bushmeat as compared with meat from livestock, at least 80% of both the rural and urban population consider bushmeat as their preferred form of animal protein, and would eat it if available, even though prices are relatively higher than that from livestock (Ntiamoah-Baidu, 1997; Tutu *et al,* 1996). It is therefore not realistic, possible, or even desirable to stop people using wildlife.

However, approaches and techniques used in bushmeat "ranching" initiatives elsewhere, e.g. Zimbabwe, Namibia and Botswana (Child, 2000; Hitchcock, 2000, Davies 2000; Prins and Groothenhuis, 2000) cannot be applied directly in the Ghana High Forest Zone. This is because the circumstances are considerably different: a forest-based agricultural system, with no pastoral traditions, and different socio-economic interactions with the environment and its resources. This is against the background of generally small land holding of less than 4 ha, and mean cultivated land size per annum of 1ha (Amanor, 1996), within a complex tenure system in which land tenure is divested from resource (e.g. tree and crop) tenure. Besides, communal land ownership and use, as practised elsewhere is currently virtually non-existent in the forest zone of Ghana (Amanor, 1996; Kasanga, 2001). Thus, the challenges are also different, and call for appropriate approaches, such as the adaptation of the general principles established in these southern African experiences to the circumstances and specific needs of Ghana.

1.2. The Problem Statement

There is a very high risk of failure for community resource management programmes such as the CREMA if high expectations about the feasibility and profitability raised amongst stakeholders are not met. This might result from two major factors. Firstly, not every agricultural landscape is suitable or capable of producing bushmeat, let alone on a sustainable basis. Integrating bushmeat production into an existing agricultural land use would entail major changes to farming practices such as conversion of land cover/use to create appropriate wildlife habitat. If the risk of failure is perceived to be high, such as resulting from the absence of a source population of the target species to restock created or existing habitat, farmers might become irrevocably disillusioned. Secondly, local communities are to regularly monitor the status of bushmeat populations and habitat on their lands in order for them to make informed management decisions. For reasons of financial, logistics and literacy limitations, it is not feasible for the Wildlife Division to train local hunters and farmers in conventional resources monitoring methods, which mainly rely on measurements and counts in plot and plotless evaluation techniques. The most realistic option seems to be the development of rapid resource evaluation techniques using indigenous knowledge and skills. This calls for the assessment of the existing indigenous techniques to verify their capability to meet scientific standards, and to improve them if necessary. For this reason the indigenous techniques must be compared with conventional scientific habitat evaluation techniques to determine their relative merits.

For bushmeat production to be fully integrated into conventional crop production as envisaged by the CREMA programme, it must be demonstrated to both farmers and land use planners as a viable land use option. This would help them make appropriate decisions about land allocation. These decisions would mostly be based on the perceived profitability of bushmeat production, dictated by economic and ecological considerations. Farmers look up to relevant state institutions like the Wildlife Division (the key implementer of the CREMA programme), the Forestry Services Division (FSD), and the Ministry of Food and Agriculture (MoFA) to provide this information. These state institutions, in turn, must make appropriate, scientifically informed policy and management decisions, based on multiple objectives and criteria. The scale of such decision-making spans the farmstead through landscape, to district, regional and national levels. Although many studies have been done on bushmeat in Ghana, especially on its trade, none of the existing data have yet been converted into a GIS database.

Under the CREMA programme the local people themselves will conduct inventory and monitoring of wildlife populations and habitats. The WD expects to play only a facilitatory role, providing technical support when needed (Murphree, 2001). This means that evaluation procedures to be developed must be simple to save cost; and yet be subject to high scientific standards. Furthermore, data resulting from this resource evaluation must be compatible with (and incorporated into) existing environmental and socio-economic databases at the district, regional and national administrative levels. The most relevant existing spatial databases for this purpose are the National Framework for Geo-spatial Information Management (NAFGIM), the Protected Areas Management Information System (PAMIS) of the WD, and the FSD's GIS database. A requirement for the development of such a bushmeat database is to establish standardised habitat assessment procedures, indigenous or otherwise, to provide relevant data. It is imperative that such assessment procedures be developed as early as possible in the programme cycle to help meet CREMA's information needs.

1.3. Objectives and Questions

The goal of this study was to assess the potential of using habitat evaluated by indigenous people (specifically hunters) in GIS-based wildlife management planning. The specific study objectives were to achieve this goal were to:

1. Evaluate the habitat of Maxwell's Duiker in Goaso, using the Habitat Suitability Index (HSI) modelling techniques.

2. Evaluate the habitat of Maxwell's Duiker, using indigenous (hunter) knowledge of the local people in Goaso, a typical agricultural community in the forest zone of Ghana.

3. Compare the two habitat evaluation techniques.

Based on the above study objectives, the study sought to answer the following questions:

1. What are the most appropriate habitat variables for the development of a conventional scientific HSI model for Maxwell's Duiker?

2. What habitat variables and criteria do indigenous people (hunters) in the Goaso area use to evaluate habitat suitability for Maxwell's Duiker?

3. Where are the most suitable Maxwell's Duiker habitat in the study area, as evaluated by the scientific HSI, and by the indigenous HSI techniques?

4. How do the indigenous and the scientific habitat evaluation techniques compare?

1.4. Hypothesis and Assumptions

Hypothesis:

The study hypothesis was that Indigenous Knowledge is equivalent to the use of conventional scientific techniques in evaluating bushmeat habitat.

The underlying assumptions were that:

1. There was suitable habitat for the production of bushmeat species as a land use option in the tropical forest agro-ecosystem.

2. There were viable source populations of the species for (re) stocking suitable habitats in the study area.

3. The local people understand were willing to adopt land use practices favourable to the creation and/or maintenance of habitat for bushmeat species as an integrated bushmeat and crop production system.

1.5. Study Approach

Figure 1.1. shows the conceptual approach used in this research work.

1.6. Study Area

The proposed study was conducted in 69,484 ha (694.9 km^2) agricultural area to the north and northeast of Goaso (6º 48' 00" N; 2º 31' 00" W). The area was generally covered by topographic map numbers 0603A2, 0703C4, 0703D3 and 0603B1, and lies between longitudes 2º 15' 00" W and 2º 45' 00" W, and latitudes 6º '45' 00" N and 7º 10' 00" N. It straddles two administrative districts: the Asunafo District Assembly and the Asutifi Districts Assembly, of the Brong-Ahafo Region, Ghana. However, it lies entirely within the Goaso Forest District of the FSD. The Goaso Study Area is a rural community that is typical of biophysical and socio-economic conditions pertaining in most of the fragmented forest agro-ecosystems in the Moist Semi-deciduous (MS) High Forest Zone (HFZ) of Ghana. The topography is gently undulating lowland. The climate is hot and humid, with a bimodal (April-July; September-November) rainfall ranging from 1,500-1,750 mm, and mean annual temperature range of 26-29 ^{o}C. Three major rivers drain the area: the Tano, Ayum and the Go. **Fig. 1.2** shows a map of the Goaso study area with an inset ASTER 321 imagery.

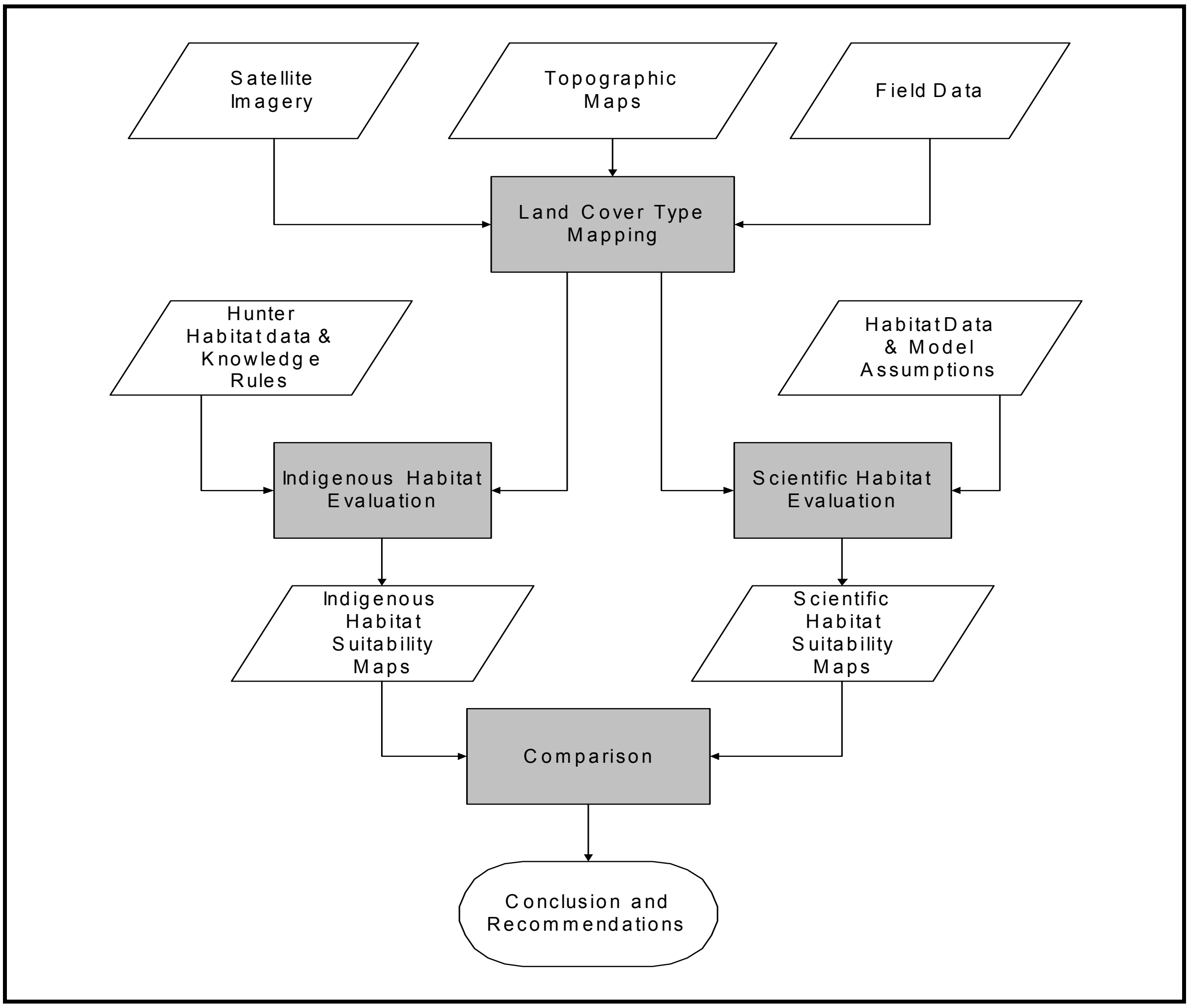


Fig. 1.1. Conceptual framework of the study.

The major land use is rain-fed agriculture , with cocoa as the major cash crop, and mixed cropping of cassava, maize and plantain for subsistence and commerce. Until recently, the ultimate goal of virtually every farming activity was a cocoa farm. The Goaso area also has the largest area of contiguous forest reserve network in Ghana. The area is currently undergoing a process of mass migration of youth from forest rural communities to urban areas; in some cases, whole villages hardly exist anymore. This is not due to land hunger *per se*, but to the fact that decline in forest soil fertility has made the conventional rain-fed agricultural practices uneconomical.

Most communities were established and thrived during the first half of the 20th century as a result of the government active promotion of the cocoa (*Theobroma cacao*) industry. Prolonged periods of severe drought in the early 1980s in the West African sub-region, coupled with economic recession over the past two decades led to a steady decline in the cocoa production. With the death of most founding cocoa farmers, large areas of cocoa farms are being converted to mixed cropping of cassava (*Manihot esculenta*), plantain (*Musa sapientum*) and maize (*Zea mays*). This conversion is largely due to the fact that renewing old cocoa farms, even with hybrid cocoa varieties, entails a higher risk of failure due to the absence of ideal micro-climatic conditions like shade trees for the seedling stage. Oil palm (*Elaeis guineensis*) plantation is emerging as an alternative to cocoa as a cash crop; this is even worse than cocoa in the removal of tree cover and reduction of biodiversity. Soil nutrient in this rain-fed, low input agricultural system gets depleted after a few years of cultivation. In the mostly gently-undulating landscape, most farmers cannot convert to the labour and capital-intensive options such as fertilizer application and irrigated farming for several reasons, chief among which is the lack of, or limited access, to funding and subsidised agricultural inputs. They are, therefore, compelled to resort to reducing fallow periods drastically from the hitherto average 5-7 years to as low as 2 years.

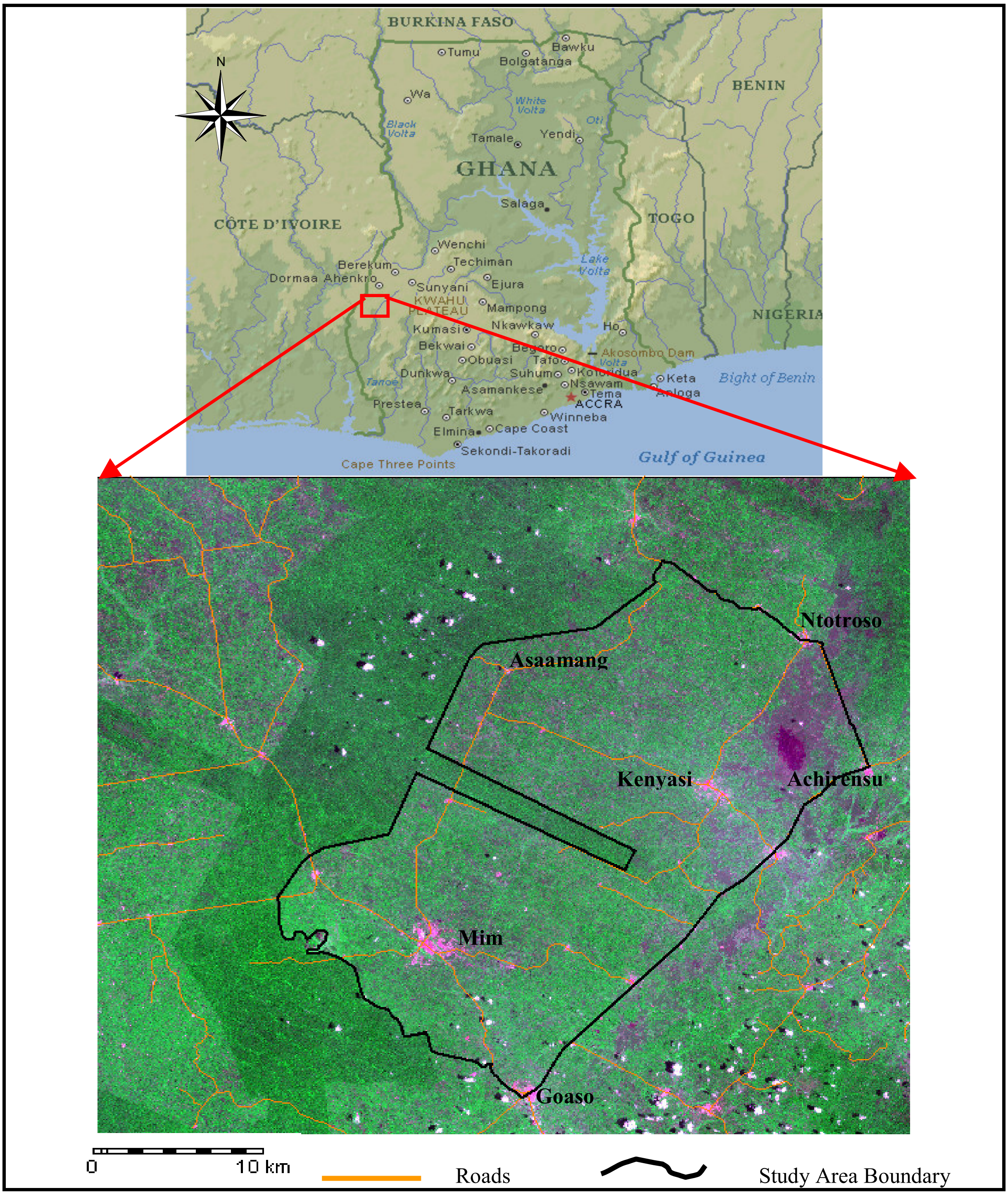


Fig. 1.2. Map of Ghana showing location of Goaso area and unclassified ASTER RGB231 image (26th April 2003) with delineated study area (inset).

In the face of growing land scarcity, which has been created by population growth and land tenure issues, the traditional fallow cultivation is becoming impractical. Beyond a certain threshold of cultivation intensity, unmanageable invasive weeds such as “Acheampong” (*Chromolaena odorata)* and, to a lesser extent speargrass (*Imperata cylindrica*), have invade most of the land; they therefore

become unsuitable for cultivation of local staples and cannot be expected to recover to desirable fertility levels within even 10 years. Thus, they are considered as practically useless for cultivation. As there is now very little extensive virgin land available for cultivation, children of the farmers, most of whom were initially settlers, have no option than to migrate to urban areas. A resulting benefit of the demographic changes is that more land is being abandoned and becoming available for "involuntary" fallow. These areas are expected to expand over time, and could be suitable habitat for the key bushmeat species. It would be reasonable to assume that, in combination with crop cultivation, the diverse habitat mosaic that has been created could make a more profitable and environmentally more suitable land use option than the existing situation.

1.6.1. Justification for Selecting Study Area

1. Availability of remote sensing and topographic maps required.

2. Relatively easy access to, and within, the study area.

3. Local people in the area have expressed a desire to try bushmeat production in their farming system.

4. Tropenbos (Ghana), a forest conservation Non-Governmental Organisation (NGO), has a project site located there. One of its objectives is to develop methods of assessing forest resources for sustainable development and would, therefore, benefit from the research results.

1.7. Choice of Evaluation Species

Two factors influenced the choice of Maxwell's Duiker (**Fig. 1.3**) as the evaluation species:

Fig. 1.3. Captive adult male Maxwell's Duiker (*Cephalophus maxwelli*)

1. It is the second most prominent species (after Grasscutter) used in the bushmeat industry in Ghana (Falconer 1993; Ntiamoh-Baidu, 1998). In a week's survey of 27 traded bushmeat species in urban markets spanning all ecological zones in Ghana, Ntiamoh-Baidu (1998) observed that Maxwell's Duiker constituted 14.5% of all carcasses (n = 48). This value may be higher when the numbers consumed or traded at source in the rural communities are taken into account.

2. Their habitat requirements represent the two ends of the habitat spectrum in the research area. Maxwell's Duiker is primarily a high forest frugivorous species; but it can adapt quite well to other habitat types created by conversion of primary forest to agriculture, such as farm-bush (Kingdon, 1997, Wilson 2001). With the on-going agricultural encroachment on the original high forest in the research area, this adaptive trait in a complex habitat mosaic should enable it flourish.

Hence, there is both a high economic demand, and an ecological adaptation that favours the evaluation species as a prime candidate for integration into the rural land use system.

1.8. Data Sources

Primary data for developing the Indigenous Habitat Suitability Index (HSI) model was derived from vegetation cover variables using line transects, and from Infrastructural network within the research area. The main interest was not only on the vegetation structural attributes, but on the floristic composition as well. This was further supported by semi-structured interview of local people, mostly hunters and farmers. For the HIS model, the primary was field-based semi-structured questionnaire interview of hunters.

Secondary data for both models were taken from two main sources. Firstly, literature (e.g. articles, books and field guides) provided background data on species habitat requirements socio-economics of the research area. Satellite images (ASTER bands 1, 2, and 3, of 26th February 2003) and 1:50,000 topographic maps of the research area were used to provide the necessary geographic information.

1.9. Materials

The following materials were used in constructing the models:

1. Maps and satellite imagery:
   a. Multi-spectral satellite imagery (ASTER bands 321 of 26th February 2003).
   b. Topographic maps (1:50,000).

2. Software:
   a. Mtb13 ® (MINITAB) and MS-Excel 2000® for data processing and statistical analysis;
   b. MS-Word 2000® for report wring;
   c. ILWIS 3.12® for image calculations and visualisation.

3. Field equipment:
   a. Garmin® GPS, Suunto® Compass, measuring tape (30m), hypsometer, binoculars.
   b. Field guides on African mammals (Kingdon, 1997 and Estes 1992).

2. Concepts and Definitions

2.1. Models and Habitat Modelling

Models are simplifications of reality, a representation of part of the real world, as seen through the eyes of modeller. For example, no two geologists (or ecologists) will produce identical maps of the same area. They observe different objects, which convey different meanings, and the interpretation of the underlying geology depends on their experience and philosophy (Bonham-Carter). In practically the same way, a wildlife ecologist may develop a habitat model based on his interpretation of the species' underlying ecological requirements, as influenced by his experience and philosophy. The representation of a model ranges from simple words to complex equations; there is often little relationship between the mathematical complexity of a model and its fit to reality (Verner *et al* 1986).

Habitat models form the basis for all inventory, management, and monitoring, and thus forms the general underlying principle of habitat management. To understand and categorise a habitat model, one needs to identify the habitat components being used as predictor, the population attribute being predicted and the type of function being used to relate the two. A habitat model, as used in this study, is defined by Cooperrider (1986) as any formal method for correlating habitat variables with population attributes of a single or multiple species. The basic components of typical habitat models are shown in **Fig. 2.1**.

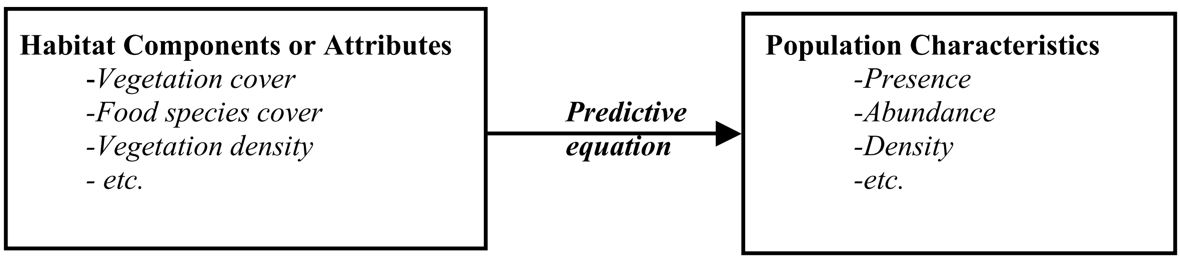


Fig. 2.1. Basic components of a typical habitat model (*Adapted from Cooperrider, 1986*).

Developing a habitat model generally consists of five phases, which occur in the following basic sequence (Cooperrider, 1986; U.S.D.I, 1981):

i) Determining model objectives: defines the desired output (e.g. species density or richness), as well as geographic area, seasons and other factors the model should predict.

ii) Selecting and quantifying habitat variables: determines the biotic and abiotic characteristics of the habitat, which, if modified, would be expected to affect its capacity to support the evaluation species.

iii) Determining the correlation or prediction function amongst habitat variables: defining the relationships between the habitat variables and representing them in a graphical display, word statement, or mathematical equation.

iv) Documenting the model: recording the assumptions and structure used in developing the model, and the steps needed for its implementation.

v) Verifying the model: testing (e.g. with field data from monitoring) the hypothesis used to develop the model so that refinements can be made to improve its reliability.

There may be some procedural overlap among these phases because they do not always represent sequential, independent steps. Thus, the model construction is best seen and applied from a holistic point of view. The conceptual approach (**Fig. 3.1**) used in this study for developing the HSI model was limited to Phases **(i)** to **(iv)** of habitat modelling as listed above, but without verification as a result of time limitations.

Over fifty habitat-based methods have been developed for addressing terrestrial and/or aquatic environments. Notable amongst these is the Habitat Evaluation Procedures (HEP) system, which was developed to assess the capability or suitability of a defined habitat to support a specified species (USDI, 1981). An HEP consists of a series of Habitat Suitability Index (HSI) models developed for individual animal species, and is based on the assumption that habitat for selected wildlife species can be described by a "habitat suitability index" (HSI) value (described below). HSI models can be used to document the quality and quantity of available habitat for selected wildlife species. Constructing a HSI model requires a structured evaluation of pertinent variables indicative of habitat quality. It focuses on the selection of representative faunal species, called "evaluation species", and the subsequent evaluation of habitat quality relative to the species, rather than the faunal community. HEPs have been used mostly in prospective studies, e.g. environmental impact studies (Canter 1996).

2.2. Habitat

Documenting a model, for possible replication and implementation, demands the use of accurate and unambiguous terminology. In view of the central role it plays in this study, it was necessary to clarify what constitutes a 'habitat'. There are numerous different definitions in literature, but the working definition here was that:

> "*habitat is the suite of resources (e.g. food, shelter) and environmental conditions (abiotic variables such as temperature, and biotic variables such as competitors and predators) that determines the presence, survival, and reproduction of a species*".

It comprises all those physical attributes of the environment that make an area habitable for a species. However, it is not in itself a specific resource but the sum of all physical resources for that species. "Habitat" is what wildlife managers see when they declare an area suitable for a particular species. They might not be able to explain logically what is they are seeing because they are summing up an amalgam of all the species' physical resources (Caughley *et al*, 1994; Hall *et al*, 1997). A habitat, as used in this model, was based on both the physiognomy and floristic composition of the vegetation cover. The basis for this approach was the observation by Elton and Miller (1954) and Elton (1966) that wildlife ecologists are interested in vegetation as a matrix in which animals live and feed, and therefore focus on the structure, usually the degree of stratification, and habitat diversity.

2.2.1. Habitat Type Characteristics

Biophysical characteristics such as vegetation, slope, aspect and soil types are attributes that influence the spectral radiance of a site on the earth's surface. Using satellite imagery to characterize vegetation cover and composition, as was done in this study, should be done only to the extent that it elucidates the likely spectral response of the field site. Not only is it important to determine the biophysical characteristics of a field sites; it is also valuable to assign each site to one of the categories of the land cover classifications (Wilkie and Finn, 1996). In order to acquire data for a vegetation classification system, which may be delineated in satellite images, and in the field, vegetation had to be analysed. The basis for this analysis was vegetation morphology (i.e., the composition and the structure), since it is not possible to describe the vegetation or make a classification without morphological definitions (Küchler and Zonneveld, 1988).

The evaluation species in this study, Maxwell's Duiker, derives its major life requirements, food and refuge (shelter from the weather and security from predation), from the vegetation in its habitat.

Therefore, in conformity with Küchler and Zonneveld (1988) this study focused primarily on the identification and analyses of the structural and compositional characteristics of the study area's vegetation that offer these life requisites. *Physiognomic-floristic combination* habitat maps were therefore used for both the scientific and indigenous habitat evaluation approaches in order to account for these life requisites at the same time.

2.2.2. Habitat Suitability Index (HSI) Models

The HSI model represents the scientific habitat evaluation component of this study. In developing the HIS model, use is made of existing data, literature, and expert opinion to develop an equation or algorithm to use a small number of selected habitat variables in predicting the suitability of a habitat for a wildlife species. The HIS is determined through an aggregation of Suitability Index (SI) scores for life requisite components such as food and shelter. Suitability for a given animal species is indicated by an index ranging from 0 to 1, with 0 indicating unsuitable habitat and 1, optimal habitat. The HSI for a species at a given site is not intended to predict population levels, but a higher HIS should indicate a better habitat quality, and therefore a greater ***potential*** carrying capacity for the evaluation species (Schamberger and O'Neil, 2000). Calculation of the HSI is based on a structured evaluation of selected variables indicative of habitat suitability. HSI models differ from the closely related Habitat Capability (HC) models in that the latter uses habitat models to predict ***animal density.*** The models developed in this study were solely for evaluating the ***potential suitable habitat*** for the evaluation species.

2.2.3. Habitat Requirements and Model Variables

A wildlife species' habitat requirements are analysed in terms of its needs for food, water, cover, and reproduction as well as the spatial and temporal distribution of these habitat variables (Cooperrider, 1986). Thus, habitat variables used in the models had to reflect, and be derived from, habitat attributes that provide these requirements. According to Schamberger and O'Neil (2000), variables used in HSI models are limited to those:

a. to which the species responds;
b. which can be measured or estimated readily;
c. whose value can be predicted for future conditions;
d. which are vulnerable to change over time; and
e. which can be influenced by planning and management decisions.

Many variables known to influence animal population are excluded from HSI models if they cannot be readily measured (e.g. predation), managed (e.g. weather), or predicted for future conditions e.g. competition). The result is a HSI model that has a very restricted operational definition of habitat for a specific purpose and for a specific geographic area.

The variables in the study area that met the above five criteria, and which I found most appropriate under the research circumstances, were related to the vegetation physiognomy (structure) and floristics (composition). They were *vegetation cover*, from which were derived the percent food species cover and *shelter*; and *security* estimated from visibility through undergrowth. The habitat variables and their interrelationships as used to estimate suitable habitat for the evaluation species are shown in **Fig 2.2.**

The objective for using line transects for data collection was to quantify habitat variables used in developing the models. Mueller-Dombois and Ellenberg (1974) listed density, frequency, and cover as the most important measures (parameters) of vegetation quantity. Vegetation cover was the parameter used in this study to measure vegetation quantity. It is defined by Mueller-Dombois and Ellenberg (1974) as the vertical projection of the crown or shoot area of a plant species to the ground surface, expressed as a fraction or percent of a reference area. The choice of vegetation cover in this

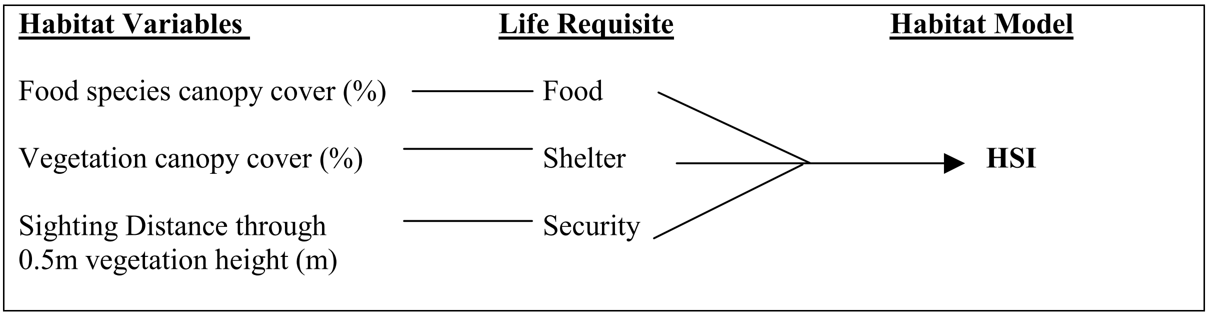


Fig. 2.2 . Tree diagram showing relationship of habitat variables, life requisites, and cover types to HSI. (*Adapted from USDI (1981*).

study is based on the observations by Rice (1967) and Daubenmire (1968) that it is of greater ecological significance than other measures of vegetation quantity, such as density. This is because cover gives a better measure of plant biomass or quantity than the number of individuals, which is what density and frequency measurements do. Mueller-Dombois and Ellenberg (1974) pointed out two further advantages of cover as a measure of vegetation quantity:

a. Nearly all plant life forms, from trees to mosses, can be evaluated by the same parameter and thereby in comparable terms. This does not apply to density and frequency. Moreover, cover can be measured in several ways, depending on the kind of vegetation and the study objectives.

b. Plant biomass is evaluated through cover only in conjunction with a measure of depth or height. For descriptive purposes, this is accomplished by the stratification of a vegetation community into various height layers. Therefore, cover must be evaluated separately for each height layer or vegetation stratum.

These advantages are important in using cover as a habitat parameter in this study because Maxwell' Duiker derives its food from herbs, shrubs and trees, which constitute the different layers in each cover type in the study area. These same vegetation life forms offer the shelter and security life requisites.

In the GIS and Remote Sensing applications, it is much easier to capture quantitative than qualitative information. One of the main problems when classifying digital images is the confusion of spectral classes: different objects may have the same spectral behaviour and one single object may correspond to several spectral classes (Jansen *et al,* 1999). Thus, there may never be a 100% classification accuracy.

2.2.4. Indigenous Knowledge (IK).

The local knowledge of a people is known by many synonymous or partially overlapping terms, but the most commonly used amongst these is Indigenous Knowledge (IK), which is defined by Grenier (1998 as:

> "*the unique, local knowledge existing within and developed around specific conditions of women and men indigenous to a particular area"*.

Ellen and Harris (2000) elaborates on this by qualifying IK as:

> "*experiential, rooted in place, transmitted orally or by practice, empirical, functional ,reinforced by trial and error, dynamic, shared in a fragmentary fashion between individuals within a population and usually distributed unevenly between them; and it is embedded in the local socio-cultural milieu*".

The study of IK is distinct from anthropology, as it focuses on development issues and problems to produce a locally informed development agenda and solutions of relevance to local people (Sillitoe, 1998). In this study, IK is limited specifically to the subset of an indigenous people's knowledge pertaining to wildlife and its ecology. According to Berkes (1999), even though clear delimitations are difficult to make and exceptions exist, traditional ecological knowledge is generally differs from Western scientific ecological knowledge in a number of ways:

i) Traditional ecological knowledge is often an integral part of a local culture, and management prescriptions are adapted to the local area.

ii) Resource users themselves are the "managers"; they identify themselves as members of a local community and not as individual scientists or resource managers answerable to their peers or to an anonymous government agency.

Since the indigenous knowledge base used in this study is a highly specialised skill acquired and exercised by hunters, it would most appropriately be called Indigenous Hunter Knowledge (IHK) to distinguish it from the general indigenous ecological knowledge. The resulting indigenous habitat model should best be considered an Indigenous Habitat Suitability Index Mode.

2.3. Geographic Information Systems (GIS) As A Management Tool

Geographic Information Systems are software packages used for the capture, analysis, manipulation and display of georeferenced data (Wilkie and Finn, 1996). GIS and remote sensing tools enable the quantification and understanding of spatial and temporal processes that accompany spatial dynamics, as well as the presentation of how extensive the phenomenon is on a spatial scale.

In the context of habitat modelling, one of the most difficult problems of combining habitat variables is taking into account their spatial arrangements. The interspersion and juxtaposition of habitat features can be very important to wildlife. However, quantifying these relationships in a meaningful way is very difficult (Cooperrider, 1986). GIS greatly assists in the analysis and visualization of these relationships. Since spatial data can be associated with specific geographic locations, GIS can model or simulate land uses and resource values (Peterson and Matney, 1986)

2.4. Fuzzy Set Theory and Fuzzy Logic

In classical set theory, the membership of a set is binary, and is defined as either true or false, 0 or 1. Only two possibilities exist, with crisp boundaries between: a parameter belongs either to a set, and is classified as 1, or it does not belong to the set, and is classified as 0. This concept is rigid, and does not accept any ambiguity, imprecision, or vagueness in an individual's membership of a set. The theories of fuzzy set and fuzzy logic were introduced by Zadeh (1965, 1978) to deal with problems characterised by vague knowledge. In contrast to crisp sets, fuzzy sets do accept vagueness and uncertainty. Membership of a fuzzy set is expressed on a continuous scale from 0 (full non-membership) to 1 (full membership). Fuzziness is a type of imprecision characterising classes that for various reasons cannot, or do not, have sharply defined boundaries; it is an admission of the possibility that an object (or elements or property) is a member of a set. The assessment of this possibility can be based on subjective, intuitive expert knowledge.

