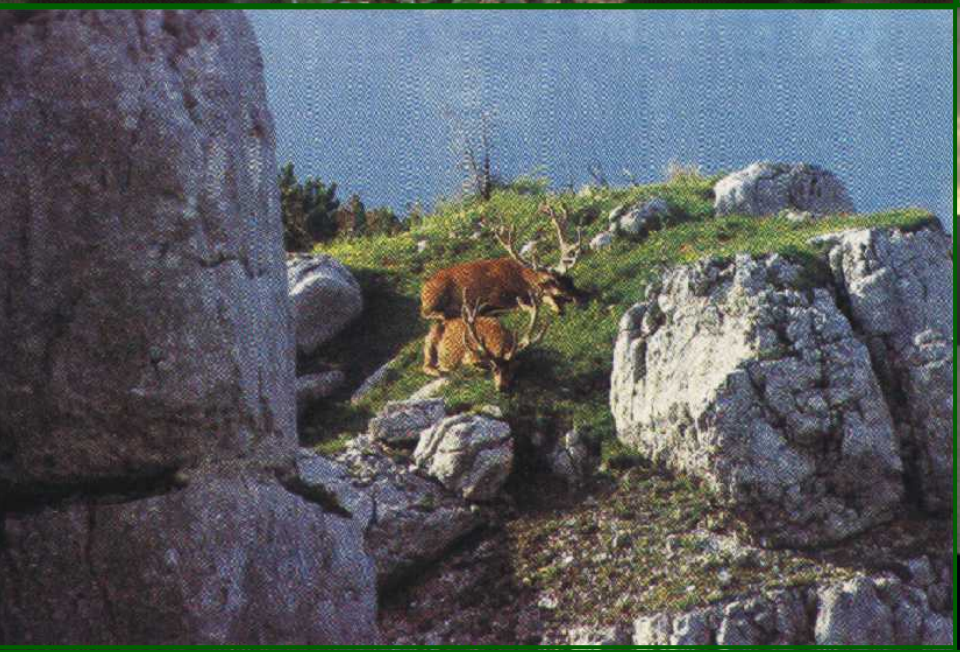
Analysis and Spatial Modelling of Winter and Annual Habitats of the Red Deer (*Cervus elaphus* L.) in the Dinaric Forests of South-Western Slovenia with Decision Trees in a Raster GIS Environment

Klemen JERINA & Miha ADAMIČ

University of Ljubljana, Biotehnical Faculty,
Department of Forestry and Renewable Forest Resources
Večna pot 83, 1000 Ljubljana, Slovenia

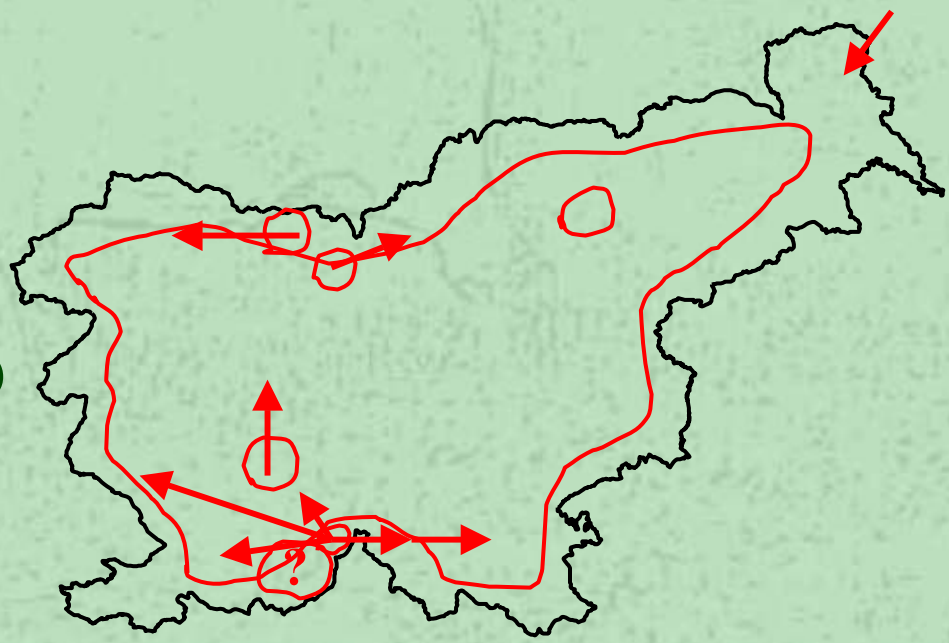
E-mail: klemen.jerina@bf.uni-lj.si



Red Deer (*Cervus elaphus*, Linnaeus 1758) **HABITAT?**

Red deer in Slovenia?

• Its population size and range was changing drastically in the past, especially during last two centuries



Red deer now inhabits major part of Slovenia (80 % of forests). Its population size is estimated at about 10.000 – 14.000 animals.

Due to increased population size and range its influences on forest communities and economic significance also become bigger.

Ecological roles of red deer:

- **vertical and horizontal transport of the nutrients**
- **speed of nutrient cycling and their availability in soil ⇒ productivity of ecosystems**
- **spatial distribution, abundancy, habitus and growth of the plants**
- **important vector of plant seed dispersal**
- **structure and developement dynamics of ecosystems**

Economic significe of the red deer:

- **browsing of new growth trees; striping bark from younger trees ⇒ deminishment of the economic value of forests. (-)**
- **important game species: average annual harvest of the red deer is more than 4.200 animals per year. (+)**

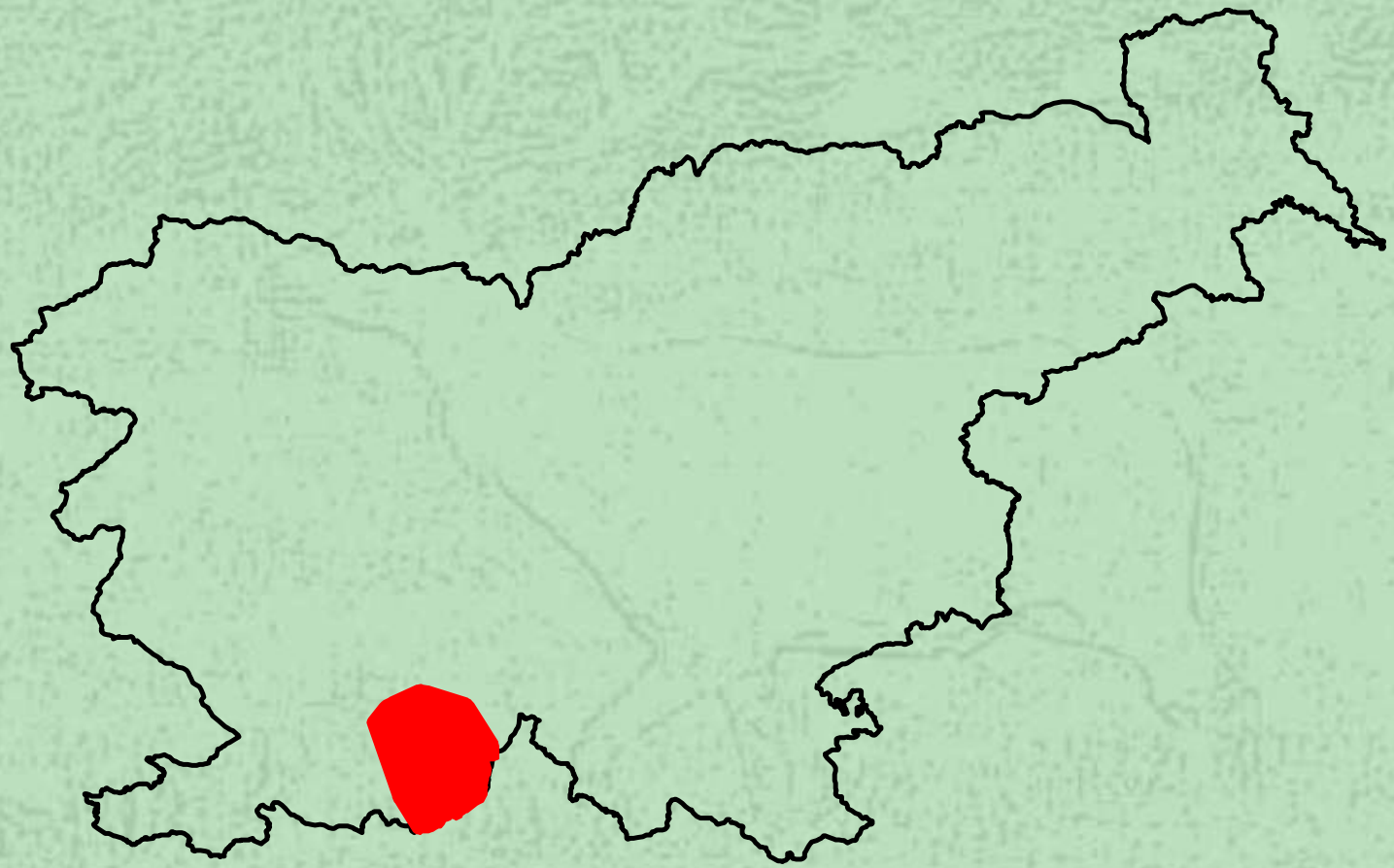
Aim of the research:

- To study the characteristics of red red deer living space and to determine which factors (biotic, abiotic, anthropogene conditioned) influence its spatial distribution most.

