ANIMAL PRODUCTION SCIENCE

CONTENTS Volume 51, Issue 4, 2011, 251–389

Deer Biology, Production, Management and Conservation

TABLE OF CONTENTS — SHORT COMMUNICATIONS

AN OPTIMUM HABITAT MODEL FOR THE WHITE-TAILED DEER (*Odocoileus virginianus*) IN CENTRAL VERACRUZ, MEXICO

B. Bolivar-Cimé[AC] *and S. Gallina*[BC]
[A]Red de Ecología Funcional. Instituto de Ecología. A.C., Carretera Antigua a Coatepec No. 351, El Haya, Xalapa C.P. 91070, Veracruz, México.
[B]Red de Biología y Conservación de Vertebrados. Instituto de Ecología. A. C. Carretera Antigua a Coatepec No. 351, El Haya, Xalapa C.P. 91070, Veracruz, México.
[C]Corresponding author. Email: beatriz.bolivar@posgrado.inecol.edu.mx, sonia.gallina@inecol.edu.mx

ABSTRACT
The modeling of wildlife habitat availability for animal species has important implications for explaining the distribution of the organisms in the wild, effective management and conservation. In this study we evaluated an Optimum Habitat Model based on estimation of the Habitat Suitability Index (HSI), for the white-tailed deer (*Odocoileus virginianus*) in Central Veracruz, Mexico. We generated a GIS-based model from a combination of the main habitat requirements that influence the presence of white-tailed deer. Six variables were used for modeling the optimum habitat. With these data layers we calculated the HSI for deer in the study area. Two strip transects (500 x 2 m) were established in 18 localities, where all tracks and signs from white-tailed deer were recorded. The HSI estimated for the study area ranging from -0.667 to 0.905, where the lowest values were associated with poor habitat quality. Eighty six percent of total surface included intermediate and low habitat quality. We found 51.16% fecal groups in intermediate habitat quality. White-tailed deer frequently used oak forest, tropical deciduous forest and pastures. A Classification Tree Analysis indicated that temperature and aspect were the main habitat features influencing the white-tailed deer presence in the study area. Although there is high anthropogenic pressure in the zone, forest patches help to maintain some suitable habitat for small populations of this species. Conservation and restoration of the vegetation cover is necessary to promote deer populations recovery in Central Veracruz, Mexico.
Additional keywords: deer signs, habitat quality, oak forest, tropical deciduous forest, anthropogenic pressure.

INTRODUCTION
To improve habitat management effectiveness, evaluation of habitat is necessary to understand how environmental factors affect distribution, density and dynamics of wildlife populations. Actually there are many techniques and tools to analyze wildlife–habitat relationships (e.g. habitat suitability models, species-use analysis and pattern recognition); these tools may use information about existing vegetation conditions or land-cover databases (Felix *et al.* 2004). Also with these methods it is possible to predict the effects of environmental changes, by natural or anthropogenic causes, in the maintenance of the species (Delfin-Alfonso *et al.* 2009; Mandujano 1994; Vaughan 1994).

The white-tailed deer (*Odocoileus virginianus*) have gained substantial management attention throughout North America due to their overabundance (McShea *et al.* 1997), emerging diseases (O'Brien *et al.* 2002; Williams *et al.* 2002), and their importance as a natural and economic resource (Halls *et al.* 1984). In Mexico since prehispanic cultures to modern times the white-tailed deer has a high value as food, hunting, ornamental, curative and in ceremonial activities (Mandujano and Rico-Gray 1991). These actions have reduced their populations and in some places this specie is locally extinct (Villarreal 1999).

Several studies have proposed some abiotic and biotic habitat attributes as essentials for the maintenance of deer populations. Some of these attributes are: vegetation cover for escape, vegetation cover for weather protection, temperature, slope, aspect, water availability, patch size and other (Gallina 1994; Mandujano 1994; Rothley 2001).

The aim of this study was to evaluate an Optimum Habitat Model based on estimation of the Habitat Suitability Index ((U.S. Fish & Wildlife Service, 1991) to identify favorable areas for the white-tailed deer (*Odocoileus virginianus*) in Central Veracruz, Mexico.

METHODS
This work was carried out in central Veracruz, Mexico (19°15′-20°00′N, 96°15′-97°30′W), within an area of 5139 km^2. This area is characterized by altitudinal gradient ranging from sea level to 4200 m above sea level, allowing the presence of a great variety of vegetation types (Fig. 1).

