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Resource selection modelling of Bushbuck (*Tragelaphus scriptus)* in Iwofin Forest, Ogun State, Nigeria.

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ABSTRACT
Resource selection modelling has become a useful ecological concept for quantifying wildlife-habitat relationships. Bushbuck (*Tragelaphus scriptus*) is well-known wildlife species in West African sub-region with a few documented evidence of their present population status. The study conducted a logistic regression modelling of bushbuck presence-absence data collected with a handheld Global Positioning System (GPS) from Iwofin Forest in Ogun State, Nigeria to predict their resource selection use for survival. The resource selection model showed that there was high probability (0.45 - 0.72) of resource selection by bushbucks in Iwofin Forest at areas that are closer to the watershed and of lower elevations covering about 45% of the entire 65.81 hectares. The study concluded that the resource selection model would assist in identifying bushbuck habitats towards developing suitable conservation plans for their management in Iwofin Forest.

Keywords: *Tragelaphus scriptus,* Resource Selection Function (RSF), Logistic Regression, GIS

INTRODUCTION

Wildlife habitats are places of safety that provide resources such as food, cover, water for the survival and procreation of wildlife species (Van Beest, Mysterud, Loe, & Milner, 2010). Vegetation composition and resource distribution of most wildlife habitats are reflections of the physical structures of the environment, and therefore, the survival of wildlife species is greatly influenced by the physical and vegetation structures within their habitats (Rovero, Martin, Rosa, Ahumada, & Spitale, 2014). The availability, selection and utilization of resources by wildlife species are some of the key ecological concepts now being studied to understand how to effectively predict wildlife species interactions with their environment for conservation and management purposes (Loe, Bonenfant, Meisingset, & Mysterud, 2012). Understanding the abundance and patterns of distribution of resources in wildlife habitats have assisted tremendously in monitoring, tracking the movement of wildlife species and how they use space and resources (McLoughlin, Morris, Fortin, Vander Wal, & Constasti, 2010).

Resource selection describes the quantity of habitat materials utilized by wildlife populations among several other alternatives available within the habitat (Alldredge & Griswold, 2006). Resource selection modelling has become one of the most popular procedures deployed by scholars in recent times to explore interactions between wildlife species and their environment (Loe, Bonenfant, Meisingset, & Mysterud, 2012). Home range modelling (Moorcroft & Barnett, 2008); habitat suitability modelling; and resource probability selection function (Loe, Bonenfant, Meisingset, & Mysterud, 2012) are various methods that have been used extensively to explore relationships between wildlife species and their environment. (McLoughlin, Morris, Fortin, Vander Wal, & Constasti, 2010). Generally, resource selection modelling involves the fitting of generalized linear regression with a logit link containing dichotomous variables of "use-available" dependent variables and a host of categorical and/or continuous predictor variables to obtain a resource selection probability function that best describes the habitat suitability scenario for a particular wildlife species (Boyce, et al., 2003). In ecological modelling with Geographic Information System (GIS), resource selection concepts have been increasingly applied to wildlife habitat study for the development of conservation strategies for mitigating wildlife species extinction and habitat loss (Hirzel & Le Lay, 2008).

Tragelaphus scriptus is considered one of the most abundant antelopes in the Sub-Saharan African continent occurring from Senegal through the Gambia in West Africa to the Cape Province in South Africa (Wronski, Apio, Wanker, & Plath, 2006). Considering the significance of *Tragelaphus scriptus* as a relatively cheap source of proteins and revenue for local hunters in most parts of Africa, this important wildlife species is prone to be endangered in the nearest future (Sillero-Zubiri, 2007). It, therefore, becomes essentially necessary to understand their habitat preferences to develop effective conservation strategy (Yosef, Addisu, & Girma, 2015). Predominant populations of *Tragelaphus scriptus* were mostly observed in the savannas and plains of West African countries such as Senegal, Gambia, Guinea, Ghana and Nigeria (Wronski & Moodley, 2009). Previous ecological studies have mainly emphasized the feeding habit, nutrition, habitat selection (Boyce, et al., 2003) of the Eastern and Southern African subspecies of bushbuck with just a few documented information on the West African bushbuck (Smits, 1986).