- To evaluate seasonal changes in the red deer habitat selection (especially differences between the winter and the rest of the year).

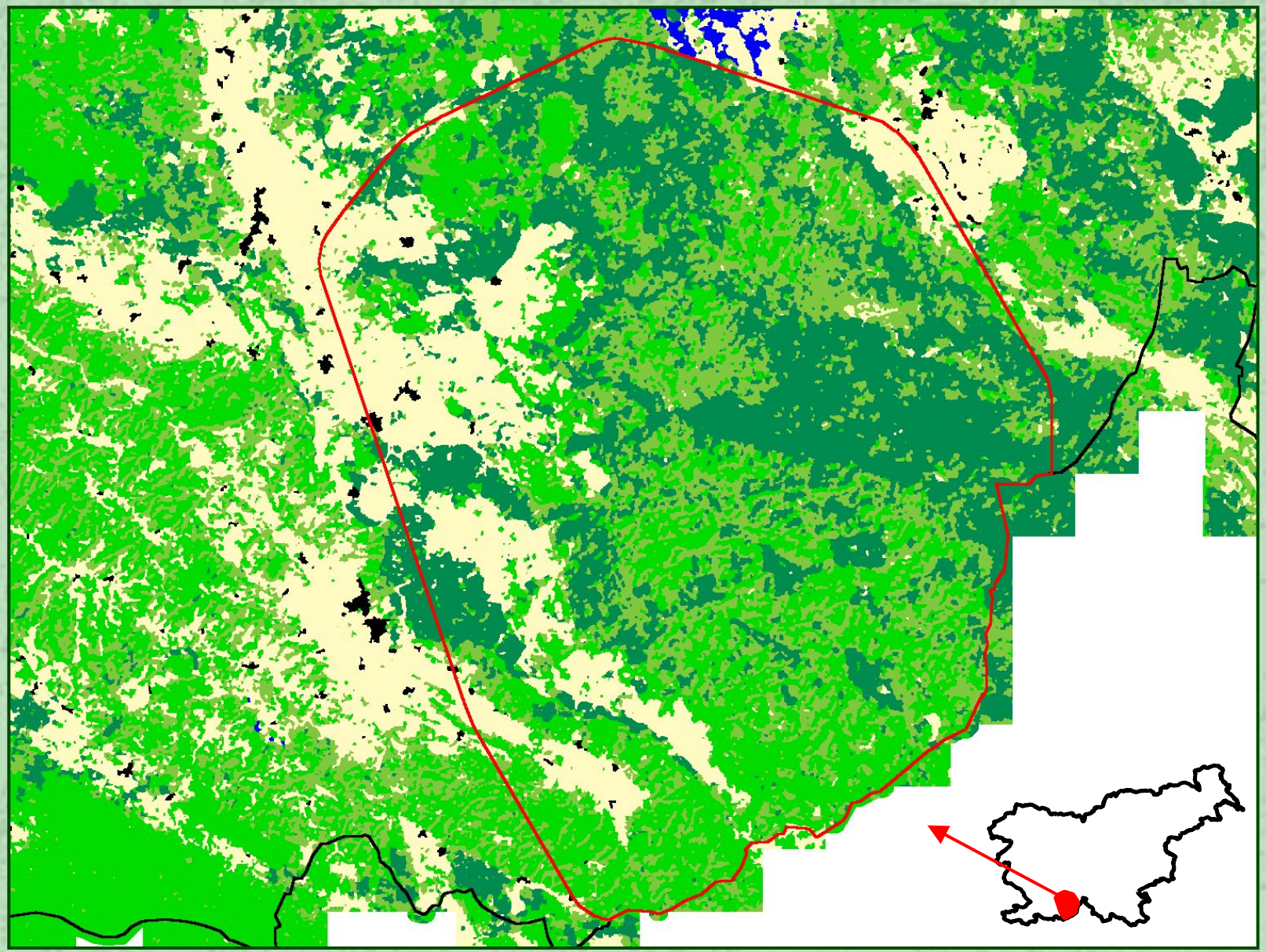
- To elaborate red deer spatially explicit habitat models:
one for the entire year, one for the winter period.

