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

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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 development dynamics of ecosystems

Economic significance of the red deer:
- browsing of new growth trees; striping bark from younger trees ⇒ diminishment 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 triangulation technique.

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

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

Raster model of the space; resolution $200 \times 200$ meters (11.287 pixels 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 $200 \times 200$ 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 $200 \times 200$ 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
Results:

Annual habitats

- Multiple classification analyses: discriminante analysis
### Annual habitats: discriminant analysis

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>b (standard.)</th>
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<th>P</th>
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<tbody>
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<td>0.0000</td>
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<tr>
<td>Distance to the feeding place</td>
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<td>-14.4</td>
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<tr>
<td>Percentage of young stands</td>
<td>0.067</td>
<td>6.7</td>
<td>0.0000</td>
</tr>
<tr>
<td>Altitude</td>
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R = 0.316; F = 252.7***; n = 9131; df1 = 4; df2 = 9126
Red deer distribution with regard to distance from the nearest road

![Graph showing red deer distribution]

- **X-axis:** Distance from the nearest road (km)
  - Categories: 0 - 0.5, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2 - 2.5, 2.5 - 3, 3 - 3.5, 3.5 - 4, 4 - 4.5, OVER 4.5
- **Y-axis:** Preference and Available (%)
- **Legend:**
  - Blue bars: Preference
  - Red line: Available

The graph illustrates the decreasing preference of red deer as the distance from the nearest road increases.
Annual habitats: discriminant analysis

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Red deer distribution with regard to the nearest feeding place

**Graph:**
- **X-axis:** Distance to the nearest feeding place (m)
- **Y-axis:** Preference (left) and Available (%) (right)

**Key:**
- Blue bars: Preference
- Red line: Available

**Statistical Data:**
- \( r = 0.837^{* * *}; P (X_{\text{max}}) / P (X_{\text{min}}) = 15 \)
Red deer distribution with regard to the nearest feeding place in winter and summer period

$r = -0.934^{***}; n = 14$

$r = -0.626^{**}; n = 14$
# Annual habitats: discriminant analysis

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\[ R = 0.316; \, F = 252.7^{***}; \, n = 9131; \, df1 = 4; \, df2 = 9126 \]
Red deer distribution with regard to the portion of young stands

![Graph showing red deer distribution with regard to the portion of young stands. The x-axis represents the portion of young stands in percentage (%), and the y-axis represents preference and available. The graph shows a decrease in preference as the portion of young stands increases, with a corresponding increase in available.](image-url)
## Annual habitats: discriminant analysis

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\[ R = 0,316; F = 252,7^{***}; n = 9131; \text{df1} = 4; \text{df2} = 9126 \]
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 %} OR

ANNUAL: 2600

Number of Leaves: 8; Size of the tree: 14
<table>
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<tr>
<th>METHOD</th>
<th>CLASSIFICATION ACCURACY (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>POSITIVE CASES</td>
</tr>
<tr>
<td>Discriminant analysis</td>
<td>70,2</td>
</tr>
<tr>
<td>Decision trees</td>
<td>80,1</td>
</tr>
</tbody>
</table>
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 preferred: 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 aggregate 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 contradictory 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.