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DIETARY COMPOSITION OF EURASIAN OTTER (*LUTRA LUTRA* LINNAEUS, 1758) IN THE EASTERN RHODOPE MOUNTAINS (BULGARIA)

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Abstract

Eurasian otter as a specialised carnivore on hydrobionts is often a subject of speculative believes from fishermen and fishery farmers. Dietary analysis of this species was performed by remnants of bones, scales, feathers and other undigestible components in the faeces. Collected in the Eastern Rhodope Mts. otter spraints showed the species composition, weight, percentage, and size and age composition of the preyed animals (mostly fishes). Food preferences of otter populations in the area and the importance of this species for the hydrobionts were analysed and evaluated. Otter's ecological plasticity was examined with regard to nutrition, in dependence on habitat's type and available food base. We found that the most preferred fish preys are with medium body size 10–12 cm and weight 80–90 g. The main fish species in the studied area are the chub, barbel and nase, and additional are the bleak, perch, roach, silver carp, bitterling, sunfish and ruffe.

Key words: diet analysis, food preferences, feeding habits, prey fish size.

Introduction

The Eurasian otter (*Lutra lutra* Linnaeus, 1758) (Carnivora: Mustelidae) is a top predator found in many aquatic and wetland ecosystems. As the highest level of food pyramid, the otter, and more precisely the condition of its population, is used as a biological indicator for the state of the environment (Chanin 2003a). The presence of a stable population of this species is a mandatory criterion in categorising a territory as prior according to the Ramsar Convention.

The otter is one of the most endangered mammals in much of Europe (Mason and Macdonald 1986). In spite of several studies, the status of its population is not known from many parts of its range (Roos et al. 2015). This makes it an interesting object for studying.

The otter suffered a rapid decline in the second half of the 20th century due to the wrong understandings about its harm-

fulness and the pursuit of fishermen, fish breeders and hunters (Spiridonov and Spassov 1998, Poledníková et al. 2013), the intensive hunting and poaching (Georgiev 2007, Almeida et al. 2012), and also because of the wide introduction of organochlorine groups of insecticides in the agriculture. As a result of the chemical contamination the otter lost a huge part of its areal – over 90 % (Chanin 2003b). The destruction of riverine habitats as result of water captation, riverbed corrections, and water abstraction also are important anthropogenic factors (Pandakov et al. 2017).

The otter is strictly protected under the Bulgarian and international legislation and conventions. It is currently protected by the Law for biological diversity (LBD 2002), Annex 3 and Annex 2. In the first edition of the Red Data Book of Bulgaria the otter is listed as 'threatened with extinction species' (Spassov and Spiridonov 1985). In the new edition the species is classified as 'vulnerable' (Spiridonov and Spassov 2015). It is also included in the Tariff for compensation in causing persistent damage to protected natural objects (1980). As an endangered in European scale species the otter is protected under the Criminal Code of the Republic of Bulgaria (Spiridonov and Spassov 1998, Georgiev and Koshev 2006). It is included in the IUCN Red List as Near Threatened (NT), Appendix I of CITES, Appendix II of the Bern Convention (strictly protected species) and in Annexes II and IV of the EU Habitats and Species Directives (Roos et al. 2015).

As a result of different by nature and intensity factors (climatic, geological, biological, anthropogenic) Bulgaria is one of the few European countries with a relatively well preserved otter population. In Bulgaria the species is widespread throughout the country (including the Black Sea coast), with exception of Dobrudzha, a large part of Ludogorie region and the high mountains. In the mountains the otter reaches 1500 m a.s.l.

The selection of the Eastern Rhodopes was connected with the fact that there is one of the best preserved otter populations not only in Bulgaria but also in Europe (Spiridonov and Spassov 1989, Borisov 2002). There its presence is registered in some mountainous river stretches – the most high-water sections of the rivers of Krumovitsa and Varbitsa, Arda River, and near the large dams, devoid of human presence and disturbance, as Studen Kladenets Dam (Borisov 2002, Georgiev 2006). In the past this species has been widely distributed on the territory of the Eastern Rhodopes, but after the urbanization and changes in the river regimes, the development of mines and clearing of forests, the otter was gradually pushed out from a bigger part of its natural distribution range.