Research area

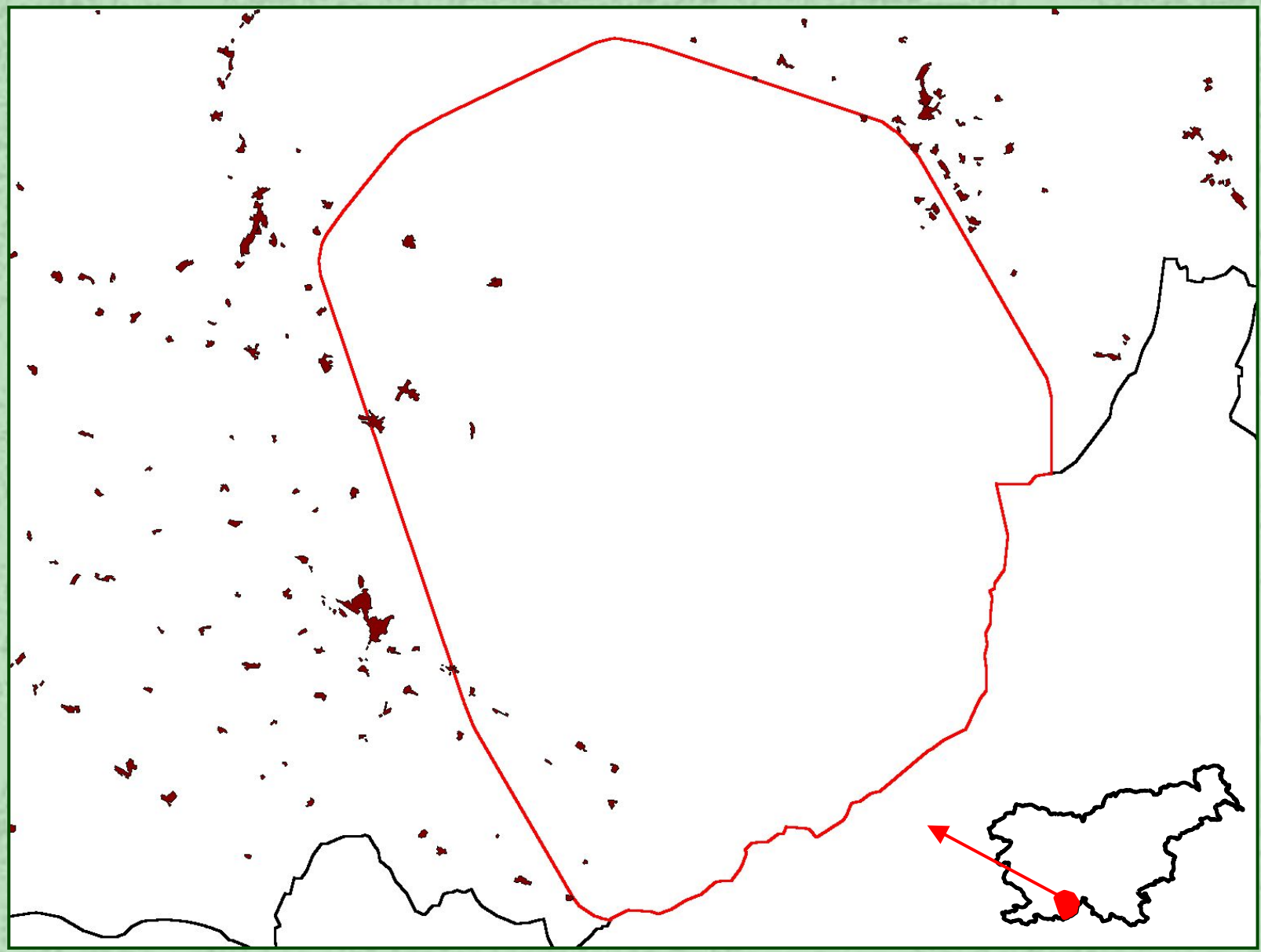


Research area

Research area: abundance of forests



Research area: human settlements



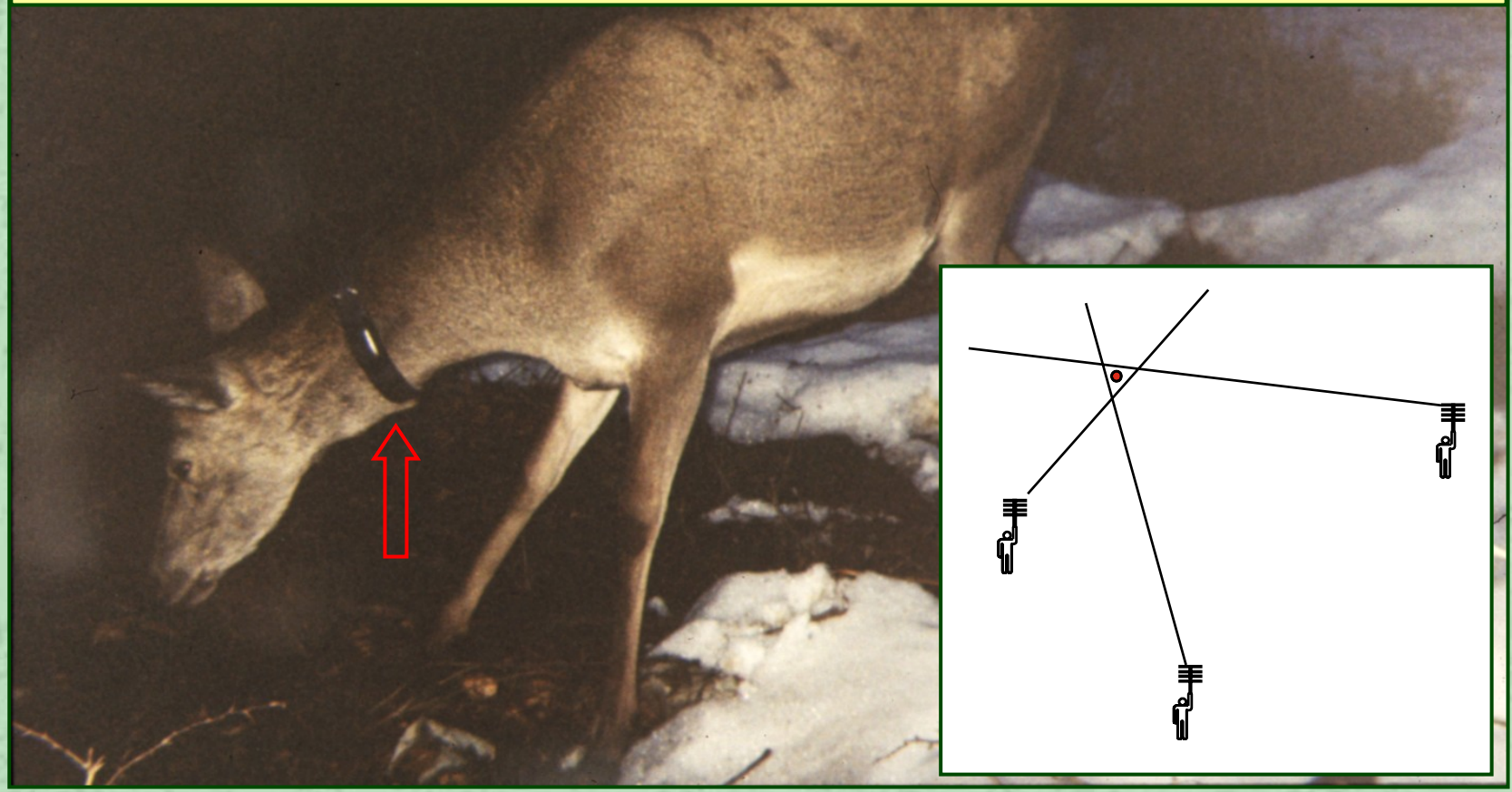
Methods:

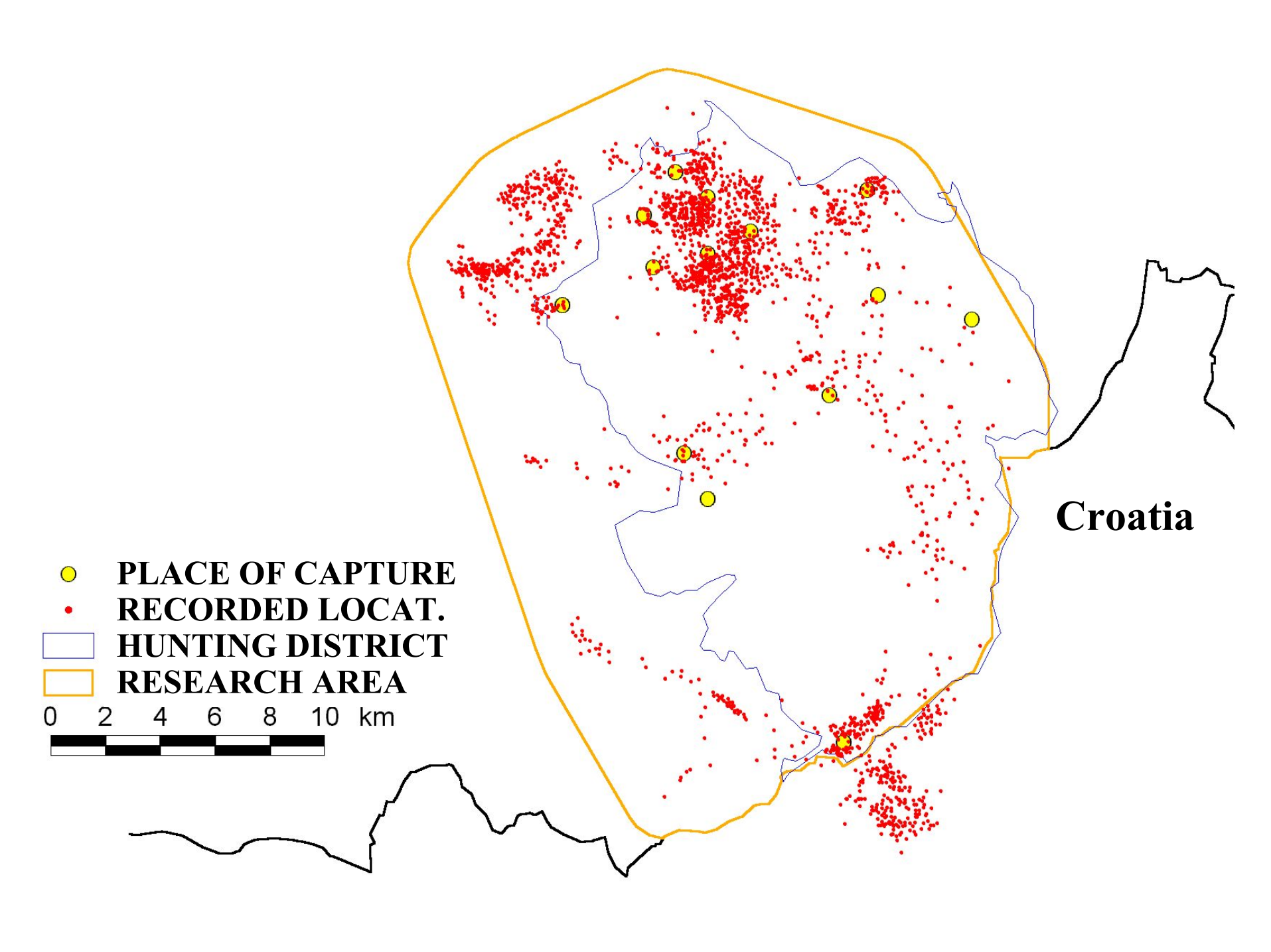
- **Data gathering**
    1. **Telemetry tracking**

1. Telemetry tracking

Red deer locations were recorded at least once per week by the use of standard tringulation technique.