Tragelaphus scriptus is small to medium-sized antelopes widely spread across West and Central Africa, belonging to the family Bovidae, and are generally referred to as Bushbuck (Wronski & Moodley, 2009). The small/medium-size body of *Tragelaphus scriptus* makes it different from other closely related tragelaphine antelopes such as *Trageloaphus angasi* –'Nyala' (Wronski & Moodley, 2009). 'Nyala' and Bushbuck show remarkable similarity in physical appearance, and they co-exist in the same area for food and habitat (Wronski, Apio, Wanker, & Plath, 2006). In parts of West Africa, bushbuck is widely recognized as more important and economically relevant than the 'Nyala' (Smits, 1986). Previous studies have identified bushbuck as solitary bush dwellers, selective browsers feeding on the highly nutritive vegetative plant in open savannas and around watersheds (Smits, 1986). Due to the economic importance of bushbuck to local hunters as a relatively easy and cheap source of revenue, their exploitation has continued to increase leading to a steady decline in their populations (Sillero-Zubiri, 2007; Evangelista, 2006). Habitat fragmentation and habitat loss, which impact directly on the availability of resources to the wildlife (Evangelista, 2006), are becoming increasingly apparent following evidence of anthropogenic activities (Kumar & Ram, 2005) in land clearing for arable farming, overgrazing through cattle herding, illegal logging, un-managed fuelwood collection and infrastructural development (Nigatu & Tadesse, 1989). The study aimed to develop a resource selection model for *Tragelaphus scriptus* in Iwofin Forest, Ogun State using logistic regression and Geographic Information System (GIS) in predicting their resource preferences and promoting their habitat protection and conservation.

METHODOLOGY

Study Area

Iwofin Forest is located in Ogun State, Southwest Nigeria from latitude 7°12'0" N to 7°24'0" N, and longitude 3°07'0" E to 3°18'0" E. (Figure 1). The forest enclave covers an area of approximately 65.81 hectares. It appears to be highly degraded and is gradually becoming a derived savanna type of ecosystem due to increased anthropogenic activities such as fuelwood gathering, land clearing for arable farming and cattle herding (Adesegun, Adesegun, Odulana, Ojelade, & Ogunbanwo, 2017). It is characterized by woody species that include *Anogeissus leiocarpus, Pterocarpus erinaceus* and grasses (e.g. *Andropogon gayanus, Hypharrhenia* sp, *Anchomanes dalzielii*) widely spread across the ecosystem.

Annual rainfall of between 100mm and 200mm Hg occurs from April to November with bi-modal peaks in June and October (Oduntan, Soaga, Akinyemi, & Ojo, 2013). Relative humidity ranges between 60% and 80% in the dry season, and above 80% with a mean maximum daily temperature ranging from 28° C to 32° C (Oduntan *et al.*, 2013). The topography is undulating at an elevation of between 30 m and 200 m above sea level with a distinct watershed traversing the Northwest – Southeast direction (Figure 1).

Iwofin, established in the 18th century, is one of the most important towns within Yewa Division of Ogun State. Apa, Ajero and Gbopaehin are some of the notable settlements in the town (Figure 1). Other major neighbouring towns include Ilaro, Ayetoro, Olorunda, Olubo, Imeko, Ipokia, and Igbogila. The inhabitants are primarily vegetable farmers and hunters who predominantly hunt for antelopes. They also produce food and cash crops such as cassava, maize, melon, cashew, citrus and kola and some of the inhabitants are into artisanal textile processing (Oduntan *et al.*, 2013).