If an object in a fuzzy set is assigned a value 1, it means that the individual belongs to the fuzzy set to a greater degree than when it is assigned a lower value. The ranked values between 0 and 1 are known as **membership grades**, or **certainty factors,** to reflect the degree of belonging (Beek, 2000). A **Fuzzy Membership Function** (FMF) is an expression defining the grade of membership of an object, $\boldsymbol{x}$, in a set ,$\boldsymbol{A}$. and may be mathematically represented (McBratney and Odeh, 1997; Sicat, 2003) as:

$$\boldsymbol{\mu}_A(x) \longrightarrow [0,1] \qquad \textbf{\textit{(eq. 2.1.)}}$$

From this can be derived the following mathematical expressions:

$$\mu_A (x) = 0 \quad \textit{(eq. 2.2)}$$

$$\mu_A (x) = 1 \quad \textit{(eq. 2.3)}$$

$$0 < \mu_A (x) < 1 \quad \textit{(eq. 2.4)}$$

Equations ***(2.2)*** and ***(2.3)*** mean that that x does not belong to and fully belongs, respectively, to the subset ***A***. Equation ***(2.4)*** means that x belongs to set ***A*** to some degree (i.e. has partial membership).

Six operators/models can be used to combine fuzzy sets in fuzzy set analysis (Beek, 2000). These are (1) Fuzzy AND, (2) Fuzzy OR, (3) Fuzzy Algebraic Product, (4) Fuzzy Algebraic Sum, and (5) a combination of Fuzzy Algebraic Product, Fuzzy Algebraic Sum (called Fuzzy Combined after Valenzuela, 1994) and (6) fuzzy Gamma operator. With specific reference to spatial analysis using maps (An *et al*, 1991); Bonham-Carter, 1994; Valenzuela, 1994; and Beek, 2000), a review of how the membership values of two or more maps with fuzzy membership functions may be combined together, using any of the fuzzy operators is as follows:

(1) Fuzzy **AND**, defined by:

$$\mu_{combination} = MIN(\mu_A, \ \mu_B, \mu_B \ \mu_C, \quad) \quad \textit{(eq. 2.5)}$$

where μ_A is the membership value for Map A at a particular location, μ_B is the membership value for Map B, etc.

The Fuzzy AND operation is controlled by the minimum fuzzy membership values occurring in the input maps, such that combining two maps with membership values of, say, 0.75 and 0.50 at a given location would result in an output value of 0.50 at that location.

(2) Fuzzy **OR** operator , defined by:

$$\mu_{combination} = MAX(\mu_A, \ \mu_B, \mu_B \ \mu_C, \quad) \quad \textit{(eq. 2.6)}$$

with definitions as in ***equation (5)*** above. In contrast to the Fuzzy AND operation, the Fuzzy OR operation is controlled by the maximum fuzzy membership values occurring in the input maps, such that combining two maps with membership values of, say, 0.75 and 0.50 at a given location would result in an output value of 0.75 at that location.

(3) Fuzzy **Algebraic Product (minimisation)**, defined by:

$$\mu_{combination} = \prod_{i=1}^{n} \mu_x \quad \textit{(eq. 2.7)}$$

where μ_x is the fuzzy membership function for the ***x***-th map, and i = 1, 2,, n maps are to be combined.

This operation is the product (multiplication) of the different maps, with fuzzy membership values in the range (0,1). The result tends to be very small with this operator, due to the effect of multiplying several numbers less than 1. For example, the algebraic product of two maps with values (0.75, 0.50) is (0.75 * 0.50) which equals 0.375. The output is always smaller than, or equal to, the smallest contributing membership value. The Fuzzy Algebraic Product is therefore decreasive. Unlike the Fuzzy AND or Fuzzy OR operators, all contributing membership values have an effect on the result.

(4) Fuzzy **Algebraic Sum (maximisation)**, defined by:

$$\mu_{combination} = 1 - \prod_{i=1}^{n} (1 - \mu_x) \qquad \textbf{\textit{(eq. 2.8)}}$$

The Fuzzy Algebraic Sum operator is complementary to the Fuzzy Algebraic Product. The result is always larger than, or equal to, the largest contributing fuzzy membership value. For example, the Fuzzy Algebraic Sum of (0.75, 0.50) is 1 – (1 – 0.75) * (1 - 0.50), which equals 0.875. The effect is, therefore, increasive; nevertheless, this increasive effect is limited by the maximum value 1.0, which can never be exceeded. Whereas the Fuzzy Algebraic Product is an algebraic product, the Fuzzy Algebraic Sum is *not* an algebraic summation.

(5) Fuzzy **Combined** operator, defined by:

$$\boldsymbol{\mu}_{combination} = W_1 * \mu(x_1) + W_2 * \mu(x_2) + \ldots W_n * \mu(x_n); \text{ where } \sum_{i=1}^{n} W = 1 \qquad \textbf{\textit{(eq. 2.9)}}$$

The Fuzzy Algebraic Product and Fuzzy Algebraic Sum respectively minimise and maximise results. To avoid these extreme values it is possible to apply method of combining the Fuzzy Algebraic product and Sum to create the Fuzzy Combined operator. In this case, the output map (or value), $\boldsymbol{\mu}_{combination}$, is the **sum** of different input maps x (x = 1, 2,….n) with fuzzy membership values in the range (0, 1), multiplied by a weight facyor (W); the sum of the the weight factors ($W_1 + W_2 + \ldots W_n$) should be equal to 1 (Valenzuela, 1994).

(6) Fuzzy **Gamma** operator, defined by:

$$\boldsymbol{\mu}_{combination} = \left(\prod_{i=1}^{n} (\mu_x)\right)^{1-\gamma} * \left(1 - \prod_{i=1}^{n} (1 - \mu_x)^{\gamma}\right) \text{ ;where } 0 < \gamma < 1 \qquad \textbf{\textit{(eq. 2.10)}}$$

The Fuzzy Gamma operator is another combination of the Fuzzy Algebraic Product and the Fuzzy Algebraic Sum operators. When the gamma factor (γ), which is a parameter in the range (0,1), is 1, the combination is the same as the Fuzzy Algebraic Sum; when it is 0, the result equals the Fuzzy Algebraic Product. Judicious choice of the γ value produces output values that ensure a flexible compromise between the increasive tendencies of the Fuzzy Algebraic Sum and the decreasive effects of the Fuzzy Algebraic Product (Bonham-Carter, 1994).

It must be noted that in using the Fuzzy AND or the Fuzzy OR operators, a fuzzy membership of a fuzzy set controls the output value. The other operators, on the other hand, combine the effects of two or more fuzzy sets in a "blended" result, so that each membership set has some effect on the output (Bonham-Carter, 1994). Fuzzy membership values must lie in the range (0,1), but there are no practical constraints on their size. Values are simply chosen to reflect the degree of membership of a set, based on subjective judgement, and do not increase or decrease monotonically with class number.

3. Scientific Habitat Suitability Index (HSI) Models

3.1. Introduction

The aim of developing the scientific habitat model, using a modified Habitat Suitability Index (HSI) modelling approach, was to provide a standardised basis of comparison with the indigenous habitat model. This chapter rests on the assumption that for the sake of expediency, a typical wildlife ecologist would use the HSI modelling technique, modified to capitalize on the advantages offered by GIS/RS tools. The underlying question for the model was: "*How would a typical wildlife ecologist, using satellite imagery and GIS, assess the suitability of the study area as habitat for either of the two bushmeat species?*". It was necessary to develop first a habitat model using scientific techniques because none had been developed for the evaluation species within or outside Ghana. Without this, it would be difficult to tell the worth of the model developed from the hunter (indigenous) knowledge. This chapter details the modelling procedure for the evaluation of Maxwell's Duiker habitat in the Goaso Study Area using scientific data collection and reasoning processes of a typical wildlife ecologist.

3.2. Methods

The Scientific HSI model essentially followed the HSI modelling technique as designed by the USDI (1981). However, some modification was necessary to account for two important factors:

a) The absence of data on the empirical relationship between habitat variables and animal presence, leading to a high level of uncertainty in the modelling process. This called for the application of fuzzy logic analysis.

b) Neighbouring habitats influenced the suitability of any particular location as a habitat for a given (spatial context). This called for the application of buffering/constraint effect.

These modifications were facilitated by the use of GIS modelling tools. **Fig. 3.1** shows the general methodology used in developing the Scientific HSI model.

3.2.1. Satellites Images and Maps Processing

Medium-resolution (15m) satellite imagery (ASTER Bands 1, 2 and 3) were combined to create a RGB 321 False Colour Composite (FCC) of the study area. These bands were georeferenced to the same coordinate system, the parameters of which are shown in **Fig. 3.2.** This was used to derive an unsupervised land cover map, using the Maximum Likelihood classifier, for fieldwork. The optimum unsupervised land cover classes were seven, beyond which cover classes were repeated. During post-fieldwork image processing, ground truth data were used to reclassify the map into a seven-class land cover map, of which five were distinct habitat types. Major infrastructural network, such as roads, settlements and water bodies, were generally not measured in the field because they could be easily observed in the satellite images. They however served as important locations for taking ground control points for the image geo-referencing. The average distinct land cover patch in the study area was about 1ha. This was the average area that could be farmed by a typical family per season in the Goaso area. Therefore, the building block for the models was 1ha, and was created from a re-sampling of all images from the original 15m.

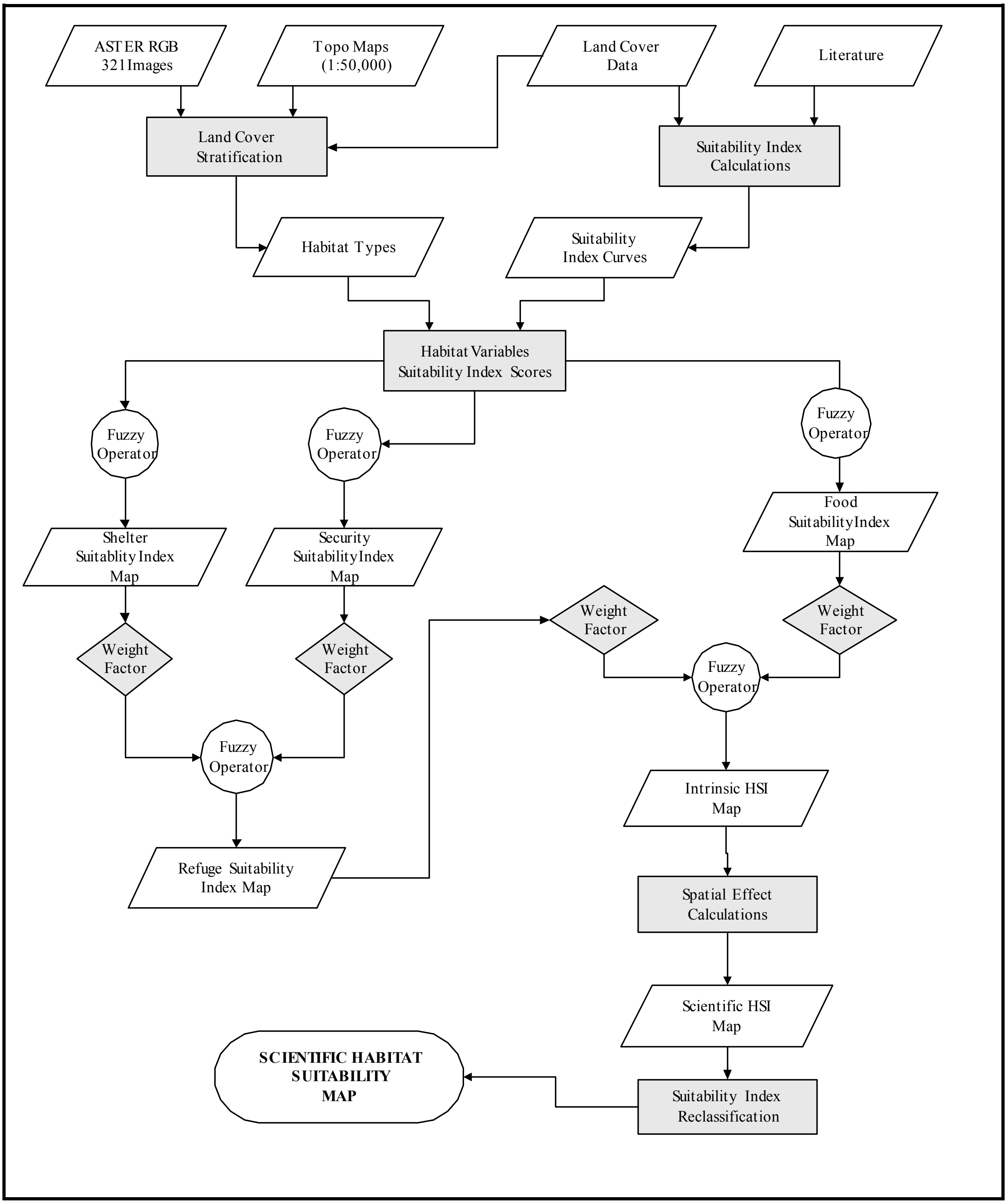


Fig. 3.1. Inference Network for the Scientific Habitat Suitability Index Model development.

3.2.2. Field Data Collection

3.2.2.1. Sample Points Allocation

I had planned using the Area Frame Sampling technique, in which grid cells of 150m x 150m (2.25 ha, made up of twenty ASTER pixels each) would be applied. However, in view of the highly fragmented land cover types and relatively small patch sizes, this technique was found to be impractical. Instead, I opted for the Stratified Random Sampling technique (Thompson, 1991). Seventy sample sites were allocated to the seven land cover types in the unsupervised ASTER image (see **Table 3.2**). However, preliminary analysis of first few samples dictated that the sample allocation should not be done strictly proportional to size of land cover types because the level of homogeneity within cover types was not equal. For example, grassland and cocoa plantations appeared structurally and floristically more homogenous than bushland; therefore, the later was allocated more samples.

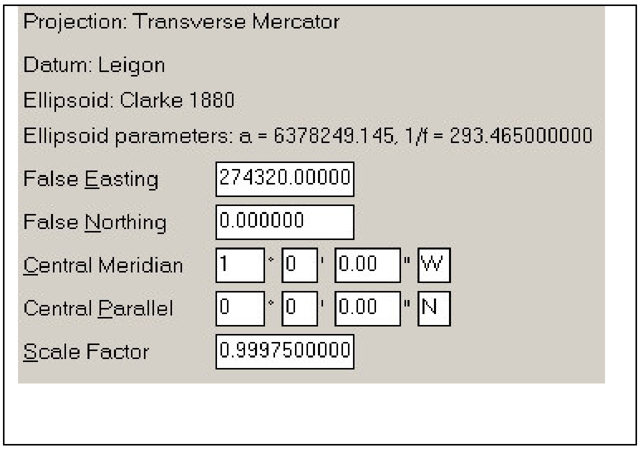


Fig. 3.2. Georeference parameters

3.2.2.2. Stakeholder Interviews

A cross-section of identified stakeholders were informally interviewed. Respondents were made up of farmers, hunters, bushmeat traders, and District Assembly, agricultural, forestry and wildlife agencies. Interviews mostly took place at the normal place of operation: government and non-governmental agency staff in their offices, farmers and hunters in the field. The objective was to identify ecological, socio-economic and policy factors that influence land use/cover, and therefore model output, for decision-making (e.g. crop type and productivity, land and resource tenure, and land use).

3.2.2.3. Habitat Data Collection

A Garmin 12XL GPS unit was used for field navigation and location of sampling areas. Fieldwork was done with three other students working on different research topics in the study area, leading to the need to share one vehicle. We, therefore, collectively selected for each day the same general location for data collection; because of our different objectives and methods, we split up afterwards.

Field guides were always the hunters from whom I collected site data for the Indigenous habitat model (see **Chapter 4**). These hunters were recruited from the nearest village whenever possible. Occasionally, they were from communities farther away, but invariably they had a first hand knowledge of the sample area for the day. Upon arrival at the general area of a pre-selected sample point, we used the point where the habitat type patch touched the access route (road, trail, footpath, etc) as the start point (0m) of a line transect. Where a route was lacking, we hacked through the vegetation from the nearest access point. This was mostly the case in bush and secondary forest area. A quick reconnaissance walk was then taken to determine the direction of the patch that would give a 200m transect within the selected habitat. Starting from 0^o and moving clockwise at 45^o intervals, a transect was cut in the direction of the first cardinal point that met this 200m length criteria. **Fig. 3.3** is a representation of the transect layout.

Wilkie and Finn (1996) recommended that data collection on vegetation cover should focus on the relative canopy closure of the trees, shrubs, saplings, or of herb and grass cover. This supported the observation by Mueller-Dombois and Ellenberg (1974) that cover layering among trees is ecologically very important, and that where crowns overlap in layered vegetation the cover should be measured separately for each height. A major disadvantage of using methods like the point-intercept in measuring cover in multi-layered vegetation is that the height or depth of the crown cover cannot be assessed. To minimise this limitation, I used the line intercept method to estimate vegetation cover. This was based on the fact that the line-intercept can assess the cover of woody plants separately for more than one height stratum (Mueller-Dombois and Ellenberg, 1974), thereby making it possible to capture the contribution of each layer to the variables under consideration. Beside this consideration

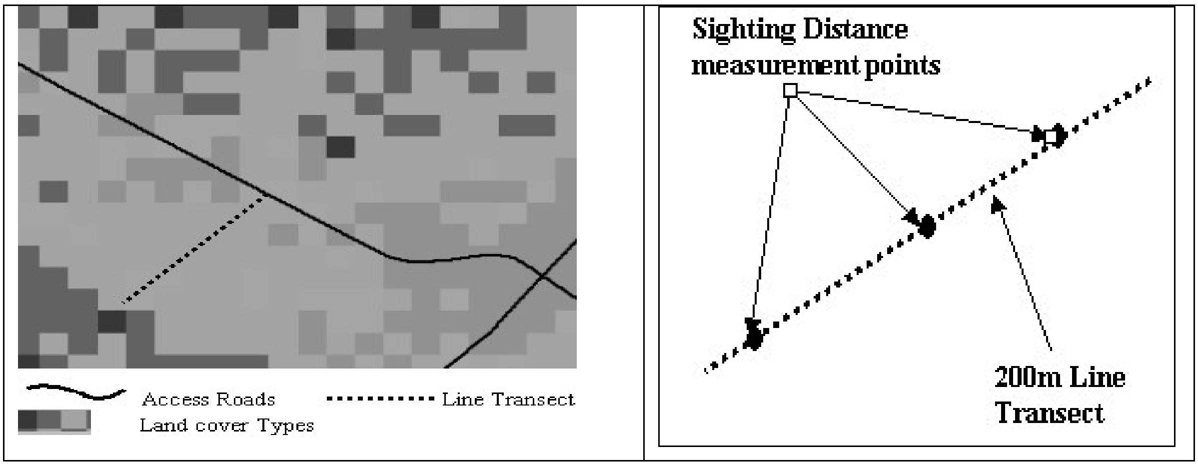


Fig. 3.3. Transect layout in a selected land cover type.

was the need to avoid (or minimise) the uncertainty of determining plot boundaries inherent in plot sample designs such as the quadrat or strip and belt transects (Thompson, 2002; Elzinga *et al*, 2001). Above all, the line transect is the simplest and fastest method to analyse the floristic composition of a plant community and therefore is particularly useful where time is essential (Küchler and Zonneveld, 1988).

Along each transect, habitat variables recorded on a field data form (**Appendix A**) for the following life requisite were:

- **Shelter:** estimated from the vertical projection of the canopy of the uppermost tree in each of the layers. The method here followed Elzinga *et al* (2001). Canopy cover was measured along the line intercept transects by estimating the point along the measuring tape where the vertical projection of the canopy begins and where it ends.

- **Food**: estimated by the vertical projection of canopy of food species for either bushmeat species was estimated. The estimation was done in the same way as for shelter. Food species were identified primarily from a list of plant species recorded by Wilson (2001) as used by Maxwell's duiker in the forest zone of Ghana. This list was upgraded by including plant species identified by the hunters and guides as Maxwell's Duiker food species (**Appendix B**).

- **Security:** sighting distance measurements from predators (limited to hunters and dogs in this study). These observations were made at the 50m, 100m and 150m points along each transect. At each of these points, distance was measured to the spot at which a 0.5m stick would become invincible, from the background vegetation, to an average 5ft 5in tall hunter. The observations were made in the North, East, South, and West compass directions, and summed up for each 50m site. This was an attempt to approximate how much concealment a stationary but active (e.g. feeding, grooming) Maxwell's Duiker would achieve at each site. It was based on the assumption that as a "hider" that quickly dives into thickets or freezes, even in mid-stride, for concealment (Wilson, 2001), sighting distance is a very important in its anti-predator strategy.

To help in the description of each vegetation cover type, I also recorded the height and diameter of all trees in the upper layer, as well as those of trees above 30cm dbh in the middle layer. This additional information was useful in determining the characteristics of habitat types.

Two very important sources of error in crown cover assessment are the relative accuracy of vertical projection, and the crown outline itself (Mueller-Dombois and Ellenberg, 1974). The line intercept method was developed primarily for plants with almost 100% crown density that at the same time also have a solid or continuous crown outline. Many trees in the study area did not meet these criteria. In conformity with observations by Mueller-Dombois and Ellenberg (1974, crown outlines of trees taller than 15m were difficult to assess accurately without a sighting tool, as was the case in this study. To reduce the projection error resulting from the visual estimation, crown cover was estimated to the nearest 1m.

To reduce estimation errors resulting from the crown outline Mueller-Dombois and Ellenberg (1974) recommended that for trees with sizeable gaps between branches, the gaps should be excluded from measurements for greater precision. The protocol for gaps used in this study was that a canopy was assumed to be closed until a gap exceeded approximately 0.3m. The estimation of this threshold was possible only for the ground and middle vegetation layers (≤ 15m). For the upper layer, a 0.5m threshold was used. Oil palm had a peculiar situation because the numerous tiny gaps in its fronds permitted light to pass through. To account for this, a 1m deduction was made for every 10m of continuous fronds.

In addition to the vegetation observations, any evidence (faeces, feeding signs, foot prints or direct sightings) of the evaluation species was recorded. Observations were for presence/absence data only and no attempts were made to estimate animal density in view of time constraints. The hunter/guides were invaluable in determining the identity of animal signs.

The current land cover and land use for each sample vegetation patch was recorded with the help of the land user (e.g. farmer) on-site. Where the land cover appeared to have been different in February, when the satellite image was taken, I got the earlier cover type from the landowner or nearby resident. In the absence of local information, I used the vegetation type and structure to extrapolate back to the cover type in February.

3.2.3. Habitat Modelling

3.2.3.1. Habitat Components Combination

Once habitat variables have been selected, defined, and quantified, the modeller must determine the relative importance of each to the others (Cooperrider, 1986). Habitat variables can be combined in unlimited number of ways using various weights and mathematical functions. In the simplest case it may be assumed, or determined, that all variables are equally important, giving a simple additive model in which all variables carry equal weights. If, on the other hand, some variables are considered more important, they are assigned higher weights, so the suitability index produced is influenced more by that variable. The relationship amongst habitat variables may be much more complicated if any of the habitat variables has a limiting effect on the evaluation species. In that case, if the variable has an SI value of zero, the overall HSI becomes zero, and the habitat is not suitable for the evaluation species.

Beek (2000) observed that models applied with GIS in relation to natural resource processes often deal with uncertainty factors, which can be of different magnitudes. Uncertainty must be accounted for in a model when certain properties are difficult to measure, e.g. habitat properties such as food abundance in this study, or when data are insufficient for statistical analysis, or even when relations between indicators (habitat variables) are not clearly known. In these cases, an approximation or evaluation can only be made based on expert experience. Fuzzy logic analysis is based on expert knowledge and experience, and can be applied to natural resources data when imprecise data have to be analysed when vague knowledge has to be represented in the form of linguistic rules, with imprecise terms.

Based on the above considerations, I chose fuzzy logic as the main reasoning mechanism in this modelling process because of four key factors:

i) Data on the exact relationship between habitat variables and suitability for the evaluation species was either very minimal or non-existent. I therefore had to rely on the characteristics of habitat preferences of Maxwell's Duiker as deduced from literature. This was reinforced by my own personal observations within and outside the study area, and before and during the study period.

ii) The variables involved were fuzzy, with a mixture of classes. For example, it was uncertain whether a Maxwell's Duiker actually distinguishes between the "shelter' and security" functions provided by vegetation cover? Furthermore, is a 0.500 Suitability Index score for Food cover worth the same as a 0.500 score for Shelter to the animal?

iii) It was uncertain what the suitability class boundaries should be in the suitability index maps produced as intermediary phases of the model development.

iv) There was no chance for model verification with either part of the field data (because it was too little to be split), or with post-fieldwork model verification data.

These factors introduced considerable uncertainty that could only be conveniently accommodated by fuzzy logic analysis because in contrast to crisp sets, fuzzy sets do accept vagueness and uncertainty (Beek 2000).

Therefore, I applied the Fuzzy Set Theory instead of Classical Set Theory in the combination of model components. The fuzzy operator (see **Section 2.4**) that proved most ideal for this study was the combination of the Fuzzy Algebraic Product and the Fuzzy Algebraic Sum operators, referred to as Fuzzy Combined (Valenzuela, 1994). This was done because, in the absence of empirical data on their relative contribution to the overall habitat suitability, each habitat variable had to be assigned a weight based on assumptions generated by the modeller, which is in turn based on his expert knowledge. The Fuzzy Combination offered more control over the size of weight assigned to each habitat variable.

3.2.3.2. Neighbouring Habitat Type Effect on Site Suitability

The overall suitability of a habitat increases (to a point) as life requisites occur closer together and as the overall quantity of life requisites resource increases (USDI, 1981). The intrinsic evaluation f a site is by itself not an accurate rating of the quality of that site (Gerrard *et al,* 2001). For example, whilst matured secondary forest may be the preferred habitat of a MD, there is a difference between a matured secondary forest site surrounded by annual bush or settlement and a site surrounded by other matured secondary forest. A site is assumed to have a high-value neighbourhood if there are other "good" cells within a specified radius of it. If the locality is composed of marginal or poor habitat type, the spatial context is downgraded. Thus, the ultimate quality of a site is the additive combination of its intrinsic and locational values or qualities (Gerrard *et al,* 2001). To address this spatial context of cells in the model, the range that an animal may move in any direction from a given point had to be established. This was used as a guide to estimate the bound on the relevant neighbour of any cell in the intrinsic suitability map.

3.3. Results

3.3.1. Habitat Variables

Using line transect as sampling units is essentially a two-stage sampling strategy. The line transects are the primary sampling units, and the points on it are the secondary sampling units (Elzinga *et al* 2001). Standard deviations are associated with both the primary sample (the line transects) and the secondary sample (recording points) so there was the need to subject the data collected to the more complex formulas of two-stage sampling. However, Cochran (1977) pointed out that in situations like this, the standard deviation of the secondary sampling unit data could be ignored, and recommended simply using the mean of each transect's data collection points as the unbiased estimate of the transect value. Therefore, for the shelter habitat variable the vertical projection of each vegetation layer along a transect were added and then divided by the total line length to give the percent vegetation cover along that transect. This was repeated for the food habitat variable, except that only canopy cover of food plant species were used. Because of the multiple vegetation layering, the total cover at sample sites often exceeded 100% in most cases.

A total of 69 food plant species from 32 families were recorded (see **Appendix A.)**. All species in the list were reported by the hunters as preferred food species of Maxwell's Duiker. Out of this, 15 were confirmed for the species lists of Wilson (2001) and Hoffmann and Roth (2003). It must be noted that this species list from literature are not exhaustive, as they were limited to fruit species as well as to the hard and fibrous components of the plant that could be retained post-mastication.

In the case of the Security habitat variable, the sighting distance values of each of the observation points (50m, 100m, and 150m) along each transect (**Section 4.2.4**) were averaged to give the score for that transect. **Appendix D** is a summary of the habitat data.

3.3.2. Habitat Type Description

Based on the spectral characteristics in an ASTER RGB 321 False Colour Composite (FCC) satellite image, seven distinct habitat types (**Fig. 3.4**), which were made up of various land cover type associations, were identified in the study area. **Table 3.1** shows that Young Secondary Forest (34.5%) and Matured Secondary Forest (32.7%) constitute the largest habitat types in the study area. With a combined total of 46,845.7 ha, (these two habitat types accounted for 67.2% of the entire study area. On the other hand, Wetlands and Built-up Areas, with a combined acreage of 1,830.9 ha, covered only 2.6% of the area.

Table 3.1. Mean Suitability Index (SI) values of habitat variables for Maxwell's Duiker in Goaso Study Area.

Habitat Type	Food species canopy cover (%)	Vegetation canopy cover (%)	Sighting Distance (m)
Matured Sec. Forest	*0.940*	*0.779*	*0.770*
Young Sec. Forest	*0.700*	*0.822*	*0.847*
Farmbush	*0.361*	*0.705*	*0.814*
Cocoa Forest	*0.866*	*0.603*	*0.422*
Monocrops	*0.328*	*0.481*	*0.274*
Wetlands	*0.000*	*0.000*	*0.000*
Built-up Areas	*0.000*	*0.000*	*0.000*

Using the structural and floristic properties, the habitat types were characterised by their major land cover and land use systems as follows:

- **Farm-bush (Fmb):**

This habitat type was made up of three sub-types: food crops farms, bush fallow land dominated by Chromolaena (*Chromolaena odorata*), and grassland. These vegetation cover types were often found together at the same site, but where they were separate the Chromolaena-dominated bush was the most abundant. They were difficult to distinguish as distinct habitat types in the ASTER images because of strong similarities in their spectral reflectance at the time the images were taken. At the peak dry season in February, most vegetation had either withered or shed their leaves. The grassland was either dominated by Elephant grass (*Pennisetum purpureum*) or Panic grass (*Panicum maximum*), or a mixture of the two. Invariably, they were mixed with varying densities of Centrosema (*Centrosema pubescence*) and Chromolaena, as well as other herbs and shrubs. Grassland might have been withered or partly burnt at the peak of the dry season, when the satellite image was taken. Food crop farms were at any stage between newly harvested to preparation (clearing) for the next season. In all instances, there was dense single ground vegetation layer of 0-3m. Thus, though there was a marked floristic diversity, the strong structural similarities resulted in their classification as one habitat type.

- **Cocoa-Forest (CFr):**

This was essentially a cocoa plantation, but with an additional relatively dense layer of broken canopy matured trees. From afar, they are indistinguishable from Matured Secondary Forest (MSFr). There are three distinct layers: very sparse ground cover (if not regularly brushed) an even-aged, closed canopy cocoa layer between to 3-15m, with an upper layer of relatively dense matured indigenous tree species with a broken canopy up to 50m. This is typical of the " Tetteh Quarshie" cocoa variety, which was the variety of choice until the 1980 and '90s. This shade tolerant cocoa variety requires low temperatures and high humidity and therefore farmers left lots of forest trees to serve as shade trees in the early stages. After the closure of the plantation species canopy, these shade trees are still left, though a few may be felled for timber or to reduce the shading effect.

Monocrops (MnCr):

Even-aged plantations of cocoa and cashew made up this cover type. Though these species may be present in other cover types as young plants, they assumed a dominant identity around 4 years, when

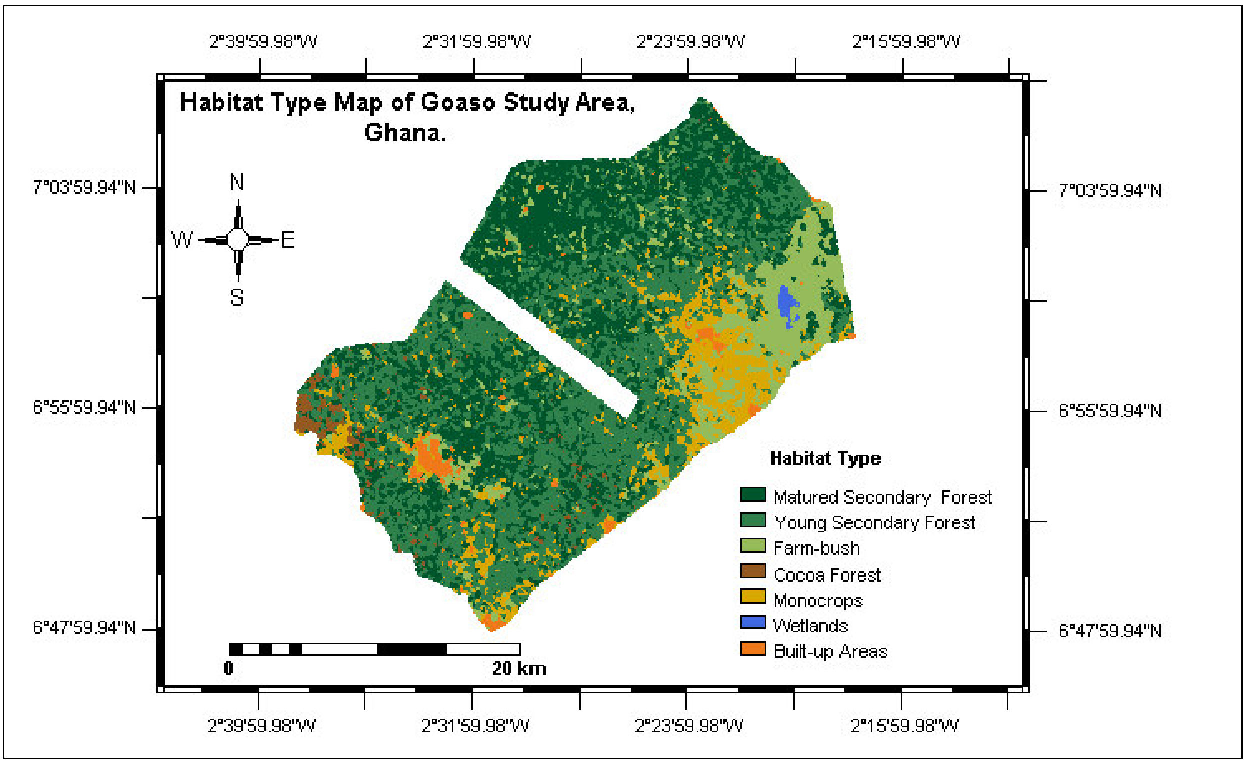


Fig. 3.4. Habitat Type distribution map of the Goaso study Area.

their canopies were closing up. There were generally two vegetation layers: a ground cover (0-3m) and an upper layer made up of the plantation species at 5-10m high. In the closed canopy cocoa, there was virtually no ground vegetation, except in situations where little under brushing had been done, or along streambeds; in such cases the vegetation was mostly herbs and young Akyeampong. In cashew plantations, the more open canopy favours grass as the undergrowth, with a few stands of Akyeampong. As a habitat type, MnCr offers little food or refuge.