14 adult hids and 10 adult stugs; together more than 2300 locations.




Croatia
PLACE OF CAPTURE
RECORDED LOCAT.
HUNTING DISTRICT
RESEARCH AREA
0 2 4 6 8 10 km

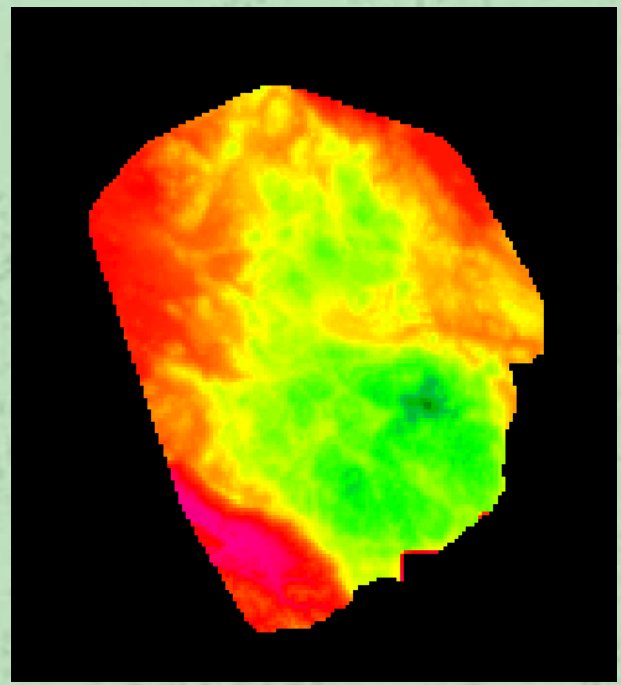
Methods:

- Data gathering
  1. Telemetry tracking data
  2. GIS data

2. GIS data

Raster model of the space; resolution 200×200 meters (11.287 pixles measuring 4 ha)

Topography variables (altitude, slope, exposition),

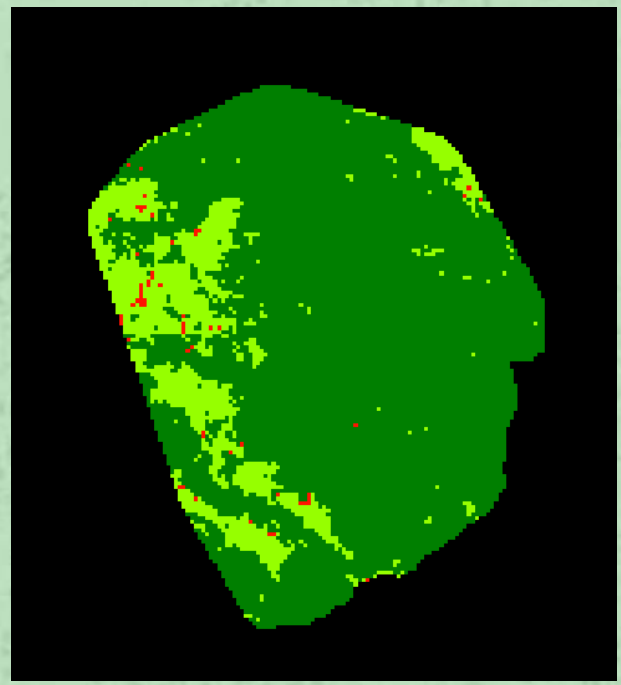


2. GIS data

Raster model of the space; resolution 200×200 meters

Topography variables

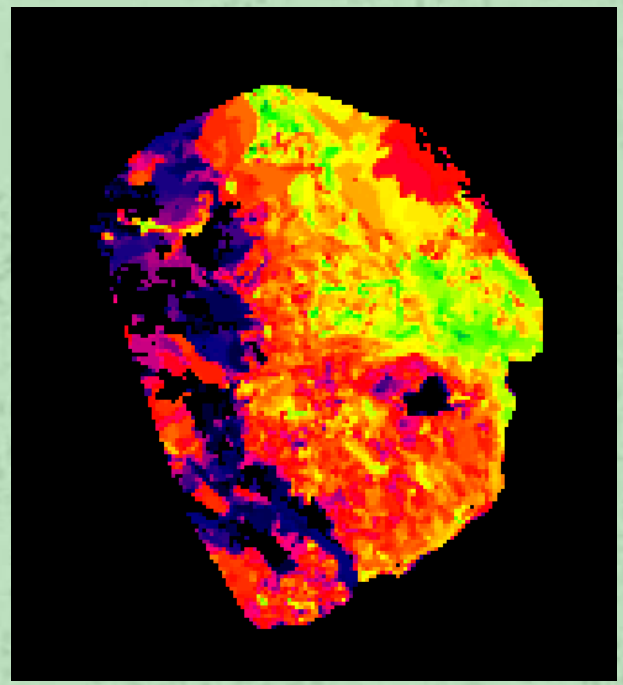
Land use (dominant land use type, percentage of forests)



2. GIS data

Raster model of the space; resolution 200×200 meters

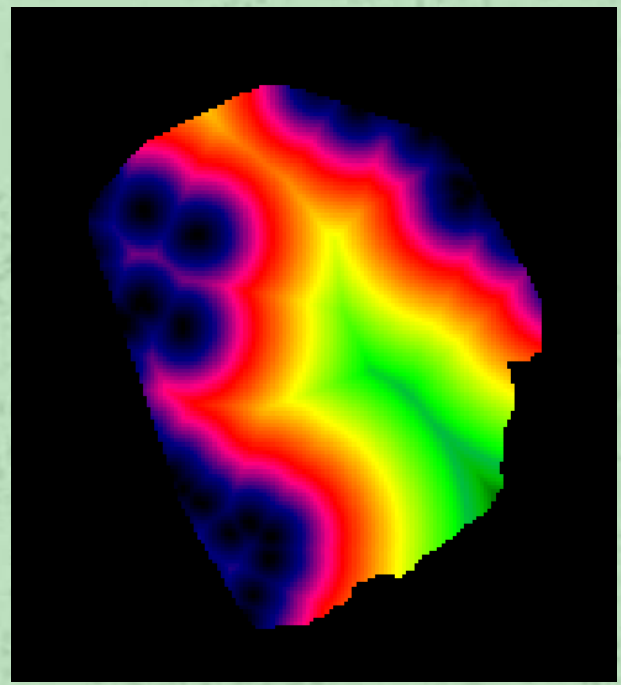
- **Topography variables**
- **Land use**
- **Stand characteristics (growing stock; percentage of conifers; percentage of young, early pole, …, stands)**



2. GIS data

Raster model of the space; resolution 200×200 meters

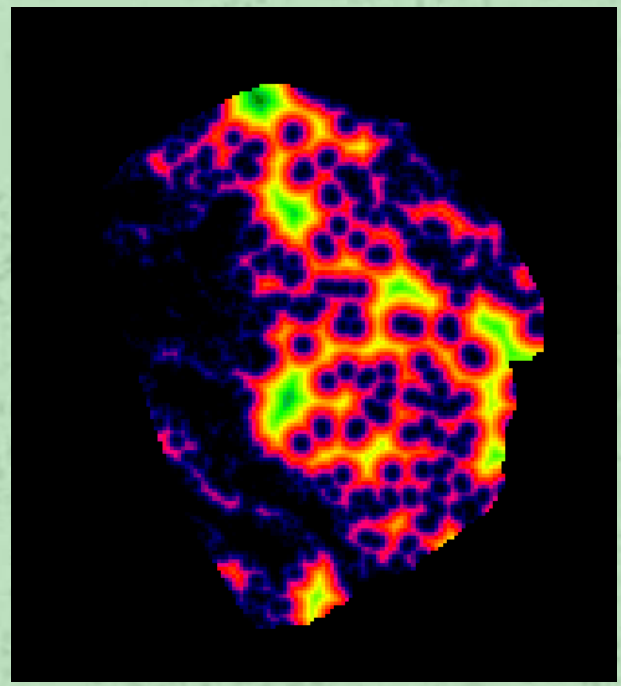
- **Topography variables**
- **Land use**
- **Stand characteristics**
- **Infrastructure and settlements (distance to the nearest settlement, main road, forest road)**