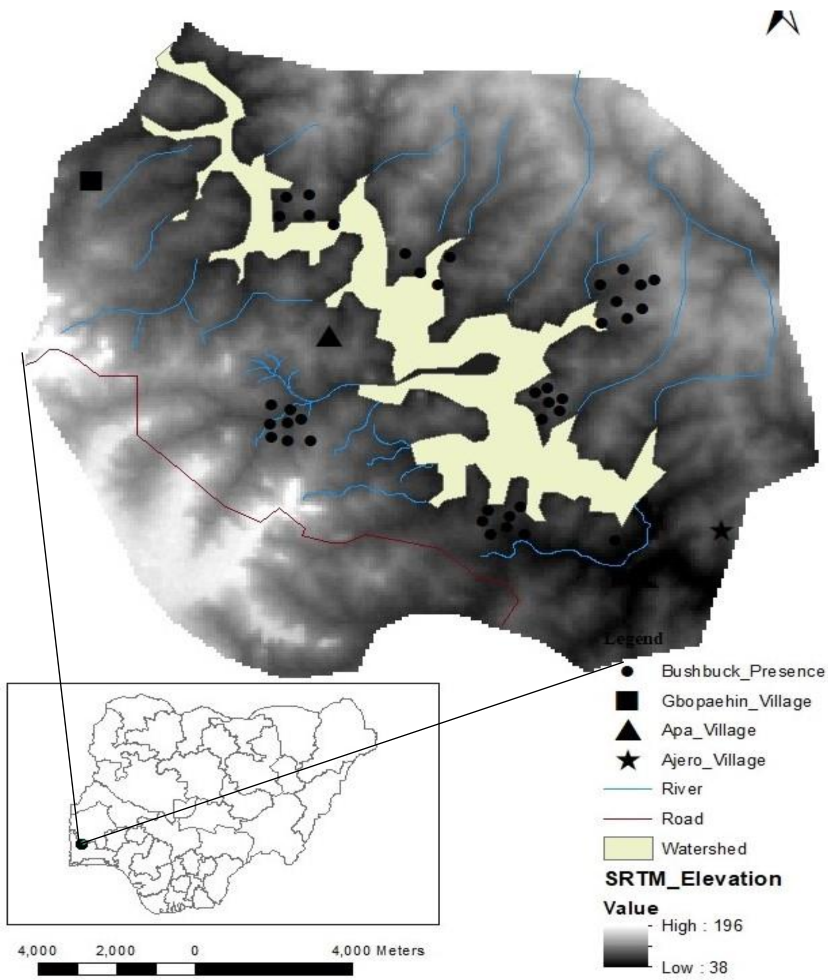


Figure 1 – Map of Iwofin forest. Inset-Map of Nigeria showing Iwofin Forest.
Source: Researcher, 2019.

Data collection

Collection of data was done along strip transect (300 m x 8 km) established by compass bearings within the study area (White & Edwards, 2000). Three observers and a local hunter walked a total of 8 km by 300 m strip random transects across the entire study area. The hunter guided the lead-member of the crew by walking a transect supported at 150 m strip on each side from the central line, walked by the remaining two (2) members of the crew. The crew was careful to observe indicators of bushbuck sightings, vocalizations and cues such as footprints, tracks, carcasses, scat piles and food remains. Two pairs of binoculars and a hand-held GPS (Garmin e-Trex 20) were carried to observe and record geographic coordinates (locations) of bushbuck sightings. Digital camera (Canon Powershot ELPH 360) was also used to take snapshots of bushbuck locations and their cues such as scat piles, footprints and food materials (Figure 2). The relief features observed during the field survey were also recorded.

Figure 2 – (L-R) Dead Bushbuck, Footprints, Scat piles, Anchomanes dalzielii

Source: Field Survey, 2019.

Data processing and preparation

Studies have shown that vegetation cover are affected by topography - elevation, relief – such that sun-facing slopes and hill shades are reflected differently by plant canopy which consequently affect the available plant resources for wildlife consumption (Bian & Walsh, 1993; Li & Wong, 2010). Digital Elevation Model (DEM) data were obtained from the National Aeronautics and Space Administration's (NASA's) Shuttle Radar Topographic Mission (SRTM) available on the website of the United State Geological Survey (USGS). 3-arc second SRTM's digital elevation data (vertical accuracy of 16 m) were downloaded in GeoTiff format and used for the data modelling in GIS (Farr & Kobrick, 2000).

