University of West Hungary

Theses of doctoral dissertation

Connections between the site conditions of North Hanság and growth of the forests

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1. Aims of the research

The presented research in the dissertation had two aims. On one hand to discover the site conditions of North-Hanság, and on the other hand to examine and analyse the connections between the site conditions and the yield potential of the main stand forming species.

The basic conception of the research was laid on the principle that the soil forming environmental factors have the leading influence on the values of different soil properties. Since these environmental variables are spatially continuous, they help to develop a continuous soil body, which can be characterized with always spatially changing properties, with gentle intergradations between property values.

Successfully identifying the most important soil forming environmental factors and incorporating them into a GIS one may have a good chance to assess the relationship between the environmental factors and the measured soil properties using statistical methods.

As part of the basic conception, the dissertation assumed that there is a strong relationship between the yield potential of the stand forming species and soil parameters, because soil is one of the most important factor among the features of sites influencing the growth rate of tree species.

If there is really a strong relationship between the two groups of variables, then with detailed analyses, one may set up some kind of statistical models between the two, and the results can be visualised within the frame of a GIS.

2. The objects of the research

The research area covered more than 7500 ha of woodlands in the North-Hanság. This includes the whole working territory of the North-Hansag Forestry Directorate. Besides this, the

research incorporated those of nature reserves of Fertő-Hanság National Park, which are situated in the North-Hanság.

Inside the research area detailed studies were carried out in order to investigate the characteristics of soils and forest stands, as the two main objects of the research. Those environmental, soil forming factors, which were judged to be the most important variables in the formation of soil properties were also put under detailed investigations. The most important environmental variables were as follows: the relief (altitude, aspect, slope), the geological formations just under the soil-mulch, and the long term change in ground water level.

a. The studied soil parameters

The followed soil properties were examined:

- Thickness of rooting depth,
- Thickness of the peat layer,
- the pH in soil horizons,
- the $CaCO_3$ content of soil horizons,
- acidity of soil horizons,
- Mechanical composition of soil horizons (Clay%, Silt%, Fine sand%, rough sand%),
- Nutrient contents of soil horizons (Carbon, Nitrogen, Sulphur, Potassium, Phosphorus).

b. The studied forest stand parameters

The followed stand properties were examined:

- species,
- age,
- diameter at breast height,
- height,

- sylvicultural class (on a scale 1-4),
- height class (on a scale 1-4)
- yield potential (from nomograms, determined on the basis of age, height and species).

c. The studied environmental variables

- altitude,
- aspect,
- slope,
- the location of ductless basins,
- geological formations at 2 m depth (parent material),
- the monthly groundwater level data observed in 15 groundwater wells in the area between 1955 and 2000 (ÉDUVIZIG).

3. Applied methods

a. Sampling

Some kind of sampling had to be carried out in order to have satisfactory data about forest stands and soils. 96 sampling plots were established by random sampling, which were weighted and distributed between forest stands according to their occupied area – proportional to their importance.

The sample plots were visited in the field using GPS whereafter they were consolidated. According to the 2nd point, at the sample plots soil survey and stand measurements were done.

b. GIS tools

A geographic information system (GIS) approach was applied to have a system structure and to achieve uniform data

processing in the dissertation The ESRI Arc View GIS 3.2a software and its extensions were the basic applications to achieve this aim.

It was used to produce the rasterised result maps, and it helped very much the spatial data processing and visualization as well. The main GIS based fields of the research were as follows:

- Producing digital elevation model (DEM),
- Producing aspect and slope maps derived from DEM,
- Modelling the monthly groundwater levels,
- Delineation of ductless basins using DEM,
- Mapping the endangered areas by internal waters,
- Visualization and mapping of sample plots,
- Coupling the sample plots data with the data of environmental variables,
- Map calculation and visualization of the regression equations between the environmental variables and soil property variables over the whole study area,
- Map calculation and visualization of the regression equations between the soil properties and the yield potentials of main stand forming species over the whole study area.

c. Statistical methods

It was necessary to apply different statistical methods for the analysis of the data of the environmental, soil and stand variables, and to discover the relationships between the three, and to handle the always existing, high level uncertainty of ecological systems

It meant the following treatments:

Fuzzy classification

The fuzzy classification of the environmental and soil variables aimed at to divide the area into characteristically similar blocks.

This comes up from the basic conception of the dissertation, which states that the soil forming environmental factors influence principally the values of different soil properties. These environmental factors have a continuous effect in space and time. Thus, it is not favourable to represent soils as discrete entities, and delineate them with sharp lines, but represent them as continuous soil bodies, with continuously changing property values, on which the effects of different environmental variables have an always changing role and importance.

In this manner, fuzzy classification helps to maintain the possibility of graduated transitions, and at the same time, helps to identify those territorial blocks (within fuzzy clusters), within which the environmental variables have a more uniform impact on developed soil properties, than on the other parts of the study area (between the fuzzy clusters).

Therefore, the relationships between the soil properties and the environmental factors became easier to assess and easier to model within the area of each fuzzy cluster.

Multiple regressions

The method of multiple regressions were applied in order to establish relationships between the investigated parameters

Multiple regressions had to be used two times, between two groups of variables:

First, the relationships between the environmental variables and the soil properties within the fuzzy clusters were assessed and formalized by multiple regressions. For this purpose the

coupled data of sample plots and the environmental variables were used.

Second, the relationship between the soil properties and the yield potential of the main stand forming species were assessed and formalized using regression techniques, which process incorporated the stands of three – the most important – species, namely: the Italian poplar (I-214), the alder and the white willow.

d. Other applied, non-standard methods

Characterization of groundwater levels

To evaluate the monthly groundwater data there was a need to introduce groundwater indexes. The value of groundwater indexes held information about not only the distance of groundwater level from the surface, but also held information on which certain soil horizon was this level situated at the certain time. According to this, different indexes belonged to different groundwater level categories from the parent material to the soil surface. Deriving the indexes for each month and averaging them, it was possible to determine standard groundwater level indexes, which indicated in which soil horizon and how deep the permanent effect of groundwater level can be expected when we are concerning the long-term average.