We generated a GIS-based model from a combination of the main habitat requirements that influence the presence of white-tailed deer in the area, five environmental variables were used for modeling the optimum habitat. We used the following data layers: Mean annual temperature (http://www.worldclim.org), vegetation cover (National Forest Inventory, Series II, 2002) 1:250,000 scale, Digital Elevation Model (DEM) 1:50,000 scale (INEGI, 1999), from which we obtained the slope and aspect for the study area using ArcView GIS 3.2. (ESRI 1996). Finally, the information on rivers, roads and villages was obtained from the 1:250,000 scale vectorial map (INEGI 1994).

With these data we calculated the Attribute Importance Index (*AII*), it value ranging from 0 (low quality) to 1 (high quality). This value is obtained with the following formula (Delfin-Alfonso *et al.* 2009): $AII = Iv/n$ where Iv is the importance value of each category for an attribute and n is the number of categories in which an attribute was divided. The importance value was assigned considering the category relevance for the white-tailed deer, using bibliographic information (Table 1).

With the *AII* we calculated the habitat quality with the Habitat Suitability Index (HSI) for deer in the study area with the following formula (Delfin-Alfonso *et al.* 2009):

$$\mathrm{HSI} = \left[\frac{IIA_1 + IIA_2 + IIA_3 + 2IIA_4 + 2IIA_5}{\sum IIA_n}\right] - pv$$

where IIA_1= aspect, IIA_2= slope, IIA_3= water availability, IIA_4= temperature, IIA_5= vegetation type and pv= pressure value.

Table 1. Habitat attributes evaluated with their respective categories and values

Habitat attributes	Category	*Iv*	*AII*	Quality
Aspect	N, NO.NE	3	1	High
	Flat	2	0.67	Intermediate
	S, SE, SO, E, O	1	0.33	Low
Slope (°)	0-9°	3	1	High
	10-13°	2	0.67	Intermediate
	>14°	1	0.33	Low
Water sources	Perennial	3	1	High
	Intermittent	2	0.67	Intermediate
	Without	1	0.33	Low
Temperature (°C)	5 a 21 °C	3	1	High
	21 a 29 °C	2	0.67	Intermediate
	>29°C	1	0.33	Low
Vegetation	Tropical deciduous forest, tropical subdeciduous forest, desert shrubland.	5	1	High
	Pine forest, Fir forest, Oak forest, Juniper forest.	4	0.80	High
	Tropical rainforest, water bodies.	3	0.60	Intermediate
	Cloud forest	2	0.40	Low
	Agriculture, pastureland, high prairie.	1	0.20	Low
	Urban areas, mangroves, dunes, without vegetation.	0	0	Not applicable

The *pressure value* was calculated using information about roads and towns. The assessment on the effect of roads and human settlements in the distribution and habitat use of white-tailed deer and other cervids, have reported that the number of fecal groups increases with the distance from them, especially during the hunting season or places where hunting is common (Rost and Bailey, 1972; Vogel, 1989; Kilgo et al., 1998; Manor and Saltz, 2005). This study established a gradient of impact where the risk for deer is a function of distance from its location to roads and human settlements, with the assumption that if the deer is very close to any of them, it is more likely to be detected by a human and therefore the level of risk will be higher. Since the differences in type of roads and human density represent a different risk for the white-tailed deer, these were divided in categories according to their potential impact on the deer. For each category three risk buffers were established: high, medium and low, depending on its proximity to the roads or settlements (Table 2). Once the maps were generated for three levels of risk, each map was assigned a *pressure value* (*pv*), where the categories high, medium and low were replaced by values 1, 0.6 and 0.3 respectively. The areas outside the risk buffers and whose level of impact was null, a value of 0 was assigned. We overlap both maps (roads and human settlements) and for the new polygons produced we assigned the highest pressure value from the base maps.

Table 2. Risk buffers for the white-tailed deer related with roads and human population

Roads	High risk buffer (m)	Intermediate risk buffer (m)	Low risk buffer (m)
Trail, dirt road	100	200	300
Paved road, railroad	200	400	600
State highway, Federal highway.	300	600	900
Population (No. of inhabitants)			
< 15	300	600	900
16 - 150	500	1000	1500
151 - 1500	1000	2000	3000
1501 - 10000	2000	4000	6000
10001 - 100000	2500	5000	7500
100001 - 1000000	3000	6000	9000

The data of white-tailed deer presence in the study area was obtained from field surveys in two dry seasons (February and May 2008; February-March de 2009) and one wet season (August-September 2008). Two strip transects (500 x 2 m) were established in 18 localities, where all tracks and signs from white-tailed deer were recorded. These transects were located in the tropical deciduous forest, oak forest and rangelands.