2. GIS data

Raster model of the space; resolution 200×200 meters

- **Topography variables**
- **Land use**
- **Stand characteristics**
- **Infrastructure and settlements**
- **Forest edge (distance to the nearest forest or non-forest)**

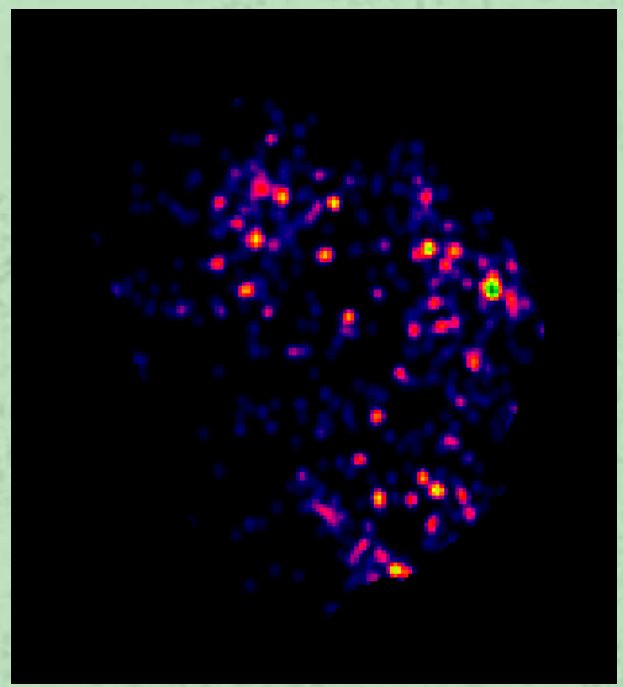


2. GIS data

Raster model of the space; resolution 200×200 meters

- Topography variables
- Land use
- Stand characteristics
- Infrastructure and settlements
- Forest edge
- Supplementary feeding place
- Density of solar radiation
- Wolf activity

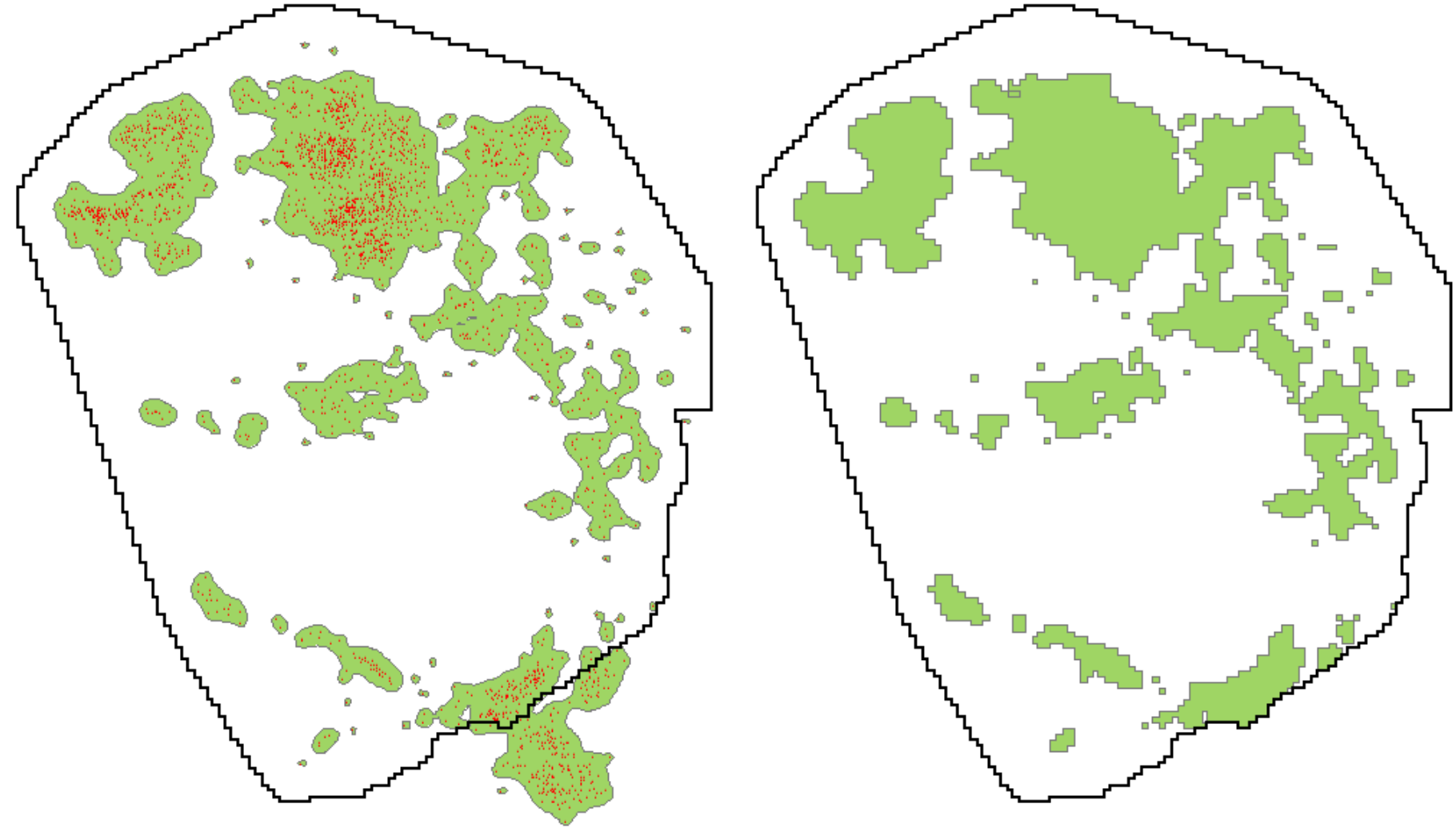
... 20 independent variables



Methods:

- Data gathering
- Data analysis

  - Multivariate classification methods
    - Discriminant analysis
    - Decision trees


RECORDED LOCATIONS
HOME RANGE (P = 0.95)
POSITIVE CASES
NEGATIVE CASES

Results:

