Functional approach in estimation of cultural ecosystem services of recreational areas

I S Sautkin and T V Rogova

Institute of Environmental Sciences, Kazan Federal University, Kremlevskaya str.,18, 420008, Russia
E-mail: sautkin.ilia@gmail.com

Abstract. The article is devoted to the identification and analysis of cultural ecosystem services of recreational areas from the different forest plant functional groups in the suburbs of Kazan. The study explored two cultural ecosystem services supplied by forest plants by linking these services to different plant functional traits. Information on the functional traits of 76 plants occurring in the forest ecosystems of the investigated area was collected from reference books on the biological characteristics of plant species. Analysis of these species and traits with the Ward clustering method yielded four functional groups with different potentials for delivering ecosystem services. The results show that the contribution of species diversity to services can be characterized through the functional traits of plants. This proves that there is a stable relationship between biodiversity and the quality and quantity of ecosystem services. The proposed method can be extended to other types of services (regulating and supporting). The analysis can be used in the socio-economic assessment of natural ecosystems for recreation and other uses.

1. Introduction

The concept of ecosystem services (ES) accepted under the UN program, the Millennium Ecosystem Assessment (MEA) [1] has become a formal approach for describing and classifying possible interactions between ecosystems and society [2]. The concept of ES has found wide application at the international level in ecology, economics and politics [3, 4, 5]. Ecosystem services are defined as conditions and processes that have value for people. MEA has defined cultural ES as "the intangible benefits that people derive from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience, including, for example, knowledge systems, social relations and aesthetic values" [1], [6]. In most studies on the assessment of ES, environmental processes that are not directly related to human well-being are considered [7]. In addition, in research, cultural services are regularly referred to as a category of ES and are therefore recognized as important, but in part because of the focus on economic evaluation, many cultural ES are subsequently ignored [8]. There are several studies on ecosystem-based recreation [9] and the attractiveness of landscapes [10, 11], but other cultural services are usually not characterized.

Modern research, focusing on ecosystem services as an instrument for assessing ecosystems and promoting their sustainable use [1], also draws attention to the ways in which different organisms contribute to the delivery of ecosystem services [12, 13, 14, 15]. The ability of the ecosystem to provide several services involves distribution of the relevant ecosystem properties to determine which organisms or groups of organisms control these properties [12, 16]. Then, it is necessary to identify the
key characteristics and mechanisms by which these organisms influence ecosystem properties [17, 18, 19]. This method has been used in a growing number of studies, e.g. [20, 21, 22]. In addition, studies have used the identification of functional traits as a key mechanism by which individual species [15] and species groups [23, 24], affect ecosystem properties. Thus, there is growing recognition that the abundance of functional traits in biotic communities can greatly contribute to the assessment and management of ecosystem services [25, 13].

The objective of this work was an attempt to identify cultural ES and functional traits of plants that supply these services. A technique was tested that allows (a) linking individual plant characteristics and services, (b) their mutual relations, and (c) the contribution of each species to the supply of cultural ES. The study was conducted in pine forests on the territory of the forest park "Lebyazhye" in suburbs of Kazan.

2. Material and methods

Forest park "Lebyazhye" occupies an area of 3729 hectares in the Kirov district of Kazan. About 16% of the area is occupied by buildings, roads, garbage, and wasteland; approximately 70% of the total area is forest. The forest park has an important recreational significance for the population of Kazan and surrounding villages. There are children's recreation camps, health and holiday facilities, and areas for sports competitions. Good transport links cause high traffic volumes to this forest most of the year.

In the forest park, 399 species of higher vascular plants are currently found. Native types of forest phytocoenoses account for no more than 6% of the forest area. Among them are associations of the classes Vaccinio-Piceetea Br.-Bl. in Br.-Bl., Siss. Et Vlieger 1939 and Carpino-Fagetea sylvaticae Jakuc ex Passarge 1968. Dominants in the forest ground cover of Pinus sylvestris-derived communities include Pteridium aquilinum, Convallaria majalis, Calamagrostis epigeous, Agrostis tenuis, Poa angustifolia, and other graminoids and ruderal plant species. In broad-leaved forests, Betula pendula and Populus tremula dominate, and graminoids and ruderal plant species dominate in the ground cover. Small fragments of area are represented by meadows and coastal vegetation around the lakes.