- **Young Secondary Forest (YSFr):**

These were 5-15 year-old fallow land made up of two vegetation layers. The ground cover was dense mixtures of Chromolaena at the verge of being shaded out by liana tangles, whilst the upper layer/canopy is predominantly pioneer species reaching heights of 10-15m Traces of food crops (plantain and cassava) and tree crops (cocoa and oil palm) may be found in this cover type, and may still be yielding. Depending on the previous land use system, there are considerable numbers of large (up to 110m dbh) trees as emergents. It was very difficult to separate stands of matured (>10 yrs) oil palm plantations from the typical YSF cover type because the spectral properties in the ASTER satellite image was nearly indistinguishable. I considered this the ideal habitat for the evaluation species in cultivated landscapes because both the fruiting trees and crop remnants offer abundant food, and the thick undergrowth is very difficult to penetrate by humans but perfect for the hunch-shaped duiker.

Table 3.2 Habitat types characteristics and line transect distribution in study area.

Habitat Type	Typical Land Cover Type	Typical Land Use System	Line Transects Allocation	Area (ha)	Percent Habitat Type
Farm-bush	*Chromolaena bush, Grassland, Food crops, or mixture.*	*Annual Cropping, Young Fallow*	*28*	*9,832.5*	*14.1*
Cocoa Forest	*Three-layered cocoa plantation with large indigenous trees*	*Perennial Cropping*	*13*	*2,318.9*	*3.30*
Monocrops	*Single layered, even-aged Cocoa or Cashew nut plantation.*	*Perennial Cropping*	*8*	*8,894.3*	*12.80*
Young Secondary Forest	*Two-layered Secondary Forest, Oil Palm plantation*	*Old Fallow*	*15*	*24,053.5*	*34.5*
Matured Secondary Forest	*Three-layered Secondary Forest*	*Old Fallow, Public Cemetery.*	*6*	*22,792.2*	*32.7*
Built–Up Areas	*Buildings and Roads*	*Settlements, Transportation*	*0*	*1,602.9*	*2.30*
Wetlands	*Marsh and open- water bodies*	*Fallow*	*0*	*228.0*	*0.30*
TOTAL			***70***	***69,722.2***	***100.00***

- **Matured Secondary Forest (MSFr):**

Matured Secondary Forests were forest areas resulting from long-term (at least 15 years) fallow from cultivation. The spectral reflectance was the same as the intensively logged forest reserves. This cover type was generally made up of three vegetation layers. The ground cover (0-3m) was sparse where the middle and upper canopies are closed. There was hardly any trace of the shade-intolerant Chromolaena; the few stands are found at the edges, or in wide gaps formed by wind-throws or fire. The middle layer was made up of saplings and poles of the upper canopy species, and reaches up to a discontinuous average height of 15m. The upper layer was far more discontinuous than the middle layer, and is mostly made up of up to 30m tall emergents left over from cultivation or (if of timber quality) tress still below the felling size. Liana tangles were less dense than in Young Secondary Forests and were mostly limited to the ground and middle layers, but their stems were thicker. In undisturbed areas, this cover type was the ideal for Maxwell's Duiker because of the abundance of fruit-bearing trees and the cool, shady undergrowth. However, the relatively open undergrowth offered less safety from hunters.

- **Wetlands (Wt):**

Wetlands in the study area were areas under permanent standing water; they were either open water areas or had various densities of elephant grass, reeds and other (semi) aquatic plants. This cover type was given a habitat suitability score of zero because water in itself was not one of the habitat variables used in the models, and the evaluation species was not aquatic or semi-aquatic to be able to utilise it.

- **Built –Up Areas (Bu):**

This "habitat" type is a combination of settlements, roads, and bare soil. Settlements ranged in size from hamlets of about 2-3 swidden huts roofed with Raphia palm (*Raphia hookeri*) thatch, to major towns of a few thousand concrete buildings roofed with corrugated iron, zinc or aluminium sheets. Roads included asphalted highways about 10m wide, to 3m-wide dirt roads. As in the Wetlands, this land cover type was not considered a true habitat for the evaluation species, and was given a suitability score of zero because there was no chance for a Maxwell's Duiker to survive in the natural state.

3.3.3. Deriving Suitability Index Curves for Habitat Variables

Empirical data on habitat variables and their suitability rating for Maxwell's Duiker were not available from literature. I therefore used field data from transect lines where Maxwell's Duiker presence was confirmed as a guide to determine the nature of the membership set of each habitat variable on a continuous 0 to 1 habitat suitability scale. Suitability Index (SI) curves are functional curves that relate habitat quality to the selected variables in the habitat of the evaluation species (USDI, 1981). Because of the uncertainty inherent in a habitat variable observation to the SI scale, I considered the SI scale a fuzzy membership set. Fuzzy membership can be expressed as an analytical function that may not necessarily be linear; in some cases, membership is defined more readily as a table (Bonham-Carter, 1994). I assumed the relationship between variables and their suitability indices to be S-shaped rather than linear to accommodate the uncertainty in the precise nature of the functional relationships. Using MS Excel ® this membership function (**Fig. 3.5**) was used to determine the Suitability Index score of all transect scores for each habitat variable (**Section 4.2.5.2**). Details of the habitat variable values and their corresponding SI scores are given in **Appendix C.1.**

$$S(x;\alpha,\beta,\gamma) = \begin{cases} 0; & x \in \,]-\infty, \alpha[\\ 2[(x-\alpha)/(\gamma-\alpha)]^2; & x \in [\alpha, \beta] \\ 1-2[(x-\gamma)/(\gamma-\alpha)]^2; & x \in [\beta, \gamma] \\ 1; & x \in [\gamma, +\infty[\end{cases}$$

where, S = Factor

$\beta = (\alpha + \gamma)/2$

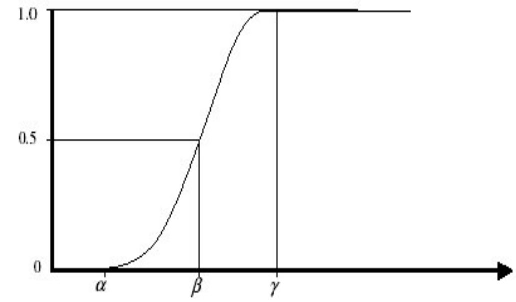


Fig. 3.5: The S-Membership Function. (Source: Tang *et al*., (1991).

The mean Suitability Index score for each of each habitat variable within a habitat stratum was used as the intrinsic (i.e. the value of the site uninfluenced by neighbouring habitat values) habitat suitability score for that land cover stratum/type. The distribution of the habitat variables and their corresponding SI curves, as derived from sample sites where Maxwell's Duiker were observe, are shown in **Fig.3.6.1 – 3.6.6**. The slight difference between the histogram distribution and the SI curve shape for the food canopy cover was based on the assumption that Maxwell's Duiker would respond positively to food abundance.

The question that arose at this stage was: "What is the guarantee that these SI curves are a realistic reflection of the functional relationship between habitat variable values and suitability?". The mere absence of physical evidence does not prove that an animal does not occur in a place. The observer could either miss existing signs or the substrate, as in the case of footprints in thick ground litter, may not pick up or retain signs. However, the presence of physical evidence is a strong indication that the animal derives at least a part of its life requisite from that site. A sensitivity analysis was therefore applied to the three habitat variables to assess their robustness, especially considering their small number. This was necessary because the SI parameters were picked by visual estimation from the frequency histograms. Randomly –selected samples of 12, 15, and 18 observation sites were selected from the 21 sites where Maxwell's Duiker presence was confirmed, and the habitat variables values there analysed. The SI curves from the different random samples showed strong similarities in ***shape***, ***pattern***, and ***range*** (see **Appendix C.2)**. They did not necessarily have to fit each other perfectly in that the objective was to find the **range** of S-membership function variables. The mean values of each habitat variable per habitat type, as derived from the SI curves are given in **Table 3.3**.

3.3.4. Life Requisite Suitability Index Mapping

Using the Attribute Map of Raster Map function of ILWIS 3.12®, the mean index values of the three habitat variables in each habitat type (Table 3.2) were used to generate suitability index maps for each of the life requisites. On a 0 to 1 suitability index range, the Food (**Fig. 3.7.1**), Shelter (Fig. **3.7.2**) and

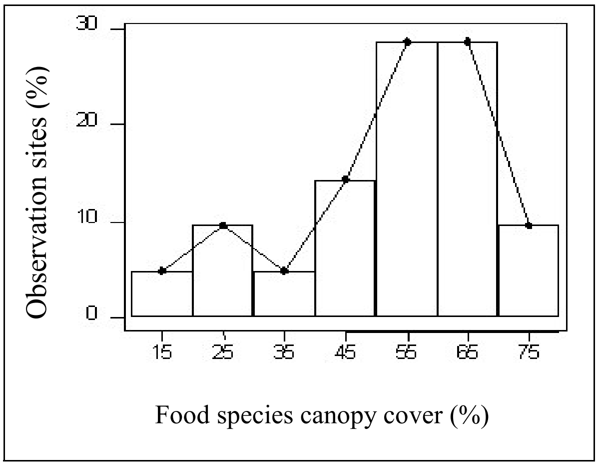
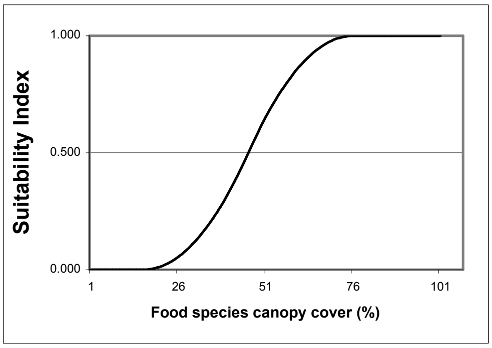


Fig. 3.6.1. Distribution of MD observations in relation to percent food species canopy cover.



Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 15 % cover, β = 35 % cover; γ = 55 % cover

Fig. 3.6.2. Food species canopy cover Suitability Index Curve for estimating Maxwell's duiker food.

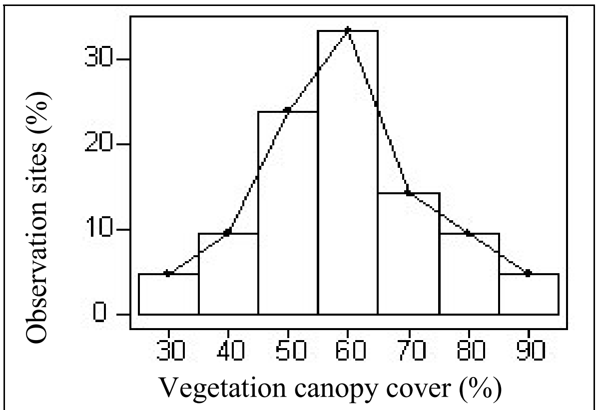
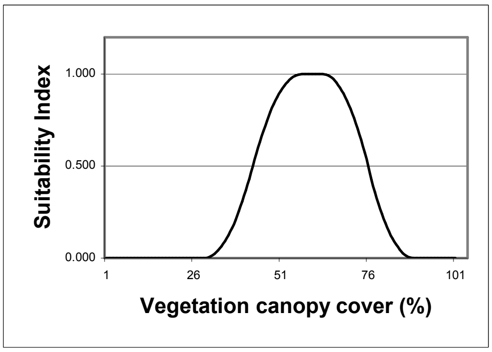


Fig. 3.6.3. Distribution of Maxwell's duiker observations in relation to percent vegetation canopy cover.



Shelter = Sh_{MD}\{ (c_{MD}, α_1, β_1, γ_1);
1–(c_{MD}, α_2, β_2, γ_2);
Where: c_{MD} = % vegetation canopy cover
α_1 = 30% cover α_2 = 60 cover; β_1 = 40% cover; β_2 = 75% cover; γ_1 = 50% cover γ_2= 90% cover

Fig. 3.6.4. Vegetation canopy cover Suitability Index Curve for Maxwell duiker shelter estimation.

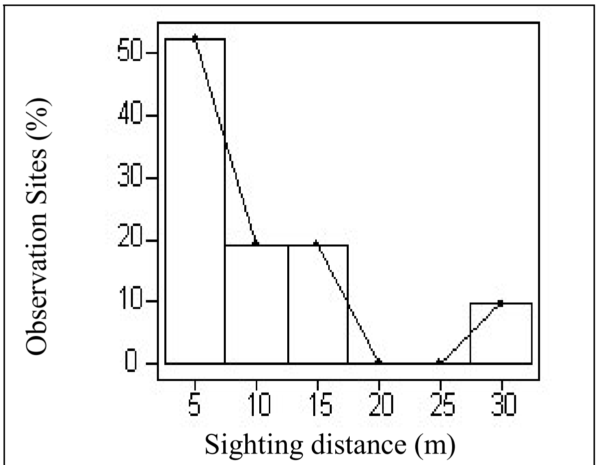
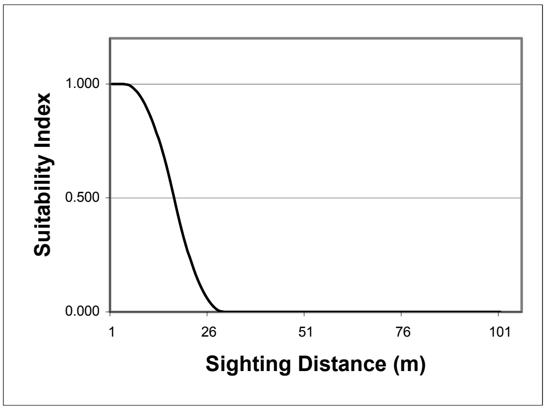


Fig. 3.6.5. Distribution of Maxwell's duiker observations in relation to Sighting Distance (m) through undergrowth.



Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 3m; β =17m; γ = 31m.

Fig. 3.6.6. Sighting Distance Suitability Index Curve for Maxwell's Duiker security estimation.

Table 3.3.. Mean Suitability Index (SI) scores of habitat variables for Maxwell's Duiker in Goaso Study Area.

Habitat Type	Food species cover (%)	Vegetation canopy cover (%)	Sighting Distance (m)	Refuge*	Intrinsic HSI **
Matured Sec. Forest	*0.940*	*0.779*	*0.770*	*0.774*	*0.890*
Young Sec. Forest	*0.700*	*0.822*	*0.847*	*0.837*	*0.741*
Farm-bush	*0.361*	*0.705*	*0.814*	*0.770*	*0.484*
Cocoa Forest	*0.866*	*0.603*	*0.422*	*0.494*	*0.755*
Monocrops	*0.328*	*0.481*	*0.274*	*0.357*	*0.337*
Wetlands	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Built-up Areas	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

Notes: * = Fuzzy combination of Shelter and Security by the equation: Refuge = ((Shelter*0.4)+(Security*0.6))
** = Fuzzy combination of Food and refuge by the equation: Intrinsic HSI = ((Food*0.7)+(Refuge*0.3))

Security (**Fig 3.7.3**) thematic maps are graphical representations of the suitability of a given site within the study area to provide food, shelter or security for Maxwell's Duiker.

3.3.5. Habitat Components Combination and Fuzzy Operator Analysis

A site within the study area must contain at least ***all*** three life requisites, at the same time, before it can be considered as suitable habitat by the evaluation species. Therefore, the life requisite thematic maps had to be combined. As in the case of the Suitability Index Curves derivation, there was no imperial data from literature about the exact contribution of each life requisite to a habitat. Under such circumstances, the tendency was for me to attempt to combine the food, shelter and security thematic maps in a single step. This could have been for the three maps at the same time, but this was found to be cumbersome. In trying to produce a realistic-looking habitat suitability map, so many different maps had to be generated that it was difficult to keep track of their differences visually, without applying statistical analysis such as Correlation Matrix assessment. To avoid the risk

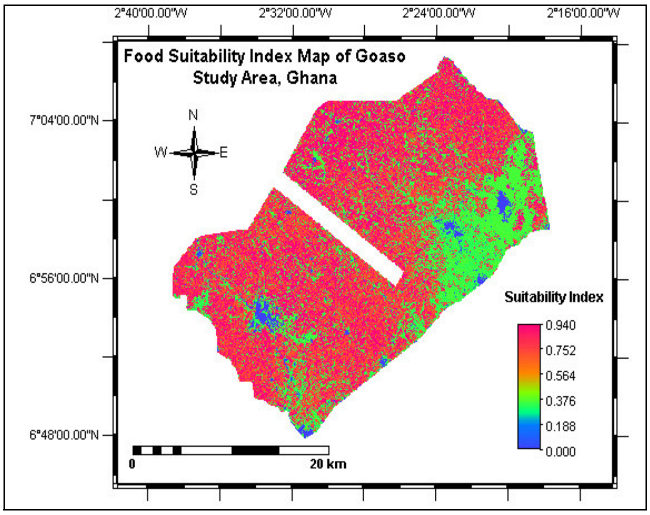


Fig. 3.7.1. Food thematic map for Maxwell's Duiker in Goaso Study Area.

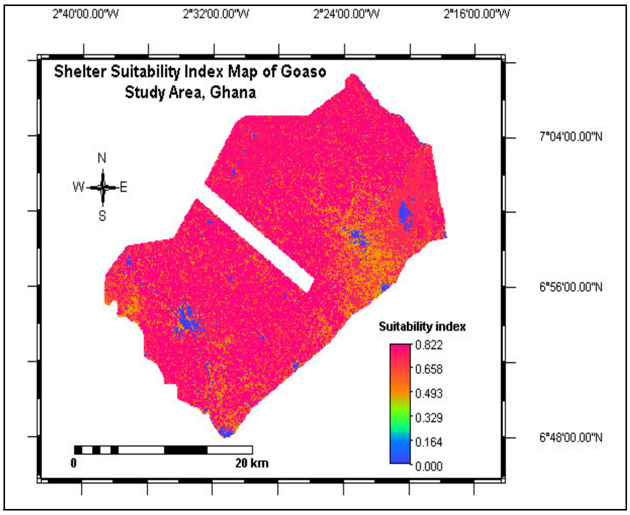


Fig. 3.7.2. Shelter thematic map for Maxwell's Duiker in Goaso Study Area.

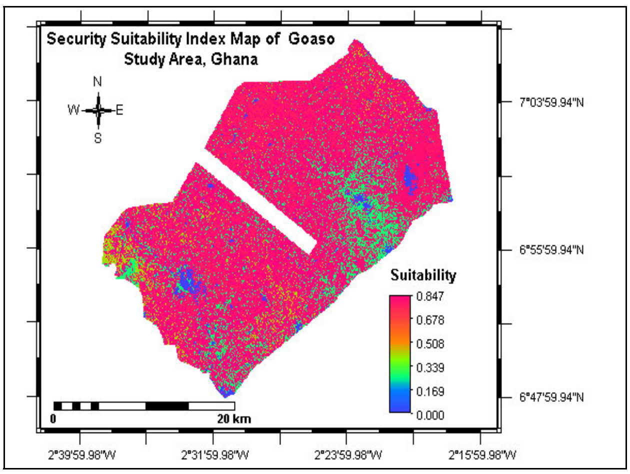


Fig. 3.7.3. Security thematic map for Maxwell's Duiker in Goaso Study Area.

of loosing track through lengthy combinations, I decided to use the approach of first combining thematic maps in intermediate steps.

The first fuzzy map combination operation (**Fig. 8**) was to create a **Refuge** life requisite thematic map, using the MapCalc function of ILWIS 3.12®. This was done through a weighted overlay of Shelter and Security thematic maps. Shelter and Security are derived from the structural attributes of vegetation cover, and their combination yields Refuge. This is quite distinct from Food, which represents the floristic component of vegetation. The Refuge thematic map was generated in ILWIS 3.12® b. The mathematical expression, using the MapCalc function of ILWIS 3.12®, for the "Combined" fuzzy operator (see **Section 1.5** above) of the Refuge Suitability Index Map was:

Refuge = ((***Shelter****0.4)+(***Security****0.6))

The resulting output map (**Fig. 3.8.c)** is a fuzzy refuge suitability index map for Maxwell's Duiker in the study area. A visual assessment showed that almost the entire study area offer good refuge to the evaluation species. Visual comparison with the Habitat Type Map (**Fig. 3.4**) also shows that the Built-up, Wetlands and Monocrops habitat types offer generally low refuge to Maxwell's Duiker, whilst Cocoa-Forest and Farm-bush showed intermediate values. The two Secondary Forest types offered the highest refuge index values. This was considered to be consistent with the structural similarities of the vegetation/land cover distribution in the study area.

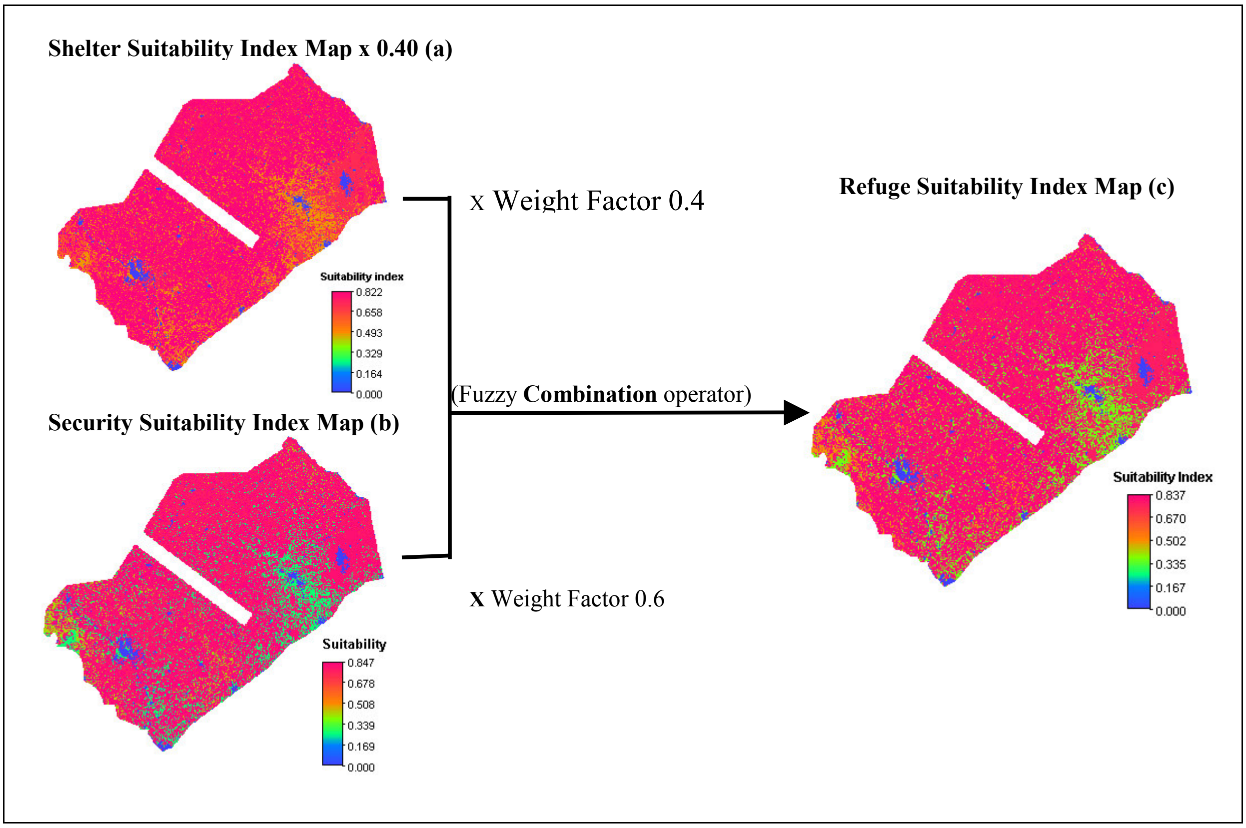


Fig. 3.8. Refuge habitat component map processing using Fuzzy Combined operator.

Next, the Food and Refuge thematic maps, representing the food and refuge habitat components respectively, were combined (**Fig. 9**) to create an "intrinsic" habitat suitability index map by the Fuzzy Combined operator, using the MapCalc function of ILWIS 3.12®, with the equation:

Intrinsic_HSI = ((Food*0.7)+(Refuge*0.3)).

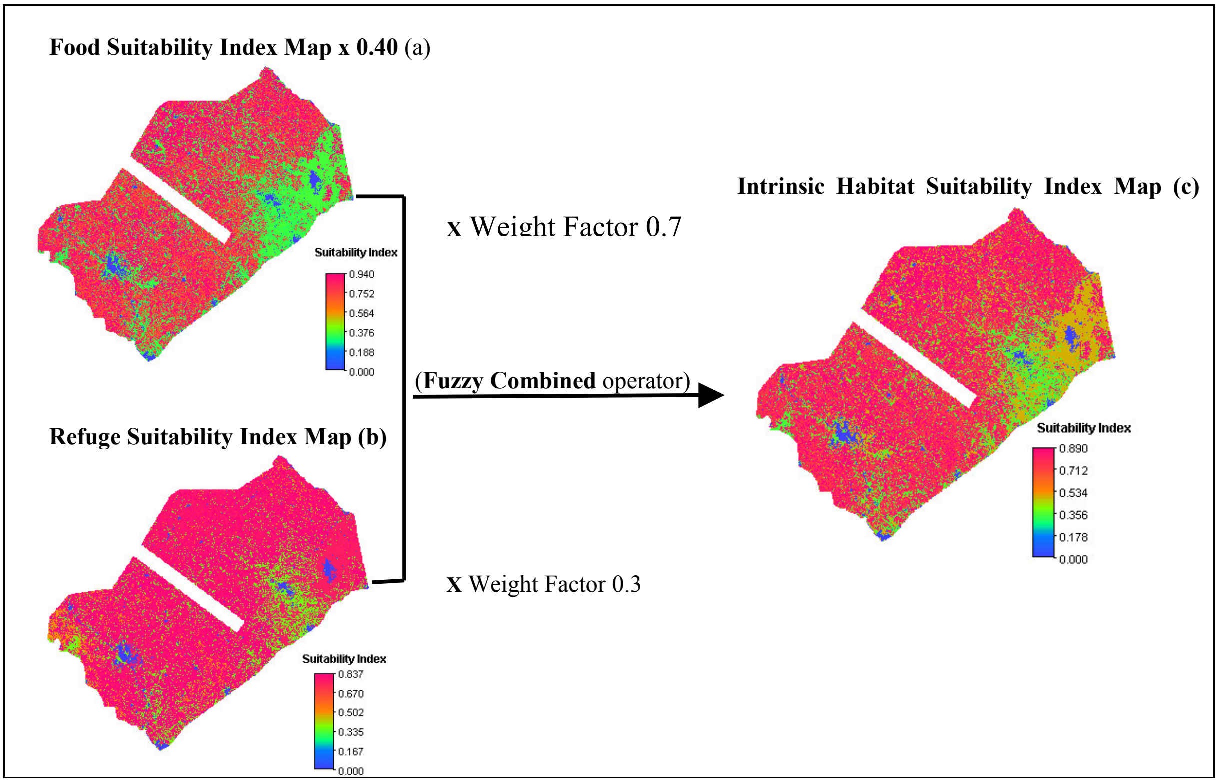


Fig. 3.9. Intrinsic Habitat Suitability Index map processing, using Fuzzy Combined operator.

The Intrinsic HSI map (**Fig. 3.9c**) could be considered as a possible final model output. However, the index values are the result of a fuzzy operation and are, therefore, fuzzy. The index values therefore need to be 'defuzzified', i.e. reclassified from fuzzy to crisp value boundaries. It is easier to understand a map with ordinal legend scale(e.g. Suitability Classes) such as Low/Moderate/High/ Very High than a numerical scale (e.g. Suitability Indices) of, say, 0 to 1 (Beek, 2000). This could have been done by breaking the range of index values into equal number of classes desired. A possible example of the upper boundaries of the map's Habitat Suitability classes would then have been: 0-2.5 for Low, 0.5 for Moderate, 0.75 for High and 1.0 for Very High. However, this approach was found to be too subjective. A less subjective approach was to plot a curve of the fuzzy suitability index values against the cumulative number of pixels (representing cumulative area) in the map. The inflection points along this curve represent a sudden change in the number of pixels with a minor change in fuzzy index value and therefore represent different populations.

The fuzzy index values at these inflection points were considered threshold fuzzy suitability values, which allow differentiation between the habitat suitability classes (or map pixels) (Sicat, 2003). The result of applying the histogram inflection point reclassification (**Fig 3.10a)** approach was a Habitat Suitability class map **(Fig 3.10b)** with the following suitability classes differentiated by fuzzy suitability index vales for their upper boundary thresholds: 0.337 for Low Suitability, 0.741 for Moderate Suitability, 0.890 for High Suitability, and 1.000 for Very High Suitability.

Subject to field validation, there was no reason to reject **Fig 3.10b** as a realistic representation of Maxwell's Duiker habitat in the Goaso Study Area. It must be noted that this map represents the suitability of each site (modelling cell), uninfluenced by the suitability condition/class of neighbouring cells. The territory size and ranging habits of the Maxwell's Duiker is, however, larger than the 1ha map cell. Therefore, neighbouring cells were expected to have an influence on the condition and subsequent suitability rating of any given cell (see **Section 3.2.).**

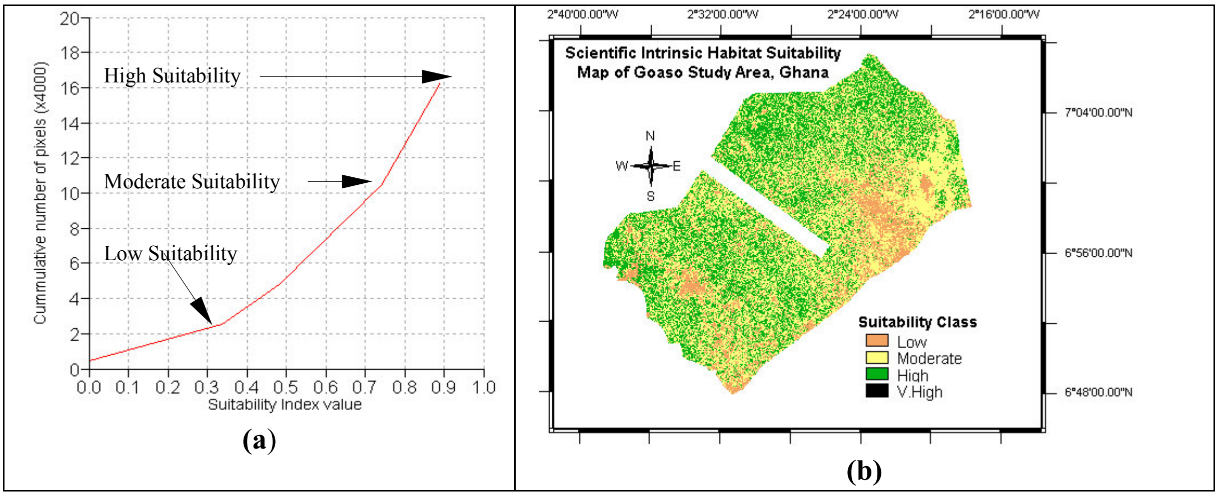


Fig. 3.10. Histogram inflection points (**a**) and reclassified Habitat Suitability class map (**b**) for Maxwell's Duiker in the Goaso Study Area.

3.3.6. Spatial Effect Application

3.3.6.1. Neighbouring Cell Effect Application

Maxwell's Duikers are very often found in pairs in well-defined and permanent home ranges of between 2.5ha and 4ha, depending on the habitat quality (Wilson, 2001). In view of the high human presence and cultivation intensity in the study area, I assumed that the overall habitat quality for this primarily frugivorous species would be on the lower side of a pristine primary forest. Therefore, 4ha was considered as a realistic approximation of range size for Maxwell's Duiker in the study area. Data specific to Maxwell's Duiker was not available but the closely related Blue Duiker (*C. monticola*) was reported to use the central part of its range the most, even though a pair would spend 1/4 - 1/3 of their time near the border (Dubost 1980). I assumed further that the farthest this highly territorial species would range in any direction from a given point is a radius of 200m. Since the model cell size was 1ha, and its boundary was the start off point for the "neighbourhood effect" (Gerrard *et al*, 2001), this translated to a ranging distance of 100m. If an individual or pair moved only within their range (radius) then the neighbourhood of a cell is 100m in any direction. This should not be confused with the total distance they would move within the range, which, according to Dubost (1980), could average a minimum of 979m (650-1770m). With these assumptions about neighbourhood of a cell, I applied the edge-enhancement filter, EDGESENH, in ILWIS 3.12®, to the intrinsic map. The EDGESENH is a linear, 3x3 matrix filter that is designed to simultaneously increase the value of cells (or pixels in a raster map surrounded by high-value cell, and reduce the value of cell surrounded by low-value cells (ITC-ILWIS, 2001).

This "neighbourhood effect" map was considered as a possible habitat suitability map. It was therefore reclassified, using the map's histogram inflection points (**Fig. 3.11**), giving a Habitat Suitability class map (**Fig.3.12**) with the following index vales for their upper boundary thresholds: -0.203 for Low Suitability, 0.596 for Moderate Suitability, 1.700 for High Suitability, and 2.000 for Very High Suitability. Only three suitability classes are produced.

From a visual appraisal, it was apparent that this suitability map (**Fig.3.12**) could not be a realistic representation of Maxwell's Duiker habitat in the study area. Even settlements and roads (Built-Up areas) are classified as having moderate suitability. In addition, almost the entire study area is assigned a blanket suitability class rating of "High", which does not reflect the diverse habitat types there. Areas with poor habitat type, e.g. within or very close to settlements (Built-Up areas), are classified as having Moderate or even High suitability. Therefore, a further fuzzy operation was necessary to see if there would be an improvement.

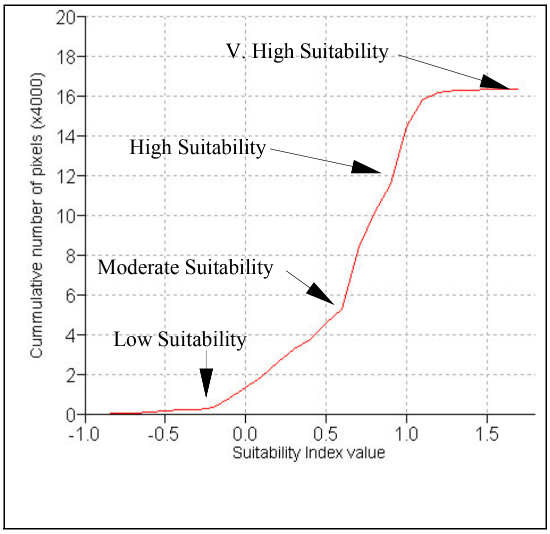


Fig. 3.11. Histogram of Neighbourhood Effect HSI map for Maxwell' Duiker showing inflection points of suitability class boundaries.

