Landscape and environmental properties of the European Russian wood species

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Abstract. The article presents original methodology of ecological evaluation of areas based on ecological modes. The know-how is based on evaluation of the following ecological modes: nutrient status \((N)\), water content \((W)\), friability \((F)\), mobility \((M)\), cryolithic zonation \((C)\), flooding \((Fl)\), drainage \((Dr)\), and disturbance \((D)\). It describes ecological areas and ecological optimums for major forest-forming species that comprise forest communities in the European Russian landscapes based on the analysis of environmental properties. The environmental properties of the wood species analysed make it possible to identify the ecotopes of species distribution, explain the structures of forest communities, and define the types of land facies with ecological modes that may prevent a species from appearing in the area. The analysed data makes it possible to define the ecological modes where a forest species grows under optimum conditions and achieves the best increment and development.

1. Introduction

According to the current knowledge, an ecological area is a conjunction of ecotopes where a wood species appears. The ecological area and its size depend on ability of plants to extract water and nutrients under various conditions [1].

Ecological optimum within an ecological area is a conjunction of ecotopes where a wood species can find the landscape ecological modes that are most suitable for its development. In the optimum ecological zone, the wood species can achieve the best growth and development, dominate the forest community, build up the biggest growing stock with best stand parameters, and form well self-pruned straight trunks of high commercial grade [1].

Pogrebnyak P S was the first forest researcher who studied the relationship between ecological modes and composition and capacity of forest communities. He developed and suggested a soil net to classify forest ecotopes (Table 1). At the X-axis, there are four nutrient status grades: A – pinewood, B – subors, C – sub-oak forests (sudubravas) and suramens, D – oak forests and ramens. At the Y-axis, there are five grades of increasing water content (hygrotopes): 1 – dry area, 2 – fresh area, 3 – humid area, 4 – damp area, 5 – wet area (swamp). The forest ecotopes are listed at the crossings of nutrient status and water content grades. The forest ecotopes reflect the site conditions of accumulative natural territorial complexes (NTC) in the Russian Plain [2].
Table 1. Forest soil net ecotopes.

| Hygrotopes | Nutrient status |
|------------|-----------------|
|            | A   | B   | C   | D   |
| 1          | A1  | B1  | C1  | D1  |
| 2          | A2  | B2  | C2  | D2  |
| 3          | A3  | B3  | C3  | D3  |
| 4          | A4  | B4  | C4  | D4  |
| 5          | A5  | B5  | C5  | D5  |

Vorobyev D V, Pogrebnyak’s follower, added multiple descriptions of forest types to the table and successfully used it to classify the Russian Plain forests by nutrient status and humidity (water content) modes [3, 4].

Kireev D M later suggested a table to evaluate wooded lands by eight ecological modes: nutrient status (W), water content (F), friability (M), cryolithologic zonation (C), flooding (Fl), drainage (Dr), and disturbance (D) [5-7]. This approach to forest land evaluation makes it possible to provide a comprehensive analysis of environmental properties of wood species. This makes it possible to find out the species distribution ecotopes, to explain the forest community structure, and to define the ecological modes that prevent the species from appearing.

2. Materials and methods

The landscape and environmental properties of wood species appear in their reaction on the wooded land ecological modes. To evaluate the environmental properties of the forest-forming wood species, the following data was analyzed:

1. Geographical range and its limits. Geographical range of plant (wood) species is a part of the continent where the species appears. On the geographical map, the range is shown as a closed circuit, outside of which the species is not present. Analysing the wood species range with landscape information sources (LIS) like common geographical maps, special maps, or remote sensing data, it is possible to find the reason why the wood species is restricted. The geographical ranges of all wood species are provided according to S.Ya.Sokolov et al.[8, 9].

2. Reasons of the wood species restriction (permafrost, salinity, soil poverty, excessive water content, dryness, aquifer depth, flooding, lapideous or rocky soil, human activities) [5, 10].

3. Wood species’ ability to occupy the open space. The pioneer-species can occupy first the open empty grounds that are free from other plants. They do not fear the light or thermal shock, from strong heating in the daytime to cooling at night. Silver Birch (Betula pendula Roth.) is an example of such species. It is the first tree that occupies bare grounds after the valley glacier melting. Grey Alder (Alnus incana (L.) Moench) occupies the land emerging from underwater, abandoned arables, and fallow lands [11].

4. Wood species’ ability to develop the root system on various soils. Relation to the forest lands ecological mode, and ability to develop the root system and fit it to various ecological modes like nutrient status, water content, friability, mobility, cryolithologic zonation, flooding, and drainage [1, 12].