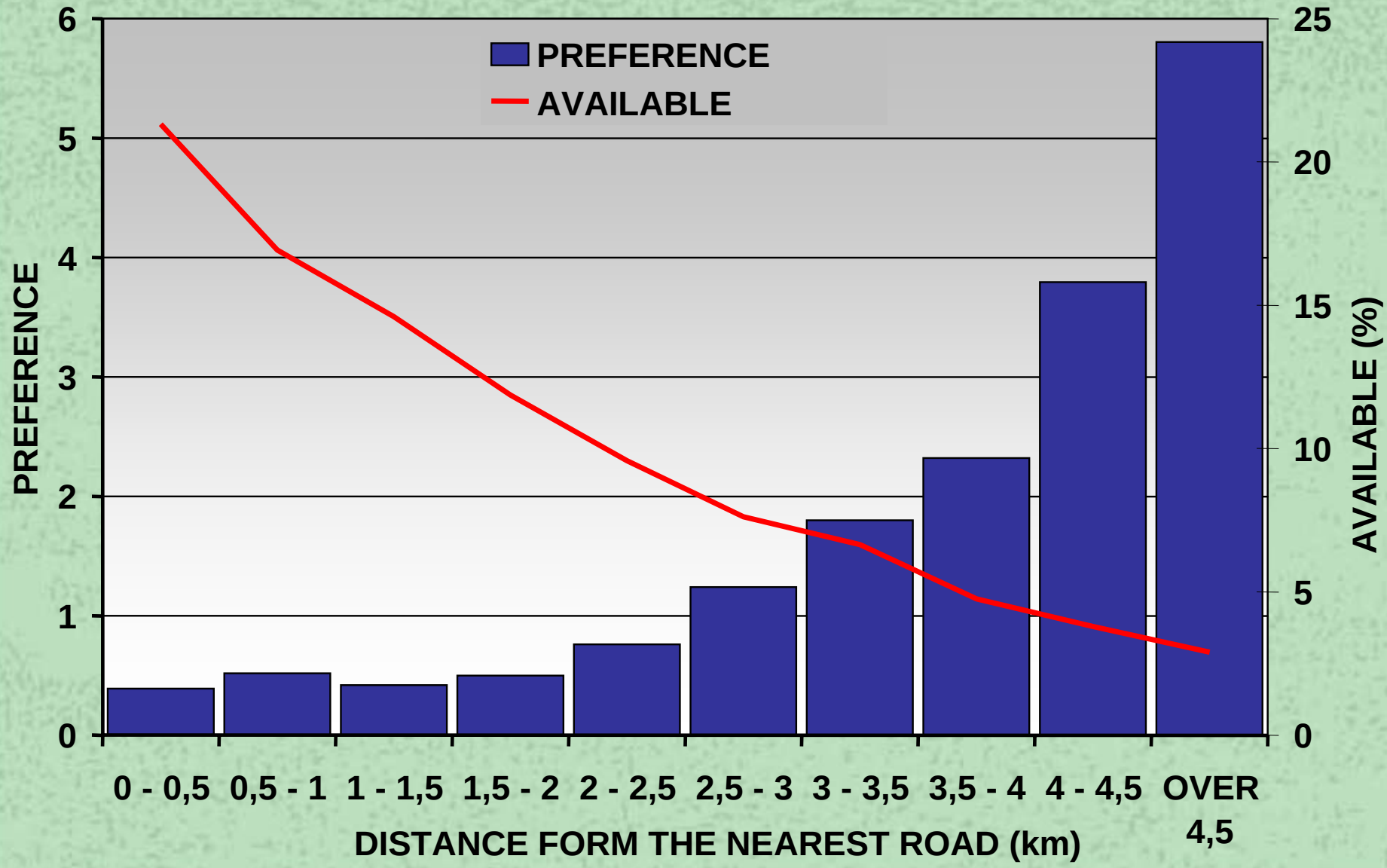
Annual habitats

- Multiple classification analyses: discriminante analysis

Annual habitats: discriminant analysis

VARIABLE	b (standard.)	t	P
Distance to the main road	0,279	26,8	0,0000
Distance to the feeding place	-0,150	-14,4	0,0000
Percentage of young stands	0,067	6,7	0,0000
Altitude	-0,056	-5,1	0,0000
R = 0,316; F = 252,7***; n = 9131; df1 = 4; df2 = 9126			

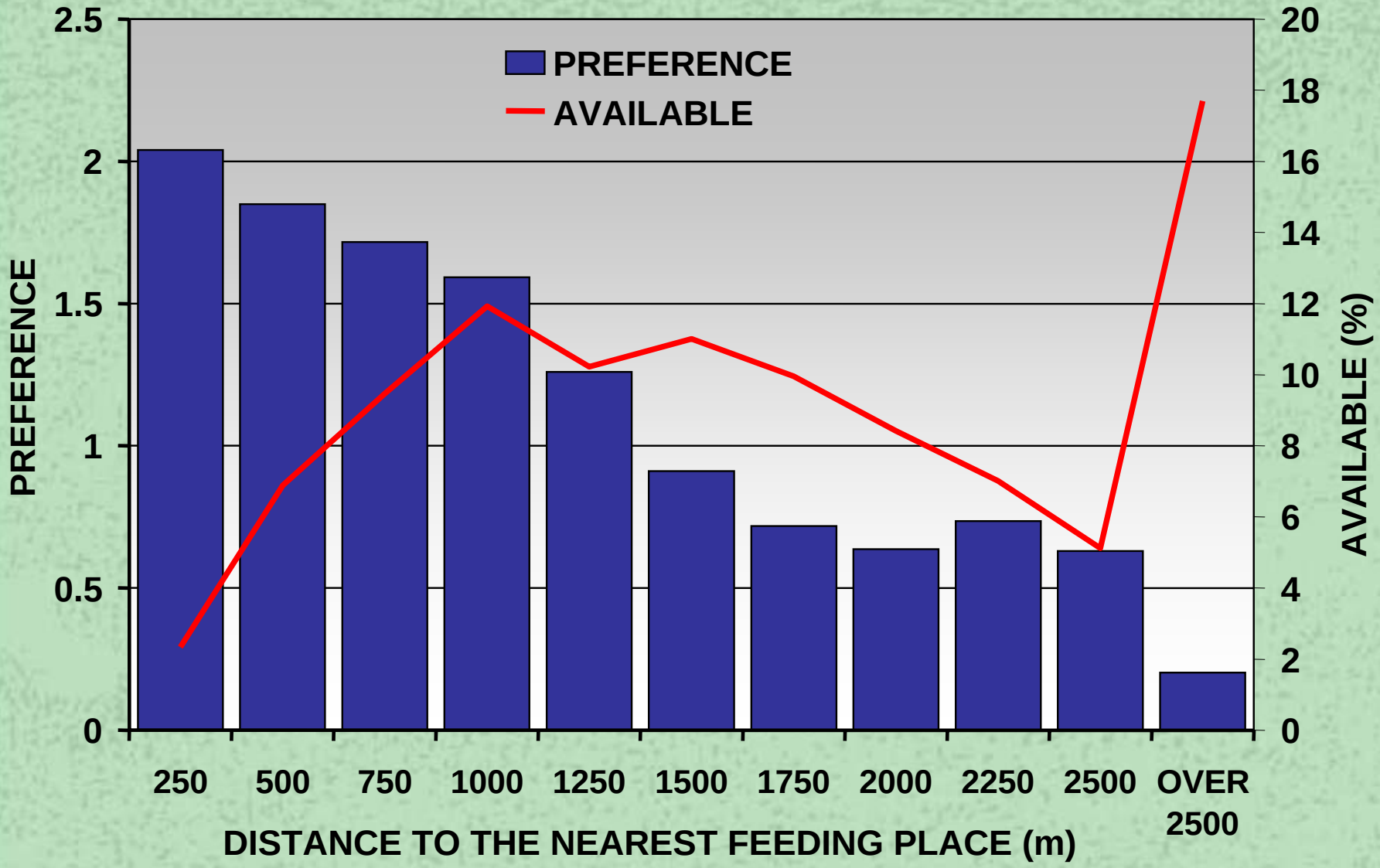
Red deer distribution with regard to distance from the nearest road