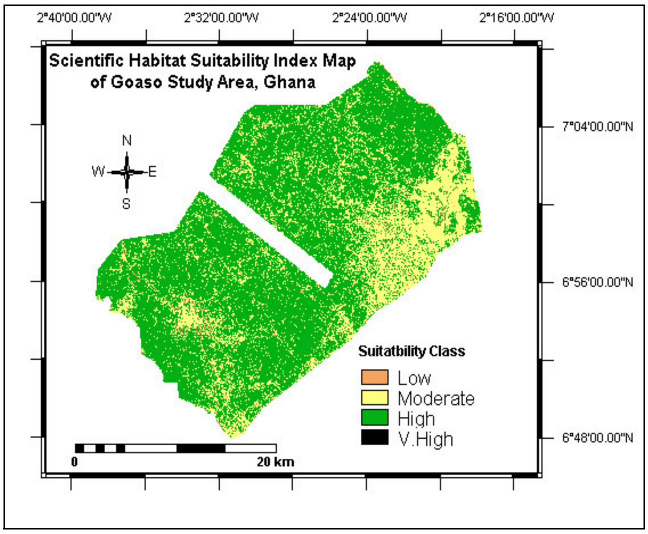


Fig. 3.12. Neighbourhood Effect Habitat Suitability class map for Maxwell's Duiker in Goaso study Area.

In a habitat model for the San Joaquin Kit Fox (*Vulpes macrotis mutica*), Gerrard *et al* (2001) had addressed a similar problem by recombining the intrinsic habitat map with a neighbourhood effect map. Again, the Fuzzy Combination was found to be the most convenient operator. The output map (**Fig. 3. 13c**) was produced using the MapCalc function of ILWIS 3.12® through the mathematical expression:

Total-HSI map = (Intrinsic HIS map)+(Neighbourhood Effect _HSl map).

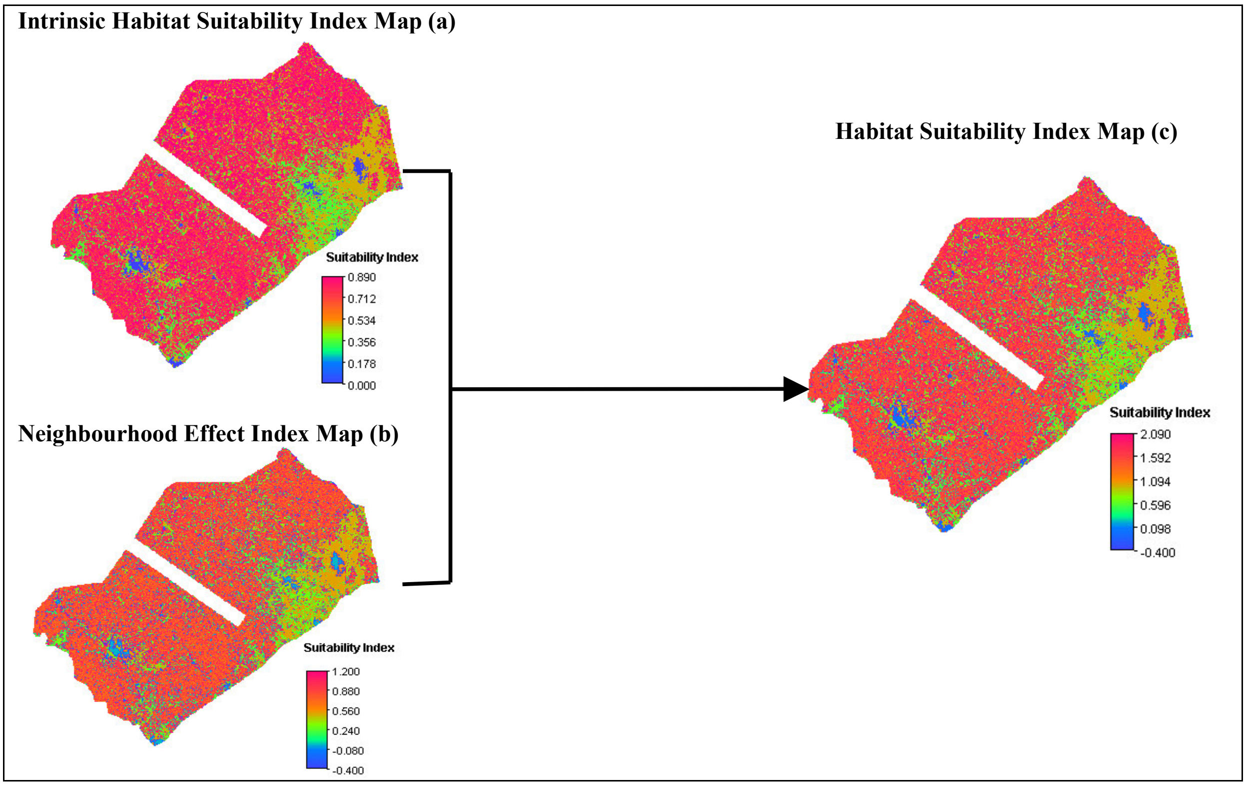


Fig 3.13. Scientists' Integrated HSI map processing.

This fuzzy habitat suitability index map was reclassified to an ordinal suitability class map (**Fig. 3.15**) by applying the values of the inflection points in the map histogram (**Fig. 3.14**). The index values for the suitability class upper boundary thresholds were: 0.148 for Low Suitability, 1.291 for Moderate Suitability, 1.855 for High Suitability, and 2.590 for Very High Suitability.

3.3.6.2. Landscape Barriers

The derivation of the intrinsic habitat value had relied so far on the vegetative cover, but other landscape features could act as considerable barriers to animal presence. Notable amongst these were roads and settlements. Habitats around these barriers were considered inhospitable due to noise and traffic and/or human danger. To account for this, I would have needed to create a buffer around all settlements, tarred and major dirt roads, using the distance function of ILWIS 3.12® software. However, as a resident from 2000 – 2002, I have personally seen group hunters flush out Maxwell's Duiker within 100m of a busy highway on at least four occasions in the study area. This suggested that Maxwell's Duiker could tolerate considerable noise from vehicular traffic.

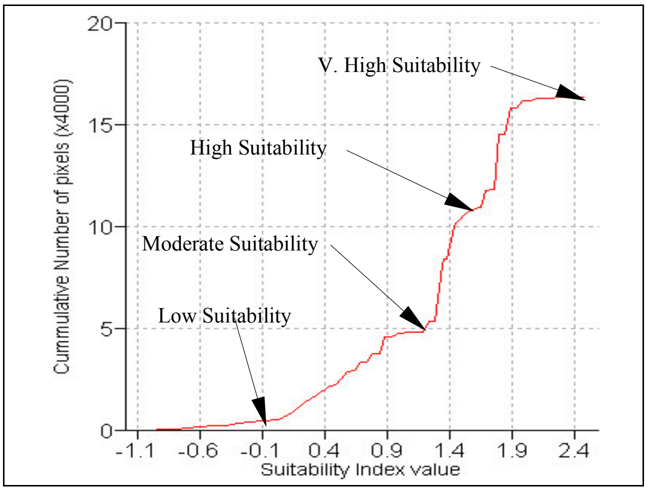


Fig. 3.14. Histogram of final HISI map for Maxwell' Duiker showing inflection points of suitability class boundaries.

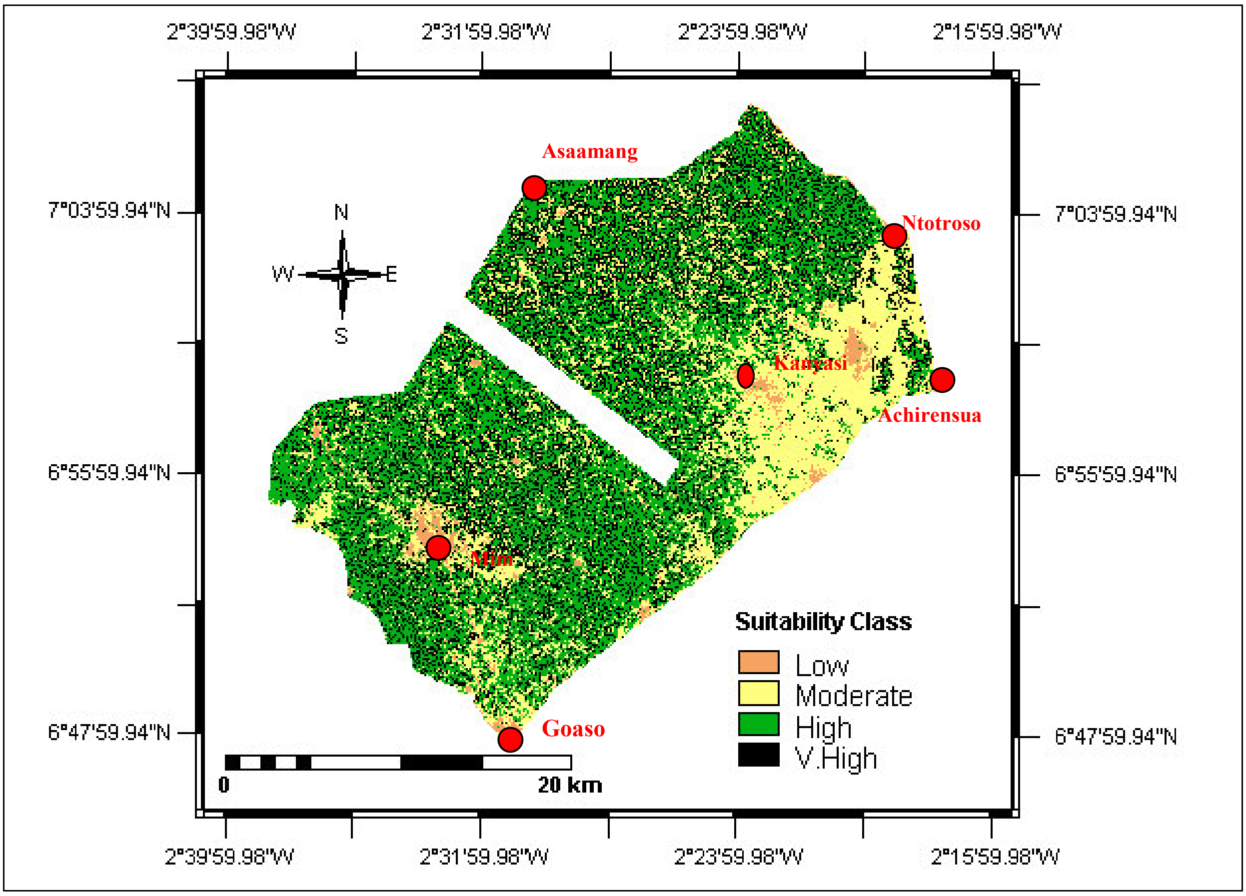


Fig. 3.15. Scientific Habitat Suitability Class Map of the Goaso Study Area.

Beside this consideration, the widths of road in the area were about 12m. This was easily accommodated by the evaluation cell size of 1ha. Bedsides, the neighbourhood effect calculation done above were expected to have accounted for the noise and movement constraints from settlements and roads that the landscape barrier effect analysis sought to address. Therefore, I considered it not necessary to apply the neighbourhood effect analysis (buffering) in this particular study.

3.3.7. Scientific Habitat Suitability Class Mapping

An analysis of how the habitat types were distributed in the suitability classes (**Table 3.4)** showed that both Built-up Areas and Wetlands were completely (100%) classified by the model as Low habitat suitability areas. With 99.8% and 97.7% coverage respectively, Farm-bush and Monocrops could be considered as constituting the Moderate habitat suitability class. Cocoa-Forest and Young Secondary Forest were classified as having High habitat suitability, with 100% and 99.9% area allocation respectively. Matured Secondary Forest essentially a Very High suitability habitat type (84.8%), but also had sizeable areas (15.2%) with High suitability ratings. Overall, 83.3% of the study area was classified as being High or Very High suitable habitat for Maxwell's Duiker.

Table 3.4. Percent area distribution of habitat suitability classes per Habitat Type in Goaso study Area.

Habitat Type	Habitat Suitability Class	Area (ha)	Suitability Class allocated by Habitat Type (%)
Built-up Areas	Low	*1602.9*	*100.0*
Wetlands	Low	*228.0*	*100.0*
Farm-bush	Moderate	*9813.1*	*99.8*
Farm-bush	High	*19.4*	*0.2*
Monocrops	Moderate	*8687.6*	*97.7*
Monocrops	Low	*206.7*	*2.3*
Cocoa-Forest	High	*2318.9*	*100.0*
Young Secondary Forest	High	*24023.4*	*99.9*
Young Secondary Forest	V. High	*30.1*	*0.1*
Matured Secondary Forest	V. High	*19331.3*	*84.8*
Matured Secondary Forest	High	*3460.9*	*15.2*
Total		***69722.2***	

3.4. Discussion

The guiding principle in developing a model is "realism". Therefore, the recurrent question at any phase of the model development was whether the assumptions and their subsequent outputs were realistic. The suitability classification by the Scientific HSI model shows a strong correlation between habitat suitability rating and habitat type. Generally, Matured Secondary Forest, Young Secondary Forest, and Cocoa-Forest were classified as offering either High or Very high habitat suitability for Maxwell's Duiker. Built-up Areas and Wetlands offered low suitability, with Farm-bush and Monocrops areas provide Moderate suitability.

The import of this correlation is that if the habitat types are regarded as representing successional stages of degradation of vegetation cover from the original primary forest, which is the Maxwell's prime habitat preference, then the higher the degree of degradation, the lower the habitat suitability. This reduction in habitat suitability could be attributed chiefly to the loss of fruit-bearing species, as Maxwell's Duiker is primarily a frugivore; and to a lesser extent, loss of refuge. With 83.3% of the study area was classified as being High or Very High suitable habitat, the study area could be said to be generally very favourable for Maxwell's Duiker production, provided other aspects, such as socio-economic factors, prove equally favourable. The favourable areas are mostly in the areas between Ntoroso, Asaamang, Mim, Goaso and Kenyasi townships; the Achierensua–Kenyasi-Ntotroso triangle had little habitat to offer.

The accuracy of this model is determined, largely, by the quality of the input data. The data quality is, in turn, is dictated by the precision of the data collection method (Mueller-Dombois and Ellenberg, 1974). It is conceivable that using the line-intercept sampling method, and the use of visual estimates, rather than actual measurements, for assessing vegetation crown cover may have reduced the accuracy of the final habitat map. However, according to Beek (2000), in most modelling cases, we are not interested in extreme values (of accuracy and precision) but in a more representative values. Bearing in mind that the model sought to identify the general distribution of potential habitat in the study area, striving for an extreme predictive accuracy would be unnecessary.

Without the inclusion of the additional food plant species by the hunters, this model would have been quite different from its current form because several transect would have had either none or very few of the 15 species confirmed from literature. This would have led to a gross under-valuation of most sites, or an increase in the fuzzy weight for food to adjust for importance in the model assumptions.

One might also question whether using food quality rather than quantity in the study could not have given a better model output. By definition, a resource is beneficial. The most obvious examples of an animal's needs are food, shelter, water, nesting sites, and a particular range of temperature (Caughley and Sinclair, 1994). Often a resource such as food is described by two attributes: the amount available to an animal and the suitability to the animal's requirement. As the availability of these resources rises, the fecundity and probability of survival of an individual is enhanced. For example, quality may be described as the percentage of digestible protein in the food, whereas quantity may be measured as dry weight of standing food per hectare. Under the study limitations, it was not feasible to factor in the ***condition*** (reflecting quality) of the food resource as most of the fruit trees were out of season. Even the quantity of food could not be estimated directly, necessitating the use of canopy cover of the food plant species were used as proxy. Several other variables, such as slope, water, or even hunting pressure, could have been used as model inputs. However, Schamberger (1986) warns that since HSI models are not carrying models, not all factors that influence animal abundance need to be included. Ecologists are constrained to use basic habitat attributes thought to be important to the evaluation species and to the specific planning or management needs. In this study, food species canopy cover, vegetation cover, and undergrowth density proved to be the optimum habitat variables needed.

The assumptions I made about the relative importance of each habitat variable used in constructing the model were based upon reasoned inferences from literature, data collected from fieldwork and from personal experience. Although these assumptions appear very realistic from the human perspective, as borne out by the final habitat map, there is still no absolute way of proving that a Maxwell's Duiker would share an identical perspective, even if subsequent field validation gives a 100% prediction accuracy. Therefore, this model is essentially a prediction of the ***potential*** habitat suitability of the ***current*** habitat types in the Goaso study Area.

The habitat maps created in this model also depend to a large extent on the use of histogram inflection points in demarcating suitability classes, especially in cases where the Fuzzy Combination operator was applied. The inflection points approach was proposed by Sicat (2003) to circumvent the problems of having index values less than 0 or greater than 1. However, the inherent limitation of this approach is that no two modellers are likely to choose the same inflection points for the same maps; even the same modeller might make different choice on different occasions.

Finally, it is important to note that the stages at which the neighbourhood effect (filter application) and the reclassification analyses are done in the modelling process have a significant effect on the final output map. In the case of the neighbourhood effect analysis, this is because values of pixels at the study area boundaries are also influenced by the values of all their immediate neighbours in the filtering process. Therefore, cutting out the study area before applying the filter would result in edge pixels having at least one of their neighbours having an undefined index value. On the other hand, immediately before the reclassification to a categorical scale, the study area must be cut out, otherwise the inflection points would represent the cumulative number of the an area much bigger than the study area.

4. Indigenous Habitat Suitability Index (HSI) Model

4.1. Introduction

Indigenous knowledge has become an important and a valuable input in the planning and decision making related to the sustainable management of natural resources. The recognition of this role by scientists, and by resource planners and managers is directly related to the growing realization that scientific knowledge has not contributed to the development of communities and societies, but rather has led to the depletion of their social and natural resources (Murdoch and Clark, 1994; Norgaard, 1992; Ulluwishewa, 1993).

Rural communities often rely on some form of indigenous land resource evaluation in their traditional land management systems. Local hunters, for example, have an in-dept knowledge of the ecology and behaviour of wildlife resources in their landscape, derived from years of critical first-hand or secondary and observation. By experience, often going back for generations, hunters have developed systems of observing and interpreting wildlife species and their habitats that are well adapted to the characteristics and constraints of their environment. The local skills and knowledge inherent in this fieldcraft, spanning the micro- to macro-scale, could surpass some conventional scientific techniques.

Data collection on wildlife populations and habitats by conventional approaches are, however, almost invariably constrained by a combination of time, space, and funds. With respect to these constraints, Geographic Information Systems (GIS) have proven to be an invaluable tool in addressing resource assessment and decision-making. Attempts to incorporate wildlife resources along with other activities for resource management on a spatial scale have included the use of GIS to develop habitat suitability models (e.g. Weiers *et al*., 2004; Store and Kangas), and the implementation of bio-climatic analysis (e.g. Lindenmayer *et al.*, 1991). Increasingly, Participatory GIS is being applied to resource management. Local people, by virtue of their long-term direct interaction and dependence, possess a considerable store of knowledge about the resources in their environments that could be vital to any quest for sustainable resource use.

However, incorporating indigenous knowledge in a GIS-based resource monitoring system requires very careful considerations. Firstly, the lack of a standardized approach in generating this immense store of local knowledge limits their potential to be used on their own as effective inputs for decision-making, unless they are subjected to scientific analysis. According to Rubino and Hess (2003), a proactive, ecosystem-level approach is needed to preserve interactions among all species and their habitats. Therefore, "community resource monitors" need to strengthen or convert (depending on the situation) their often single- species perspective to a more dynamic, holistic ecosystem approach.

Secondly, a major challenge in these efforts worldwide is how to effectively balance rigorous science with the need for expediency. Ideally, strategies would be based on a detailed knowledge of the life history and habitat requirements of all species, and in-depth surveys of available habitat within the planning region. This information is often unavailable to non-local scientists and planners, and is difficult to obtain in the timeframe within which decisions affecting landscapes are made. Choices will have to be made on the modification of established monitoring techniques to suit local information needs, thereby optimising the relative benefits of scientific rigour and expediency.

Goaso is one of the agricultural areas in Ghana where local people have expressed the desire to try bushmeat production in their agricultural landscape (Ntiamoah-Baidu, 1998). Hunters and bushmeat traders here have been involved in wildlife research since the 1960s (Asibey, 1969; 1974) and Ntiamoah-Baidoo, 1998) and are therefore no strangers to bushmeat conservation issues. In addition, the Biodiversity Monitoring Unit (BMU) of the Wildlife Division is located there, and is likely to play a significant role in the monitoring aspect of the CREMA programme. These institutional and social settings favour the consideration of the study area as a potential CREMA demonstration area. This chapter presents the evaluation of Maxwell's Duiker habitat in the Goaso Study area using bushmeat hunter

4.2. Methods

The aim for developing the Indigenous HSI model was to assess its potential to replace conventional scientific HSI techniques for wildlife habitat evaluation (see **Section 1.3**). With the exception of the field data observation, the modelling phases and analytical tools used in developing the Indigenous HSI model were practically the same as that for the Scientific HSI model (**Fig. 4.1**). They involved the use of satellite imagery, GIS and Fuzzy Set Theory to develop spatial models of suitable habitats in the study area.

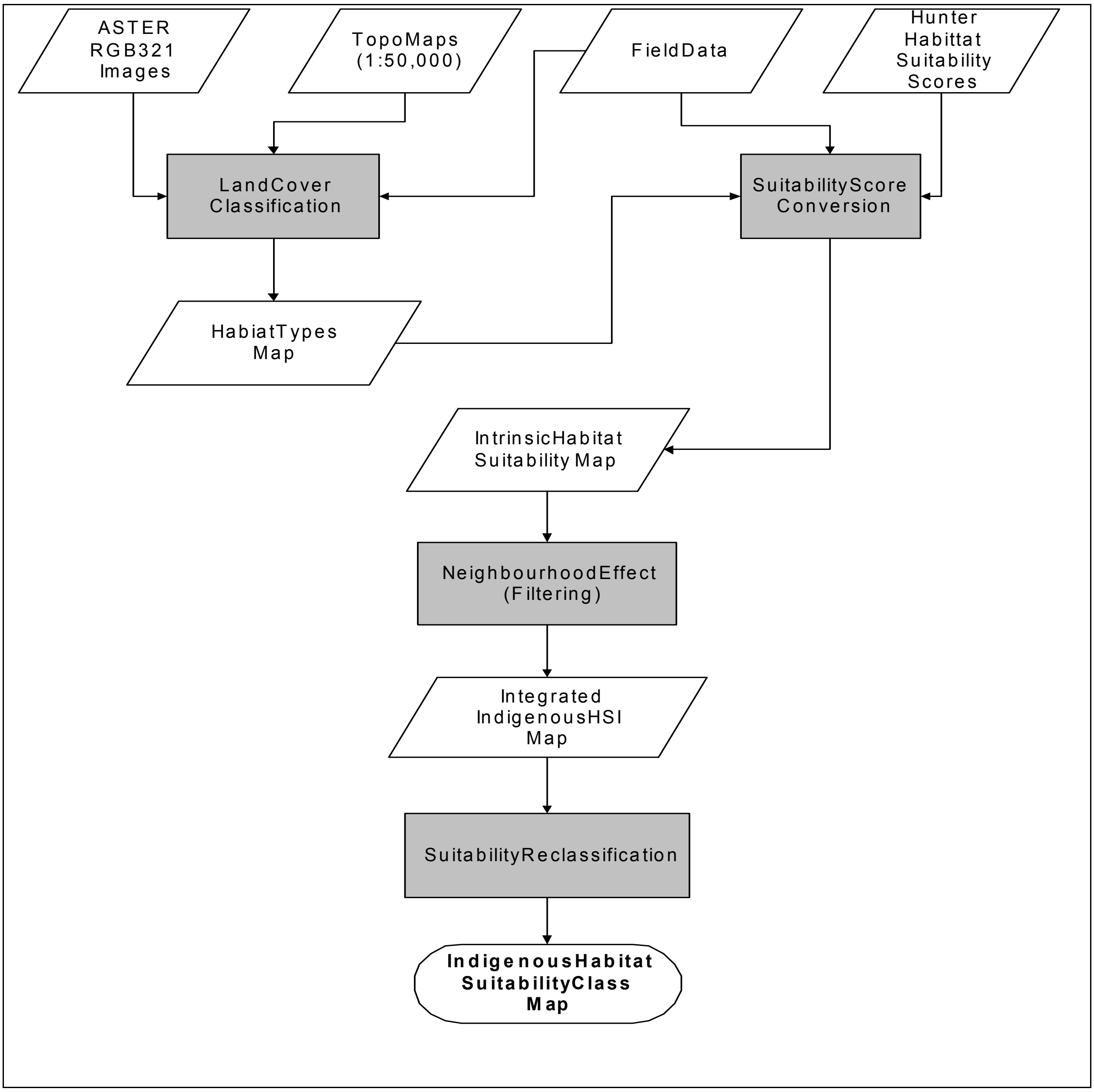


Fig. 4.1. Inferential Network for Indigenous HSI model of Goaso Study Area.

4.2.1. Field Data Collection

4.2.1.1. Hunter Recruitment

Recruiting a hunter called for exercising a lot of tact because they feared owning up to illegally hunting without permits from the WD. A village close to a sampling area was visited at least 12 hours before a survey to ensure that a hunter/guide would be available and to verify the condition of access roads. Based on recommendations from other residents, about three of the most active hunters were contacted and interviewed to find out the extent of their knowledge of the natural history of local bushmeat and their habitat, and their familiarity with the terrain. In almost all instances, every hunter qualified in their in-depth knowledge of Maxwell's Duiker ecology and the local terrain, so the deciding factor for recruiting a particular hunter/guide were his physical strength and willingness to offer his services. This later factor was not easy because it was the major cocoa harvesting season as well as field preparation time for the minor farming season. Virtually all hunters are also farmers who hunt to supplement their income, so loosing a day's farm work meant the hiring fee had to be high enough to enable them also hire a labourer for their farm whilst they were away. My knowledge of the local protocol, and of the mentality of hunters in the study area, was invaluable in helping me select the best guide for each day.

4.2.1.2. Hunter Habitat Data

Since the main aim of this study was to compare scientific and indigenous habitat evaluation methods for the same area and at the same time, field navigation and location of sampling sites were done in the same way (see **Section 1223**). Hunters knew all access roads and major footpaths, but not necessarily all the minor footpaths and trails to a selected land cover patch for laying line transects. However, their in-depth local knowledge of the relationship between landforms and footpath network saved us from getting lost many times.

At the beginning of fieldwork, hunters were asked to explain the way they assessed a sampling site along a transect as a habitat for Maxwell's Duiker, as well as factors that they considered in this assessment. Initially, a linguistic ordinal classification scale was used which scored a site as "good", "fair" and "poor". However, I observed after the first few transects that even the same hunters expressed more degrees of suitability than could be accommodated by these three classes. Expressions like: "it is good a little", "it is good very much", "it is not good", and it not good at all" were difficult for me to rationalise. Besides the same hunter, even on the same day, tended to vary in his explanation of what constituted a suitability score such as "good" or "poor" for practically the same area. Thus, even thought this fuzzy ordinal scales was expected to accommodate ambiguity, the differences (inconsistencies) in meanings appeared too high to me. Quite by accident, my attempt to explain the concept of probability, using betting as an example, was very readily accepted by the hunters as a realistic means of expressing their evaluation process. This was done by a hunter betting any amount out of an imaginary stock of ₵10,000.00 (Ten thousand Cedis*) in ₵1,000.00 denominations. A ₵10,000.00 bet represented the upper end of the scoring scale, and expressed a hunter's absolute certainty that a Maxwell's Duiker *might* be found at a site (or that the animal would find the site absolutely suitable). At the lower end of the scale, a zero bet (₵0.00) represented an absolute certainty that Maxwell's Duiker *might not* be found at the site (or would not find the site suitable). The advantage of this monetary betting approach stems from the fact that it was very practical to apply in the field, as well as in the subsequent data analysis.

Each of the 50m, 100m, and 150m points along a transect (**Fig. 3.3**) served as "hunter sampling points", where hunters were asked to evaluate the suitability of that point as a Maxwell's Duiker habitat. The sites' habitat variables scores were recorded on the same field data form (**Appendix A**) as the Scientific HSI, whilst formal hunter interviews were recorded on a questionnaire interview form (**Appendix E**). It was established early in the fieldwork period (recruitment stage) that hunters consi-

** 1.00 euro approximately 10,000.00 Cedis at time of study.*

dered ***food plant species*** and ***refuge*** (a combination of vegetation cover and density) as the key habitat components they looked for in evaluating a site's suitability. These were equivalent to the ***habitat components*** of the Scientific HSI model. The hunters' field data are summarised in **Appendix F.**

In addition to identifying the food species, the hunters specified which parts were consumed by the evaluation species. Though fruits and flowers were reported to be the main preferred parts of a plant, even fruit trees out of season were considered as still useful sources of food to Maxwell's Duiker by the consumption of at least their leaves (green or dry). These leaves were either taken directly from the plant, if within reach, or from the ground if dislodged by other animals or wind.

As a supplement to the formal interviewing of hunters along the transect lines, I gathered a considerable amount of information in conversations at any opportunity, especially along footpaths between transects. This covered issues like their perception of bushmeat population and habitat trends, and prospects for integrated bushmeat farming. Speaking the local Twi language was an immense advantage, in that it enabled me to detect and probe deeper for answers which meanings were not initially clear, and to pick up information outside interview periods and from non-interviewees.

4.2.1.3. Stakeholder Interviews

The objective of informal interviews was identical for both the Scientific and Indigenous HSI models: to identify ecological, socio-economic and policy factors that influence land use/cover, and therefore model output, for decision-making. Therefore, the same individuals (i.e. farmers, other hunters, and bushmeat traders) and institutions (i.e. District Assembly, agricultural, forestry and wildlife agencies) were interviewed in both instances.

4.3. Results

4.3.1. Habitat Types

The Habitat Types used in this model were the same as that for the Scientific HSI model (see **Section 3.3.2**). This was due to the fact that both models were for the same area, and the data were collected at the same sites and at the same time.

4.3.2. Hunters' Knowledge Base

The habitat variables relating to the food habitat component were ***quantity, type, and condition*** (fruiting stage) of fruit tress and shrubs, and herbs. For the refuge component, the habitat variables used were density of undergrowth vegetation and canopy layering. Unlike in the Scientific HSI habitat variable data, the hunters did not make a clear distinction between these two aspects of refuge: they considered the ***structure*** and ***density*** as well as the ***juxtaposition*** of the vegetation in arriving at a site's refuge score. In their opinion, Maxwell's Duiker prefers "cool, shady and quite" places for refuge. They explained that the Twi (local language) word for "quite" implied both "cool" and "shady" as well, and not just absence of noise. This was due to their observation that the animal could tolerate considerable noise from settlements and vehicular traffic, provided it is not excessive, if the vegetation was dense enough to offer a cool and shady environment. Precisely how these habitat factors interrelated could not however be clearly explained, other than that food weighed more in the assessment process than refuge. The monetary scores was used by the hunters to represented two things: a hunters' expression of his probability of finding a Maxwell's Duiker at that site, or his perception of the probability of a Maxwell's Duiker using the site for food, movement or refuge.

4.3.3. Fuzzy Membership Functions for habitat variables

Initially, hunters were asked to give scores for the separate habitat variables, and then a lump score (called "Overall Score") at each of the sampling points. My intention was to find out the relative contribution of each of the habitat components to the total score for that point. However, I detected that all the hunters felt some discomfort in this apparently "double assessment" and mostly repeated (in a sort of off-hand manner) the scores given in the separate habitat scores. This repetition was confirmed by preliminary data analysis; I therefore shifted to asking the overall scorings first. However, I still continued with asking for the separate scores, but did not use that data in the final analysis.

The hunters' raw suitability scores (on a 0.00 to 10,000.00 (monetary) range) were re-scaled to a fuzzy suitability index score range of 0.000 to 1.000. As in the case of the Scientific HSI, the site scores were then averaged to give a line transect score, which were subsequently used to calculate mean intrinsic habitat type scores.

The respective scores given in **Table 4.1** indicate that hunters considered Matured Secondary Forest as offering the highest average habitat suitability for Maxwell's Duiker. Cocoa-Forest and Young Secondary Forest, with lower scores than Matured Secondary Forest, were considered as being almost equal to each other in habitats scores, as was the case for Monocrops and Farm-bush, which had even lower scores. Wetlands and Built-up Areas were considered non-habitats, and therefore scored 0.000.

Table 4.1. Mean habitat variable Suitability Index (SI) scores for Maxwell's Duiker in Goaso Study Area.

Cover Type	Mean Raw Hunter Scores	Mean Fuzzy Habitat SI Scores*
Matured Secondary Forest	*80,300*	*0.803*
Cocoa-Forest	*54,500*	*0.545*
Young Secondary Forest	*51,600*	*0.516*
Monocrops	*39,900*	*0.399*
Farm-bush	*38,800*	*0.388*
Wetland	*0*	*0.000*
Built-up Areas	*0*	*0.000*

*Notes: * = Fuzzy habitat scores =Raw habitat scores/100,000.*

4.3.4. Hunter Intrinsic Habitat Suitability Classification

Fig 4.2 represents the habitat suitability score for a given site. Therefore, it could be considered as the hunters' "intrinsic habitat index" map, similar to that of the Scientific HSI model (see **Section 1.3.5, Fig. 3.10**). Just as in the Scientific HSI model, this intrinsic index map could be considered the hunters' final habitat suitability index map. In that case, applying the histogram inflection points (**Fig. 4.3**) gave a habitat suitability class map (**Fig. 4.4**) with the following suitability classes differentiated by fuzzy suitability index vales for their upper boundary thresholds: 0.388 for Low Suitability, 0.399 for Moderate Suitability, 0.516 for High Suitability, and 1.000 for Very High Suitability. This output map was a very good reflection of the habitat type distribution. For instance, the Low Suitability area in the southeast of the map, was extensive grassland, even though it was incorporate d into the Farm-bush habitat type. This remarkable ability to show a land cover component out of a habitat type and give it a lower class in conformity with hunter scores suggested that **Fig. 4.4** could be a very realistic representation of the hunters' habitat evaluation.