The attractiveness of forests for recreation is largely determined by their aesthetic properties, which depend on various characteristics of the stand, including its composition, because wood species are characterized by different decorative qualities. The composition of the stand influences the stability of forest ecosystems devoted to recreational uses, because woody species differ in their susceptibilities to the effects of recreation. The most attractive are pine forests with a share of other species of 30-50%. Variable tree distributions and low stand densities of pine forests, clustered in groups with a rare juvenile and / or undergrowth, significantly increase the attractiveness of forests for recreation [26].

Nine test plots of 20 × 20 m² were established on four quarters (83, 82, 101, and 102) of the “Lebyazhye” forest park. For each plot a geobotanical description was compiled. The plot laid in quarter 83 belonged to the Pinus sylvestris forest at the 2nd and 3rd stages of recreational uses with the dominance of Convallaria majalis in the ground cover. Mosses were found only near tree trunks (5-10%). Grass stands cover 80-90%, of which 10-20% are meadow grasses. The plots on 82, 101, and 102 belonged to Pinus sylvestris forests at the 3nd and 4rd stages of the recreational use with the dominance of grasses and ruderal herbs. All plots were outside the road network and trampled and dead-cover sites. A total of 76 plant species were identified at all sites.

Based on the methods of Garcia-Llorente [27], the functional features of plants and socio-cultural ES of interest were identified. Information for the search and identification of traits and socio-cultural services was from [28, 29, 30, 31, 32].

For the analysis, the following functional traits were selected:

- Life form: herbs, shrubs, dwarf shrubs and trees;
- Plant height;
- Attractiveness of flowers, fruits and leaves: For fruit, attractiveness is determined by bright color; for flowers, by size, bright color, and pleasant fragrance; and for leaves by size, architecture, presence of pubescence, and changed colors in autumn;
• Early phenology: active growth and flowering until June;
• Lifespan: annual / biennial and perennial;
• Not poisonous.

The classification of functional plant groups was carried out by cluster analysis. Data on 76 described species and 11 selected traits were used. The cluster analysis was carried out according to Ward's algorithm, and the Euclidean distance was used as a metric of similarity [33].

Based on the classification of MEA services, two types of cultural services were selected for research: aesthetic and recreational services. For each type of service, an influential set of functional plant traits was determined.

For aesthetic services, the following traits were selected: life form (herbs, shrubs and dwarf shrubs); plant height; attractiveness of flowers, fruits and leaves; early phenology; and lifespan.

For recreational services, the following traits were selected: life form (trees and herbs); plant height; attractiveness of leaves; lifespan, and not poisonous.

The classification of functional groups and data on the sets of characteristics affecting the selected types of services were used to assess the contributions of each species to the provision of services.

3. Result and discussions

The results of cluster analysis showed the presence of 4 functional groups (figures 1 and 2).

Figure 1. Cluster dendrogram based on 11 functional traits.

Group 1. It includes 6 species (8%) belonging to 5 families (Pinaceae, Betulaceae, Fagaceae, Tiliaceae and Salicaceae). Species in this group (Pinus sylvestris, Picea fennica, Betula pendula, Quercus robur, Tilia cordata, Populus tremula) are tree forms and are characterized as perennials with high growth (more than 20 m) and high leaf attractiveness. This set of indicators indicates the high (100%) contribution of the group to recreational services. In aesthetic services, the contribution of the group is insignificant.

Group 2. It includes 11 species (14%) belonging to 6 families (Rosaceae, Fabaceae, Ericaceae, Cupressaceae, Celastraceae and Rhamnaceae). Species in this group are predominantly shrubs, and 4 species are dwarf shrubs. Representatives of all six families are characterized by the high contribution to aesthetic services (100%). The leading species are the following representatives of the Rosaceae (Amelanchier canadensis, Padus avium, Rubus idaeus, Sorbus aucuparia), Fabaceae (Chamaecytisus ruthenicus, Genista tinctoria) and Ericaceae (Vaccinium myrtillus, Vaccinium vitis-idaea). Only 3 species (Padus avium, Sorbus aucuparia, Vaccinium vitis-idaea) are characterized by a contribution to recreational services (27%).