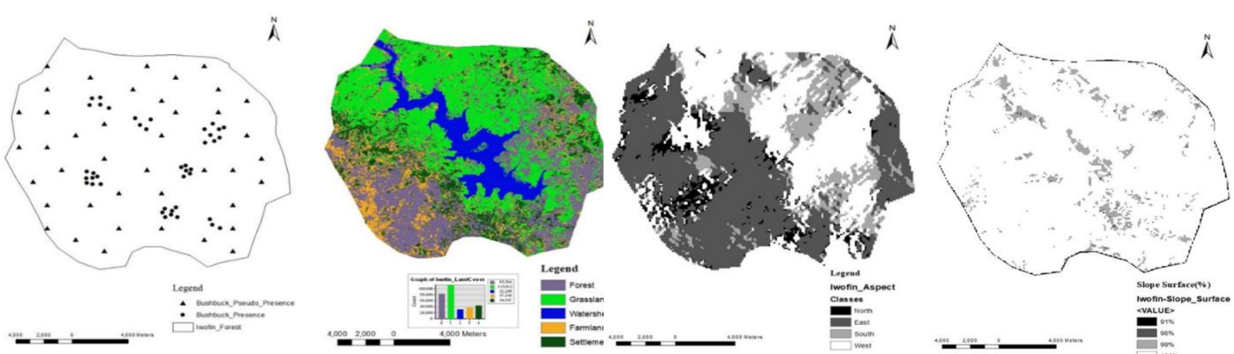


Figure 3 – (L-R): Bushbuck locations, Landcover types, Aspects and Slopes of Iwofin Forest

Relief features that include watersheds, rivers, lakes and other physical features such as roads, campgrounds and settlements observed during the data collection were obtained from the topographic map of Ogun State and digitized as map layers in GIS environment. Forty-one (41) presence points of bushbuck sightings were recorded and uploaded as a single (GIS) shape file (Figure 3). Randomly generated absence points of bushbuck were also created as another GIS layer (Figure 3). These two sets of points were merged to create a single dichotomous dependent variable of presence and absence points used in the binary logistic regression modelling (Warton & Geert, 2013). Satellite imagery from the United States Earth Explorer Landsat 8 image scene taken on board Operational Land Image (OPI) and the Thermal Infrared Sensors (TIRS) at 30-m spatial resolution (USGS, 2019) was also downloaded in GeoTiff format in January 2019 for the study area. The DEM data and the image data (Landsat) were projected to Nigeria's geographic coordinate system (Universal Transverse Mercator - UTM WGS84 Zone 31N) and clipped to the study area. Surface slopes and aspects (Figure 3) were derived from the SRTM's DEM using ArcGIS 10.3 Spatial Analyst tool (ESRI, 2015). Based on prior knowledge of the observed vegetation features during the field survey and the features evident in the topographic maps of the local area, land-cover in the Landsat image scene for the study area was categorized using the supervised classification algorithm (maximum likelihood function) in ArcGIS into the forest, grassland, watershed, farmland and settlement (Figure 3). The response variables for this study were represented in vector format in ArcGIS as point shape file. However, all the explanatory variables used in the model were processed in raster format including the road, river and watershed features for which their Euclidean distances were derived and used directly in the model. Pixel values of the rasterized explanatory variables were extracted to the bushbuck points using the multi-extraction tool in ArcGIS (ESRI, 2015).

Data analysis and model assessment

Generalized linear model with a binomial logit link function was used to perform the statistical analysis on the generated data. The general logistic model is described by the equation presented in equation (1). The full model was run in R statistical package 3.5.2 (R Core Team, 2013) and a stepwise backward selection model procedure with Akaike Information Criterion (AIC) was used to select the parsimonious model containing significant variables that best explained the presence or otherwise of bushbuck in the study area. Non-significant variables (i.e. variables with high p-values) were iteratively removed from the model and the outputs assessed in turn using their AIC values. Model with the lowest AIC value was adjudged to be most parsimonious (Harrel, 2001). Estimates of the parsimonious model were extracted and then used to create the resource selection model of bushbuck using the Raster Calculator tool in ArcGIS 10.3 (Pearce & Ferrier, 2000).

$$Log\left(\frac{P}{1-P}\right) = \beta + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn \ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where: P – Probability of presence

β – Intercept of the model

$\beta_{(1-n)}$ – i th coefficient of the model

$X_{(1-n)}$ – X^{th} explanatory or independent variable

n – number of explanatory or independent variables

RESULTS

The candidate models and their correseponding AIC values are as presented in Table 1. The full model that included all the explanatory variables had the highest AIC value of 97.002 while the selected model with the lowest AIC value (82.651) consisted of distance to watershed and elevation. The estimates of the selected model were -327.65 and -0.058 for distance to watershed and elevation respectively as presented in Table 2. Figure 4 also shows inverse relationships between the log odds of presence-absence of bushbuck in the study area with respect to distance to watershed and elevation. Table 3 represents bushbuck resource selection function and their relative spatial coverages (hectares) in Iwofin Forest, further shown as a map in Figure 5 and described in Table 3 as low (0.00 - 0.17), moderate (0.17 – 0.45) and high (0.45 – 0.72) probabilities of resource selection over spatial coverages of 4.84, 12.82 and 48.14 hectares respectively.