4.3.5. Hunter Habitat Suitability Class Mapping

Taking **Fig 4.4** as the final suitability map of the hunters implies that they had taken in to account the neighbouring habitat type (spatial effect) in assessing a particular site or transect. However, the hunters explained that they mainly considered the land cover type within their immediate vicinity of their point of observation in their evaluation. This spatial extent was subject to the visibility through the undergrowth, and turned out to be approximately 50m radius of a sampling point. This translates to approximately 1ha as the size of the evaluation cell in the map. Therefore, the resampling of the maps to 1ha cells was equally valid for both the Scientific and indigenous habitat models.

Although the hunters used only a 1ha (cell) area in their habitat evaluation, in a typical hunting expedition they would considered the ***location*** of that cell before going there for the "direct" evaluation. Therefore, irrespective of what a Maxwell's Duiker might think (see **Section 3.3.6.1**.), the neighbouring habitat types would influence a cell's evaluation by the hunters. This assumption called for the application of a spatial effect analysis.

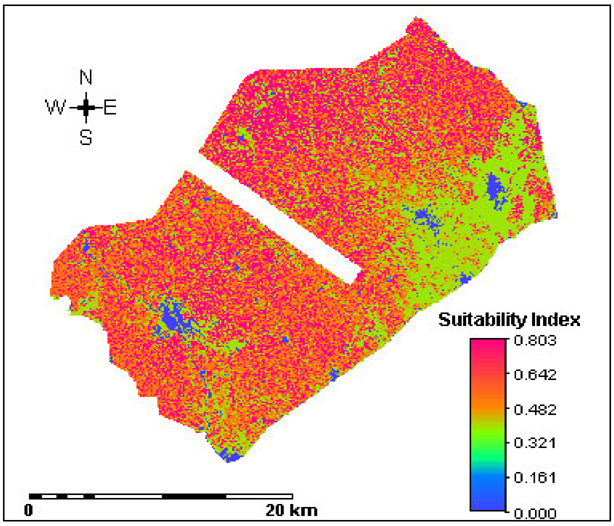


Fig. 4.2. Hunter mean Intrinsic HSI map of the Goaso study Area.

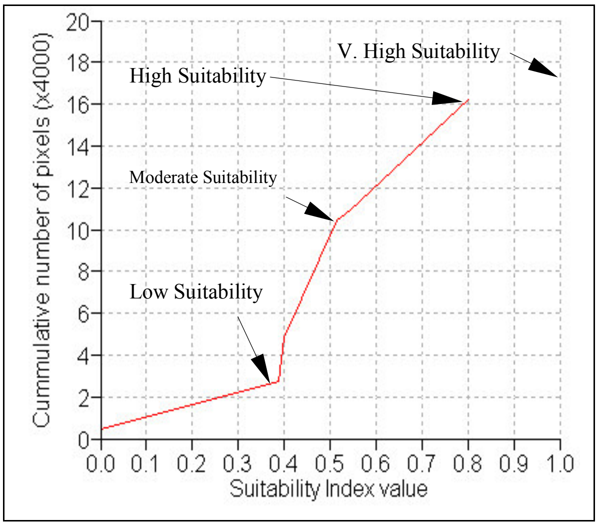


Fig. 4.3. Histogram inflection points for Hunters' Intrinsic HSI class map

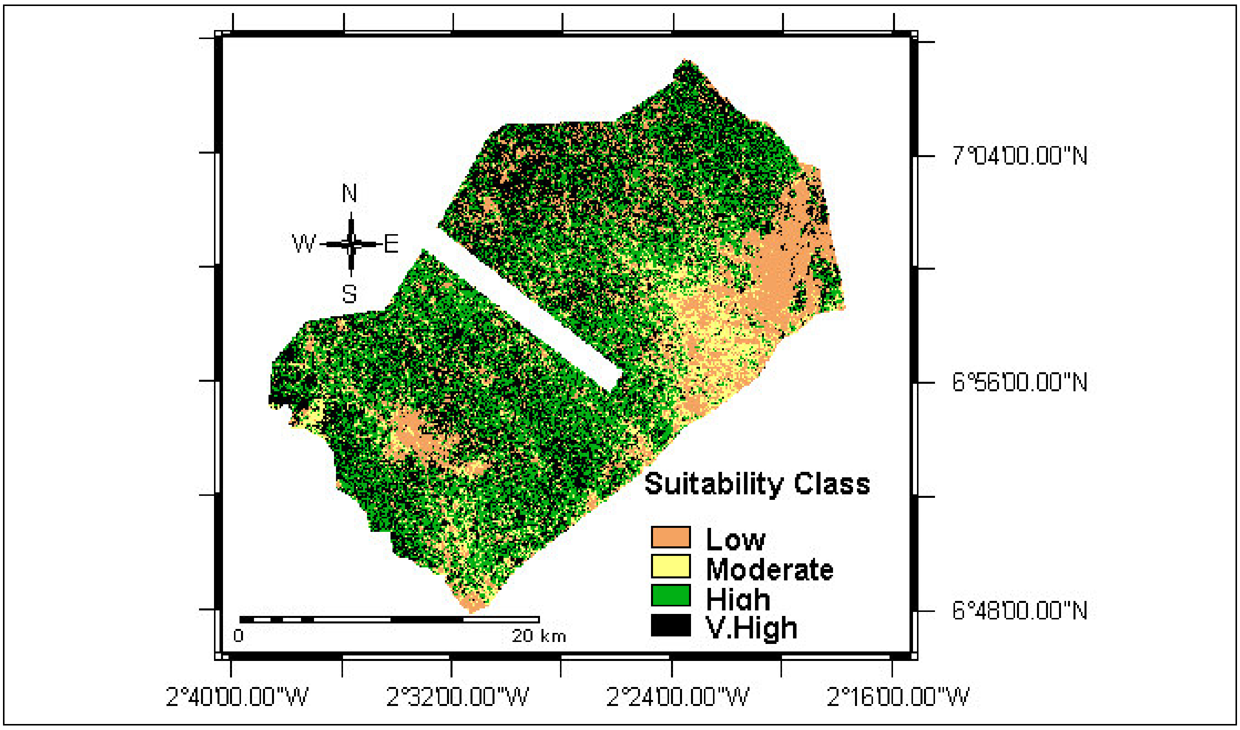


Fig. 4.4. Hunters' Intrinsic HSI class map for Maxwell's Duiker in the Goaso Study Area..

Applying the edge-enhancement filter, EDGESENH, in ILWIS 3.12® to the hunter intrinsic habitat suitability index map (**Fig. 4.2**) gave a new habitat suitability index map (**Fig. 4.5**). When reclassified with the histogram inflection points (**Fig. 4.6**), a habitat suitability class map (**Fig. 4.7**) was produced, with upper boundary thresholds of 0.002 for Low Suitability, 0.795 for Moderate Suitability, 1.600 for High Suitability, and 2.000 for Very High Suitability.

Fig. 4.7 appeared to bear very little relations with the underlying habitat types in the study area. Even areas known from field data to have ha very good combination of food and refuge, and which were scored highly by the hunters, show only moderate suitability in this output map. In essence, this map classifies virtually all areas outside Built-up Areas as either Moderate or High Suitability, with no regard to the many areas that were considered to be of Very High suitability in the Intrinsic Habitat class map (**Fig. 4.4**).

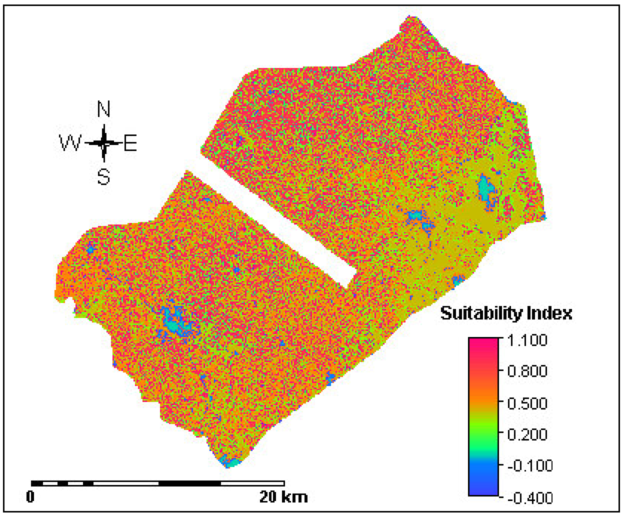


Fig. 4.5. Hunters' neighbourhood effect habitat suitability index map of the Goaso study Area.

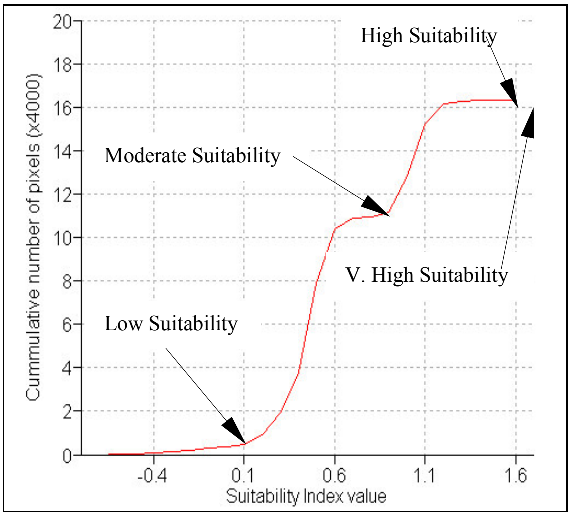


Fig. 4.6. Histogram inflection points for Hunter Habitat Suitability class map

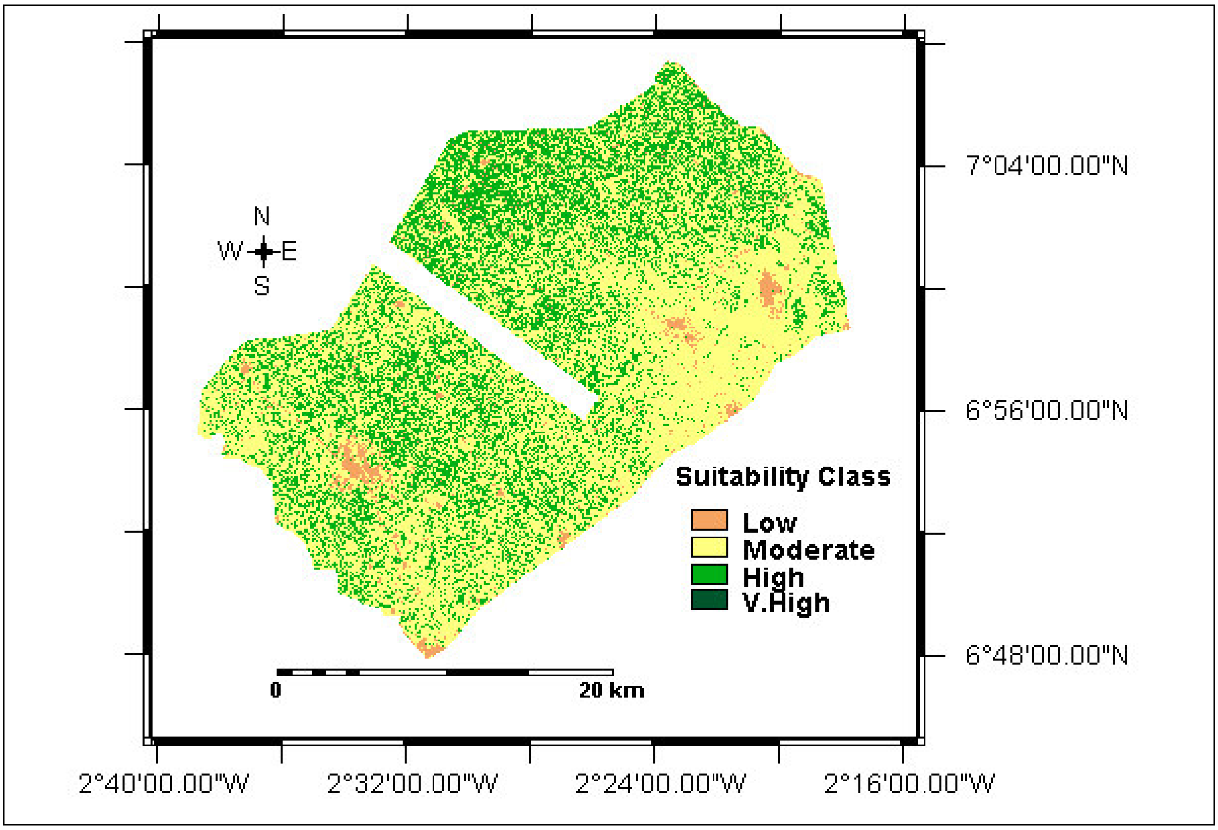


Fig. 4.7. Hunters' Habitat Suitability class map for Maxwell's Duiker in Goaso Study Area with neighbourhood effect applied to evaluation cells.

As in the Scientific HSI model (**Section 3.3.6.2**), landscape barrier effect was not applied to the neighbourhood effect map because it was assumed to have been catered for in the resampling and in the site scorings by the hunters. Therefore, as recommended by Gerrard *et al* (2001), the intrinsic and neighbourhood effect maps were combined to give an "integrated" habitat suitability index map (**Fig. 4.8c**), using the overlay operation in ILWIS 3.12®:

Hunters' Integrate HIS map = (Hunters' Intrinsic HIS map)+(Hunters' Neighbourhood Effect _HSl map)

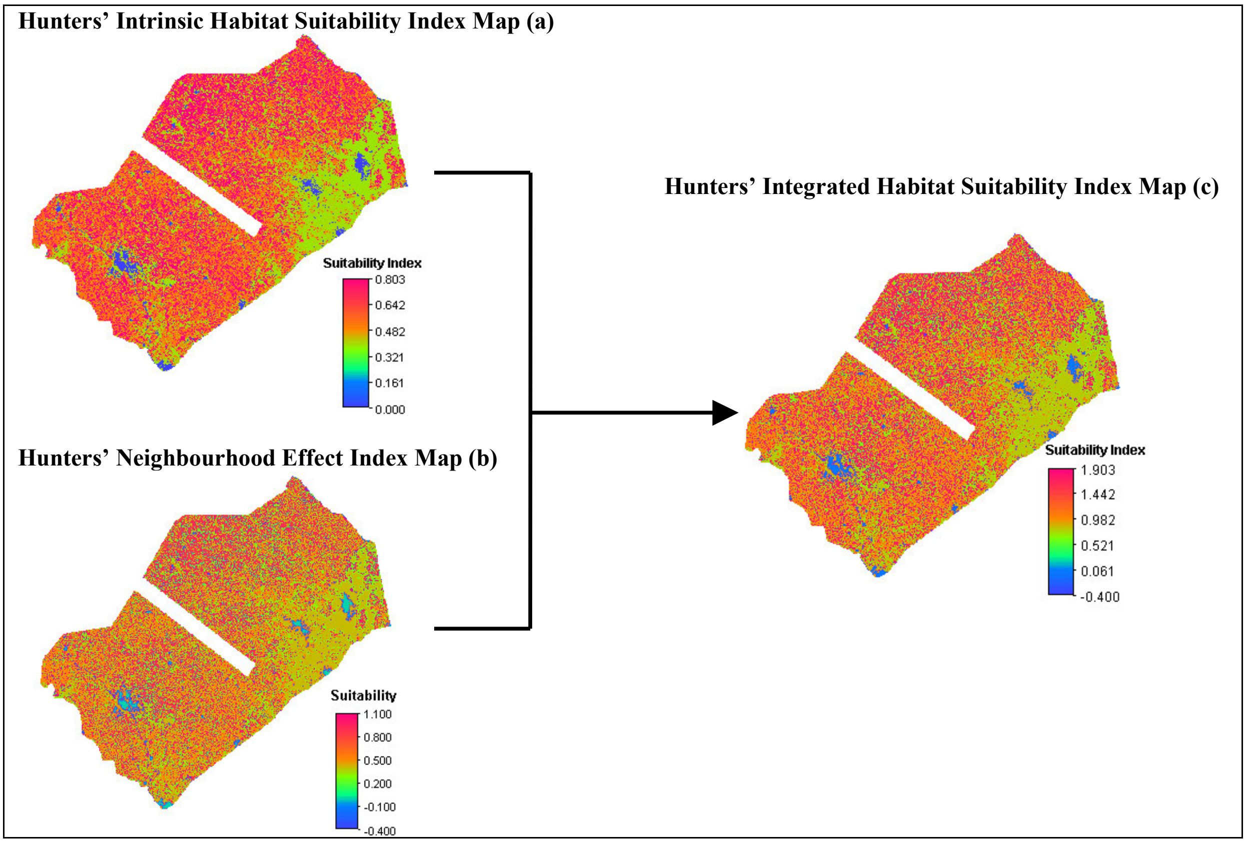


Fig 4.8. Hunters' Integrated Habitat Suitability Index map processing.

Reclassifying this fuzzy habitat suitability index map by applying the inflection points values in the map histogram (**Fig. 4.9**) gave a hunters' Integrated HSI class map (**Fig. 4.10**) with the following class upper boundary thresholds: 0.445 for Low Suitability, 0.897 for Moderate Suitability, 1.612 for High Suitability, and 3.000 for Very High Suitability. This was an improvement over even the intrinsic His class map (**Fig. 4.3**). For example, using the Habitat Type map (**Fig. 3.4**) as background, it was sensitive enough to make a further distinction between areas with Built-up or Wetlands, and Farm-bush and assigned correspondingly different suitability classes. Again, as in **Fig. 4.3**, the discrimination was more obvious in the south-eastern section of the map. Therefore, **Fig. 4.10** could be considered as the final l output map of the hunters for the Indigenous HSI model.

The distribution of the suitability classes with respect to the Habitat Types (**Table 4.2**) showed that all Built-up Areas and Wetlands were classified by the model as Low habitat suitability areas. Farm- bush and Monocrops could be considered as constituting the Moderate habitat suitability class, getting 96.4% and 93.1% coverage respectively. Cocoa-Forest and Young Secondary Forest constituted almost all the High habitat suitability class, with 98.7% and 88.3% of their areas respectively. Matured Secondary Forest was considered as having the highest suitability classification, Very High, with 96.6% of its area being allocated to this class.

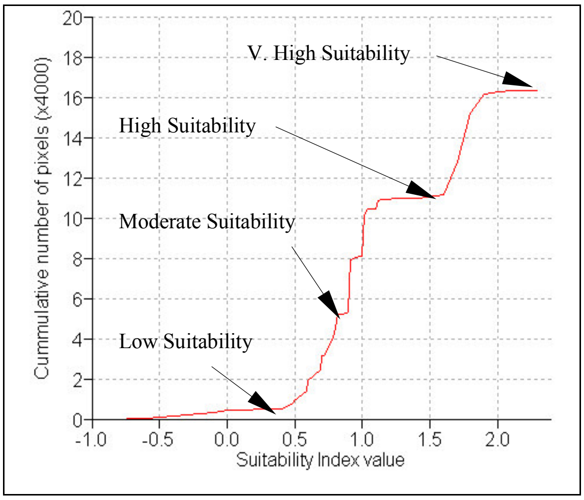


Fig. 4.9. Histogram of final HISI map for Maxwell' Duiker showing inflection points of suitability class boundaries.

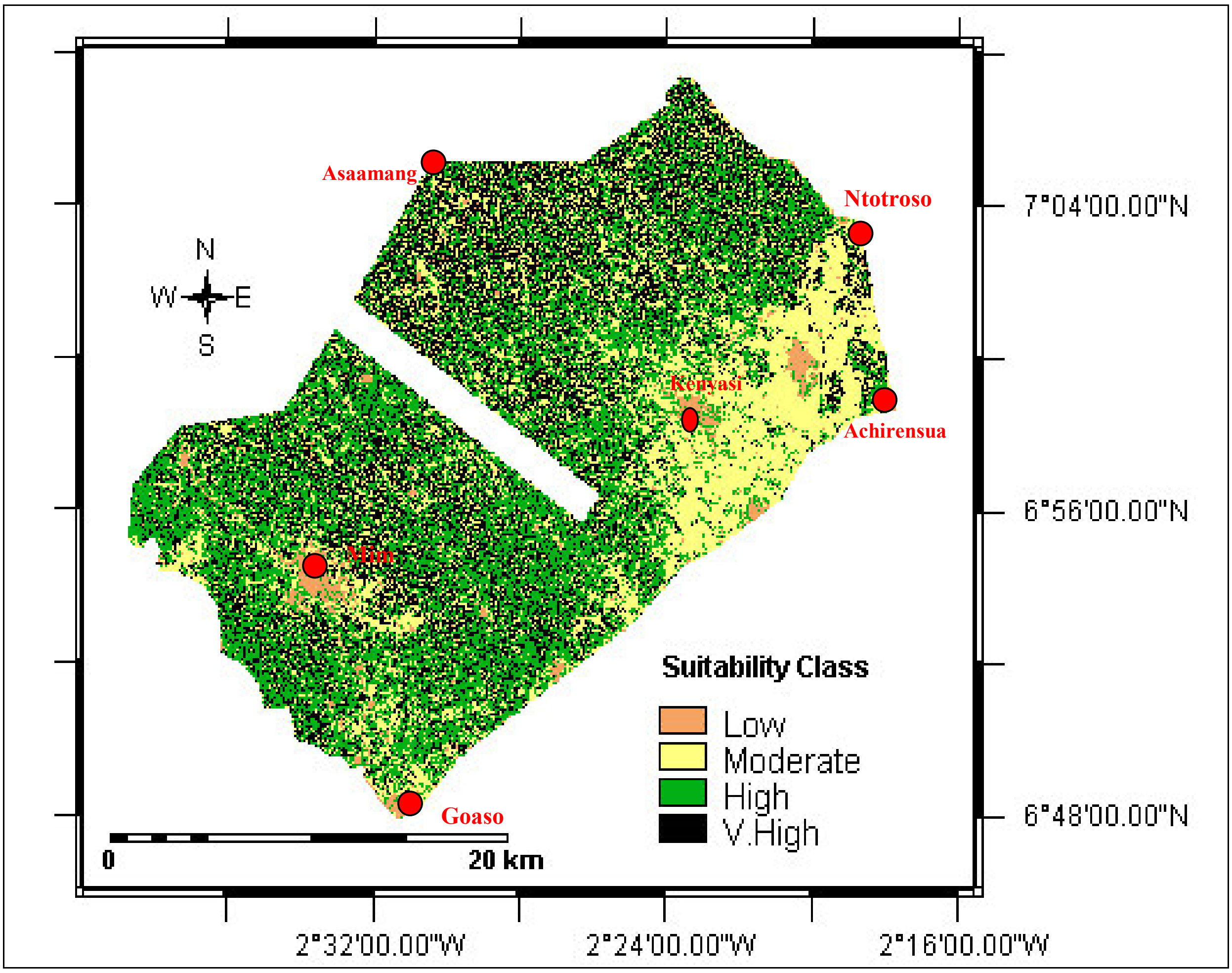


Fig 4.10. Hunters' Integrated Habitat Suitability Index map processing.

Table 4.2. Percent area distribution of hunter' habitat suitability classes per Habitat Type in Goaso study Area.

Habitat Type	Habitat Suitability Class	Area (ha)	Suitability Class allocation per Habitat Type (%)
Built-up Areas	Low	*1602.9*	*100.0*
Wetlands	Low	*228.0*	*100.0*
Farm-bush	Moderate	*9477.4*	*96.4*
Farm-bush	Low	*206.7*	*2.1*
Farm-bush	High	*148.4*	*1.5*
Monocrops	Moderate	*8277.2*	*93.1*
Monocrops	High	*576.3*	*6.5*
Monocrops	Low	*40.8*	*0.5*
Cocoa-Forest	High	*2289.8*	*98.7*
Cocoa-Forest	Moderate	*29.1*	*1.3*
Young Secondary Forest	High	*21326.1*	*88.7*
Young Secondary Forest	Moderate	*2727.4*	*11.3*
Matured Secondary Forest	V. High	*22008.2*	*96.6*
Matured Secondary Forest	High	*784.0*	*3.4*
Total		***69722.2***	

4.4. Discussion

The indigenous habitat model supports the observation by Caughley *et al* (1994) that in declaring an area as suitable habitat for a given species wildlife managers might not be able to explain logically what is they are seeing because they are summing up an amalgam of all the species' physical resources. What they simply see is: "habitat". The output of the Indigenous HSI model shows that a hunter's perception of an area's suitability as habitat for a given species is essentially the same as that of a wildlife manager. Any differences may stem from the mental process (decision rules) involved in deciding what environmental factors are relevant and how they are combined to reflect their interrelationships in a holistic functioning system. The implication, then, is that bushmeat hunters are simply the indigenous version of scientifically trained wildlife managers.

The model has correctly classified the general area between Achirensua and Kenyasi townships as having "Moderate" suitability as habitat for Maxwell's Duiker. This area has experienced heavy faming activities for centuries (as confirmed from stakeholder and hunter interviews), leading to an irreversible conversion of a once high forest vegetation to a predominantly grassland area. Therefore its ability to offer suitable habitat is very limited, as captured by the model. With the exception of the areas immediately around the other large settlements, e.g. Goaso and Mim, the rest of the study area has been classified as offering good habitat, virtually all of which is "High" or "Very High".

For the sake of a fair comparison of the two evaluation techniques, it was necessary that any step taken after the habitat scorings (intrinsic habitat mapping stages), should be identical for both methods/techniques. Judging from the hunter's obvious signs of discomfort, asking them to separate their habitat scores on the basis of food and refuge, as might be done by a typical wildlife ecologist, was apparently too coercive. This indicates that hunters do not evaluate wildlife habitat in the same way as scientists, i.e., they do not consciously separate the habitat factors and make fixed inferential rules about habitat suitability. It is possible that a different outcome would have emerged if they had been asked to rank the habitat suitability on the basis of a categorical scale (e.g. "high", "medium" and "low"). However, this, as well as other equally interesting alternatives, was beyond the scope of this study.

The use of money as an evaluation/scoring tool is debatable, but I consider it justified in this situation. Much as the study's aim was to let the hunters evaluate the habitat in their own way, I expected that the diversity of the hunters' socio-economic background and hunting experience would significantly influence their individual perception of a given habitat site. As to how much Fuzzy Set Theory could have accommodated the ambiguity in a non-monetary scoring scheme could not be tested during this study due to time constraints. Nevertheless, I suspect that this monetary scoring scheme, by virtue of the uniform value of money within a given socio-economic setting in a rural community, offers the most practical option to reducing ambiguity in habitat evaluation by different hunters.

Finally, the in-depth knowledge of the ecology of the evaluation species exhibited by the hunters, especially its feeding habits, indicates that they constantly carry out a spatio-temporal assessment of the condition of the resources in their landscape. This should not be too surprising if one considers the fact their livelihood depend on such skills.

5. Comparative Analysis Of The Habitat Models

5.1. Introduction

A major issue in the development of analytical techniques for spatial data is the comparison of maps (Hagen, 2002). However, most GIS applications still rely on visual analysis for determining similarities within and among maps (Sousa *et al*, 2002). Map comparison procedures can express the similarity between two maps by looking at simple proportions of areas or by numerical measurements. The result of a map comparison can be an overall value for similarity, such as a value between 0 and 1, or an output map. This means that the result of a comparison of two maps is a third map, which indicates per location the strength of similarity (Hagen, 2002).

The Scientific HSI and Indigenous HSI models developed in the previous chapters produced two maps which represented the potential Maxwell's Duiker habitat in the Goaso Study Area, as would be evaluated by a typical wildlife ecologist using standard HSI methods, and by hunters, respectively. In the absence of field validation, their accuracy could not be verified. However, the core objective of the study was to ***compare*** the two evaluation methods to see if they significantly differ from each other, irrespective of the outcome of field validation. Comparing the final output maps, as presented in this chapter, was the best means to achieve this objective. It is followed by an analysis of the significance of differences between the maps, and a comparison of the field time differences.

5.2. Methods

The main method used in assessing the similarities between the two model output maps was the *Kappa* statistics. The statistical aspect of the model comparison draws heavily from the work of Hagen (2002). In addition, field observations on how scientists differed from hunters in conducting the habitat evaluation, vis-à-vis data collection and analysis, was also assessed.

Assessing association between categorical maps in GIS typically involves overlay operations, representation of overlay results as a contingency table, followed by statistical analysis with various integral measures of association, log-linear model, etc (Zaslavsky, 1995). In many analytical situations, it is preferable to express the level of agreement to a single number (Sousa et al, 2002). When the comparison consists of a number of pairwise comparisons, the *Kappa* statistics can be a suitable approach (Carletta, 1996). It has become common to assess the similarity between observed and predicted results, using the *Kappa* index of agreement for categorical data, which was developed by Cohen (1960). Though first used in the context of psychology and psychiatric diagnosis, the *Kappa* statistics has been subsequently adopted by the remote sensing community as a useful measure of classification accuracy (Sousa *et al*, 2002). Its use in this study was, therefore, based on a lot of precedence.

5.2.1. Contingency Table

The calculation of *Kappa* for map comparison is based upon the Contingency Table (sometimes also referred to as the Confusion Matrix). Monserud and Leemans (1992) gave the generic form of the Contingency Table, which details how the distribution of classification categories in two maps, Map A and Map B, relate to each other (**Table 5.1).**

Table 5.1. Generic form of Contingency Table (*Source: Monserud and Leemans, 1992*).

		Map B Categories				Total
		1	2	…	c	
Map A Categories	1	P_{11}	P_{12}	…	P_{1C}	P_{1T}
	2	P_{21}	P_{22}	…	P_{2C}	P_{2T}
	c	P_{C1}	P_{C2}	…	P_{CC}	P_{CT}
Total		P_{T1}	P_{T2}	P_{11}	P_{TC}	1.0

The table's cell contents represent the fraction of cells in a category in Map A (matrix rows) that is taken up by the corresponding category in Map B (matrix column). For example, a value of 0.25 for the table's cell P_{12} would indicate that 25 percent of the mapped area (represented by map cells/pixels) is of category 1 in Map A and category 2 in Map B. Each row total, (P_{iT}), represents the total fraction of cells in a given category, *i*, in Map A, whilst each column total (P_{Ti}), represents the total fraction of cells in the given category, *i*, in Map B. The last row and column give the column and row totals. All fractions together make up the whole output cross-map, and therefore give a total sum of 1 (Monserud and Leemans, 1992; Hagen, 2002).

Many statistical analyses could be derived from the Contingency Table (Hagen, 2002), but the three most relevant for the calculation of *Kappa* in this study, using the notation in **Table 5.1**, were:

P(A), represents the Fraction of Agreement, and is calculated as:

$$P(A) = \sum_{i=1}^{c} p_{ii} \qquad \textbf{(eq. 5.1)}$$

P(E) represents the Fraction of Agreement ***subject to the observed distribution***, i.e, when the maps are expected to agree by chance, and is calculated as:

$$P(E) = \sum_{i=1}^{c} p_{iT} * \ p_{Ti} \qquad \textbf{(eq. 5.2)}$$

P(max), representing the ***Maximum*** Fraction of Agreement subject to the observed distribution, i.e., the maximum agreement that could be attained if the location of the cells in one of the maps were to be rearranged, and is calculated as:

$$P(\max) = \min \sum_{i=1}^{c} (p_{iT}, p_{Ti}) \qquad \textbf{(eq. 5.3)}$$

5.2.2. The *Kappa* Statistics

The *Kappa coefficient* (κ) measures pairwise agreement among a set of coders (e.g. map classifications) making categorical judgements, with a correction for chance (Carletta, 1996). Using **equations 5.1** and **5.2** above, it is represented as:

$$\kappa = \frac{P(A) - P(E)}{1 - P(E)} \qquad \textbf{(eq. 5.4)}$$

Kappa, therefore, is the proportion of agreement, *P(A)*, after chance agreement, *P(E)*, has been removed. If $\kappa = 1$, there is perfect agreement. If $\kappa = 0$, the agreement is the same as would be expected by chance, i.e. by a random arrangement of the map cells. Therefore, the higher the κ value, the stronger the arrangement, as shown in **Table 5.2**. Negative values occur when the agreement is weaker than expected by chance, but this rarely happens (Landis and Koch, 1977; Sousa *et al*, 2002).

Table 5.2. Strength of agreement of maps according to Kappa values (source: Landis and Koch, 1977)

Kappa Values	Strength of Agreement
< 0.00	Poor
0.00 – 0.20	Slight
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Substantial
0.81 - 100	Almost Perfect

5.2.3. Time and Financial Cost Comparison

I had initially planned to compare the differences in time and financial cost between the two evaluation techniques. Field condition made it difficult to objectively estimate the financial cost, but it was possible to estimate the time taken for either group of evaluators to complete field data collection. It must be noted that this did not cover the entire duration of the study, i.e. from planning, time taken to access a sample site, and post fieldwork (analysis and reporting) time. Therefore, this is not a cost-benefit analysis of the two evaluation techniques *per se*.

5.3. Results

5.3.1. Map Overlay

The aim of a pairwise post-classification is to identify areas of categorical disagreement between two maps by determining the pixels with a difference in theme (Sousa et al, 2002). Using the MapCalc function of ILWIS 3.12®, the two model final output maps (**Fig. 3.15** and **Fig. 4.10**) were overlaid on a cell-by-cell basis to produce a cross-map (**Fig. 5.1**) and an attribute table of site-specific differences (**Table 5.3**). The final output map of the Scientific HSI model was considered as the map test map, against which the classification by the hunters was compared.