Group 3. The group includes the largest number of species – 39 (51%) belonging to 16 families (Asteraceae, Caryophyllaceae, Lamiaceae, Rosaceae, Convallariaceae, Violaceae, Crassulaceae, Scrophulariaceae, Hypericaceae, Onagraceae, Poaceae, Chenopodiaceae, Dipsacaceae, Fabaceae, Rubiaceae, Ranunculaceae and Solanaceae). The group is represented by herbaceous plants.
Representatives of the group have a high contribution to both aesthetic (66%) and recreational services (79%). The greatest effect on services is rendered by the representatives of the Asteraceae (Centaurea sumensis, Trommsdorfia maculata, Hieracium pilosella, Tanacetum vulgare, Hieracium umbellatum, Leontodon hispidus, Solidago virgaurea, Antennaria dioica), Scrophulariaceae (Veronica spicata, Veronica chamaedrys, Veronica officinalis, Linaria vulgaris), Caryophyllaceae (Dianthus deltoides, Dianthus pratensis, Steris viscaria, Silene nutans), Lamiaeae (Prunella vulgaris, Glechoma hederacea), Rosaceae (Fragaria vesca, Potentilla argentea), Convallariaceae (Convallaria majalis, Polygonatum odoratum), Violaceae (Viola canina, Viola rupestris), and Crassulaceae (Sedum maximum, Sedum telephium).

Figure 2. Ordination of species on 11 functional traits.

Note. Group 1. (A, 1). Group 2. (B, 2, 3, 4, 5, 6, 7, 8, 9). Group 3. (C, D, E, F, G, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19). Group 4. (H, J).

Group 4. The group includes mostly graminoid herbs (Poaceae, Juncaceae and Cyperaceae), but there are representatives of other families also (Pyrolaceae, Polygonaceae, Asteraceae and Apiaceae). In total, the group has 20 species (27%). A high contribution of the group to recreational services was found (90%), provided by the representatives of the Poaceae (Agrostis tenuis, Agrostis vinealis, Anthoxanthum odoratum, Calamagrostis arundinacea, Calamagrostis epigeios, Melica nutans, Phleum phleoides, Poa angustifolia, Poa nemoralis, Poa trivialis), Cyperaceae (Carex digitata, Carex ericetorum, Carex rhizina), Juncaceae (Luzula pilosa, Juncus atratus) and Pyrolaceae (Chimaphila umbellata, Orthilia secunda). The contribution of the group to aesthetic services is negligible.

Analysis of the data made possible the following conclusions. Among the 76 species, 41 species (54%) contribute to aesthetic services, and 59 species (77%) to recreational services. The greatest contribution to aesthetic services is provided by beautifully flowering and ornamental shrubs, dwarf shrubs and herbs, as well as plants with early vegetation. They include representatives of the families Rosaceae (6 species), Asteraceae (5 species), Caryophyllaceae (3 species), Cyperaceae (3 species), Fabaceae (3 species), Convallariaceae (2 species), Crassulaceae (2 species), Ericaceae (2 species), Lamiaeae (2 species), Violaceae (2 species). The high contribution of sedge to aesthetic services is due to the early vegetation of the species encountered. A lower contribution to aesthetic services is provided by trees, herbs, and ruderal species. Recreational services were more influenced by trees and
herbs, and the ruderal species have a low impact. The largest contribution made by the following families: Poaceae (10 species), Asteraceae (8 species), Caryophyllaceae (5 species), Rosaceae (4 species), Scrophulariaceae (4 species), Juncaceae (2 species), Pinaceae (2 species), Cyperaceae (3 species), Crassulaceae (2 species), Pyrolaceae (2 species), Violaceae (2 species).

The results obtained show that the contribution of species diversity to services can be characterized through the functional traits of plants. This shows a relationship between biodiversity and the quality and quantity of ecosystem services. The proposed method, in the future, can be extended to other types of services (regulating and supporting); the data can also be used in the socio-economic assessment of natural ecosystems for recreational and other uses. Using more species and functional traits will improve the accuracy of estimates.

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