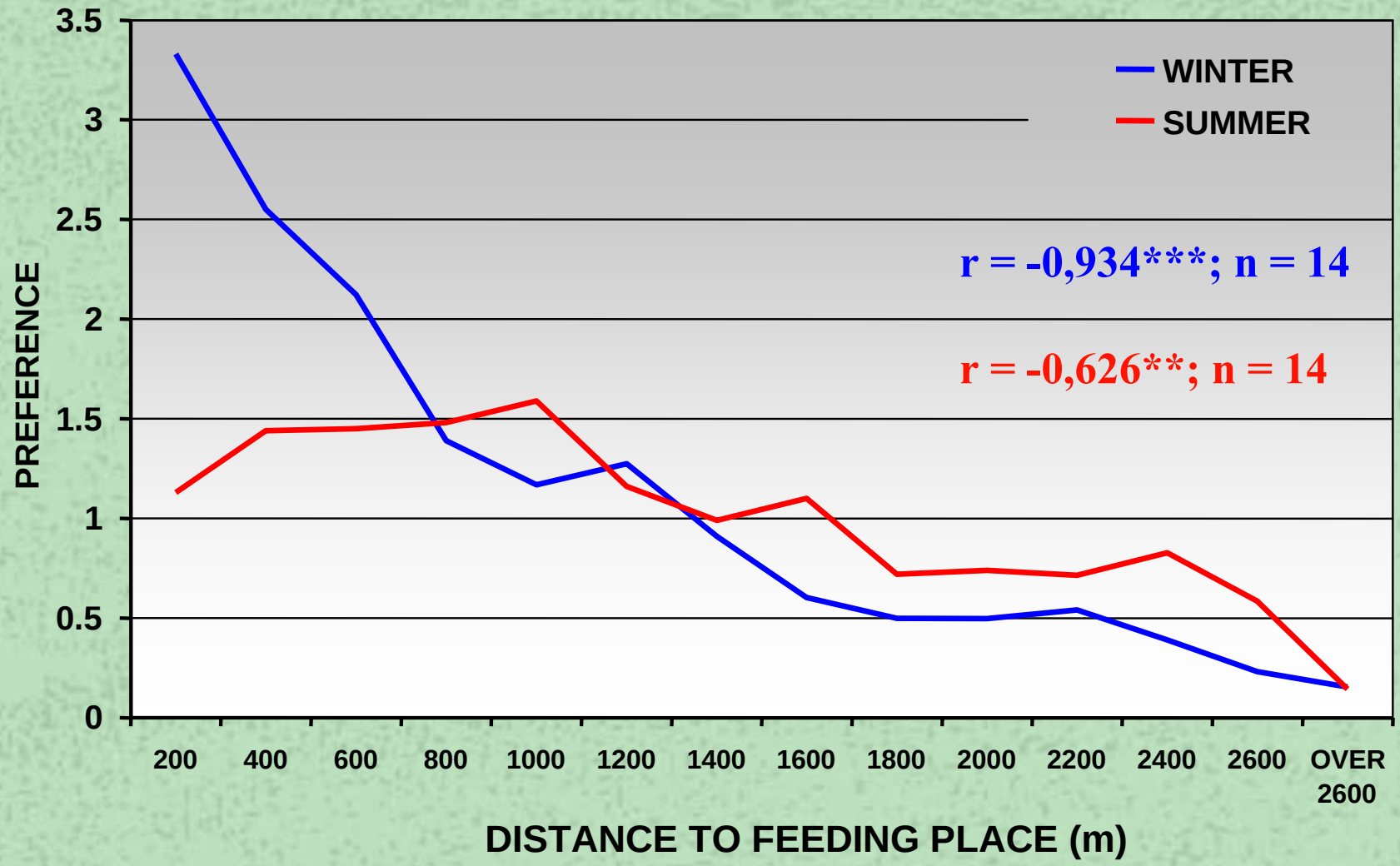
Annual habitats: discriminant analysis

VARIABLE	b (standard.)	t	P
Distance to the main road	0,279	26,8	0,0000
Distance to the feeding place	-0,150	-14,4	0,0000
Percentage of young stands	0,067	6,7	0,0000
Altitude	-0,056	-5,1	0,0000
R = 0,316; F = 252,7***; n = 9131; df1 = 4; df2 = 9126			

Red deer distribution with regard to the nearest feeding place



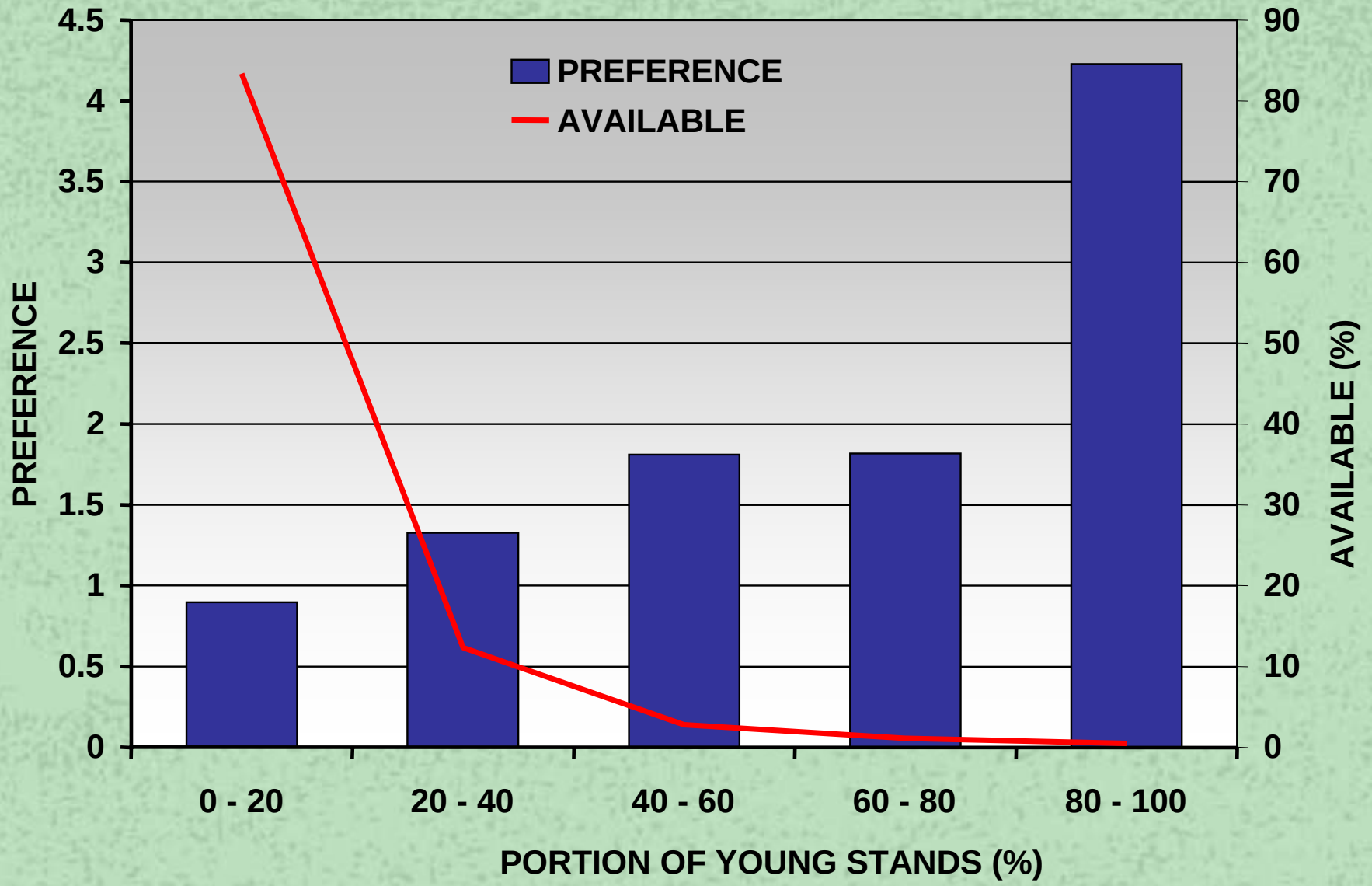
Red deer distribution with regard to the nearest feeding place in winter and summer period



Annual habitats: discriminant analysis

VARIABLE	b (standard.)	t	P
Distance to the main road	0,279	26,8	0,0000
Distance to the feeding place	-0,150	-14,4	0,0000
Percentage of young stands	0,067	6,7	0,0000
Altitude	-0,056	-5,1	0,0000
R = 0,316; F = 252,7***; n = 9131; df1 = 4; df2 = 9126			

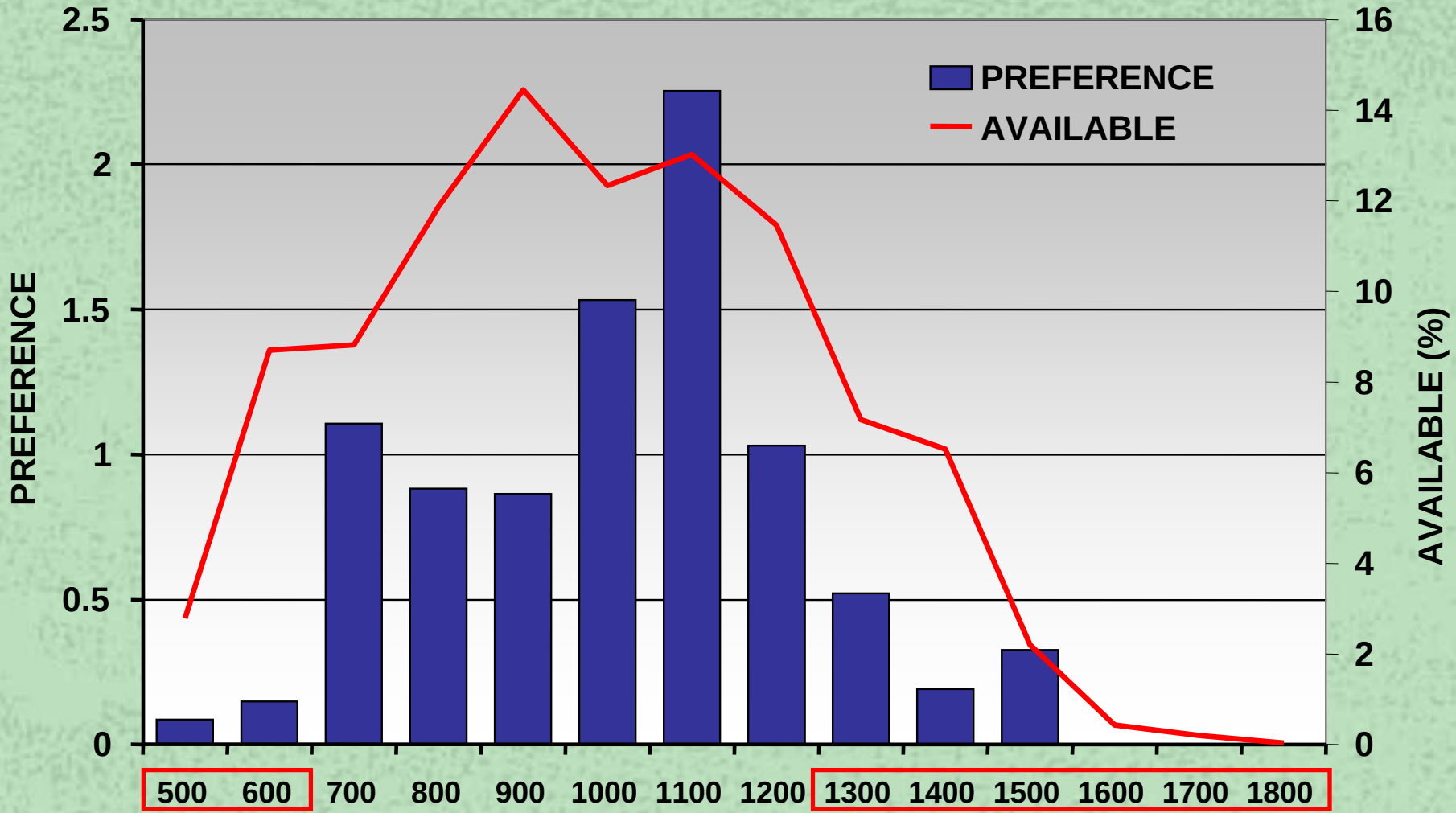
Red deer distribution with regard to the portion of young stands