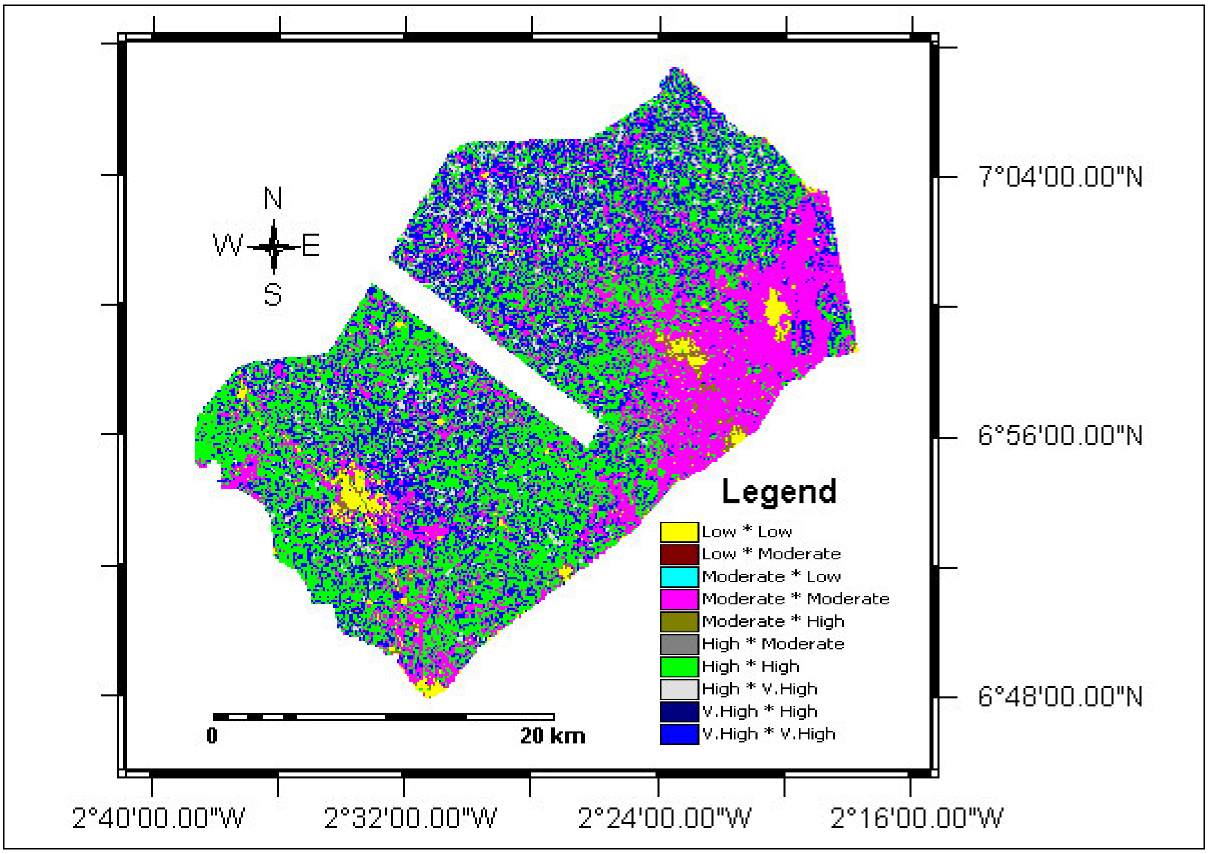


Fig. 5.1. Overlay map of Scientific HSI model map and Indigenous HSI model map.

Table 5.3. Attribute table of Scientific HSI model map and Indigenous HSI model map overlay.

Cross-Map	Scientific HSI Map	Indigenous HSI Map	No. Pixels	Area (ha)
Low * Low	Low	Low	*1927*	*1869.7*
V. High * V. High	V. High	V. High	*19924*	*19331.3*
Moderate * Moderate	Moderate	Moderate	*18126*	*17586.8*
Moderate * Low	Moderate	Low	*215*	*208.6*
High * High	High	High	*25136*	*24388.2*
High * Moderate	High	Moderate	*2841*	*2756.5*
High * V. High	High	V. High	*2759*	*2676.9*
Low * Moderate	Low	Moderate	*173*	*167.9*
Moderate * High	Moderate	High	*727*	*705.4*
V. High * High	V. High	High	*32*	*31.0*
Total			***71860***	***69722.2***

The Contingency Table (**Table 5.4**) derived from the cross-map's attribute table gave an Overall Accuracy of 0.93, indicating that on 93% occasions, the hunters assigned the same habitat suitability classification to map cells as the wildlife ecologist. The distribution of misclassified cells and their associated histogram distribution are shown in **Fig. 5.2** and **Fig. 5.3**, respectively.

Table 5.4. Contingency Table of cross-map, with number of classified cells.

	Hunter HSI Map				**Total**	**User Accuracy (UA)**
Scientific HSI Map	Low	Moderate	High	V. High		
Low	*1927*	*173*	*0*	*0*	***2100***	***0.918***
Moderate	*215*	*18126*	*727*		***19068***	***0.951***
High	*0*	*2841*	*25136*	*2759*	***30736***	***0.818***
V. High	*0*	*0*	*32*	*19924*	***19956***	***0.998***
Total	***2142***	***21140***	***25895***	***22683***	**71860**	
Producer Accuracy (PA)	***0.900***	***0.857***	***0.971***	***0.878***		**Overall Accuracy = *0.93.***

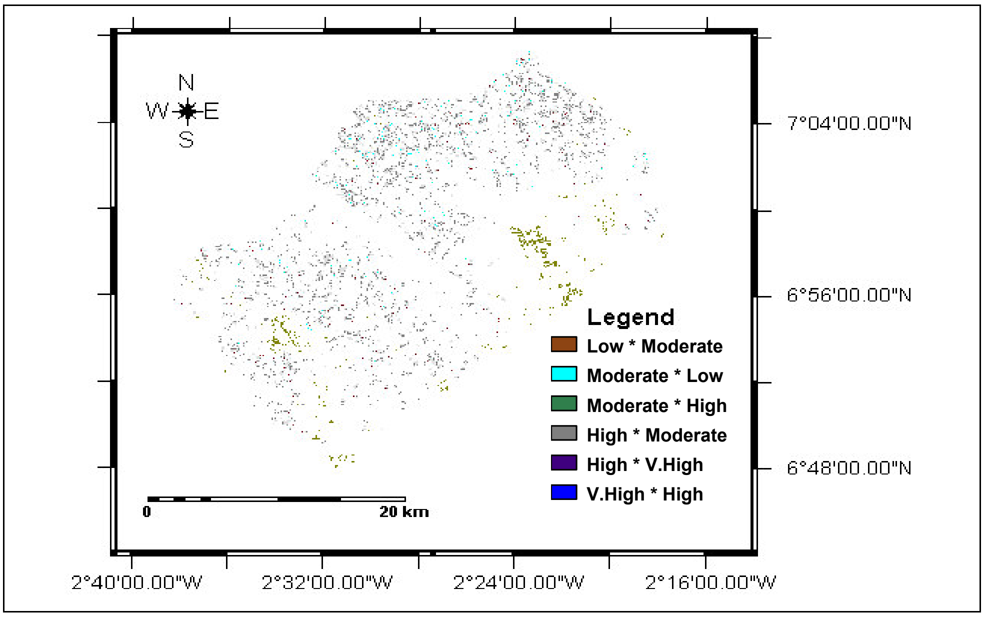


Fig. 5.2. Distribution map showing areas of suitability class differences between the Scientific and Indigenous habitat models.

5.3.2. Overall Similarity (standard)

The values in the Contingency Table (**Table 5.2**) were further converted to proportions of classified map cells in each suitability class (**Table 5.5**). Inserting the relevant cell values from **Table 5.3** into **equations 5.1** and **5.5** resulted in:

$$P(A) = \sum_{i=1}^{c} p_{ii} = 0.93 \qquad \textbf{(eq. 5.5),}$$

and:

$$P(E) = \sum_{i=1}^{c} p_{iT} * p_{Ti} = 0.32. \qquad \textbf{(eq. 5.6)}$$

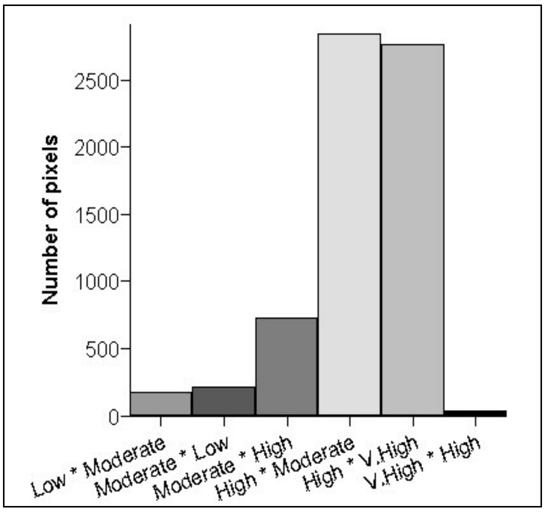


Fig. 5.3. Histogram distribution for number of pixels (cells) for suitability class differences.

The *Kappa* value thus derived was:

$$\kappa = \frac{(0.93) - (0.32)}{1 - (0.32)} = 0.90. \qquad \textbf{(eq. 5.7)}$$

Table 5.5. Contingency Table of cross-map, with proportion of classified cells.

	Indigenous HSI Model Map				
Scientific HSI model map	Low	Moderate	High	V. High	**Total**
Low	*0.027*	*0.002*			*0.029*
Moderate	*0.003*	*0.252*	*0.010*		*0.265*
High		*0.040*	*0.335*		*0.375*
V. High			*0.015*	*0.316*	*0.331*
Total	***0.030***	***0.294***	***0.360***	***0.316***	***1***

This κ value indicated that the hunters rated 90% of the study area with the same suitability classes as the wildlife ecologist. With this value, the two model outputs were considered as having an "*Almost Perfect*" agreement (refer to **Table 5.2** above).

However, *Kappa*, as given here, mixes up (or confounds) similarity of quantity with similarity of location (Pontius, 2000). This stems from the fact that, *Kappa,* in essence*,* is the fraction of agreement, *P(A)*, with correction for the fraction of agreement statistically expected from the random allocation of all cells in the map, *P(E)*. The 'quantity' merely means the total presence of a category over the *whole* map, whilst 'location' refers to the spatial allocation of the quantity over the map. For example, two maps may each have 70% of their cells in a given category, thus giving a very high quantitative similarity; but virtually all these cells may be at different locations in either map, thereby giving poor locational similarity. Therefore, two additional steps were taken to separate similarity in quantity and similarity in location.

5.3.3. Locational Similarity

The statistics for similarity of locations, called $\kappa location$, compares the actual success rate to the expected success rate relative to the maximum success rate, given that total number of cells in each category does not change (Sousa *et al,* 2002). The maximum success rate, P(*max*), is calculated by **equation 5.3** above. $\kappa location$ is calculated as:

$$\kappa_{location} = \frac{P(A) - P(E)}{P(\max) - P(E)} \qquad \textbf{(eq. 5.8)}$$

The maximum value for $\kappa location$ is 1; there is no minimum value. The advantage over *Kappa* is that $\kappa location$ is independent of the total number cells in each category.

Using **equation 5.8**, the $\kappa location$ value was:

$$\kappa_{location} = \frac{0.93 - 0.32}{0.97 - 0.32} = 0.94. \qquad \textbf{(eq. 5.9)}$$

This result indicated that on 94% occassions, the hunters classified the same map cells, i.e. *same locations,* with the same suitability classes as the wildlife ecologist.

5.3.4. Quantitative Similarity

The statistics for quantitative similarity is called $\kappa quantity$. It is a statistics for assessing disagreement due to quantitative differences. The equation for $\kappa quantity$ is poses many practical problems (see Sousa *et al* (2002), for details). This led to the proposition of an alternative expression by Hagen (2002) called $\kappa histo$, because it can be calculated directly from the histograms of two maps, and is defined as:

$$\kappa_{histo} = \frac{P(\max) - P(E)}{1 - P(E)} \qquad \textbf{(eq. 5.10)}$$

When applied to the Contingency Table, the resulting $\kappa histo$ was:

$$\kappa_{histo} = \frac{0.97 - 0.32}{1 - 0.32} = 0.96. \qquad \textbf{(eq. 5.11)}$$

This indicated that on 96% occasions, the hunters classified the *same number of map cells* with the same suitability classes as the wildlife ecologist.

5.3.5. Overall Similarity (adjusted)

Kappa, representing the overall similarity of the two model output maps could therefore be adjusted, or re-defined, as the product of $\kappa location$ and $\kappa histo$:

$$\kappa = \kappa location * \kappa histo \qquad \textbf{(eq. 5.12)}$$

which gave:

$$\kappa = 0.94 * 0.96 = 0.90. \qquad \textbf{(eq. 5.12)}$$

It must be noted that both the standard *Kappa* (**equation 5.7**) and Hagen's (2002) alternative (**equation 5.12**) yielded the same results. Once again the strength of agreement was interpreted as "*Almost Perfect*" (reference to **Table 5.2** above).

5.3.6. Significance of Strength of Agreement

To determine whether the apparently strong agreement between the two habitat models was significant, I next applied a *z-test*. Since the number of cells was very large, I assumed that the distribution of κ was close to 'normal', following the Central Limit theorem. Application of the Anderson-Darling normality Test Fig. 5.3), confirmed that with a P-value = 0.001, the normality of the distribution was significant ($A^2 = 1.307$, $p < 0.05$). Using the notation and computation of significance for κ used by Cohen (1960) and Hagen (2002):

$$\text{var}(\kappa) = \frac{P(E)}{N(1 - P(E))} \quad \textbf{(eq. 5.13)}$$

where:

var (κ) = variance of the κ value.
N = the total number of cells in each map that were compared, taken as 71860 from Table (Table 5.1),
P(E) = Proportion of expected agreement.

$$z = \frac{\kappa}{\sqrt{\text{var}(\kappa)}} \quad \textbf{(eq. 5.14)}$$

When the various values were inserted into **equation 5.14**, the result was:

$$z = \frac{0.90}{\sqrt{0.000006548}} = 351.713 \quad \textbf{(eq. 5.15)}$$

This extremely high z-value obviously stems from the very large number of cells used in the comparison, which gave the *var* (κ) a correspondingly small value.

The ***hypotheses*** regarding the comparison the two habitat models was that:

H_o: The agreement observed between the classification of habitat suitability for Maxwell's Duiker in the Goaso study area ***is not*** significantly different from an agreement that could have been achieved purely by a chance allocation of map cells.

H_a: The agreement observed between the classification of habitat suitability for Maxwell's Duiker in the Goaso study area ***is*** significantly different from a chance agreement.

Using **equation 5.15**, the P-value was $P = 2P(Z \geq 351.713)$. Since the largest *z*-value in the Standard Normal Probabilities table (*Table A* in Moore and McCabe, 2003) was 3.49, the Z-value that could be used was 0.9998. A re-computation therefore gave $P < 2(1-0.9998) = 0.0004$. With and α-value of 0.05, I concluded that since $P < 0.05$, the strength of agreement between the two model output maps was significant and could not have happened purely by chance. Therefore, the null hypothesis, H_o, was rejected in favour of the alternative hypothesis, H_a.

5.3.7. Time and Cost Comparison

Hunters consistently used much less time in evaluating a site. In general, they spent between 20% and 25% of the time taken by the wildlife ecologist to evaluate a site (**Table 5.6**.). The wildlife ecologist spent the most time in Matured secondary Forest, and the least in Farmbush, same as for the hunters.

It should be noted that wetlands and Built-up areas were not sampled, but they are included here for the sake of uniformity in presentation.

Table 5.6. Mean time (min) for data collection per transect line per Habitat Type.

Habitat Type	Scientific HIS (min.)	Indigenous HIS (min.)	Differences (min)	Differences (%)
Matured Secondary Forest	*42.3*	*8.7*	*33.6*	*20.6*
Young Secondary Forest	*33.0*	*6.8*	*26.2*	*20.6*
Farmbush	*28.4*	*6.1*	*22.3*	*21.5*
Cocoa-Forest	*28.5*	*6.2*	*22.3*	*21.8*
Monocrops	*30.3*	*7.5*	*22.8*	*24.8*
Wetlands	*0.0*	*0.0*	*0*	*0*
Built-up Areas	*0.0*	*0.0*	*0*	*0*

The financial cost of evaluation by the hunters was subject to negotiation, but was eventually pegged at twice the daily farm labour rate, which normally covers about four hours in the morning (08:00 hrs – 12:00 hrs). At the time of the study, this was about ¢15,000.00 (approximately 1.50 Euros). Doubling this rate to ¢30,000.00 was to compensate for a full day's hire. The wildlife ecologist (student) daily cost of accommodation and food was about ¢ 100,000.00 (approximately 10 Euros). These costs did not include materials and transportation charges.

5.4. Discussion

An "Almost Perfect" agreement between the two evaluation techniques is so significant that there is only a 0.04% probability that it could have occurred by chance alone. This high level of significance is of practical importance because it also supports the close correlation between the individual models outputs and the habitat types in the study area. Besides, the possibility that either team of evaluators influenced each other to cause this strong similarity is very minimal, as they used different approaches and criteria in the data collection and subsequent analysis.

The major areas of disagreement are concentrated in the northern sector of the study area. The reason for this appears to be related to the fact that there is a very diverse mosaic of vegetation cover types in the area. The area is predominated by Matured Secondary Forests and Young secondary Forests, but there are numerous pockets of other land use types, such as food crops and grassland, that were masked out in the image classification. These relatively smaller areas were, however, evaluated for what they were by the hunters, leading to locational disagreements between the two models. Furthermore, there were differences in the intra-class disagreements between the two models. Both models had little disagreement in the suitability ratings of the habitat type representing the extreme end of the vegetation successional stages. In particular, they virtually agree on the "Very High" suitability class. However, strong differences occurred in the intermediate suitability classes, representing the intermediate vegetation successional stages. Most obvious is the case in which a lot of the areas classified as "High" by the wildlife ecologist are considered as either "Moderate", an under-valuation, or "Very High", an over-valuation. This could also be due to the hunters' incorporation of the phenological and structural complexity (juxtaposition of individual plants) in evaluating a site.

In addition, there are important differences between how scientists and indigenous people view their habitats. The typical wildlife ecologist could be said to deliberately 'dissect' the habitat into several components (food, shelter, security, etc.) and attempt to find their individual contribution to the overall habitat suitability for the evaluation species. The scientific approach warrants a justification of every phase of the model development, especially in the statement of assumptions, leading to a lengthy process. Thus, errors at any phase are transferred to the final output. Failure to capture the true relationships between the components, especially in unfamiliar environments, result in a habitat map that that is either inaccurate, or calls for lengthy processing and validation, with attendant costs.

The typical hunter, on the other hand, appears to sub-consciously combine the habitat components in a 'single' process borne of years of personal experience. He is more likely to have operated in the same or very similar environment and therefore his evaluation of a site may be closely related to (or influenced by) a previous evaluation. Thus, the indigenous evaluation process would tend to be less prone to trials than would the wildlife ecologist, but this is a hypothesis that is yet to be tested.

The study also brings out the fact that in their evaluation process, hunters consider not just the diversity and abundance (for food) and density (for refuge) of vegetation cover. For food, they factored in the condition (herbage and tree leaf) as well as the age and/or fruiting stage in giving the food scores. This phenological aspect was not considered in the scientific food scoring. For refuge, the configuration of the vegetation, especially of the lower and middle layer, might have influenced the refuge scorings of the hunters, a factor not captured by the scientific model. The inferential system (decision rules) used by the hunters to capture these phonological and configuration vegetation attributes were outside the scope of this study, but are worth further consideration in later studies. It is quite likely that a wildlife ecologist (or manager) very experienced in a particular area would tend to behave as a local hunter in evaluating that habitat for a given species, but this would require a departure from the "dissecting" approach.

The scale at which the habitat variables were assessed was distinctly different in the two models, and could also have influenced the strength of agreement. The wildlife ecologist looks at details with up to a precision of 1m. It is, however, not clear the level of precision the hunters use, but visibility through the undergrowth seems to be of some considerable importance, as inferred from the fact that the average maximum scale of their evaluation was approximately 50m.

The fact that hunters spent less than 25% of the time used by wildlife ecologist to evaluate a site should not be too surprising. This is because they were unencumbered by measuring equipment of any kind; evaluation time was essentially the time taken to walk the length of a transect, with periodic stops to verify an observation (e.g. tree species, animal footprint, etc.). Unlike the wildlife ecologist, hunters used a mental compass, an entirely ocular estimation of variables (e.g. distances and tree quantities).

The hunters' daily labour cost computed for this study has no medical insurance or social security components, just as for the wildlife ecologist. Under the CREMA programme, the same situation would be expected to prevail, in that the ecologist is most likely to be a WD staff, with a fixed salary. However, this rate is subject to the expertise of the ecologist, and may be very much higher than the student's rate given here. Thus, the fact that hunter's daily cost during the study is about a third of the ecologist' is not likely to be a standard practice. Nevertheless, it is extremely unlikely that hunters' rate will ever exceed that of an ecologist.

Perhaps the most important aspect of this comparison is that the long and relatively more complex modelling process for the Scientific model is in itself a disadvantage in that each phase introduces uncertainties with the possibility of increasing errors. With the Indigenous model, these errors can be minimised. It is also likely to be more reliable because it is based on individually acquired or shared common knowledge gained over a long period of time in the same area.

Whilst the models developed here are not the only ones that could be developed for the study area for Maxwell's Duiker, they are arguably the most realistic, based on data at hand. Any conclusions are also subject to field validation. One must always bear in mind, however, that no matter how useful models (especially for wildlife habitat) may be for a given objective, they must not be viewed as permanent expression of the truth, (Salwasser, 1986).

6. Conclusion And Recommendations

6.1. Main Findings

The hypothesis that Maxwell's Duiker habitat evaluated by indigenous people is no different from that of scientists has been fully supported by the results of this study. It has demonstrated that indigenous people (hunters) can evaluate habitats for bushmeat in agricultural landscapes equally as well as scientists (wildlife ecologists). Furthermore, if other factors, such as time and labour cost, are considered, hunters could be said to actually do much better than wildlife ecologists. It has further demonstrated that collecting genuine information from indigenous people and using a GIS to analyse and display inherent spatial and geographic information maximizes the usefulness of the data for resource planning and management. The results provided the following answers to the study questions:

- *What are the most appropriate habitat variables for the development of a conventional scientific HSI model for Maxwell's duiker?*

The optimum variables for Maxwell's Duiker habitat modelling are: (1) percent canopy cover of food plant species; (2) percent vegetation canopy cover; and (3) sighting distance (in meters) at 0.5m above ground level through the undergrowth. These provided, respectively, food, shelter from sun and rain, and security form predation for Maxwell's Duiker. Application of Fuzzy Set analysis showed that food weighed more than security, which in turn weighed more than shelter.

- *What habitat variables and criteria do indigenous people (hunters) in the Goaso area use to evaluate habitat suitability for Maxwell's Duiker?*

Hunters consider food plant species and refuge as the key habitat components in evaluating a site's suitability. These were equivalent to the habitat components of the Scientific HSI model. The habitat variables relating to the food habitat component were quantity, type, and condition (fruiting stage) of fruit tress and shrubs, and herbs. For the refuge component, the habitat variables relating to refuge were density of undergrowth vegetation, and complexity of canopy layers. Hunters did not make a distinction between these two aspects of refuge; they considered the structure and density as well as the juxtaposition of the vegetation in arriving at a site's refuge score. Precisely how these habitat factors interrelated could not be clearly determined during the study other than that, as in the scientific evaluation, hunters accorded more weight to food than to refuge in the evaluation process.

- *Where are the most suitable Maxwell's Duiker habitat in the study area, as evaluated by the scientific HSI, and by the indigenous HSI techniques*?

Both habitat evaluation models classified most of the study area as having high or very high suitability Maxwell's Duiker habitat. Generally, the best areas are between Ntotroso and Asaamang in the northeast, and between Asaamang and Mim, in the north and mid-west. The area between Achirensua and Kenyasi in the southeast of the study area has little Maxwell's Duiker habitat to offer.

- *How do the indigenous and the scientific habitat evaluation techniques compare?*

The study indicated that on 94% of the time, hunters classified the same locations with the same suitability classes as the wildlife ecologists ($\kappa location$ = 0.94). On the other hand, hunters classified the same total area (*number of map cell*) *with* the same suitability classes as the wildlife ecologist on 96% of the time ($\kappa histo$ = 0.96). Overall, the evaluation of Maxwell's Duiker habitat by indigenous people (hunters) showed an "Almost Perfect" agreement with scientific evaluation of the same study area (Overall Accuracy = 0.93; *Kappa*=0.90). The strength of agreement between the two evaluation techniques is so significant that there is only a 0.04% probability that it could have occurred by chance alone ($P < 0.05$).

Two important differences between how scientists and indigenous people view their habitats, and which reflect in their evaluation, are that:

a. the typical wildlife ecologist consciously breaks down the habitat into several components (food, shelter, security, etc.) and attempts to find their individual contribution to the overall habitat suitability, whilst the typical hunter appears to sub-consciously combine the habitat components in a 'single' process, borne of years of personal experience;

b. hunters consider not just the diversity and abundance (for food) and density (for refuge) of vegetation cover, but also factor in the *phenology* (condition of herbage and tree leaf, as well as the age and/or fruiting stage) in giving the food scores. This phenological aspect was not considered in the scientific food scoring in this study. For refuge, the *configuration* of the vegetation, especially of the lower and middle layers, seem to have influenced the refuge scorings of the hunters, a factor not captured by the scientific model.

Hunters consistently used much less time in evaluating a site, spending between 20% and 25% of the time taken by the wildlife ecologist per site. The relative cost of habitat evaluation by hunters, limited to daily labour cost, without medical end social security, accommodation, is less than a third of the daily food boarding and lodging cost of an ecologist; it is highly unlikely the gap will ever close up.

Based on the above, the final conclusion is that hunters could be entrusted with the inventory and monitoring of bushmeat habitat in their communities with a degree of accuracy equalling that of wildlife ecologists, but at a very small fraction of the cost. However, because of the advantages of GIS, indigenous people cannot go it alone. A strong partnership between them and other stakeholders, spearheaded by the WD, using a participatory GIS approach, offers the best long-term solution to wildlife resource management in this (and similar) agro-ecosystem.

6.2. Management Considerations

These models are not meant to be sacrosanct, but a practical guide to evaluating bushmeat habitat for a typical forest agro-ecosystem. Inasmuch as the findings could be used for other purposes, it is best suited to the needs of the CREMA programme in Ghana, and related programmes elsewhere. The proximity of suitable habitat, even close to densely populated settlements (e.g. Mim and Goaso), suggests that from the ecological perspective, settlements have little effect on Maxwell's duiker habitat in the Goaso area (i.e. provided hunting is controlled). These settlements could serve as potential base camps for a demonstration programme on integrated agricultural-wildlife production in the Goaso area. The territorial behaviour of Maxwell's Duiker is good for the CREMA. Considering the land and resource tenure situation there may be considerable difficulties in creating co-operatives for lager areas at the initial stages of the CREMA programme foe most areas, but small to medium sized areas that fit into an average family land holdings could be better controlled from the resource management perspective. Thus, Maxwell's Duiker production could be actively promoted for the rural forest areas, whilst the Grasscutter is promoted for the urban areas.

The study has suggested that the typical hunter appears to sub-consciously combine the habitat components in a 'single' process borne of years of personal or shared experience. He is more likely to have operated in the same or very similar environment and therefore his evaluation of a site may be closely related to, or influenced by, a previous evaluation (hunting expedition). Thus, the indigenous evaluation process would tend to be less prone to trials than would the wildlife ecologist. This is a hypothesis that is has to be verified if national wildlife management authorities or researchers are to harness the expertise of hunters. The study also brings out the fact that in their evaluation process, hunters consider not just the diversity and abundance (for food) and density (for refuge) of vegetation cover. For food, they factored in the condition (herbage and tree leaf) as well as the age and/or fruiting stage in giving the food scores. This phenological aspect was not considered in the scientific food scoring. For refuge, the configuration of the vegetation, especially of the lower and middle layer, might have influenced the refuge scorings of the hunters, a factor not captured by the scientific model. The inferential system (decision rules) used by the hunters to capture these phenological and configuration vegetation attributes were outside the scope of this study, but are worth further consideration in later studies.

It is highly probable that a wildlife ecologist (or manager) with long experience in a particular area would tend to behave as a local hunter in evaluating that habitat for a given species, but this would require a departure from the "dissecting" approach. It would be of considerable research and management interest to know how hunters' knowledge evolve over time, as well as how local communities adapt to integrated agriculture-bushmeat production.

6.3. Recommendations

The usefulness of this study's output can be maximized if the following recommendations are considered:

i) Field validation to test the accuracy of the models.

ii) Detailed ecological studies to determine the precise contribution (Suitability Index functions) of selected habitat variables, especially on quantification of food species, shelter and cover, to Maxwell's Duiker habitat.

iii) A village immersion methodology to improve our understanding of the knowledge acquisition process of hunters. Emphasis should be on the exact inferential system used by the hunters, especially regarding the site conditions (phenology).

iv) The creation of a Bushmeat Geo-Information Database to facilitate the storage analysis and presentation of bushmeat information. Compatibility with existing or future Geo-databases in the agricultural forestry and wildlife sectors is essential.

v) A multi-criteria analysis to assess the future direction of the CREMA programme under different ecological and socio-economic scenarios, preferably with Goaso as a case study area to ensure continuity with the data already accrued in this study.

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APPENDIX A. Transect Habitat Description for Scientific and indigenous habitat data.

Field Site Description Form 1

Observer:					**Date:**		**Start Time:**		**Gen. Area**			
Site/Block ID:					**Transect Start. X**		**Y:**					
Land cover type:	MSF	YSF	YB	RF	TM	FC	Gr	Sw	Wt	BS	Stt	Rk
Land use type:												

A. Vegetation Cover (%; Line Transect 200m) :

Upper Layer (>5m)				Middle Layer (2-5m)				Ground Layer (<2m)				Animal Obs		Land cove/use	
Cover Distance			Cover Type.	Cover Distance			Cover Type	Cover Distance			Cover Type	Spp	Obs. Code*	Cover	Use
Start	End	Total		Start	End	Total		Start	End	Total					

[2]Details on Form 2

.COMMENTS:

B. Security (Ground Cover Density; Line Transect):

Start Point (m)	Sight. Dist.(m)				Avg. Sight Dist. (m)	Hunter Sight. Dist. Score [2]	Hunter Hab. Suit[2]	Comments	
	N	E	S	W					
0									
50									
100									
150									
200									

C. Key Food Species (abundance; Circular Plots; dirct observations)

Start Point (m)	Species*	Number	%
50			
100			
150			

A. Animal Observations.

Observation Point		Species	Transect dist. mark#	Obs. Type	Number individuals	Comment
X-coordinate	Y-coordinate					

End Time:

Transect End. X: **Y:**

TOTAL TIME:

COMMENTS:

Recording Codes For Land Cover Type Description

:

Land Cover Type	**Code**	**Description**	
		Dominant vegetation	**Comments**
Mature Secondary Forest	MSF		
Old Bush	YSF		
Young Bush	YB		
Riverine Forest	RF		
Tree Monocrop	TM		
Food Crops	FC		
Grassland	Gr		
Swamp	Sw		
Water	Wt		
Bare Soil	BS		
Rock/Gravel	Rk		
Settlement	Stt		

GENERAL DAILY FIELD PROTOCOL

A. Pre-departure:

- Review/Confirm itinerary for the day.
- Check all equipment, data sheet and maps.

B. Fieldwork:

i) Transect observations

- Arrival rally point. Get GPS coordinates; confirm location on GPS, field sheet,map. Check distance and bearing of sample site from disembarkation point. maps, protractor, compass
- Navigate team to sample site. Take coordinates of most convenient access point. Calculate bearings and distances from access point to plots (flat and slope). Verify if distance between plots at least 200m.
- Fill in field data sheet for this phase.
- Lay transect and record relevant observations on data sheets.
- End of transect work

ii) Preliminary summary

- Summarise observations in relevant columns of data sheets. Include necessary comments.
- Return to rally point for entire group.
- Go to next plot; or GO HOME!

C. Post Fieldwork

- Check field data for errors or incomplete data, etc.
- Organise materials for next day.
- Plan itinerary for next day.
- Don't forget dinner.
- Sleep.

APPENDIX B: Food plant species list.

No.	Scientific Family	Scientific Name	Local Name	From Literature*	From Hunters
1	Acanthaceae	*Carica papaya*	Brofere	x	x
2	Anacardiaceae	*Mangifera indica*	Amango	x	x
3	Anacardiaceae	*Antrocaryon micraster*	Aprokuma		x
4	Anacardiaceae	*Anacardium occidentale*	Cashew		x
5	Apocynaceae	*Funtumia elastica*	Fruntum		x
6	Apocynaceae	*Alstonia boonei*	Nyamedua		x
7	Araceae	*Xanthosema sagittifolium*	Mankani		x
8	Bignoniacea	*Spathodea campanulata*	Akuakuo-ninsuo		x
9	Bombaceae	*Bombax buonopozense*	Akata		x
10	Bombaceae	*Cieba pentandera*	Onyina		x
11	Caesalpiniaceae	*Daniella ogea*	Hyedua		x
12	Caesalpiniaceae	*Berlina spp*	Kwatafompaboa		x
13	Caesalpiniaceae	*Hymenostegia afzelii*	Takorowa		x
14	Caesalpiniaceae	*Amphimas pterocarpoides*	Yaya		x
15	Capparaceae	*Bulchozia coriacea*	Konini		x
16	Combretaceae	*Terminalia ivorensis*	Emire		x
17	Combretaceae	*Terminalia superba*	Framu		x
18	Euphorbiaceae	*Alcornea cordifolia*	Agyama	x	x
19	Euphorbiaceae	*Manihot esculenta*	Bankye		x
20	Euphorbiaceae	*Macaranga barteri*	Opam		x
21	Euphorbiaceae	*Margaritaria discoidea*	Pepea		x
22	Euphorbiaceae	*Ricinodendron heudelotii*	Wama	x	x
23	Fabaceae	*Centrosema pubescens*	Esere		x
24	Fabaceae	*Cassia siamea*	Kassia		x
25	Flacourtiaceae	*Scottelia klaineana*	Tiabutuo		x
26	Gramineae	*Zea mays*	Aburo		x
27	Gramineae	*Panicum maximum*	Esere		x
28	Gramineae	*Pennisetum purpureum*	Esere		x
29	Lauraceae	*Persea spp.*	Paya	x	x
30	Loganiaceae	*Anthocleista nobilis*	Bontodee	x	x
31	Marantaceae	*Thaumatococcus daniellii*	Awonomo		x
32	Meliaceae	*Entandrophragma angolense*	Edinam		x
33	Meliaceae	*Entandrophragma utile*	Efoobodedwo		x
34	Meliaceae	*Trichilia spp.*	Tanuro	x	x
35	Mimosaceae	*Albizia ferruginea*	Awiemfosamina		x
36	Mimosaceae	*Albizia zygia*	Okuro		x
37	Mimosaceae	*Albizia adianthifolia*	Pampena		x
38	Mimosaceae	*Tetrepleura tetraptera*	Prekese		x
39	Moraceae	*Ficus sur*	Domoni		x
40	Moraceae	*Antiaris spp.*	Kyenkyen	x	x
41	Moraceae	*Ficus exasperata*	Nyankyerene		x
42	Moraceae	*Ficus capensis*	Odoma	x	x
43	Moraceae	*Milicia excelsa*	Odum		x
44	Moraceae	*Musanga cercropioides*	Oduma	x	x
45	Moraceae	*Trilepisium madagascariense*	Okure		x
46	Moraceae	*Morus mesozygia*	Wonton		x
47	Musaceae	*Musa sapientum*	Brodee		x
48	Musaceae	*Musa paradisiaca*	Kwadu	x	x

49	Myristicaceae	*Pycnanthus angolensis*	Otie		x
50	Palmaceae	*Elaeis guineensis*	Abe	x	x
51	Palmaceae	*Raphia hookeri*	Adobe/Odoka		x
52	Palmaceae	*Calamus deeratus*	Demere		x
53	Papilionaceae	*Baphia nitida*	Edwono		x
54	Pittosporaceae	*Marianthus spp.*	Nyankoma		x
55	Rutaceae	*Citrus spp.*	Ankaa		x
56	Sapindaceae	*Blighia sapida*	Akye	x	x
57	Sapotaceae	*Aningeria spp.*	Asamfena		x
58	Sapotaceae	*Tieghmella heckelli*	Bako		x
59	Simaroubaceae	*Hannoa klaineana*	Fotie		x
60	Sterculiaceae	*Cola nitida*	Bese		x
61	Sterculiaceae	*Theobroma cacao*	Kookoo	x	x
62	Sterculiaceae	Pterygota macrocarpa	Kyereye		x
63	Sterculiaceae	*Cola gigantea*	Watapuo	x	x
64	Sterculiaceae	*Triplochiton scleroxylon*	Wawa		x
65	Sterculiaceae	*Sterculia rhinopetela*	Wawabima		x
66	Ulmaceae	*Celtis mildbraedii*	Esa		x
67	Ulmaceae	*Celtis wightii*	Esafufuo		x
68	Verbenaceae	*Lantana camara*	Anansedokono		x
69	Zingiberaceae	*Aframomum spp.*	Akakaduro		x
	32	**69**	**69**	**15**	**69**

Note: * Main literature source: Wilson (2001); Hofmann and Roth (2003).
Note that the food species list from literature were limited to fruit species from stomach contents. It is likely that many other plant parts were consumed by Maxwell's duiker than were discernible from the masticated stomach contents.

