Landolt Indicator Values in Modern Research

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The conservation of biodiversity and ecosystem sustainability is essential for human well-being. An important tool for addressing this issue is ecological indicators.

Keywords: bioindication ; ecological indicator values ; environmental gradients

1. Introduction

The anthropogenic impacts on natural ecosystems are constantly increasing and multiplying the effects of global climate warming, with serious and sometimes catastrophic consequences. The likelihood of local and global environmental crises is steadily increasing [1,2]. The biodiversity of natural ecosystems is decreasing every year. This is causing concern about the preservation of a favorable habitat for humanity [3,4].

The compositions, structures and dynamics of plant communities are determined by a complex of environmental factors [5,6,2]. However, it is practically impossible to evaluate these factors by one-time accounting without long-term stationary studies, since daily, seasonal and year-to-year variability of indicators will not be taken into account. Ecological indicator values make it possible to assess the cumulative impact of factors, since they link the signs of vegetation and gradients of the leading environmental factors [2]. The assessment of habitats by ecological indicator values has a number of advantages. Firstly, this is not an economically costly method. Secondly, the assessment takes into account not only the total impact of the environment but also the influence of each factor on the vital activity of plants.

The first version of the Landolt indicator values characterized more than 3000 species of flora in Switzerland according to 17 different ecological characteristics [1]. Over the next 30 years, he continued to collect information on the ecology of individual species from the literature and compare it with his own research. As a result, Landolt and his colleagues published the second edition of ecological indicator values—“Flora indicativa” [1]. More than 3400 species and intraspecific taxa of plants were characterized in relation to light availability (L), temperature (T), continentality (K), soil moisture/water availability (F), soil reaction/pH (R), soil nutrients/fertility (N), soil dispersion/aeration (D) and humus content (H). Each environmental factor is evaluated with five scores, where 1 means low, and 5 means high. In addition, Landolt and others [1] assigned plant species to eight different habitat groups: plants of fertile meadows, mountain plants, plants of dry and nutrient-poor meadows, pioneer plants at low elevation, moor and marsh plants, weeds and ruderal plants, forest plants and water plants.

Mean ecological indicator values are calculated at the community level by weighing the species values according to the width of their niche, that is, giving twice as much weight to species with narrow requirements [1] without taking into account the relative coverage of species. The calculation of the ecological indicator values can be carried out using Vegan and BiodiversityR packages in the free software environment R. For these purposes, the lvalue function in the vegan package [7] and the lindval function in the BiodiversityR package [8] are used. These functions calculate the Landolt indicator values for each species in a set of vegetation plots based on the method described by Landolt [1]. This method involves weighing the abundance of each species by its fidelity (i.e., the proportion of plots in which it occurs) and the average fidelity of the indicator group. Russian developers have also developed software for calculating environmental indicators [9].

Landolt indicator values are used less frequently than Ellenberg indicator values. The use of Landolt ecological indicators is particularly successful in the analysis of alpine communities [10], since many alpine plant species are included in them. The popularity of Landolt indicator values is due to the following positive qualities: numerous plant species are described, more (compared to Ellenberg indicator values) environmental parameters are included, and the availability of software for calculation. The negative qualities of using these indicators are that they are not suitable for all plant communities, and also that they need to be adapted for new regions where the flora is very different from that of the European Alps.

Some researchers carried out work on recalibrating the Landolt indicator values and adapting them for the use in new regions [1]. It was found that 2000 vegetation records are a sufficient basis for an optimal recalibration of vegetation types [1]. Recalibrated ecological indicator values and niche width increase ecological knowledge on plants. The research results show that the use of the Landolt indicator values is possible for such regions as the Caucasus [11]. The Landolt indicator values are used in Russia (often in combination with the Ellenberg indicators) to characterize habitats and study the dynamics of vegetation cover and other important environmental problems [1].

The Landolt indicator values are discussed. Researchers have proven that restrictions in the use of the mean indicator values' species-based traits concern statistical tests (ANOVA, especially when using PCA scores) that assume statistical independence from species scores when there is none [12]. It was published that the analysis of habitats using these ecological indicator values can produce fairly reliable information regarding the thickness of the humified residue horizon and, thus, the humus form [13].