Annual habitats: discriminant analysis

VARIABLE	b (standard.)	t	P
Distance to the main road	0,279	26,8	0,0000
Distance to the feeding place	-0,150	-14,4	0,0000
Percentage of young stands	0,067	6,7	0,0000
Altitude	-0,056	-5,1	0,0000
R = 0,316; F = 252,7***; n = 9131; df1 = 4; df2 = 9126			

Red deer distribution with regard to altitude



roads, fragmentation

ekstr. abiotic factors

Decision tree of annual habitat

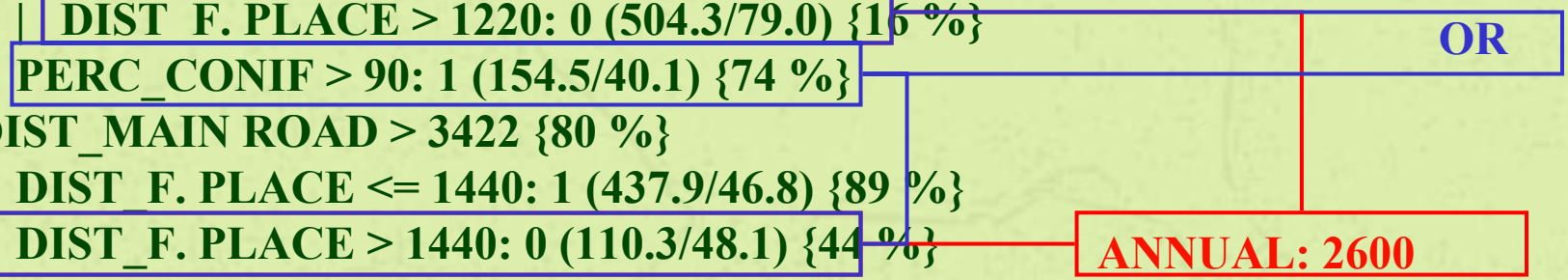
```
DIST_MAIN ROAD <= 2657 {35 %}
|  ALT <= 589: 0 (203.5/18.0) {9 %}
|  ALT > 589 {43 %}
|  |  ALT <= 1135 {49 %}
|  |  |  PERC_FOR <= 36: 0 (219.0/56.0) {26 %}
|  |  |  PERC_FOR > 36 {53 %}
|  |  |  |  PERC_YOUNG  <= 32 {50%}
|  |  |  |  |  DIST_SETT <= 5200 {44 %}
|  |  |  |  |  |  DIST_NON_FOREST <= 520 {49 %}
|  |  |  |  |  |  |  DIST_MAIN ROAD <= 651: 0 (171.0/49.0) {29 %}
|  |  |  |  |  |  |  DIST_MAIN ROAD > 651: 1 (433.9/185.9) {57 %}
|  |  |  |  |  |  DIST_NON_FOREST > 520: 0 (170.0/40.5) {24 %}
|  |  |  |  |  DIST_SETT > 5200: 1 (292.9/99.0) {66%}
|  |  |  |  PERC_YOUNG > 32: 1 (123.1/25.0) {80 %}
|  |  ALT > 1135: 0 (341.0/68.0) {20 %}
DIST_MAIN ROAD > 2657 {74 %}
|  DIST_F. PLACE <= 2600: 1 (734.2/148.6) {80 %}
|  DIST_F. PLACE > 2600: 0 (125.3/49.9) {40 %}

Number of Leaves  :          10; Size of the tree :          18
```

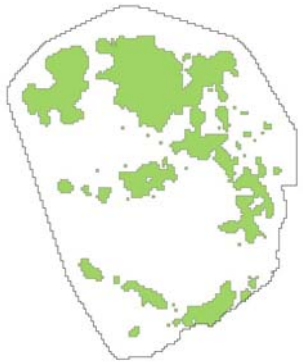
Decision tree of winter habitat

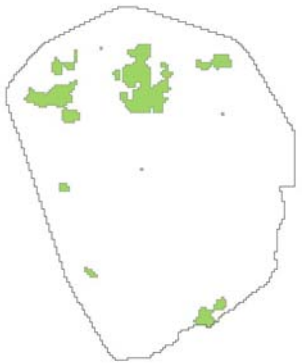
```
DIST_MAIN ROAD <= 3422 {38 %}
|   PERC_CONIF <= 90 {33 %}
|   |   DIST_F. PLACE <= 1220 {46 %}
|   |   |   ALT <= 1059 {59 %}
|   |   |   |   DIST_MAIN ROAD <= 1535 {41 %}
|   |   |   |   |   PERC_YOUNG <= 10: 0 (99.4/22.8) {23 %}
|   |   |   |   |   PERC_YOUNG > 10: 1 (112.5/48.6) {57 %}
|   |   |   |   DIST_MAIN ROAD > 1535: 1 (228.2/56.5) {75 %}
|   |   |   ALT > 1059: 0 (102.54/24.5) {24 %}
|   |   DIST_ F. PLACE > 1220: 0 (504.3/79.0) {16 %}
|   PERC_CONIF > 90: 1 (154.5/40.1) {74 %}
DIST_MAIN ROAD > 3422 {80 %}
|   DIST_F. PLACE <= 1440: 1 (437.9/46.8) {89 %}
|   DIST_F. PLACE > 1440: 0 (110.3/48.1) {44 %}

Number of Leaves :          8; Size of the tree: 14
```



METHOD	CLASSIFICATION ACCURACY (%)	
	POSITIVE CASES	ALL CASES
Discriminant analysis	70,2	65,4
Decision trees	80,1	73,6





WINTER HABITAT
ANNUAL HABITAT
FOREST
RESEARCH AREA

0 2 4 6 8 km

N
W E
S

Conclusions:

The annual habitat selection of the red deer on Sneznik-Javorniki region is most strongly influenced by the following variables: distance to the nearest main road, distance to the nearest feeding place, percentage of young stands and altitude.

In wintertime two types of habitat were preffered: nearly pure conifer stands, generally situated in the lower part of study area, or the areas near the feeding places (<1400 meters).

Results of present study are also important for the management of the red deer and its environment.

Spatial distribution of the feeding places strongly influences the distribution of the red deer: deer concentrate around feeding places; the presence of main roads or other vectors of human induced disturbances evidently diminish the area usable for the red deer.

Consequently, red deer tend to agregate in smaller areas, which may trigger additional difficulties in natural forest regeneration and affect the development dynamics of the entire forest ecosystems.

On the other hand, the spatial distribution of red deer and also the impact strength of red deer populations on forests can easily be manipulated by distributing the feeding places and by closing some of the less important roads.

Habitat selection patterns based on decision tree classifier were rather hard to interpret.

Different input parameters (confidence factor, minimum number of objects in leaf) sometimes yielded contradictive results.

However, due to relatively high classification accuracy and the ability to reveal non-linear associations between variables, the method proved to be useful tool in this type of analysis.