APPENDIX C. Suitability Index Values and Curves for habitat variables (Scientific Habitat model)

Appendix C.1a.

Suitability Index (SI) values (or Fuzzy Membership Grades) derived for percent food species canopy cover (Food habitat component) and percent vegetation canopy cover (Shelter habitat component).

Canopy Cover (%)	SI Food	SI Shelter	Canopy Cover (%)	SI Food	SI Shelter
0	0.000	0.000	**51**	0.980	1.000
1	0.000	0.000	**52**	0.989	1.000
2	0.000	0.000	**53**	0.995	1.000
3	0.000	0.000	**54**	0.999	1.000
4	0.000	0.000	**55**	1.000	1.000
5	0.000	0.000	**56**	1.000	1.000
6	0.000	0.000	**57**	1.000	1.000
7	0.000	0.000	**58**	1.000	1.000
8	0.000	0.000	**59**	1.000	1.000
9	0.000	0.000	**60**	1.000	1.000
10	0.000	0.000	**61**	1.000	0.998
11	0.000	0.000	**62**	1.000	0.991
12	0.000	0.000	**63**	1.000	0.980
13	0.000	0.000	**64**	1.000	0.964
14	0.000	0.000	**65**	1.000	0.944
15	0.000	0.000	**66**	1.000	0.920
16	0.001	0.000	**67**	1.000	0.891
17	0.005	0.000	**68**	1.000	0.858
18	0.011	0.000	**69**	1.000	0.820
19	0.020	0.000	**70**	1.000	0.778
20	0.031	0.000	**71**	1.000	0.731
21	0.045	0.000	**72**	1.000	0.680
22	0.061	0.000	**73**	1.000	0.624
23	0.080	0.000	**74**	1.000	0.564
24	0.101	0.000	**75**	1.000	0.500
25	0.125	0.000	**76**	1.000	0.436
26	0.151	0.000	**77**	1.000	0.376
27	0.180	0.000	**78**	1.000	0.320
28	0.211	0.000	**79**	1.000	0.269
29	0.245	0.000	**80**	1.000	0.222
30	0.281	0.000	**81**	1.000	0.180
31	0.320	0.005	**82**	1.000	0.142
32	0.361	0.020	**83**	1.000	0.109
33	0.405	0.045	**84**	1.000	0.080
34	0.451	0.080	**85**	1.000	0.056
35	0.500	0.125	**86**	1.000	0.036
36	0.549	0.180	**87**	1.000	0.020
37	0.595	0.245	**88**	1.000	0.009
38	0.639	0.320	**89**	1.000	0.002
39	0.680	0.405	**90**	1.000	0.000
40	0.719	0.500	**91**	1.000	0.000
41	0.755	0.595	**92**	1.000	0.000
42	0.789	0.680	**93**	1.000	0.000
43	0.820	0.755	**94**	1.000	0.000
44	0.849	0.820	**95**	1.000	0.000
45	0.875	0.875	**96**	1.000	0.000
46	0.899	0.920	**97**	1.000	0.000
47	0.920	0.955	**98**	1.000	0.000
48	0.939	0.980	**99**	1.000	0.000
49	0.955	0.995	**100**	1.000	0.000

50	0.969	1.000

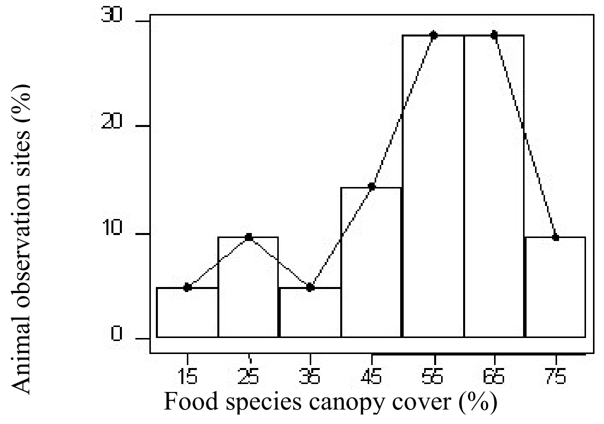
Appendix C.1b

Suitability Index (SI) values (or Fuzzy Membership Grades) derived for sighting distance through undergrowth (Security habitat component). For Scientific Habitat model.

Sighting Distance	SI Security
0	1.000
1	1.000
2	1.000
3	1.000
4	0.997
5	0.990
6	0.977
7	0.959
8	0.936
9	0.908
10	0.875
11	0.837
12	0.793
13	0.745
14	0.691
15	0.633
16	0.569
17	0.500
18	0.431
19	0.367
20	0.309
21	0.255
22	0.207
23	0.163
24	0.125
25	0.092
26	0.064
27	0.041
28	0.023
29	0.010
30	0.003
31	0.000
32	0.000
33	0.000
34	0.000
35	0.000
36	0.000
37	0.000
38	0.000
39	0.000
40	0.000
41	0.000
42	0.000
43	0.000
44	0.000
45	0.000
46	0.000
47	0.000
48	0.000
49	0.000
50	0.000
51	0.000
52	0.000
53	0.000
54	0.000
55	0.000

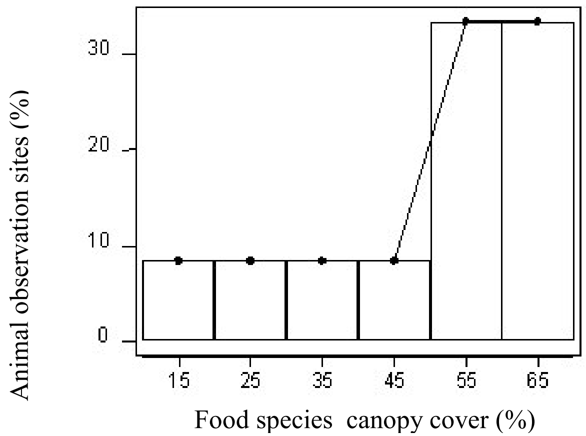
Appendix C.2. Sensitivity Analysis graphs for Scientific HSI model habitat variables SI values. Samples taken from sites where Maxwell's Duiker were observed. Three replicates each of 12, 15, and 18 samples taken from, and compared against, the set of 21 observation sites.

i. **Food cover**



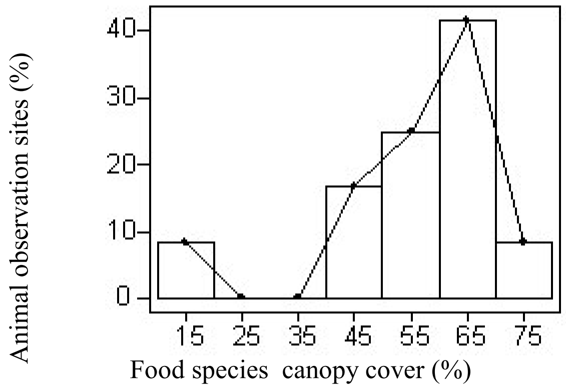
Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 15 % cover, β = 35 % cover; γ = 55 % cover

All 21 observation sites



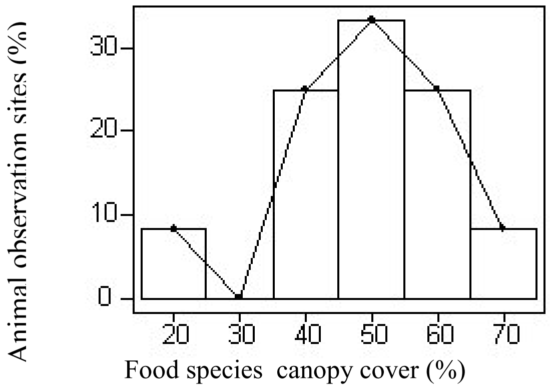
Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 15 % cover, β = 35 % cover; γ = 55 % cover

Random sample 12a



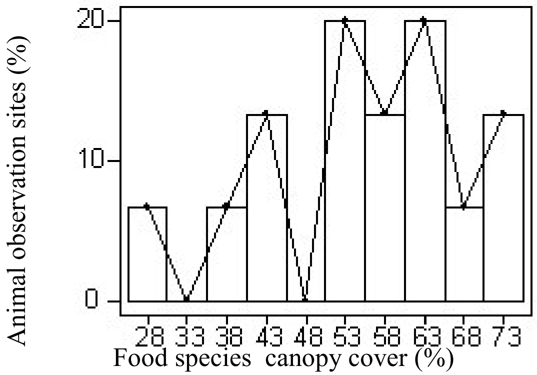
Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 15 % cover, β = 40 % cover; γ = 65 % cover

Random sample 12b



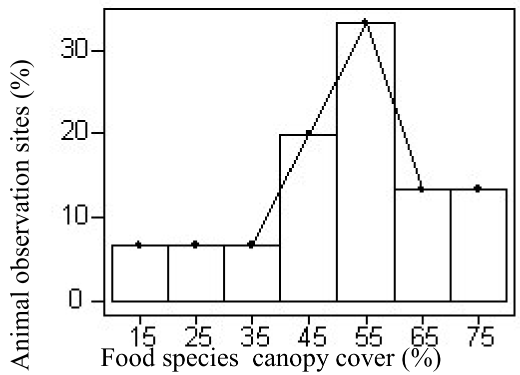
Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 20 % cover, β = 40 % cover; γ = 60 % cover

Random sample 12c



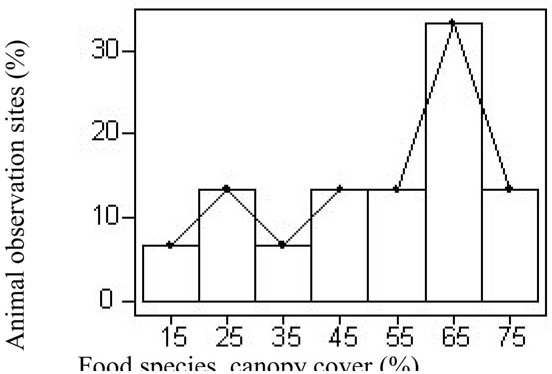
Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 28 % cover, β = 43 % cover; γ = 58 % cover

Random sample 15a



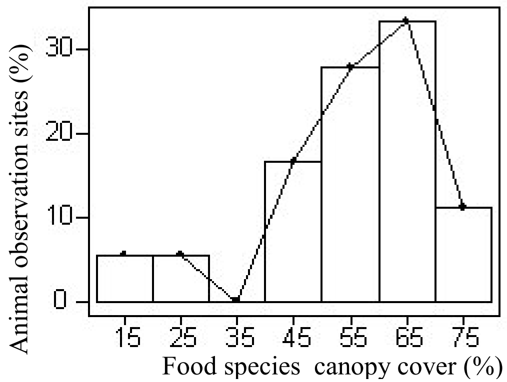
Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 15 % cover, β = 40 % cover; γ = 65 % cover

Random sample 115b



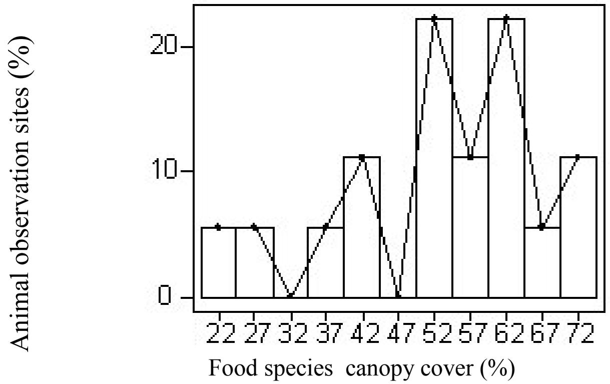
Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 15 % cover, β = 35 % cover; γ = 55 % cover

Random sample 15c



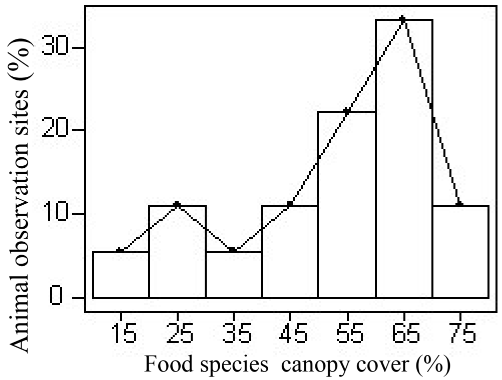
Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 15 % cover, β = 40 % cover; γ = 65 % cover

Random sample 118a



Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 22 % cover, β = 37 % cover; γ = 52 % cover

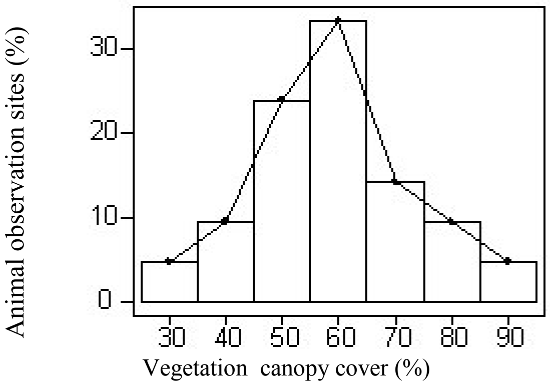
Random sample 18b



Food Cover = F_{MD} (a_{MD}, α, β, γ);
Where: a_{MD} = % food species cover
α = 15 % cover, β = 45 % cover; γ = 75 % cover

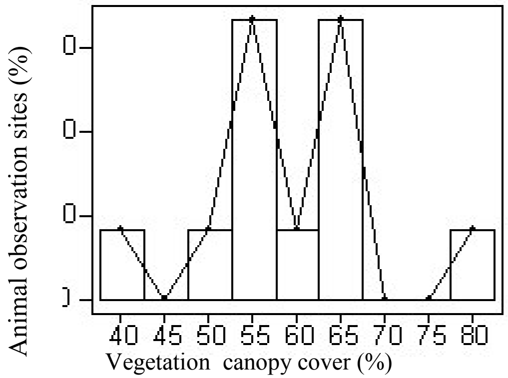
Random sample 18c

SHELTER



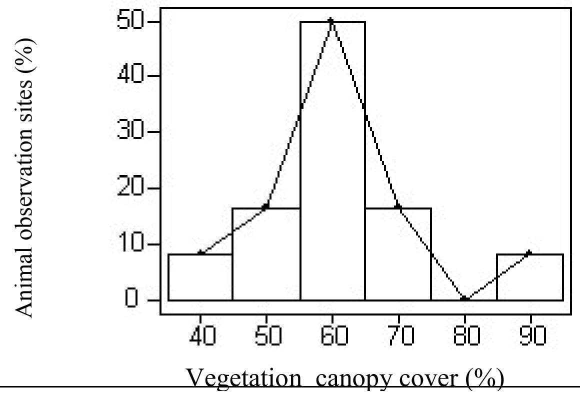
Shelter = Sh_{MD}\{ (c_{MD}, α_1, β_1, γ_1);
1–(c_{MD}, α_2, β_2, γ_2);
Where: c_{MD} = % vegetation canopy cover
α_1 = 30% cover α_2 = 60 cover β_1 = 40% cover; β_2 = 75% cover
γ_1 = 50% cover γ_2= 90% cover

All 21 observation sites



Shelter = Sh_{MD}\{ (c_{MD}, α_1, β_1, γ_1);
1–(c_{MD}, α_2, β_2, γ_2);
Where: c_{MD} = % vegetation canopy cover
α_1 = 40% cover α_2 = 64 cover; β_1 = 48% cover ; β_2 = 72% cover
γ_1 = 56% cover γ_2= 80% cover

Random sample 12a



Shelter = $Sh_{MD}\{(c_{MD}, \alpha_1, \beta_1, \gamma_1);$

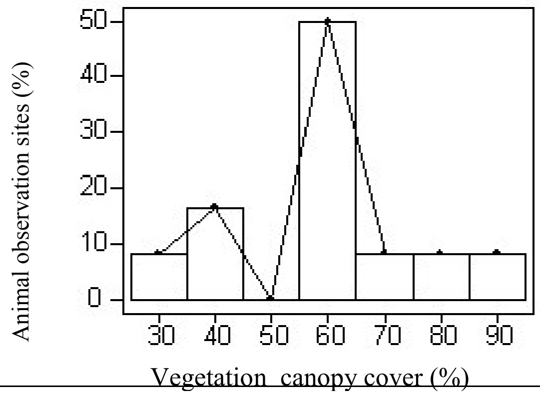
$1-(c_{MD}, \alpha_2, \beta_2, \gamma_2);$

Where: c_{MD} = % vegetation canopy cover

α_1 = 40% cover α_2 = 60 cover; β_1 = 50% cover; β_2 = 75% cover

γ_1 = 60% cover γ_2= 90% cover.

Random sample 12b



Shelter = $Sh_{MD}\{(c_{MD}, \alpha_1, \beta_1, \gamma_1);$

$1-(c_{MD}, \alpha_2, \beta_2, \gamma_2);$

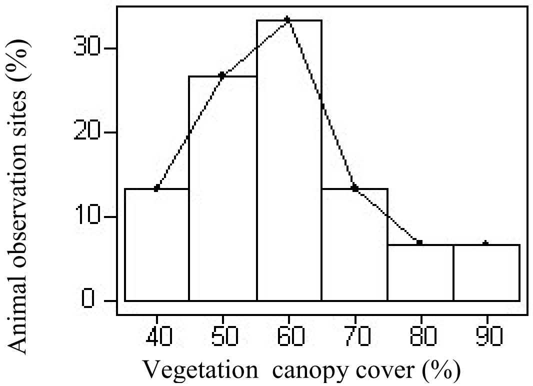
Where: c_{MD} = % vegetation canopy cover

α_1 = 30% cover α_2 = 60 cover; β_1 = 45% cover ;

β_2 = 75% cover

γ_1 = 60% cover γ_2= 90% cover.

Random sample 12c



Shelter = $Sh_{MD}\{(c_{MD}, \alpha_1, \beta_1, \gamma_1);$

$1-(c_{MD}, \alpha_2, \beta_2, \gamma_2);$

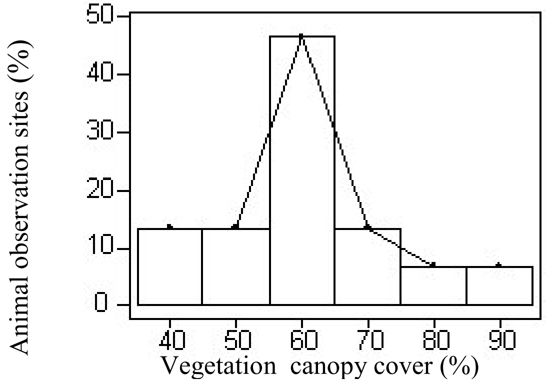
Where: c_{MD} = % vegetation canopy cover

α_1 = 40% cover α_2 = 60 cover; β_1 = 50% cover;

β_2 = 75% cover

γ_1 = 60% cover γ_2= 90% cover.

Random sample 15a



Shelter = $Sh_{MD}\{(c_{MD}, \alpha_1, \beta_1, \gamma_1);$

$1-(c_{MD}, \alpha_2, \beta_2, \gamma_2);$

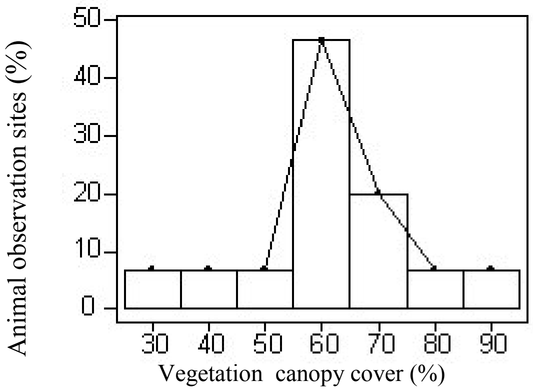
Where: c_{MD} = % vegetation canopy cover

α_1 = 40% cover α_2 = 60 cover; β_1 = 50% cover;

β_2 = 75% cover

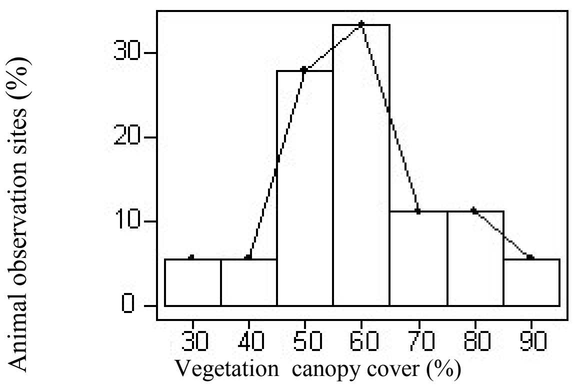
γ_1 = 60% cover γ_2= 90% cover.

Random sample 115b



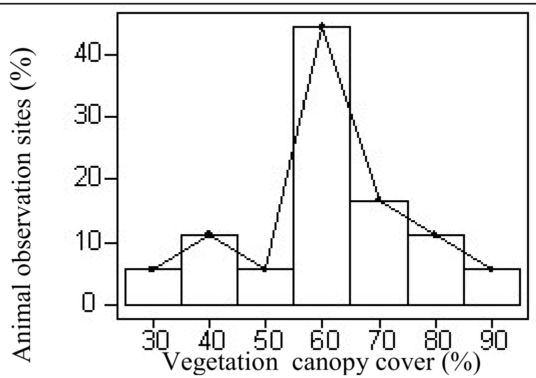
Shelter = $Sh_{MD}\{(c_{MD}, \alpha_1, \beta_1, \gamma_1);$
$1-(c_{MD}, \alpha_2, \beta_2, \gamma_2);$
Where: c_{MD} = % vegetation canopy cover
α_1 = 30% cover α_2 = 60 cover; β_1 = 45% cover;
β_2 = 75% cover
γ_1 = 60% cover γ_2= 90% cover.

Random sample 15c



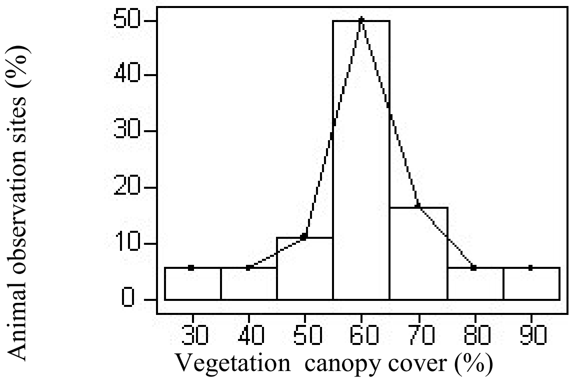
Shelter = $Sh_{MD}\{(c_{MD}, \alpha_1, \beta_1, \gamma_1);$
$1-(c_{MD}, \alpha_2, \beta_2, \gamma_2);$
Where: c_{MD} = % vegetation canopy cover
α_1 = 30% cover α_2 = 60 cover; β_1 = 40% cover;
β_2 = 75% cover
γ_1 = 50% cover γ_2= 90% cover.

Random sample 118a



Shelter = $Sh_{MD}\{(c_{MD}, \alpha_1, \beta_1, \gamma_1);$
$1-(c_{MD}, \alpha_2, \beta_2, \gamma_2);$
Where: c_{MD} = % vegetation canopy cover
α_1 = 30% cover α_2 = 60 cover; β_1 = 45% cover;
β_2 = 75% cover
γ_1 = 60% cover γ_2= 90% cover.

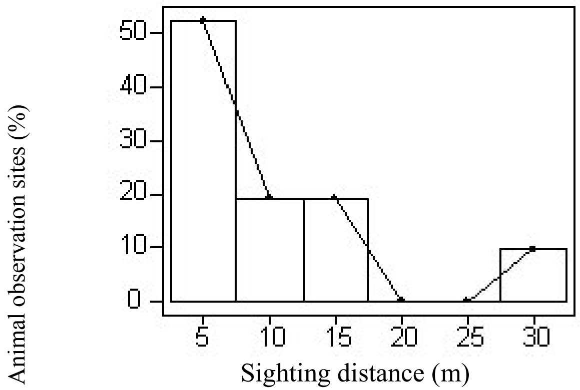
Random sample 18b



Shelter = $Sh_{MD}\{(c_{MD}, \alpha_1, \beta_1, \gamma_1);$
$1-(c_{MD}, \alpha_2, \beta_2, \gamma_2);$
Where: c_{MD} = % vegetation canopy cover
α_1 = 30% cover α_2 = 60 cover; β_1 = 45% cover ;
β_2 = 75% cover
γ_1 = 60% cover γ_2= 90% cover.

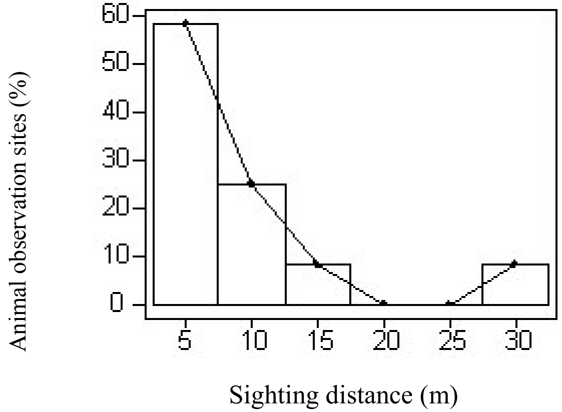
Random sample 18c

i) SECURITY



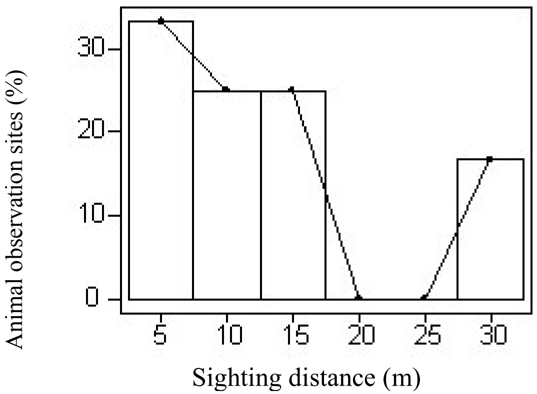
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 3m; β =17m; γ = 31m.

All 21 observation sites



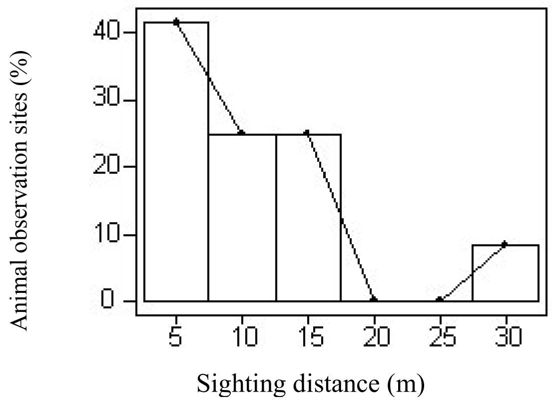
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 3m; β =16m; γ = 29m.

Random sample 12a



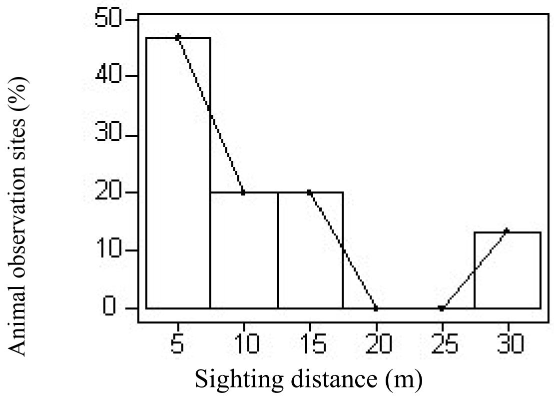
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 4m; β =18m; γ = 32m.

Random sample 12b



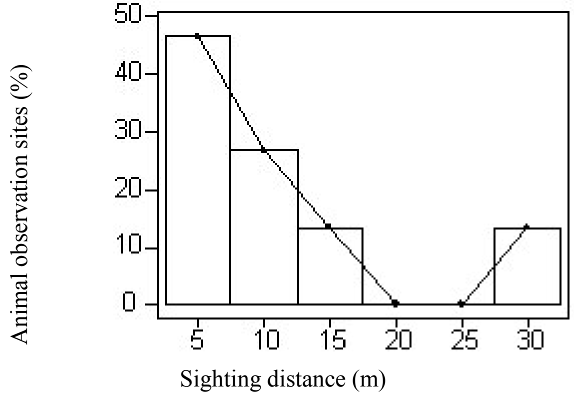
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 3m; β =16m ; γ = 29m.

Random sample 12c



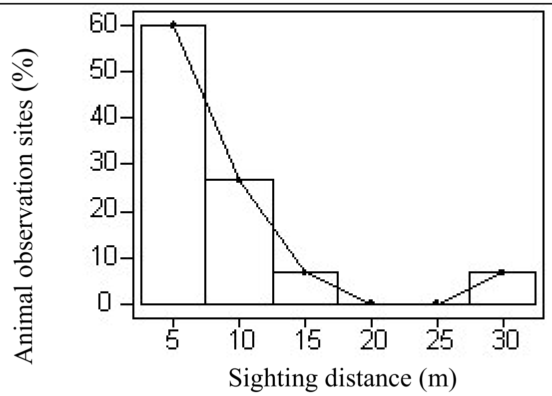
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 4m; β =18m; γ = 32m

Random sample 15a



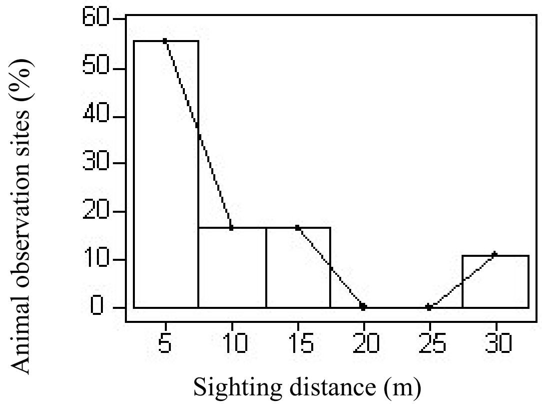
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 4m; β =18m; γ = 32m

Random sample 115b



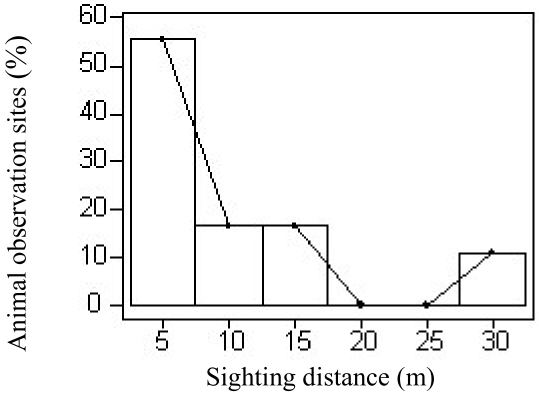
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 3m; β =16m; γ = 29m

Random sample 15c



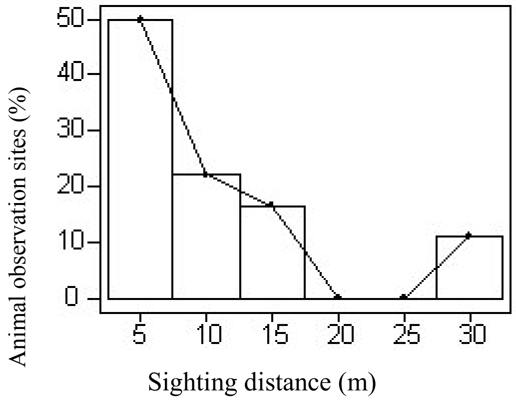
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 3m; β =16m; γ = 29m

Random sample 118a



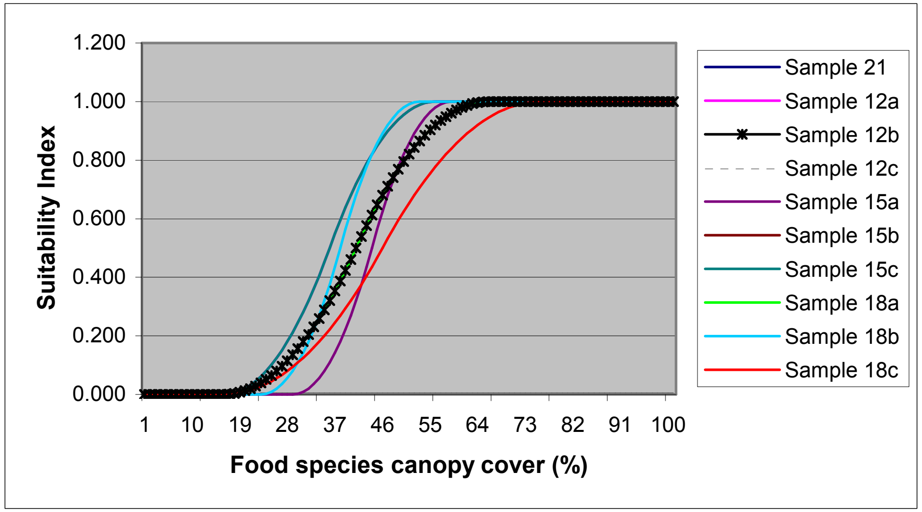
Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 4m; β =18m; γ = 32m.