The visualization of fuzzy clusters

To visualize the spatial pattern of fuzzy clusters it was necessary to classify every pixel of the digital map, representing the study area. To achieve this, the distance of the pixels from the central concepts of fuzzy clusters had to be clarified concerning the environmental variables (because the soil data were only known at the sample plots). The class membership value of every pixel had to be defined on the basis

of environmental variables. For this, the difference between each cluster central concept among the environmental variables and the environmental variable values of a certain pixel had to be calculated, then the squared difference was divided by the standard deviation of the given environmental variable in the given class gaining a normalized distance value, which represented the distance of every pixel from every central concept of classes. The less this value is, the closer the given pixel is to the given class. The visualization of the minimum pixel distance values shows up the spatial pattern of all classes.

4. Results

The research conduced to the following results, grouped into the chapters below:

a. GIS databases

Two of these results have to be highlighted: First, the map of endangered areas by internal waters produced by the analysis of digital elevation model and second, the spline-interpolated groundwater level maps from the data of groundwater wells.

The former one has a significance in the delineation of the areas which may be flooded temporarily by internal waters, the later may offer possibility for the delineation of hydrological categories, and it can contribute to map the extent of and changes of the referred categories in time and space.

b. Digital soil maps

Soil property maps were produced using the regression equations, which established to model the relationships between the soil parameters and the environmental variables.

These maps represent the spatial pattern of the most important soil parameters over the whole study area.

The following, environmental factor based soil property maps were produced with the resolution of 20x20 m:

- *Thickness of rooting depth*, which shows how thick the directly exploitable soil layer for the trees from the surface;
- *Thickness of the peat layer*, which shows how thick the undecomposed peat layer between the rooting zone and the base of the fen;
- *$CaCO_3$ content of the rooting zone*, which shows the expected lime content in the rooting zone;
- *Average pH value of the rooting zone*, which shows the chemical reaction of the soil in the rooting zone;
- *Clay content of the rooting zone,* assess the clay % of topsoil from mechanical composition;
- *C-content of the rooting zone*;
- *N-content of the rooting zone*;
- *P-content of the rooting zone*.

c. Yield potential maps of the main species

The regression equations, which establish relations between soil properties and the yield potential of main stand forming species, can be used to derive the yield potential maps of those species over the study area. These maps show the expected yield potential values for three species in the North-Hanság. On the basis of these maps it was possible to produce a species composition map, which means the maximum yield potential utilization, and it assesses the exact values of possible yield potential (m^3/ha/year) for every pixel of the map.

In this way, in the case of the next species

- Italian poplar (I-214), the

- alder and the
- white willow

yield potential maps were made depending on soil properties for the whole study area.

5. Possible applications

The question of applicability of the presented methods and the maps produced with them in this dissertation may affect several aspects of forestry, whereof the most important one could be the practice of forest planning, and other forestry activities connected with site-evaluation. The next section briefly discusses some obvious way of application, among which some are bound closely to the Hanság, but some have a general significance. They are as follows:

1. The map of the areas endangered by internal waters can be used together with the map of the standard groundwater level for species composition planning in the affected forestry compartments. Hence, both the permanently high groundwater level and the waterlogged soil can constrain the growth rate of forest stands and require the application of flood tolerant species.
2. The utilization of the produced soil property maps of the woodlands of North-Hanság have rather a local importance, but the application of the methodology, with which they were produced on other forest areas, however may have a general importance providing new opportunities for site evaluation when generate detailed soil property maps. Some examples:
   2.1 With the map about thickness of the rooting zone there is a possibility to delineate the boundaries of thickness categories exactly such as very shallow, shallow, medium deep, deep and very deep.

2.2 On the basis of the pH and $CaCO_3$ content maps it is possible to identify those areas, where inadequate chemical properties may occur, such as too high or too low pH values, or too high $CaCO_3$ contents are expected. Comparing these maps with the maps of groundwater levels come up the possibility of the identification of the areas affected by surplus water, which may ease or neutralize the higher $CaCO_3$ contents in the soil.

2.3 The nutrient content maps together with the map of pH and groundwater levels may give a standing-ground for the estimation of the available amount of nutrients for trees uptake. Soils with a relatively high amount of available nitrogen for example can provide better growth rates, but simultaneously they mean an increasing risk of weediness.

2.4 Soils with high carbon content, together with the map of peat layer thickness outline where had been major organic matter accumulation in the past, and what is the extent of these areas today.

2.5 The map of peat layer thickness provides a good base for studying the accelerated decompositional processes due to the exsiccation of the area. It provides a good reference map for future studies.

3. The yield potential maps of the most important species have great significance from point of view of the forest management. It gives the opportunity to map yield classes for every species and helps to decide on species composition. Coupling them with profitableness calculations it become possible to delineate forest areas primarily designated for wood production or utilized for other purposes. It helps the assignment of managed forested lands into different utilization classes, and takes also the ecological pattern into account.

4. The presented methodology is suitable to produce detailed soil property and yield potential maps, which may highly contribute to develop a forest management planning practice within which the site conditions are fully taken into consideration.

6. Publications

Illés G., Kovács G., Bidló A., Heil B. 2003: Az Észak-Hanság termőhelyi viszonyainak modellezése „fuzzy"-klasszifikáció és GIS eszközök felhasználásával. Acta Agraria Kaposváriensis. Vol. 7. No. 3. p.: 45-68.

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