Table 1-Candidate models and their corresponding AIC values

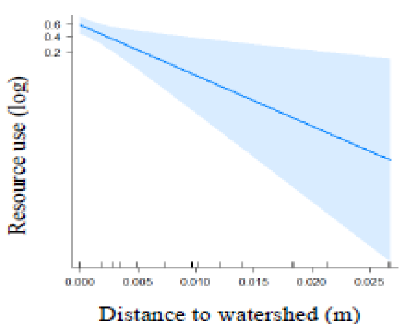
#	MODEL	AIC
1	Pres_Abs = Aspect + Dist_River + Dist_Road + Dist_Watershed + Elevation + LandCover + Slope	97.002
2	Pres_Abs = Aspect + Dist_River + Dist_Road + Dist_Watershed + Elevation + Slope	92.350
3	Pres_Abs = Aspect + Dist_River + Dist_Road + Dist_Watershed + Elevation	90.570
4	Pres_Abs = Aspect + Dist_River + Dist_Watershed + Elevation	89.612
5	Pres_Abs = Dist_Road + Dist_Watershed + Elevation	83.821
6	Pres_Abs = Dist_Watershed + Elevation	82.651

Source: Field Survey, 2019.
Pres_Abs – Log odds of presence of bushbuck; Aspect – ASPECT; Dist_River – DISTANCE TO RIVER; Dist_Road – DISTANCE TO ROAD; Dist_Watershed – DISTANCE TO WATERSHED; Elevation – ELEVATION; LandCover – LANDCOVER TYPE

Table 2-Estimates of selected model

VARIABLES	Estimates	Standard Error	z-value	p-value
CONSTANT	5.564	1.535	3.625	0.0003***
DISTANCE TO WATERSHED	-327.647	126.884	-2.582	0.009**
ELEVATION	-0.058	1.535	-3.373	0.0007***

Source: Field Survey, 2019. *Significant at 10% level. ** Significant at 5% level. ***Significant at 1% level



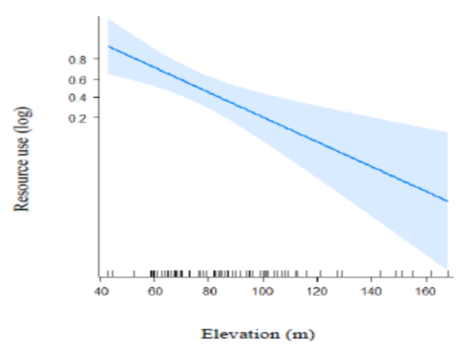


Figure 4 (L-R): Relationship between resource use (log) and distance to watershed and elevation

RSF = exp(“DISTANCE TO WATERSHED” *-327.647 + “ELEVATION” * -0.058)……….(2)
RSF_{STD} = (RSF – lowest_value)/(highest_value – lowest_value) ……………………………….(3)
Where: RSF – Resource Selection Function
RSF_{STD} – Standardized Resource Selection Function (0 – 1)