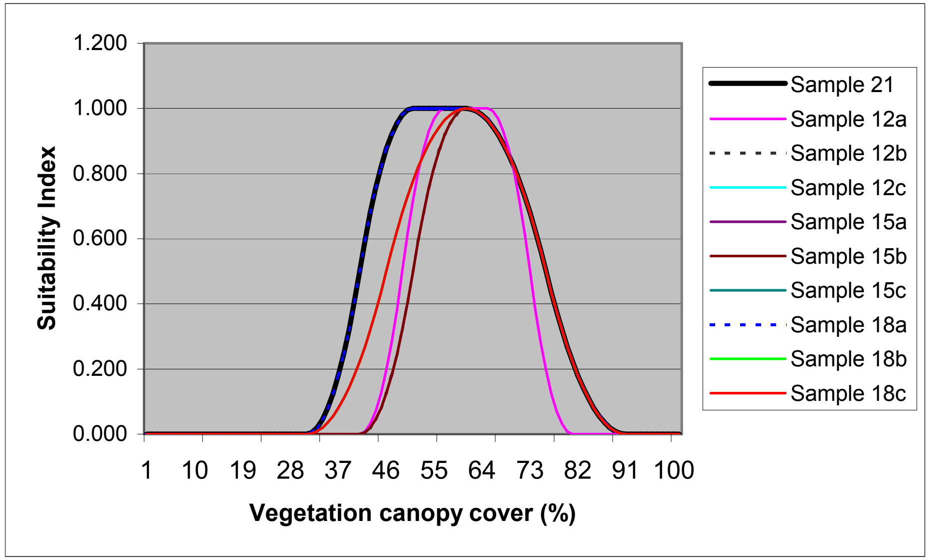
Random sample 18b

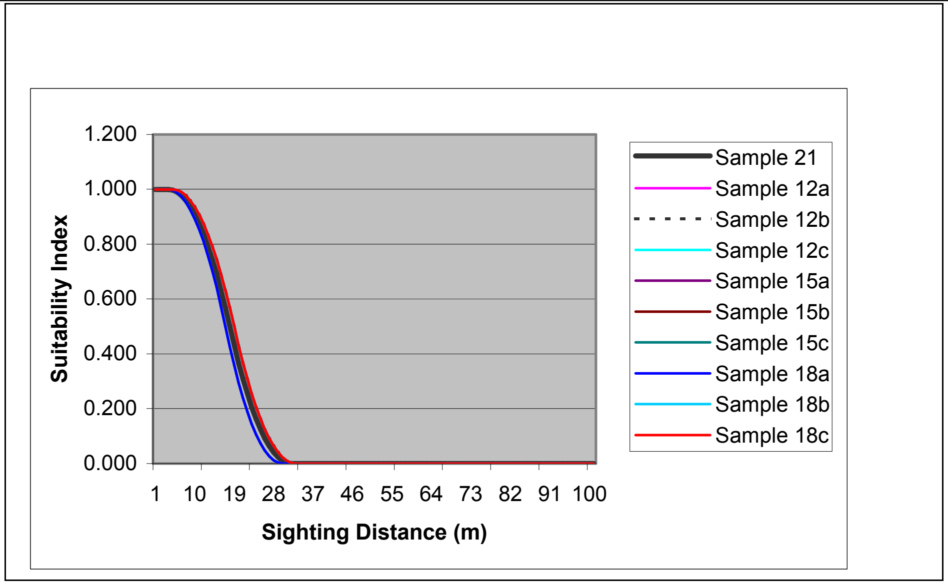


Security = 1-Sc_{MD} (s_{MD}, α, β, γ)
Where: s_{MD} = sighting distance
α = 4m; β =18m; γ = 32m.

Random sample 18c






1.200
1.000
0.800
0.600
0.400
0.200
0.000
Suitability Index
1
10
19
28
37
46
55
64
73
82
91
100
Sighting Distance (m)
Sample 21
Sample 12a
Sample 12b
Sample 12c
Sample 15a
Sample 15b
Sample 15c
Sample 18a
Sample 18b
Sample 18c

APPENDIX D: Summary of habitat data collected by wildlife ecologist for Scientific HSI model.

Site ID.	General Locality	X-Coord	Y-Coord	Transect Orientation	Obs. Time (min)	Upper Layer Canopy (%)	Middle Layer Canopy (%)	Lower Layer canopy (%)	Avg. Sighting Dist. (m)	Food Spp.Upper layer (%)	Food Spp.Middle Layer(%)	Food Spp. Lower Layer (%)	Tot. Sc. Food (%)	Tot.. Shelter (%)	Tot. Security (m)	Maxwel's duiker Obse	Hab. Type	
1A	Mim-Goaso road	103330	760985	N	45	30	37	94	18	30	37	84	50.3	53.7	18.3	No	Farm-bush	Maize, cassava and plantain mixed with a few cocoyam, with some large trees.
1B	Min, Mortar	105547	759940	NW	31	35	9	96	22	35	9	30	24.7	46.7	21.5	No	Farm-bush	Maize, cassava and plantain mixed with a few vegetables, interspersed with Chromolaena, new oil palm.
6C	Nkensere	105861	772289	E	16	0	0	98	37	0	0	90	30.0	32.7	37.0	No	Farm-bush	Maize, (no cassava), new oil palm.
9C	Nkaseim	115069	760455	N	27	29	42	94	13	29	42	60	43.7	55.0	13.0	Yes	Farm-bush	Cassava, cocoyam and plantain mixed with Chromolaena and some Pennisetum.
11D	Atronie	125419	783093	NW	35	43	71	73	3	43	71	67	60.3	62.3	3.3	Yes	Farm-bush	Foodcrop farm last weeded about 1yr ago; Chromolaena fast taking over.
12B	Goaso Agric Jnct	108688	754458	NW	30	0	50	97	11	0	5	40	15.0	49.0	10.5	Yes	Farm-bush	Maize, cassava and plantain mixed with a few vegetables, interspersed with Chromolaena, new oil palm.
13D	Goaso SSNIT	105188	753247	SW	15	0	18	92	5	0	18	80	32.7	36.7	5.3	No	Farm-bush	Cassava and Plantain mixed crop, with young Panicum
14F	Goatifi Jnct North	103801	771786	NE	21	6	48	39	8	6	4	14	8.0	31.0	8.3	No	Farm-bush	Plantain and cassava farm approx (2yr).
15D	Nkensere-Bediako Jnct	97291	769192	SE	18	14	47	40	33	14	47	36	32.3	33.7	33.0	No	Farm-bush	Young (1.5yr) Plantain, Cassava and cocoyam; young Oil Palm (1yr).
16C	Nyamebekyere	104075	755437	S	21	5	56	70	17	5	48	63	38.7	43.7	17.3	No	Farm-bush	Cassava and Plantain mixed crop, with Chromolaena
18B	Bediako-Nkensere	97145	769742	N	21	0	9	95	5	0	9	81	30.0	34.7	5.0	No	Farm-bush	Cassava and cocoyam, with a few young Oil Palm undergrowth.
1C	Nyamebekyere Curve	106098	756981	SW	26	16	93	15	19	16	93	15	41.3	41.3	19.0	No	Cocoa-forest	Hybrid Cocoa, with trees ; approx 20yrs

2A	Goamu K'dua	111001	782834	NW	37	71	58	25	11	71	58	15	48.0	51.3	11.0	No	Cocoa-forest	Tetteh Quarshie cocoa; lots of fruit trees and herbaceous undergrowth
2B	Goamu K'dua	111951	782969	E	48	7	67	10	15	4	65	4	24.3	28.0	15.3	Yes	Monocrop	Young cocoa plantation (approx 8yrs) with crops and vegetables in gaps.
3A	Asuoadei	105166	757750	W	31	4	90	5	20	0	84	0	28.0	33.0	20.3	No	Monocrop	Young cocoa plantation (approx 10yrs, 4-5m); with crops and vagetables in gaps.
5B	Kenyasi	125570	778037	SW	34	38	50	98	19	34	50	72	52.0	62.0	18.8	No	Farm-bush	Old, weedy cocoa farm, with abundant Chromolena and panicum grass , plus food remnants
7A	Asukese Village	108564	768425	N	36	50	37	10	22	50	35	2	29.0	32.3	21.5	No	Monocrop	Young cocoa plantation (approx 6yrs) with crops and vegetables in gaps.
7B	Nkrankrom (Nkaseim)	106823	764888	NE	26	35	16	79	10	35	16	64	38.3	43.3	9.8	No	Monocrop	Very young cocoa plantation (approx 3yrs) mixed with Oil Palm and food crops
8C	Nkrankrom (Nkaseim)	110064	762270	NW	25	39	80	30	18	39	80	48	55.7	49.7	17.8	No	Cocoa-forest	Old, moderately weedy cocoa farm, with lots of matured trees, and food crop remnants in sections
9B	Apenamadi (AttaneAtta)	114925	762350	SE	33	75	69	20	32	75	69	15	53.0	54.7	31.8	Yes	Cocoa-forest	Old Tetteh Quarshie cocoa (>20yrs); lots of fruit trees and herbaceous undergrowth
11A	Atronie -Ntotroso road	119995	785642	SE	22	43	78	46	4	36	77	40	51.0	55.7	4.0	Yes	Cocoa-forest	Old hybrid Cocoa (approx 20yrs), with few big trees ; food crop remnants,
11B	Atronie -Ntotroso road	121892	783890	W	35	57	88	98	6	57	88	10	51.7	81.0	6.0	Yes	Cocoa-forest	Old, cocoa farm (approx 30yrs), very weedy , with lots of fruit trees, little sign of food crop remnants .
11C	Atronie SW	121406	783055	NW	35	75	70	96	11	74	70	10	51.3	80.3	10.8	No	Cocoa-forest	Old, Tetteh Quarshie cocoa farm (approx 25yrs), very weedy , with lots of fruit trees, and moderately abundant food crop remnants .
11E	Atronie SW	119776	781807	S	31	84	87	95	10	84	87	46	72.3	88.0	10.0	Yes	Cocoa-forest	Old, Tetteh Quarshie cocoa farm (approx 30yrs), weedy , with lots of fruit trees, and moderately abundant food crop remnants .

13B	Goaso Agric (Apotoyowa)	107443	757383	S	29	45	81	36	29	45	81	30	52.0	54.0	28.8	Yes	Monocrop	Young (12yrs) even height cocoa , with very few trees; very sparse Chromolaena undergrowth, food crop remnants.
13E	Asuoadei	104138	754001	SW	22	49	79	15	28	49	79	10	46.0	47.7	27.8	No	Cocoa-forest	Old hybrid Cocoa (approx 20yrs), with lots of fruit trees .
14E	Goatifi Jnct (North)	106665	778455	SW	28	42	33	13	31	35	33	8	25.3	29.3	31.3	No	Cocoa-forest	Old hybrid Cocoa (approx 35yrs), with lots of fruit trees .
16B	Mim Little Juju Rock	93117	766849	W	19	25	88	5	42	25	88	5	39.3	39.3	41.8	No	Cocoa-forest	Old hybrid Cocoa (approx 20yrs), with fruit trees .
17A	AttaneAtta north	114892	764585	SW	28	40	86	38	25	57	69	10	45.3	54.7	24.5	No	Cocoa-forest	Old, moderately weedy cocoa farm, with lots of matured trees, and food crop remnants in sections
17C	AttaneAtta north	115951	763720	NE	22	0	85	2	51	0	85	0	28.3	29.0	51.0	No	Monocrop	Young, pure, hybrid cocoa (approx. 12yrs) virtually bare undergrowth, occassional plantain only.
18E	Bediako-Nkensere North	102815	770676	NE	29	52	60	5	48	83	70	42	65.0	39.0	48.3	No	Cocoa-forest	Hybrid Cocoa, with trees ; approx 18yrs
4A	Desmond's Oil palm, Mim	100081	763502	W	24	0	60	92	51	0	0	60	20.0	50.7	51.0	No	Monocrop	Young Oil Palm plantation with very short, cut Panicum grass; not a single tree
4B	Desmond's Quarters	100170	763322	S	36	0	35	98	17	0	35	20	18.3	44.3	16.8	No	Young Sec. For.	Citrus plantation approx. 19 years old, with panicum grass undergrowth at 1m hieght.
10C	Nkaseim-Goaso	111582	756648	SW	21	28	55	97	7	22	54	39	38.3	60.0	6.5	No	Young Sec. For.	Matured (approx 8yr) Oil Palm with food crop remnants, thick Panicum and Chromolaena undergrowth
12A	Goaso Bridge	107435	752591	NE	29	0	63	82	12	0	63	40	34.3	48.3	12.3	No	Young Sec. For.	Matured (approx 10yr) Oil Palm with food crop remnants, thick Panicum and Chromolaena undergrowth
16A	Desmond, Mim	93087	765204	SE	26	0	79	98	23	0	79	0	26.3	59.0	23.3	No	Monocrop	Cashew plantation (6m) with grass undergrowth (1m)
17D 1	Attaneatta North	117051	763950	SW	15	31	81	25	30	31	81	22	44.7	45.7	30.0	No	Young Sec. For.	Matured (approx 18yr) Oil Palm with young herbs and very few Panicum ; well tended.

17F	Hwidiem-Achirensua	126149	768607	NE	16	0	44	99	9	0	44	33	25.7	47.7	8.8	No	Young Sec. For.	Matured (approx 20yr) Oil Pal with Panicum and Pennisetum grass mixed with Chromoleana and Combretum
18A	Mim-Bediako	98189	766455	NE	22	0	84	80	11	0	84	10	31.3	54.7	11.3	No	Young Sec. For.	Matured (approx 18yr) Oil Palm with young herbs and very few Panicum, Chromolaena and Combretum
2C	Goamu Koforidua	113586	782108	SE	34	14	0	99	10	14	0	40	18.0	37.7	10.0	No	Farm-bush	Now rice farm; but was Chromolaena bush in February similar to nearby cover.
10D	Nkaseim-Daaba Jnct	110852	755970	W	31	19	28	93	5	19	28	46	31.0	46.7	5.3	No	Farm-bush	Mixed Chromolaena, Panicum, grass food crops remnants approx 4yrs.
13C	Nyamebekyere/ Asuadei	103791	756253	W	25	19	51	95	3	19	45	78	47.3	55.0	3.0	Yes	Farm-bush	Young Chromolaena fallow approx 3yrs.
14D	Goatifi Junction North	106729	778260	W	32	40	45	100	4	66	45	79	63.3	61.7	3.8	Yes	Young Sec. For.	Old Chromolaena fallow approx 5yrs (Note: becomes Secondary Forest at +5yrs); with food crop remnants and som Oil Palm.
15C	Nkensere-Bediako Halfway	100497	769882	SE	25	13	28	98	1	13	28	36	25.7	46.3	1.3	No	Farm-bush	Young Chromolaena fallow approx 2yrs; interspersed with Panicum grass.
16D	Goaso Outskirts	102800	754986	SE	35	17	43	97	6	0	42	50	30.7	52.3	6.3	No	Farm-bush	Young Chromolaena fallow approx 2yrs; interspersed with Panicum grass; with food crop remnants and som Oil Palm..
16E	Goaso Outskirts	106310	753123	N	22	9	42	98	5	48	30	50	42.7	49.7	5.3	No	Farm-bush	Young Chromolaena fallow approx 2yrs; interspersed with Panicum grass; with food crop remnants and som Oil Palm..
17B	AttaneAtta North (3km)	115862	764488	N	17	21	48	96	3	40	23	64	42.3	55.0	2.8	No	Farm-bush	Young Chromolaena fallow approx 3yrs; reverting to Pennisetum grass in place.
3D	Goaso Agric	108549	755009	NE	39	67	64	98	6	60	57	98	71.7	76.3	5.5	Yes	Young Sec. For.	Old remnant forest pocket along stream; lots of climbers, impenetrable in sections.

5C	Kenyasi-Achirensua	126166	780157	SE	44	58	43	96	7	53	40	82	58.3	65.7	7.3	Yes	Young Sec. For.	Old fallow dominated by Okore, Chromolaena almost shaded out, lots of climbers.
5D	Gyedu/Ntotroso	127668	781532	S	39	93	70	94	9	93	70	91	84.7	85.7	8.8	No	Young Sec. For.	Old remnant forest pocket along dry stream; lots of climbers, especially in middle layer, impenetrable in sections.
6A	Nkensere	106848	771947	W	54	27	87	87	7	27	87	76	63.3	67.0	6.8	Yes	Young Sec. For.	Old fallow from food crops (remnant cassava), regenerated plants mostly at pole and tree stage.
6B	Nkensre south	106956	772314	SE	30	40	93	93	6	35	85	32	50.7	75.3	6.3	No	Young Sec. For.	Old fallow approx 15 yrs, with lots of Okore in middle layer.
7C	Nkrankrom/Nkaseim	110564	765242	NE	46	12	82	97	5	12	71	0	27.7	63.7	4.5	Yes	Young Sec. For.	Old fallow approx 9yrs; lots of climbers; food crop remnants.
8A	Nkrankrom/Nkaseim	109476	760758	NW	37	38	61	91	7	38	60	87	61.7	63.3	6.5	Yes	Young Sec. For.	Old fallow approx 6yrs; lots of shrubs, climbers; food crop remnants; Chromolaena still plentiful in undergrowth.
9A	Apenamedi Tweapease	111963	764448	E	35	31	66	99	8	26	66	40	44.0	65.3	8.3	Yes	Young Sec. For.	Old fallow approx 6yrs;food crop remnants; thick Chromolaena in undergrowth in most sections.
12C	Goaso Cemetry	107153	752538	SE	39	66	42	89	14	66	37	89	64.0	65.7	13.8	No	Matured sec. For	Remnant forest; invaded by eg Flamboyant etc.
14B	Kenyasi No. 3	109609	777240	W	50	59	55	50	16	55	51	85	63.7	54.7	15.5	Yes	Matured sec. For	Very old fallow (matured sec. forest) >25yrs ; lots of big trees and climbers; ideal MD habitat.
14C	Kenyasi No. 4	109193	777794	NE	53	68	36	95	2	58	78	80	72.0	66.3	2.0	No	Matured sec. For	Old fallow approx 6yrs;food crop remnants;lots of thick Chromolaena in undergrowth .
15A	Mim-Nkensere(Biney)	101355	767388	E	43	36	43	29	17	36	40	88	54.7	36.0	17.0	Yes	Matured sec. For	Very old fallow (matured sec. forest) approx 15yrs ; lots of big trees and climbers, with cnopy mostly closed; ideal MD habitat.
15B	Nkensere-Bediako Jnctm	101569	770032	W	31	59	36	30	11	54	36	24	38.0	41.7	10.8	Yes	Matured sec. For	Very old fallow (matured sec. forest) approx 20yrs ; lots of big trees and

																		climbers, with cnopy mostly closed; good MD habitat.
18D	Near Nyamebekyere Jnct	104359	757221	NW	38	64	59	41	7	76	82	41	66.3	54.7	6.8	Yes	Matured sec. For	Very old fallow (matured sec. forest) approx 20yrs ; lots of big trees and climbers, with cnopy mostly closed; good MD habitat.
5A	Kenyasi	124397	776316	SW	23	5	95	60	2	5	0	10	5.0	53.3	2.0	No	Farm-bush	Pennisetum, Chromelaena, Combretum mixed with herbs and sapplings
10A	Nkaseim Nkrankrom	112212	759831	SE	26	21	64	96	3	16	4	20	13.3	60.3	2.8	No	Farm-bush	Pennisetum mixed with Chromelaena
10B	Nkaseim	111272	757952	E	23	20	61	96	3	18	4	26	16.0	59.0	2.8	No	Farm-bush	Pennisetum mixed with Chromelaena
13A	Akwasidibi	108006	756820	SW	21	15	37	89	2	11	37	55	34.3	47.0	2.0	No	Farm-bush	Panicum and Pennisetum grass with young Oil Palm , with lots of climbing herbs
14A	Goatifi Nsiakrom	109233	775100	W	78	16	35	94	3	16	23	60	33.0	48.3	2.5	No	Farm-bush	Pennisetum, Chromelaena, mixed sapplings and climbers
17E	Subriso	120817	764804	NE	38	0	0	100	2	5	0	0	1.7	33.3	1.8	No	Farm-bush	Mixed Panicum and Pennisetum grass ,with rice fallow (last year)
17G	Subriso	126206	770637	SE	21	2	26	99	2	2	0	0	0.7	42.3	2.0	No	Farm-bush	Panicum grass , with remnants of two seasons old food crops (maize & cassava)
17H	Subriso	127243	771424	N	28	10	12	98	1	10	12	20	14.0	40.0	1.0	No	Farm-bush	Mixed Panicum and Pennisetum grass , with remnants of two seasons old food crops (maize & cassava)
18C	Bediako NE	97419	770212	E	33	0	11	98	8	0	11	5	5.3	36.3	8.0	No	Farm-bush	Panicum mixed with Centrosema creeper

APPENDIX E.

GENERAL HUNTER FIELD QUESTIONNAIRE FORM

Observer:	**Date:**			**Start Time:**		**Gen. Area**					
Site/Block ID:	**Transect Start. X**			**Y:**							
Land cover type:	MSF	YSF	YB	RF	TM	FC	Gr	Sw	Wt	BS	Stt	Rk
Land use type:												

Name*:…………………………………… Age*………………………… Sex ………
Occupation:………………………………. Residence…………………… Distance(hrs)…..............

What bushmeat species could be found in this locality?

No.	Species	Rank Desc.	Why?
1			
2			
3			
4			
5			

Would this site be good/not for a Maxwell's Duiker?
....……………………………………………………………………………..
Why?...
……………………………...……………………

No.	Habitat variable	Measurements	Comments
1			
2			
3			
4			

COMMENTS:……………………………………………………………………………………......................
....
....

APPENDIX F: Summary of habitat data collected by hunters for Indigenous HSI model.

Site ID.	General Locality	X-Coord	Y-Coord	Transect Orientation	Obs. Time (min)	Tot.HHSr. MD (%)	SI value	Maxwell's duiker Obs	Hab. Type	Site Description
1A	Mim-Goaso road	103330	760985	N	45	60.000	0.600	No	Farm-bush	Maize, cassava and plantain mixed with a few cocoyam, with some large trees.
1B	Min, Mortar	105547	759940	NW	31	60.000	0.600	No	Farm-bush	Maize, cassava and plantain mixed with a few vegetables, interspersed with Chromolaena, new oil palm.
6C	Nkensere	105861	772289	E	16	30.000	0.300	No	Farm-bush	Maize, (no cassava), new oil palm.
9C	Nkaseim	115069	760455	N	27	73.000	0.730	Yes	Farm-bush	Cassava, cocoyam and plantain mixed with Chromolaena and some Pennisetum.
11D	Atronie	125419	783093	NW	35	77.000	0.770	Yes	Farm-bush	Foodcrop farm last weeded about 1yr ago; Chromolaena fast taking over.
12B	Goaso Agric Jnct	108688	754458	NW	30	63.000	0.630	Yes	Farm-bush	Maize, cassava and plantain with a few vegetables, interspersed with Chromolaena, new oil palm.
13D	Goaso SSNIT	105188	753247	SW	15	50.000	0.500	No	Farm-bush	Cassava and Plantain mixed crop, with young Panicum
14F	Goatifi Jnct North	103801	771786	NE	21	50.000	0.500	No	Farm-bush	Plantain and cassava farm approx (2yr).
15D	Nkensere-Bediako Jnct	97291	769192	SE	18	0.000	0.000	No	Farm-bush	Young (1.5yr) Plantain, Cassava and cocoyam; young Oil Palm (1yr).
16C	Nyamebekyere	104075	755437	S	21	33.000	0.330	No	Farm-bush	Cassava and Plantain mixed crop, with Chromolaena
18B	Bediako-Nkensere	97145	769742	N	21	30.000	0.300	No	Farm-bush	Cassava and cocoyam, with a few young Oil Palm undergrowth.
1C	Nyamebekyere Curve	106098	756981	SW	26	43.000	0.430	No	Cocoa-forest	Hybrid Cocoa, with trees ; approx 20yrs
2A	Goamu K'dua	111001	782834	NW	37	40.000	0.400	No	Cocoa-forest	Tetteh Quarshie cocoa; lots of fruit trees and herbaceous undergrowth
2B	Goamu K'dua	111951	782969	E	48	33.000	0.330	Yes	Monocrop	Young cocoa plantation (approx 8yrs) with crops and vagetables in gaps.
3A	Asuoadei	105166	757750	W	31	60.000	0.600	No	Monocrop	Young cocoa plantation (approx 10yrs, 4-5m); with crops and vagetables in gaps.
5B	Kenyasi	125570	778037	SW	34	27.000	0.270	No	Farm-bush	Old, weedy cocoa farm, with abundant Chromolena and Panicum grass , plus food remnants
7A	Asukese Village	108564	768425	N	36	37.000	0.370	No	Monocrop	Young cocoa plantation (approx 6yrs) with crops and vagetables in gaps.
7B	Nkrankrom (Nkaseim)	106823	764888	NE	26	47.000	0.470	No	Monocrop	Very young cocoa plantation (approx 3yrs) mixed with Oil Palm and food crops
8C	Nkrankrom (Nkaseim)	110064	762270	NW	25	53.000	0.530	No	Cocoa-forest	Old, moderately weedy cocoa farm, with lots of matured trees, and food crop remnants in sections
9B	Apenamadi	114925	762350	SE	33	67.000	0.670	Yes	Cocoa-forest	Old Tetteh Quarshie cocoa (>20yrs); lots of fruit trees and herbaceous undergrowth
11A	Atronie -Ntotroso road	119995	785642	SE	22	83.000	0.830	Yes	Cocoa-forest	Old hybrid Cocoa (approx 20yrs), with few

										big trees ; food crop remnants,
11B	Atronie -Ntotroso road	121892	783890	W	35	77.000	0.770	Yes	Cocoa-forest	Old, cocoa farm (approx 30yrs), very weedy , with lots of fruit trees, little sign of food crop remnants .
11C	Atronie SW	121406	783055	NW	35	57.000	0.570	No	Cocoa-forest	Old, Tetteh Quarshie cocoa farm (approx 25yrs), very weedy , with lots of fruit trees, and moderately abundant food crop remnants .
11E	Atronie SW	119776	781807	S	31	73.000	0.730	Yes	Cocoa-forest	Old, Tetteh Quarshie cocoa farm (approx 30yrs), weedy , with lots of fruit trees, and moderately abundant food crop remnants .
13B	Goaso Agric (Apotoyowa)	107443	757383	S	29	82.000	0.820	Yes	Monocrop	Young (12yrs) even height cocoa , with very few trees; very sparse Chromolaena undergrowth, food crop remnants.
13E	Asuoadei	104138	754001	SW	22	57.000	0.570	No	Cocoa-forest	Old hybrid Cocoa (approx 20yrs), with lots of fruit trees .
14E	Goatifi Jnct	106665	778455	SW	28	60.000	0.600	No	Cocoa-forest	Old hybrid Cocoa (approx 35yrs), with lots of fruit trees .
16B	Mim Little Juju Rock	93117	766849	W	19	27.000	0.270	No	Cocoa-forest	Old hybrid Cocoa (approx 20yrs), with fruit trees .
17A	AttaneAtta north	114892	764585	SW	28	37.000	0.370	No	Cocoa-forest	Old, moderately weedy cocoa farm, with lots of matured trees, and food crop remnants in sections
17C	AttaneAtta north	115951	763720	NE	22	30.000	0.300	No	Monocrop	Young, pure, hybrid cocoa (approx. 12yrs) virtually bare undergrowth, occassional plantain only.
18E	Bediako-Nkensere	102815	770676	NE	29	34.000	0.340	No	Cocoa-forest	Hybrid Cocoa, with trees ; approx 18yrs
4A	Desmond's Oil palm, Mim	100081	763502	W	24	30.000	0.300	No	Monocrop	Young Oil Palm plantation with very short, cut Panicum grass; not a single tree
4B	Desmond's Quarters	100170	763322	S	36	30.000	0.300	No	Young Sec. For.	Citrus plantation approx. 19 years old, with Panicum grass undergrowth at 1m hieght.
10C	Nkaseim-Goaso	111582	756648	SW	21	57.000	0.570	No	Young Sec. For.	Matured (approx 8yr) Oil Palm with food crop remnants, thick Panicum and Chromolaena undergrowth
12A	Goaso Bridge	107435	752591	NE	29	54.000	0.540	No	Young Sec. For.	Matured (approx 10yr) Oil Palm with food crop remnants, thick Panicum and Chromolaena undergrowth
16A	Desmond, Mim	93087	765204	SE	26	0.000	0.000	No	Monocrop	Cashew plantation (6m) with grass undergrowth (1m)
17D1	Attaneatta North	117051	763950	SW	15	0.000	0.000	No	Young Sec. For.	Matured (approx 18yr) Oil Palm with young herbs and very few Panicum ; well tended.
17F	Hwidiem- Achirensua	126149	768607	NE	16	10.000	0.100	No	Young Sec. For.	Matured (approx 20yr) Oil Pal with Panicum and Pennisetum grass mixed with Chromoleana and Combretum
18A	Mim-Bediako	98189	766455	NE	22	20.000	0.200	No	Young Sec. For.	Matured (approx 18yr) Oil Palm with young herbs and very few Panicum, Chromolaena and Combretum
2C	Goamu Koforidua	113586	782108	SE	34	10.000	0.100	No	Farm-bush	Now rice farm; but was Chromolaena bush

										in February similar to nearby cover.
10D	Nkaseim-Daaba Jnct	110852	755970	W	31	36.000	0.360	No	Farm-bush	Mixed Chromolaena, Panicum, grass food crops remnants approx 4yrs.
13C	Nyamebekyere/ Asuadei	103791	756253	W	25	77.000	0.770	Yes	Farm-bush	Young Chromolaena fallow approx 3yrs.
14D	Goatifi Junction North	106729	778260	W	32	67.000	0.670	Yes	Young Sec. For.	Old Chromolaena fallow approx 5yrs with food crop remnants and som Oil Palm.
15C	Nkensere-Bediako Halfway	100497	769882	SE	25	63.000	0.630	No	Farm-bush	Young Chromolaena fallow approx 2yrs; interspersed with Panicum grass.
16D	Goaso Outskirts	102800	754986	SE	35	10.000	0.100	No	Farm-bush	Young Chromolaena fallow approx 2yrs; interspersed with Panicum grass; with food crop remnants and som Oil Palm..
16E	Goaso Outskirts	106310	753123	N	22	10.000	0.100	No	Farm-bush	Young Chromolaena fallow approx 2yrs; interspersed with Panicum grass; with food crop remnants and som Oil Palm..
17B	AttaneAtta North (3km)	115862	764488	N	17	43.000	0.430	No	Farm-bush	Young Chromolaena fallow approx 3yrs; reverting to Pennisetum grass in place.
3D	Goaso Agric	108549	755009	NE	39	50.000	0.500	Yes	Young Sec. For.	Old remnant forest pocket along stream; lots of climbers, impenetrable in sections.
5C	Kenyasi-Achirensua	126166	780157	SE	44	63.000	0.630	Yes	Young Sec. For.	Old fallow dominated by Okore, Chromolaena almost shaded out, lots of climbers.
5D	Gyedu/Ntotroso	127668	781532	S	39	50.000	0.500	No	Young Sec. For.	Old remnant forest pocket along dry stream; lots of climbers, especially in middle layer, impenetrable in sections.
6A	Nkensere	106848	771947	W	54	80.000	0.800	Yes	Young Sec. For.	Old fallow from food crops (remnant cassava), regenerated plants mostly at pole and tree stage.
6B	Nkensre south	106956	772314	SE	30	43.000	0.430	No	Young Sec. For.	Old fallow approx 15 yrs, with lots of Okore in middle layer.
7C	Nkrankrom/Nkaseim	110564	765242	NE	46	100.000	1.000	Yes	Young Sec. For.	Old fallow approx 9yrs; lots of climbers; food crop remnants.
8A	Nkrankrom/Nkaseim	109476	760758	NW	37	90.000	0.900	Yes	Young Sec. For.	Old fallow approx 6yrs; lots of shrubs, climbers; food crop remnants; Chromolaena still plentiful in undergrowth.
9A	Apenamedi	111963	764448	E	35	60.000	0.600	Yes	Young Sec. For.	Old fallow approx 6yrs;food crop remnants; thick Chromolaena in undergrowth in most sections.
12C	Goaso Cemetry	107153	752538	SE	39	85.000	0.850	No	Matured sec. For	Remnant forest; invaded by eg Flamboyant etc.
14B	Kenyasi No. 3	109609	777240	W	50	100.000	1.000	Yes	Matured sec. For	Very old fallow (matured sec. forest) >25yrs ; lots of big trees and climbers; ideal MD habitat.
14C	Kenyasi No. 4	109193	777794	NE	53	67.000	0.670	No	Matured sec. For	Old fallow approx 6yrs;food crop remnants;lots

										of thick Chromolaena in undergrowth .
15A	Mim-Nkensere(Biney)	101355	767388	E	43	80.000	0.800	Yes	Matured sec. For	Very old fallow (matured sec. forest) approx 15yrs ; lots of big trees and climbers, with cnopy mostly closed; ideal MD habitat.
15B	Nkensere-Bediako Jnct	101569	770032	W	31	80.000	0.800	Yes	Matured sec. For	Very old fallow (matured sec. forest) approx 20yrs ; lots of big trees and climbers, with cnopy mostly closed; good MD habitat.
18D	Nyamebekyere Jnct	104359	757221	NW	38	70.000	0.700	Yes	Matured sec. For	Very old fallow (matured sec. forest) approx 20yrs ; lots of big trees and climbers, with cnopy mostly closed; good MD habitat.
5A	Kenyasi	124397	776316	SW	23	50.000	0.500	No	Farm-bush	Pennisetum, Chromelaena, Combretum mixed with herbs and sapplings
10A	Nkaseim Nkrankrom	112212	759831	SE	26	50.000	0.500	No	Farm-bush	Pennisetum mixed with Chromelaena
10B	Nkaseim	111272	757952	E	23	50.000	0.500	No	Farm-bush	Pennisetum mixed with Chromelaena
13A	Akwasidibi	108006	756820	SW	21	40.000	0.400	No	Farm-bush	Panicum and Pennisetum grass with young Oil Palm , with lots of climbing herbs
14A	Goatifi Nsiakrom	109233	775100	W	78	73.000	0.730	No	Farm-bush	Pennisetum, Chromelaena, mixed sapplings and climbers
17E	Subriso	120817	764804	NE	38	0.000	0.000	No	Farm-bush	Mixed Panicum and Pennisetum grass ,with rice fallow (last year)
17G	Subriso	126206	770637	SE	21	0.000	0.000	No	Farm-bush	Panicum grass , with remnants of twoseasons old food crops (maize & cassava)
17H	Subriso	127243	771424	N	28	10.000	0.100	No	Farm-bush	Mixed Panicum and Pennisetum grass , with remnants of two seasons old food crops (maize & cassava)
18C	Bediako	97419	770212	E	33	10.000	0.100	No	Farm-bush	Panicum mixed with Centrosema creeper