Science of the Total Environment 613–614 (2018) 263–270

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Abundance of large old trees in wood-pastures of Transylvania (Romania)

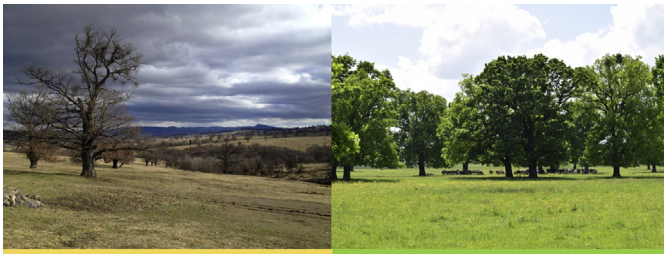
Tibor Hartel [a,b,*], Jan Hanspach [c], Cosmin I. Moga [d], Lucian Holban [d], Árpád Szapanyos [d], Réka Tamás [e], Csaba Hováth [f], Kinga-Olga Réti [g]

[a] Ecosystem Services Laboratory, Department of Environmental Sciences, Sapientia Hungarian University of Transylvania, Cluj-Napoca, Romania
[b] Babes-Bolyai University, Hungarian Department of Biology and Ecology, Strada Clinicilor, Cluj-Napoca, Romania
[c] Institute of Ecology, Leuphana University Lueneburg, Scharnhorstrtr 1, 21335 Lueneburg, Germany
[d] Ecotransilvania Assoctiation, str. Tabacarilor 1, Sighisoara, Romania
[e] Pogány-havas Association, 530203 Romania, Csíksomlyó, Szék street 123, Romania
[f] Babes-Bolyai University, Physical and Technical Geography Department, Str. Clinicilor Clinicilor 5-7, 400006, Romania
[g] Faculty of Environmental Science and Engineering, RO-400294, Fântânele Street 30, Babes-Bolyai University, Cluj-Napoca, Romania

HIGHLIGHTS

- We comprehensively surveyed large old trees in Transylvanian wood-pastures.
- Tree abundance of four species was modeled using generalized linear models.
- Species differed in their sensitivity to different environmental variables.
- Transylvanian ancient wood-pastures have global agriculture heritage values.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 25 June 2017
Received in revised form 5 September 2017
Accepted 6 September 2017
Available online xxxx

Editor: Elena Paoletti

Keywords:
Ecological keystone
Large old tree
Veteran tree
Wooded pasture
Conservation
Remarkable trees of Romania
Transylvania
Eastern Europe

ABSTRACT

Wood-pastures are special types of agroforestry systems that integrate trees with livestock grazing. Wood pastures can be hotspots for large old tree abundance and have exceptional natural values; but they are declining all over Europe. While presence of large old trees in wood-pastures can provide arguments for their maintenance, actual data on their distribution and abundance are sparse. Our study is the first to survey large old trees in Eastern Europe over such a large area. We surveyed 97 wood-pastures in Transylvania (Romania) in order to (i) provide a descriptive overview of the large old tree abundance; and (ii) to explore the environmental determinants of the abundance and persistence of large old trees in wood-pastures. We identified 2520 large old trees belonging to 16 taxonomic groups. Oak was present in 66% of the wood-pastures, followed by beech (33%), hornbeam (24%) and pear (22%). For each of these four species we constructed a generalized linear model with quasi-Poisson error distribution to explain individual tree abundance. Oak trees were most abundant in large wood-pastures and in wood-pastures from the Saxon cultural region of Transylvania. Beech abundance related positively to elevation and to proximity of human settlements. Abundance of hornbeam was highest in large wood-pastures, in wood-pastures from the Saxon cultural region, and in places with high cover of adjacent forest and a low human population density. Large old pear trees were most abundant in large wood-pastures that were close to paved roads. The maintenance of large old trees in production landscapes is a challenge for science, policy and

* Corresponding author at: Ecosystem Services Laboratory, Department of Environmental Sciences, Sapientia Hungarian University of Transylvania, Cluj-Napoca, Romania.
E-mail address: hartel.tibor@gmail.com (T. Hartel).

http://dx.doi.org/10.1016/j.scitotenv.2017.09.048

local people, but it also can serve as an impetus for integrating economic, ecological and social goals within a landscape.

1. Introduction

Achieving biodiversity conservation in commodity production landscapes has become a key challenge for scientists, policy makers and practitioners alike (Foley et al., 2011). Particularly traditional farming landscapes provide powerful examples of simultaneously providing economic, social and ecological benefits from single landscapes (Barthel et al., 2013; Fischer et al., 2017). However, the unbroken trend of land use intensification puts many of these traditional systems at risk of losing their unique and multifunctional characteristics including their small natural features that often have disproportionally high natural values (Bignal and McCracken, 2000; Benton et al., 2003; Lindenmayer, 2016). Large old trees (sometimes referred to as 'veteran trees') are such 'small natural features' acting as keystone habitats in many terrestrial ecosystems (Lindenmayer, 2016). The hollowing parts and the ageing bark of these trees provides a wide diversity of microhabitats (Paillet et al., 2017) from which several organisms can benefit, such as lichens (Paltto et al., 2011), insects (Sverdrup-Tygeson et al., 2010; Lachat et al., 2012; Landvik et al., 2016; Milberg et al., 2016), and vertebrates (e.g. Piraccini et al., 2017; Dorresteijn et al., 2013; Lindenmayer, 2016). Large old trees play an important role in nutrient cycling (Lindenmayer and Laurance, 2016), carbon storage (Fedrigo et al., 2014; Sist et al., 2014) and as biological legacies (Manning et al., 2006, 2009). Large old trees can also have high socio-cultural importance in particular contexts (Blicharska and Mikusiński, 2014), but are typically removed from landscapes managed for commodity production (Orlowski and Nowak, 2007; Lindenmayer, 2016). Nevertheless large old trees are generally not covered by policy regulations (e.g. forestry, agricultural and nature conservation, Lindenmayer et al., 2014).