We used a Tree Analysis to explain variation of a single response variable (white-tailed deer presence) by one or more explanatory variables (environmental variables and anthropogenic pressure). Due the response variable is categorical we apply a Classification Tree Analysis to identify the main environmental variables related with the white-tailed deer presence in the study area (Andersen *et al.* 2000). The tree is constructed by repeatedly splitting the data, defined by a simple rule based on a single explanatory variable. At each split the data is partitioned into two mutually exclusive groups, each of which is as homogeneous as possible. The splitting procedure is then applied to each group separately. The objective is to partition the response into homogeneous groups, but also to keep the tree reasonably small. The size of a tree equals the number of final groups (De'Ath and Fabricius 2000).
Also we apply a Chi-squared test to know if there were significant differences in the deer presence between sites with different habitat quality and vegetation type. The Bonferroni Confidence Interval was used when we found these differences (Neu *et al.* 1974).

RESULTS

The HSI estimated for the study area was from -0.667 to 0.905, where the lowest values were associated with poor habitat quality. Eighty six percent of total surface (5167.71 km^2) included intermediate and low quality habitat (4455.9 km^2) and only 13.52% was high quality habitat (711.81 km^2) (Fig. 2).

We recorded 203 faecal groups at 18 sites sampled, furthermore another 30 tracks were found (rubbings, bedsites and fingerprints). We found two times more tracks in the intermediate quality habitat than in high and low quality habitats. The Chi-squared test found significant differences in the use of habitat taking into account the quality ($\chi^2 = 9.82$, d.f. = 2, $\alpha = 0.05$). Considering the available surface of each type of habitat quality and applying the Bonferroni Confidence Interval, the low quality habitats were avoided by white-tailed deer. Intermediate and high quality habitats were used by the deer as the intervals predicted.

White-tailed deer frequently used oak forest (58.6% of the tracks), rangelands (23.6%) and tropical deciduous forest (17.7%). We found significant differences in the use of the vegetation types by the

deer ($\chi^2 = 8.97$, $\alpha = 0.05$). The oak forest was preferred, whereas the tropical deciduous forest and the rangelands were avoided, considering the results of the Bonferroni Confidence Interval.
]
A Classification Tree Analysis indicated that temperature and aspect were the main habitat features influencing the white-tailed deer presence in the study area. When the temperature was higher than 28.15 °C and the aspect was W, NW or N the analysis predicted the deer presence. Other important habitat attributes were anthropogenic pressure and slope; we found that in localities with high anthropogenic pressure on the deer, refuge in sites with pronounced slope.

DISCUSSION

The analysis of the environmental variables that influence the presence of white-tailed deer in the study area, considered the temperature as the most important in explaining the occurrence of this species. Although temperatures between 20-25°C are usually considered as thermoneutral for most medium-large animals (Moen 1968), for white-tailed deer thermoneutral limit is 30°C. Above this temperature the deer extensive loss of water from evaporate cooling, could threatens their survival (Moen, 1973). Although the model predicts that with temperatures below to 28.15°C deer will be absent, this boundary is because most of our records were restricted to warm thermal zone in the study area, where temperatures range from the 22°C to ≥26°C. The absence of tracks for the temperate zone in the study area is because these animals were removed from the region due to excessive hunting and wood cutting in the middle of last century (*com. pers.* Gallina). So the model will have more accurate predictions in places where exist a better representation of the all environmental variables that satisfies the species requirements. Although we try to obtain more representative records of deer presence in the zone, most of them were located outside of the study area.

The aspect was also an important variable to predict the deer presence, mainly West, North West and North are preferred (Sánchez-Rojas *et al.* 1997; Mandujano *et al.* 2004), the latter two types of orientation are used preferentially by deer because having less sunshine have more favorable microclimatic conditions (Mandujano and Gallina, 1994) and retain more moisture due to the presence of trees with dense foliage (Mandujano *et al.* 2004).