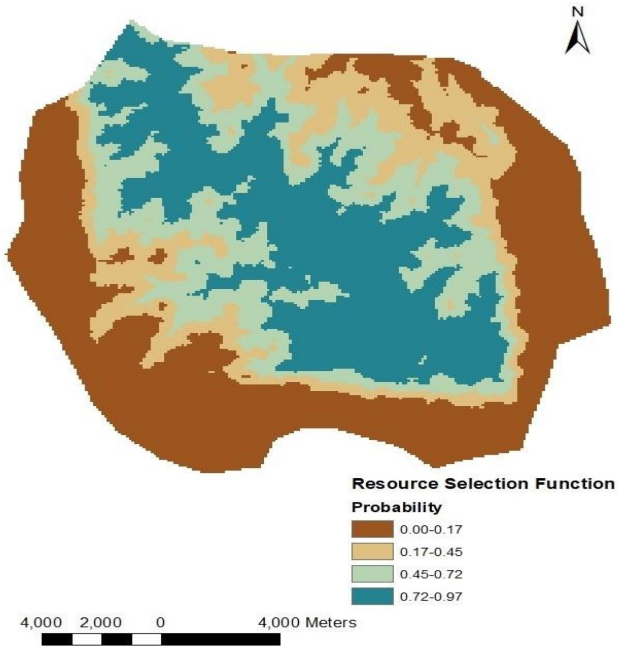


Figure 5: Resource selection model for bushbuck in Iwofin Forest

Table 3: Probabilities of Resorce Selection Functions and spatial coverage in Iwofin Forest

	Probability	Spatial Coverage (ha)
Low	0.00 – 0.17	4.84
Moderate	0.17 – 0.45	12.82
High	0.45 – 0.97	48.15

Source: Field Survey, 2019.

DISCUSSION

Past research studies have alluded survival of wildlife species to the presence of relief features and essential habitat characteristics that include topography, vegetation, and climate (Warton & Geert, 2013). The grassland was observed to be the dominant landcover type in Iwofin Forest. With this observation, it was expected that bushbuck would likely be found in the grassland landcover type where there were abundant food resources but the final model showed contrary as landcover type was not an influential variable in this study. It appeared that bushbuck avoided the grassland and sporadically utilized this essential food resource, i.e. *Anchomanes dalzielii* (Smits, 1986). This was similar to the findings of (Brnesh, Tsegaye, Tadese, & Gelaye, 2015) who reported that bushbuck do not favour open vegetation but prefer to browse woody plants and forbs in more covered vegetation. In the research work done by Duchesne, Fortin, & Courbin, 2010, it was observed that logistic regression could successfully model the relationship between dichotomous dependent variables and independent environmental variables. Therefore, the observed inverse relationship of bushbuck presence with respect to distance to watershed and elevation were valid. The statistical analysis showed that distance to watershed and elevation were the significant variables that contributed to the observed presence of bushbuck in the study area. This result showed that the log odds of bushbuck being present in the areas where they were sighted actually decreased with increasing elevation when the distance to the watershed was held constant. Also, the log-odds of bushbuck presence decreased with increasing distance to the watershed, holding elevation constant. In other words, bushbucks were mostly sighted at areas of lower elevations that were closer to the watersheds. This conforms with (Yelden, Largen, & Kock, 1984) who reported that bushbuck ecologically occupy lower altitudes near watercourses where there are high species richness in food materials and vegetation cover to hide from predation and harsh weather conditions. The Resource Selection Function (RSF) for bushbuck was standardized (RSF_{STD}) to probability value between 0 and 1. The prediction map derived from the back-transformed logistic model and the model validation check confirmed that bushbucks were present within the high probability area of the resource selection function. Therefore, there was a high probability (0.45 to 0.72) of bushbuck selecting food and water resources located close to the watershed at lower elevations covering 48.15 hectares within Iwofin forest. This finding was similar to (McDonald, Alldredge, Boyce, & Erickson, 2006) who reported that wildlife tends to select food and water resources in their habitat according to the prevalence of the environmental features that maximise the availability of such resources. This study revealed that locations of high resource selection probabilities were preferred habitats and appeared suitable for bushbuck in Iwofin forest, a position that was also supported by (Hirzel & Le Lay, 2008). However, moderate (0.17 – 0.45) and low (0.00 – 0.17) probabilities for resource selection by bushbuck were predicted for areas of higher elevations, i.e. covering 4.84 hectares and 12.82 hectares respectively of the forest, and away from the watershed where bushbuck were less prevalent.

CONCLUSION

This study provided further information on *Tragelaphus scriptus* in Ogun State Nigeria by exploring the use of resource selection modelling concept to predict the relationship between bushbuck presence and the distribution of resources in Iwofin Forest, Ogun State, Southwest Nigeria. It was discovered that the bushbuck selected material resources at lower elevations near the watershed. This information would aid subsequent research surveys and assist in developing effective conservation strategies through the identification of resource selection pattern of *Tragelaphus scriptus* in Iwofin Forest.

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