Wood-pastures are a particular land use type that traditionally combined scattered trees with livestock grazing all over Europe (Plieninger et al., 2015a). While this land use type in Europe is sometimes referred to as 'wooded pasture' or 'pasture woodland' (for other names see Hartel and Plieninger, 2014), we use the term wood-pasture (as used in e.g. Vera, 2000), which emphasizes the equal importance of trees and pasture. Traditionally managed wood-pastures typically concentrate proportionally more large (old) trees than (managed) forests (Hartel et al., 2013; Plieninger et al., 2015b). This is because the scattered trees on pastures are also valued for other products than just timber, such as shade and fruits and trees can fulfill these functions even if they age. Although large old trees may be commonly present in wood-pasture systems (see e.g. Quelch, 2002 for Scotland), studies addressing the factors affecting their abundances are still scarce in Central and Eastern Europe. For example Varga and Molnár, 2014 showed that large old trees are characteristic but highly vulnerable features of Hungarian wood-pastures, and they are diminishing due to forestation and removal. In the present study we assessed the abundance of large old trees belonging to multiple taxa in wood-pasture systems across Transylvania in order to understand what determines the persistence of large old trees in this landscape. More specifically we are pursuing the following goals:

(i) To provide a descriptive overview over the size distribution and abundance of the large old trees in wood-pastures of Transylvania; and.

(ii) To explore the environmental determinants of the current abundance of large old trees in wood-pastures of Transylvania.

We hypothesized that:

- The number of large old trees is higher in wood-pastures at higher elevation, wood-pasture with larger size and wood-pastures with larger proportion of forest cover in their surroundings (H1).
- The number of large old trees is higher in wood-pastures situated at larger distances from human settlements, roads and with low human population in the vicinity (H2).
- There are regional differences in the abundance of large old trees in wood-pastures because of historical differences in land use and management (H3).

We tested these three hypotheses using the four most abundant deciduous tree species from the surveyed wood-pastures (oak, beech, hornbeam, pear).

2. Materials and methods

2.1. Defining large old trees

There is no unanimously accepted definition for what is a large old tree; this will depend on the specific ecosystem where the tree developed, the region addressed, the species specific biological characteristics as well as subjective judgments of various authors (summarized in Lindenmayer and Laurance, 2016). Most commonly the sizes of trees are assessed by measuring circumference (cm) or diameter (cm) of the trunk. Although we acknowledge that the size may not always indicate age (and vice versa), we used trunk circumference as a 'proxy' for tree age, assuming that within the same ecosystem type, environmental conditions and tree species, larger trees may indicate older ages (Lindenmayer and Laurance, 2016). Nevertheless, the trees from the size categories presented below typically showed several of the physiognomic characteristics of the large old trees including ageing and detaching bark, large hollows in the trunks and dried components.

Table 1 presents the lower threshold size of trunk circumferences for considering a tree to be 'large old'. For the most common trees (oak, beech, hornbeam, pear) the selected thresholds includes between 2 and 6% of the measured trees in a large sample size of trees for the continental biogeographic region of Transylvania (Hartel et al., 2013). For the other taxa (Table 1) we choose thresholds based on our intuition gathered after intensive wood-pasture and forest surveys across Transylvania.

2.2. Field surveys

We surveyed 97 wood-pastures, within the elevation range of *ca* 200–1000 m above sea, in an area of *ca* 25,000 km^2 in Transylvania (Romania). Surveys were conducted in 2015 and 2016, within the project Remarkable Trees of Romania (RToR, available at this website, also in English: https://arboriremarcabili.ro/en/). The surveyed wood-pastures are presented in Fig. 1 and the Google Earth map of Annex 1. Wood-pastures were primarily identified with the free program Google Earth Pro. Tree canopies were clearly visible in the satellite images covering the whole surface of our study region. Thus, we were able to effectively identify wood-pastures based on the typical scattered distribution of tree canopies (Hartel et al., 2013). Field surveys confirmed the existence of wood-pastures as derived from Google Earth in every case. We did not detect any wood-pasture in the Transylvanian Plain (3900 km^2), therefore this region of Transylvania is not represented by any wood-pastures in our database. Large old trees were surveyed by two experienced persons across the entire surface of the wood-pasture. Trunk circumference was individually measured for each tree at the level of stems at a height of 130–150 cm (Moga et al., 2016). Trees were furthermore uploaded in the online database RToR (see above) with characteristic picture, exact