At the moment, there are no studies with a comprehensive analysis of the use of Landolt indicator values. The lack of this information complicates the development and practical application of the Landolt indicator values. Therefore, a comprehensive review of this method is necessary for the scientific community and important for the practical application of environmental indicators.

2. Materials and Methods

Data collection was carried out for the period from 2018 to 2022. We used the PRISMA guidelines and guidelines for environmental science studies [1] in conducting this research. "Landolt indicator values" was the search term. Google Scholar, ScienceDirect, Mendeley, SciProfiles were selected to search for information. This research stage was conducted in the period from December 2022 to January 2023.
This scientific analysis was limited to articles with DOIs that were published between 2018 and 2022. However, the use of PRISMA guidelines and guidelines for environmental science research, as well as the strict selection/quality criteria for reviewing papers, enabled us to conduct our research analysis at a high scientific level and to achieve the set aim.

3. Main results

The analysis of modern studies based on the Landolt indicator values revealed their effectiveness for solving a whole range of urgent problems, including for assessing environmental factors, habitat stability, vegetation dynamics, climate changes and ecological niches. All of these scientific fields are extremely important for solving the problems of sustainable nature management and biodiversity conservation. The range of plant communities for which the Landolt indicator values performed well is quite diverse and is not limited only to mountain meadows, for which they were originally developed. Although the Landolt indicator values were originally developed for the analysis of mountain vegetation in the Alps, studies demonstrated their effectiveness for the analysis of environmental factors in forests, fens, riparian vegetation, quarries, coarse quarry waste dumps, as well as for urban planting and landscaping. We assume that using the Landolt indicator values to study forest-meadow and forest-steppe ecotones, including the upper and northern Teeline, will give clearer results than the Ellenberg indicator values. We base this conclusion on the fact that the Landolt indicator values are specifically designed for the study of mountain areas. We therefore recommend their wider use in these plant communities. This recommendation aims to address the lack of information on environmental factors in a number of studies [14, 15]. For sustainable management of natural resources, monitoring of climate change and anthropogenic changes, this method is therefore important. The geography of using the Landolt indicator values is quite wide, while they are more often used in Switzerland, Italy and Russia. The active citation of the papers confirms the interest of researchers in the Landolt indicator values and their theoretical and practical importance. In general, our study revealed that the Landolt indicator values can serve as an effective universal method that integrates many aspects of the environment and allows for a comprehensive multicriteria analysis of environmental factors, habitat stability, vegetation structure and dynamics for different plant communities at different spatial scales over a wide geographical area. Mining and mineral processing wastes occupy vast areas around the world and are pollution sources [1, 16,17]. Therefore, it is very important to recycle industrial wastes and reclaim the disturbed landscapes. The result of successful reclamation is sustainable, productive and economically valuable ecosystems. We hope that our research analysis will contribute to the expansion of the use of the Landolt indicator values in this extremely important scientific field, and that they will be used more widely to create sustainable and favorable living conditions for people not only in rural areas but also in cities. We recommend the Landolt indicator values for a wider use, including monitoring of the sustainability of habitats, ecosystems and individual species for their conservation and sustainable management.
Unfortunately, our findings reveal inadequate scientific collaboration among researchers using the Landolt indicator values. Only a few researchers actively interact with the scientific community and create centers of cooperation in the

form of large scientific projects (including interdisciplinary projects), which attract researchers from different countries to working together [18]. These centers create the most significant and highly cited works. We hope that our research will provide a new impetus for further development of the methodology of ecological indicators, foster its more extensive use and strengthen the understanding of the necessity and prospects of scientific collaboration. The Landolt indicator values will undoubtedly be useful in forest typology, which is the basis for forest management and reforestation in many countries [19, 20]. We also hope that the results obtained will be beneficial to young researchers in choosing their scientific paths in the development of sustainable natural resource management, biodiversity conservation and habitat preservation.
