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Phytoindication evaluation of ecological regimes

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Abstract

The calculation of environmental parameters was conducted using phytoindication scales. The scale developed by Didukh [1] enables ordination analysis based on 12 factors: soil humidity (Hd), soil moisture variability (fH), soil aeration (Ae), soil nitrogen content (Nt), soil acidity (Rc), salt regime (SI), carbonate content (Ca), temperature regime (Tm), ombroregime (Om), climate continentality (Kn), cryoregime (Cr), and light intensity (Lc). The method offers a technique for converting phytoindication scales into measurable physical units

1 Phytoindication evaluation of ecological regimes

The calculation of environmental parameters was conducted using phytoindication scales. The scale developed by Didukh (Didukh, 2011) enables ordination analysis based on 12 factors: soil humidity (Hd), soil moisture variability (fH), soil aeration (Ae), soil nitrogen content (Nt), soil acidity (Rc), salt regime (Sl), carbonate content (Ca), temperature regime (Tm), ombroregime (Om), climate continentality (Kn), cryoregime (Cr), and light intensity (Lc). The plant ecological groups are categorised into 23 gradations based on their relationship to the humidity regime (Didukh, 2011). The moisture regime scores can be converted into phytoindication estimates of the productive moisture stock within the one-meter soil layer, as outlined by Maslikova (2018a) and Molozhon *et al.* (2023):

$$W = 18.65 \exp(0.15H),$$

where W represents the content of productive moisture in the one-meter layer of soil (measured in millimetres), and H indicates a score of the moisture regime. A productive moisture content of less than 60 mm in a one-meter layer is classified as very low; a content ranging from 60 to 90 mm is classified as low; a content between 90 and 130 mm is deemed satisfactory; a content ranging from 130 to 160 mm is considered good; and a content exceeding 160 mm is classified as very good for agricultural plants (Vadunina & Korchagina, 1986).

The plant ecological groups were categorised into 12 gradations based on their relationship to the soil moisture variability. These scores can be converted into the coefficient of irregularity of soil moisture (ω), which ranges from 0 (indicating the lowest level of contrast in moisture conditions, such as consistently moist or consistently dry habitats) to 0.5 (indicating the highest level of contrast in moisture conditions, where nearly complete water immersion is followed by drought). The indicator scores of soil moisture variability can be converted to

the moisture irregularity coefficient as follows (Maslikova, 2018):

$$\omega = 0.042fH - 0.032,$$

where ω is the coefficient of irregularity of soil moisture, and fH is an indicator score of soil moisture variability.

The plant ecological groups were categorised into 15 gradations based on their relationship to the aeration regime. These scores can be converted into the percentage of air-filled porosity relative to the total porosity volume as follows (Maslikova, 2018):

$$P = \frac{100 - Ae^4}{100 * (Ae^4 + 1700)},$$

where P represents the air-filled porosity percentage, which is the percentage of the total volume of pore space in the soil, and Ae denotes the score of the aeration regime.

The plant ecological groups are categorised into 15 gradations based on their tolerance to soil acidity. These scores can be converted to the pH of the soil aqueous solution as follows (Maslikova, 2018c):

$$\text{pH} = 2.26 \ln(Rc) + 1.88,$$

where pH is defined as the negative logarithm of the concentration of hydrogen ions in the soil solution, while Rc represents the acidity score.

The plant ecological groups are categorised into 19 gradations based on their relationship to the overall salt regime. These gradations can be converted into water-soluble salt content as follows (Maslikova, 2018c):

$$S = 2^{0.6SI+1},$$

where S represents the salt content in the soil solution, measured in micrograms per litre ($\mu\text{g/l}$), and SI denotes the score of the soil salinity regime.

The plant ecological groups were categorised into 13 gradations based on their response to the carbonate content of the soil. The scores can be converted to $\text{CaO} + \text{MgO}$ content as follows (Maslikova, Zhukov & Kovalenko, 2019):

$$\text{CaO} + \text{MgO} = 14 \frac{Ca^{4.5}}{Ca^{4.5} + 45000},$$

where $\text{CaO} + \text{MgO}$ is the carbonate content, expressed in terms of calcium and magnesium oxides (%). Ca serves as a score for the carbonate content.

The plant ecological groups are categorized into 11 gradations based on their relationship to soil nitrogen content. The scores can be converted to soil nitrogen content as follows (Maslikova, Zhukov & Kovalenko, 2019):

$$N = 5 \frac{Nt^{3.7}}{Nt^{3.7} + 345},$$

where N represents the soil's nitrogen content, measured in grams per kilogram (g/kg), and Nt is a score that indicates the soil's trophic regime.

The plant ecological groups are categorised into 17 gradations based on their relationship to the thermal regime. These scores can be translated into a radiation balance as follows (Molozhon et al., 2023):

$$RB = 0.21 Tm,$$

where *RB* is the radiation balance measured in $gJ\ m^{-2}\ year^{-1}$, while *Tm* represents the thermal regime score, one must note that if the radiation balance is expressed in $Kcal\ cm^{-2}\ year^{-1}$, one can multiply the score by 5.

The plant ecological groups are classified into 23 categories based on their relationship to atmospheric humidity regimes. Ombroclimate scores can be interpreted as the difference in the amount of precipitation before evaporation from open water surfaces, measured annually in terms of average days (Molozhon et al., 2023):

$$Hum = 0.54 Om - 7,$$

where *Hum* represents the difference between the average daily precipitation and the evaporation from the open water surface over the same period, measured in millimetres (mm). *Om* denotes the climate humidity score.

The plant ecological groups are categorized into 17 gradations based on their relationship to continentality. The continentality scores can be converted to the Ivanov continentality scale (Ivanov, 1959) as follows (Molozhon et al., 2023):

$$SKn = 10 Kn + 41,$$

where *SKn* represents the Ivanov continentality scale, *Kn* denotes the score of the continentality regime.

The plant ecological groups are divided into 15 gradations based on their relationship to the cryoclimate. The cryoclimate scores can be converted to reflect the average temperature of the coldest month of the year as follows (Molozhon et al., 2023):



$$Temp = 3.83 Cr - 38.17,$$

where *Temp* represents the average temperature of the coldest month of the year, measured in degrees Celsius (°C), while *Cr* is a score that indicates the cryoclimate.

The relationship between the measured light and the photoinduction assessment of light levels is as follows:

$$\begin{aligned} \log_Lighiting \\ = 0.22 * L\text{-value}, \end{aligned}$$

where $\log_Lighiting$ is the decimal logarithm of the relative light level, *L*-value is the phytoindication assessment of the light level according to the Ellenberg scale.

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