5. Wood species’ relation to atmospheric conditions (air temperature, humidity) and light [1].

6. Wood species’ resistance to plant diseases, animal and plant pests, human impact, in particular, various types of forest exploitation and felling, land farming, melioration; facilities construction; consolidation and trampling; soil, atmosphere and water pollution; environmental impacts like fire, storm, landslide, avalanche, or landfall. The wood species’ resistance varies depending on the part of ecological area where the species is developing. Under the optimum ecological condition, the stand is notable for its durability, high immunity, and resistance to diseases and damage [1].
7. Wood species’ role in various plant aggregations in areas with various environmental properties [7].

8. Wood species’ role in the succession array of forest community development. The wood species depending on various environmental properties can take part in the formation of upper, subordinate layer or underwood. Sometimes they can form only temporary groups, giving place to climax wood species that complete the succession array [1, 10].

Having defined the stages of an ecological mode within a certain natural territorial complex (NTC), we can then complete the formula of ecological evaluation. All eight mode symbols of are written down with the stages given as indexes or in the brackets. The stages of the soil net are used to evaluate the nutrient status and water content of land facies. The environmental evaluation of an area defines the conditions of water mineral and aerial nutrition for ligneous and non-ligneous plants [5].

Table 2. Environmental evaluation of areas (according to D M Kireev).

| Substrate model | Ecological mode by stage |
|-----------------|--------------------------|
| Nutrient status | N0 (A, B) N1(C, D) N2(E) |
| Water content   | W0 (0, 1) W1(2) W2(3, 4, 5) |
| Friability      | F0 F1 F2 |
| Mobility        | M0 M1 M2 |
| Cryolithic zonation | C0 C1 C2 |
| Flooding        | Fl0 Fl1 Fl2 |
| Drainage        | Dr0 Dr1 Dr2 |
| Disturbance     | D0 D1 D2 |

* Optimum ecological mode stages are given in bold.

N0W2F2M2C2Fl0Dr1D0 is the formula for damp fir subor land on the near-watershed part of lower glaciolacustrine plane of Luzhsko-Tosnensky landscape, N0W2F2M2C2Fl0Dr1D0 – for the lands of wet pine forest of peripheral oligotrophic facia of proud swamp stow of the same landscape, while N0W2F2M2C2Fl0Dr1D0 is for the lands of maiden park like larch-pine pyrogenic forests of Kansko-Brysinsky loessic plain of Middle Siberia. The modes deviating from ecological optimum are marked by light-faced type and the optimum mode stages are given in bold [5, 7].

The above-mentioned formula indexes, excluding the disturbance (H), were used to evaluate the landscape and environmental properties of various wood species. The landscape and environmental properties of 18 European Russian forest-forming species were analyzed: Scots pine (Pinus sylvestris L.), Norway spruce (Picea abies (L.) Karst), Siberian fir (Abies sibirica Ledeb.), Siberian larch (Larix sibirica Ledeb.), Siberian pine (Pinus sibirica Du Tour), Silver birch (Betula pendula Roth.), Downy birch (Betula pubescens Ehrh.), Aspen (Populus tremula L.), Common oak (Quercus robur L.), Black alder (Alnus glutinosa (L.) Gaertn.), Grey alder (Alnus incana (L.) Moench.), European beech (Fagus sylvatica L.), Hornbeam (Carpinus betulus L.), Small-leaved lime (Tilia cordata Mill.), Norway maple (Acer platanoides L.), European white elm (Ulmus laevis Pall.), Mountain elm (Ulmus glabra Huds.), and ash (Fraxinus excelsior L.) [13].

In the undertaken study, it was found that the mode stages could be optimum and deviating from optimum negatively, thus affecting the development of a given wood species.

The identified and mapped natural territorial complexes (NTC), their natural borders like landscape countries, regions, districts, landscapes, landscape spots, facies were used to define ecological areas for certain wood species [5, 7, 14]. All the above-mentioned landscape units were treated as NTC of different scale level [15].
Ecological areas and optimum ecological areas were specified for each wood species.

1. *Pinus sylvestris* L.
   - Ecological area: $N_{(A,B,C,D)}W_{(0,1,2,3,4)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(0,1,2)}$
   - Optimum ecological area: $N_{(C,D)}W_{(2)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

2. *Picea abies* (L.) Karst.
   - Ecological area: $N_{(A,B,C,D)}W_{(2,3,4,5)}F_{(1,2)}M_{(1)}C_{(1)}Fl_{(0)}Dr_{(1,2)}$
   - Optimum ecological area: $N_{(D)}W_{(2,3,2)}F_{(1,2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

3. *Abies sibirica* Ledeb.
   - Ecological area: $N_{(C,D)}W_{(2,3,4)}F_{(1,2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(1,2)}$
   - Optimum ecological area: $N_{(D)}W_{(2)}F_{(1,2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