The oak forest was the most used habitat by the white-tailed deer, the presence in this type of vegetation of *Quercus* sp. and *Leucaena leucocephala* as dominant species promotes it use due both species form a major part of the deer diet (Gallina *et al.* 1981). This type of vegetation has been associated with greater abundance of deer, especially when presented in rough terrain and has a good percentage of vertical vegetation cover, which allows protection from natural predators and humans (Ortiz-Martinez *et al.* 2005). In this study the oak forest was located in areas with a lower degree of anthropogenic pressure and pronounced slopes.
Although tropical deciduous forests have higher plant species richness, a high production of biomass (Arceo 1999) and species with high nutritional value (Silva-Villalobos *et al.* 1999) this type of vegetation was not used by the white-tailed deer as we expected. One factor that may have influenced the reduced use of this type of vegetation is the high anthropogenic pressure in the zone. A study carried out in a tropical deciduous forest in Puebla, Mexico showed a higher density of deer in areas with lower levels of human disturbance (López-Téllez *et al.* 2007), so possibly this could explain the low number of tracks found in this type of vegetation in this study.

Conservation and restoration of the vegetation cover is necessary to promote deer populations recovery in Central Veracruz, Mexico.

ACKNOWLEGEMENTS

Support for this study was obtained from CONACYT (Project number 52925 "Situación actual de la distribución del venado cola blanca en el Estado de Veracruz" to Sonia Gallina and fellowship number 212500 to Beatriz Bolivar) and Veracruz Estate Government for support the project "Estudio poblacional del venado cola blanca en la Sierra Madre Oriental del Estado de Veracruz" (SEDESMA/UA/PDIA/008/06). We want thank Norma Corona for her help with the GIS and Octavio Rojas for his comments. We are gratefull for the field help to: Antonio Vázquez, Luis Arturo Escobedo, Arturo González and Rolando González Trápaga.

REFERENCES

Andersen MC, Watts JW, Freilich JE, Yool SR, Wakefield GI, Mccauley JF, Fahnestock PB (2000) Regression-Tree Modeling of desert tortoise habitat in the central Mojave desert. *Ecological Applications* **10**, 890-900.

Arceo G (1999) Hábitos alimentarios del venado cola blanca en el bosque tropical caducifolio de Chamela, Jalisco.Tesis de Maestría. Facultad de Ciencias, Universidad Nacional Autónoma de México. D.F. México. 66 pp.

CONAFOR (2002) 'Inventario Nacional Forestal, Serie II' (Modificado).

De'Ath G, Fabricius KE (2000) Classification and regression trees: a powerful yet simple technique for original data analysis. *Ecology* **81**, 3178-3192.

Delfín-Alfonso CA, Gallina S, López-González CA (2009) Evaluación del hábitat del venado cola blanca utilizando modelos espaciales y sus implicaciones para el manejo en el centro de Veracruz, México. *Tropical Conservation Science* **2**, 215-228.

Environmental Systems Research Institute, Inc. 1996. ArcView^{R}

Felix AB, Campa III H, Millenbah KF, Winterstein SR, Moritz WE (2004) Development of landscape-scale habitat-potential models for forest wildlife planning and management. *Wildlife Society Bulletin* **32**, 795-806.

Gallina S (1994) Uso del hábitat por el venado cola blanca en la Reserva de la Biosfera La Michilía, México. In 'Ecología y Manejo del venado cola blanca en México y Costa Rica'.(Eds Ch Vaughan, M. Rodríguez) pp. 299-314. (EUNA, Universidad Nacional, Costa Rica).

Gallina S, Maury E, Serrano V (1981) Food habits of white tailed deer. In 'Deer Biology, Habitat Requirements and Management in Western North America'. (Eds PF Ffolliott, S Gallina) pp. 135-148. (Instituto de Ecología, A.C. México, D.F.).

Halls LK (1984) 'White tailed deer ecology and management'. (Stackpole Books, Harrisburg, Pennsylvania, USA).

INEGI (1999) 'Modelo Digital de Elevaciones 1:50,000'.

INEGI(1994) 'Conjunto de Datos Vectoriales 1:250,000'.

Mandujano S, Rico-Gray V (1991) Hunting, use and knowledge of the biology of the White-tailed deer *Odocoileus virginianus* (Hays), by the maya of central Yucatan, Mexico. *Journal of Ethnobiology* **11**, 175-183.

Kilgo JC, Labisky RF, Fritzen DE (1998) Influences of hunting on the behavior of white-tailed deer: Implications for conservation of the Florida panther. *Conservation Biology* **12**, 1359-1364.