4. *Fagus sylvatica* L.
   - Ecological area: $N_{(A,B,C,D,E)}W_{(1,2,3,4)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$
   - Optimum ecological area: $N_{(D)}W_{(2)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

5. *Betula pendula* Roth.
   - Ecological area: $N_{(A,B,C,D)}W_{(1,2,3,4,5)}F_{(0,1)}M_{(1)}C_{(1)}Fl_{(0)}Dr_{(1,2)}$
   - Optimum ecological area: $N_{(D)}W_{(2)}F_{(1,2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

6. *Betula pubescens* Ehrh.
   - Ecological area: $N_{(A,B,C,D,E)}W_{(2,3,4,5,2)}M_{(0)}C_{(0)}Fl_{(0,1,2)}$
   - Optimum ecological area: $N_{(C,D)}W_{(2,3,4)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

7. *Quercus robur* L.
   - Ecological area: $N_{(B,C,D,E)}W_{(2,2,3,4,1)}F_{(0,1)}M_{(0)}C_{(0)}Fl_{(0,1)}Dr_{(1,2)}$
   - Optimum ecological area: $N_{(D)}W_{(2)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

8. *Alnus glutinosa* (L.) Gaertn.
   - Ecological area: $N_{(A,B,C,DE)}W_{(1,2,2,3,4)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0,1,2)}$
   - Optimum ecological area: $N_{(D)}W_{(2)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

9. *Alnus incana* (L.) Moench.
   - Ecological area: $N_{(A,B,C,D,E)}W_{(2,3,4,5)}F_{(0,1)}M_{(0)}C_{(0)}Fl_{(0,1)}Dr_{(1,2)}$
   - Optimum ecological area: $N_{(D)}W_{(2,3)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

10. *Fagus sylvatica* L.
    - Ecological area: $N_{(A,B,C,D,E)}W_{(2,3,4,5)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0,1,2)}Dr_{(1,2)}$
    - Optimum ecological area: $N_{(D)}W_{(2)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

11. *Carpinus betulus* L.
    - Ecological area: $N_{(A,B,C,D,E)}W_{(2,3,4,5)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0,1,2)}Dr_{(1,2)}$
    - Optimum ecological area: $N_{(D)}W_{(2)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

12. *Tilia cordata* Mill.
    - Ecological area: $N_{(A,B,C,D,E)}W_{(2,3,4,5)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(1,2)}$
    - Optimum ecological area: $N_{(D)}W_{(2)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

13. *Acer platanoides* L.
    - Ecological area: $N_{(A,B,C,D,E)}W_{(2,3,4,5)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(1,2)}$
    - Optimum ecological area: $N_{(D)}W_{(2)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

14. *Ulmus laevis* Pall.
    - Ecological area: $N_{(A,B,C,D,E)}W_{(2,3,4,5)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0,1,2)}Dr_{(1,2)}$
    - Optimum ecological area: $N_{(D)}W_{(2,3)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$

15. *Ulmus glabra* Huds.; *U. scabra* Mill.; *U. montana* With.
    - Ecological area: $N_{(A,B,C,D,E)}W_{(2,3,4,5)}F_{(0,1,2)}M_{(0)}C_{(0)}Fl_{(0,1,2)}Dr_{(1,2)}$
    - Optimum ecological area: $N_{(D)}W_{(2,3)}F_{(2)}M_{(0)}C_{(0)}Fl_{(0)}Dr_{(2)}$
Optimum ecological area: $N_{(2)}W_{(2,3)}F_{(2)}M_{(0,0)}C_{(0,0)}Fl_{(0,0)}Dr_{(2)}$

18. *Fraxinus excelsior* L.

Ecological area: $N_{(0)}W_{(1,2,3,4)}F_{(2)}M_{(0,0)}C_{(0,0)}Fl_{(0,1,2)}Dr_{(2)}$

Optimum ecological area: $N_{(2)}W_{(2)}F_{(2)}M_{(0,0)}C_{(0,0)}Fl_{(0,0,01)}Dr_{(2)}$

3. Conclusions

The study considered the mainwood species that comprise forest communities of the European Russian landscapes. Particular attention was paid to the relationship between various wood species and ecological modes in areas, since this relationship defines geographical coverage of crop canopy in natural territorial complexes.

The analysed data on environmental properties of wood species makes it possible to identify the ecotopes of the species distribution, thus explaining the forest community structure and identifying the types of landscape facies whose ecological modes preventa species from appearing in the area.

The study results make it possible to define the ecological mode where the wood species vegetates under optimum conditions and achieves best growth and development. In other words, it gives ground for establishment planning, stand renewal prospects, forest valuation, accounting for different forest resources, monitoring areas with different ecological modes, and simplifies the decoding of data collected during forest landscape remote sensing.

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