López-Téllez MC, Mandujano S, Yánes G (2007) Evaluación poblacional del venado cola blanca en un bosque tropical seco de la mixteca poblana. *Acta Zoológica Mexicana* **23**, 1-16.

Mandujano S, Gallina S, Arceo G, Pérez-Jiménez RA (2004) Variación estacional del uso y preferencia de los tipos vegetacionales por el venado cola blanca en un bosque tropical de Jalisco. *Acta Zoológica Mexicana (n.s.)* **20**, 45-67.

Mandujano S (1994) Método para evaluar el hábitat del venado cola blanca en un bosque de coníferas. In 'Ecología y Manejo del venado cola blanca en México y Costa Rica'.(Eds Ch Vaughan, M. Rodríguez) pp. 283-297. (EUNA, Universidad Nacional, Costa Rica).

Mandujano S, Gallina S (1994) Comparación de métodos para estimar la densidad poblacional del venado cola blanca en un bosque tropical caducifolio de México. . In 'Ecología y Manejo del venado cola blanca en México y Costa Rica'.(Eds Ch Vaughan, M. Rodríguez) pp 263-280. (EUNA, Universidad Nacional, Costa Rica).

Manor R, Saltz D (2005) Effects of human disturbance on use of space and flight distance of mountain gazelles. *The Journal of Wildlife Management* **69**, 1683-1690.

McsheaWJ, Underwood HB, Rappole JH (1997) 'Science of overabundance'. (Smithsonian Institute Press,Washington, D.C., USA).

Moen AN (1973) Wildlife Ecology. Freeman and Company. Library of Congress Cataloging in Publication Data.

Moen AN (1968) The critical termal environment: a new look at an old concept. *BioScience* **18**, 1041-1043.

Neu CW, Byers CR, Peek, JM (1974) A technique for analysis of utilization-availability data. *The Journal of Wildlife Management* **83**,541-545.

O'Brien DJ, Schmitt SM, Fierke JS, Hogle SA, Winterstein SA, Cooley TM, Moritz WE, Diegel KL, Fitzgerald SD, Berry DE, Kaneene JB (2002) Epidemiology of *Mycobacterium bovis* in free-ranging white-tailed deer, Michigan, USA, 1995–2000. *Preventive Veterinary Medicine* **54**, 47–63.

Ortíz-Martínez T, Gallina S, Briones-Salas M, González G (2005) Densidad poblacional y caracterización del venado cola blanca (*Odocoileus virginianus oaxacensis*, Goldman y Kellog,

1940) en un bosque templado de la sierra norte de Oaxaca, México. *Acta Zoológica Mexicana* **21**, 5-78.

Rost GR, Bailey JA (1979) Distribution of mule deer and elk in relation to roads. *The Journal of Wildlife Management* **43**, 634-641.

Rothley KD (2001) Manipulative, multi-standard test of a White-tailed deer hábitat suitability model. *The Journal of Wildlife Management* **65**, 953-963.

Sánchez-Rojas G, Gallina S, Mandujano S (1997) Area de actividad y uso del hábitat de dos venados cola blanca (odocoileus virginianus) en un bosque tropical de la costa de Jalisco, México. *Acta Zoológica Mexicana (n.s.)* **72**, 39-54.

Silva-Villalobos G, Mandujano S, Arceo G, Gallina S, Pérez-Jiménez LA (1999) Nutritional characteristics of plants consumed by the White-tailed deer in a tropical forest of Mexico. *Vida Silvestre Neotropical* **8**, 38-42.

U.S. Fish and Wildlife Service (1991) 'Habitat Evaluation Procedure (HEP)'. (Division of Ecological Services, Department of the Interior. Washington, D.C.).

Vaughan C (1994) El futuro del manejo del venado cola blanca en América Latina In 'Ecología y Manejo del venado cola blanca en México y Costa Rica'. (eds C Vaughan, M Rodríguez) pp. 445-447 (EUNA, Universidad Nacional, Costa Rica).

Villarreal J (1999) 'Venado cola blanca: manejo y aprovechamiento cinegético'. (Unión Ganagera Regional de Nuevo León. Monterrey, N.L.).

Vogel WO (1989) Response of deer to density and distribution of housing in Montana. *Wildlife Society Bulletin* **17**, 406-413.

Williams ES, Miller MW, Kreeger TJ, Kahn RH, Thorne ET (2002) Chronic wasting disease of deer and elk: a review with recommendations for management. *Journal of Wildlife Management* **66**, 551–563.

Figure 1. Study Area of Central Veracruz, Mexico, with classification of vegetation types.

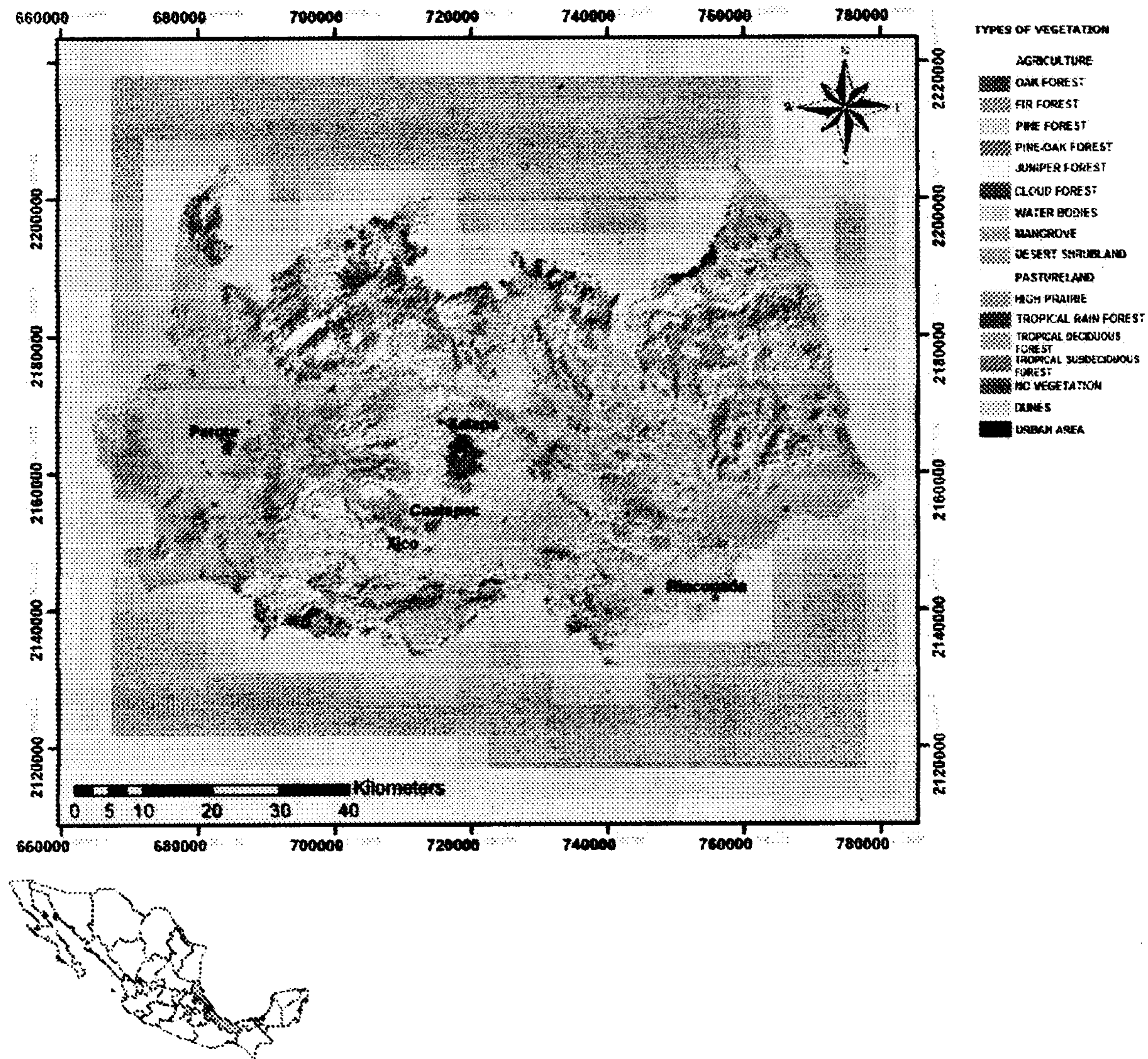

Figure 2. Deer Habitat Quality Categories in Central Veracruz, Mexico, according the Optimum Habitat Model. The blue points are the presence of deer.