Diet composition analysis is convenient to establish links with other groups of organisms and feeding plasticity of the otter, depending on the type of the habitat and the available food base. The analysis of spraints' (faeces) content or food remnants is very convenient, and sometimes the only possible method for studying secretive or nocturnal animals, such as the otter (Putman 1984, Ruiz-Olmo et al. 2001).

This study aims at exploring the particularities in the feeding of otter population in the Eastern Rhodope Mts. The implementation of diet analysis seeks to establish the links with other groups of organisms and dietary characteristics of the otter depending on the type of habitat and available food base. In this connection, the main purposes of the work are: per-

forming of detailed analysis of the dietary spectrum of the otter and its peculiarities related to the characteristics of the area, and mapping of this species in this region through found food remnants.

Material and Methods

Periods of the study and basic groups of sampling plots

For the purposes of the study during the period from 29 March 2003 to 06 May 2003 were selected the main groups of sections on the territory of the Eastern Rhodopes, covering: i) the valley of the river of Arda; ii) major tributaries of Arda River (the rivers of Varbitsa, Krumovitsa, etc.); iii) Byala Reka River (and its tributaries including the river of Luda Reka); iv) dams (medium sized – with perimeter 3–7 km, and large – with a perimeter of over 7 km); v) other basins (micro dams, channels, pools of pumping stations).

For the investigation 28 sections of different in nature basins with total length of 99.3 km were selected. They were explored by the 'positive and negative sites' method, proposed by Mason and Macdonald (1983, 2004). The longest of sections was 22.4 km, although the presence of the otter was established in all transects within 600 m. The shortest stretch was 348 m.

Material for the realization of the analysis was collected from 6 sections characterized with a presence of water quantity even during the period of low water level – 3 from the valley of Byala Reka River, 2 along Arda River and 1 from Krumovitsa valley (Table 1).

Table 1. Sections from the rivers in the Eastern Rhodopes used for the dietary analysis.

Code	River	Location	Date of visiting
BR1	Byala Reka	Near the road to Zhelezari village	
BR2	Byala Reka	Near Siv Kladenets village	29 March–1 April 2003
BR3	Byala Reka	Near Meden Buk village	
A1	Arda	Between the walls of Studen Kladenets and Ivailovgrad Dams	2–6 May 2003
A2	Arda	Along the banks of the river before Kardzhali Dam	23–26 May 2003
K	Krumovitsa	From the village of Stari Chal to the village of Potochnitsa	1–2 May 2003

Analysis of the dietary spectrum

During the field investigation of the transects, in each group of sections otter spraints or food remnants (if found near the spraints) were collected. Spraint analysis was carried out using standard methods recommended by Webb (1976). Accordingly, faecal material was collected in small individual bags, the contents of which were washed with water afterwards through a sieve to remove the unnecessary impurities. In the next step samples were dried and broken up by hand, and identifiable prey items were separated. The solid components were divided in groups – scales, fish bones, crabs remains, bones of amphibians, birds and others. Then the materials from each group were analysed (for the fishes – species, body length (TL, cm), weight (g) and age (years); for the other groups of animals – only taxonomic

belonging) and the number of individuals of a given species in each sample was designated. Species, size and age of the fishes were determined by using comparative osteological (mostly cranial) collections and specifics in the morphology of the scales and vertebrae.

The marking of otter territory has its particularities, namely each individual has preferred latrines and in many cases the spraints accumulate in heaps. Thus, after a certain period it is extremely difficult to separate individual excrement, as under the influence of environmental conditions, they lose their shape and deteriorate. Therefore, the exact number of individual spraints used for the analysis is not clear.

Results and Discussion

We found signs for the presence of otters (spraints) in all 28 surveyed river sections. Therefore, the 'positive' sites are 100 % of the studied areas. Studied sections along with the data of other sources are presented on Figure 1.

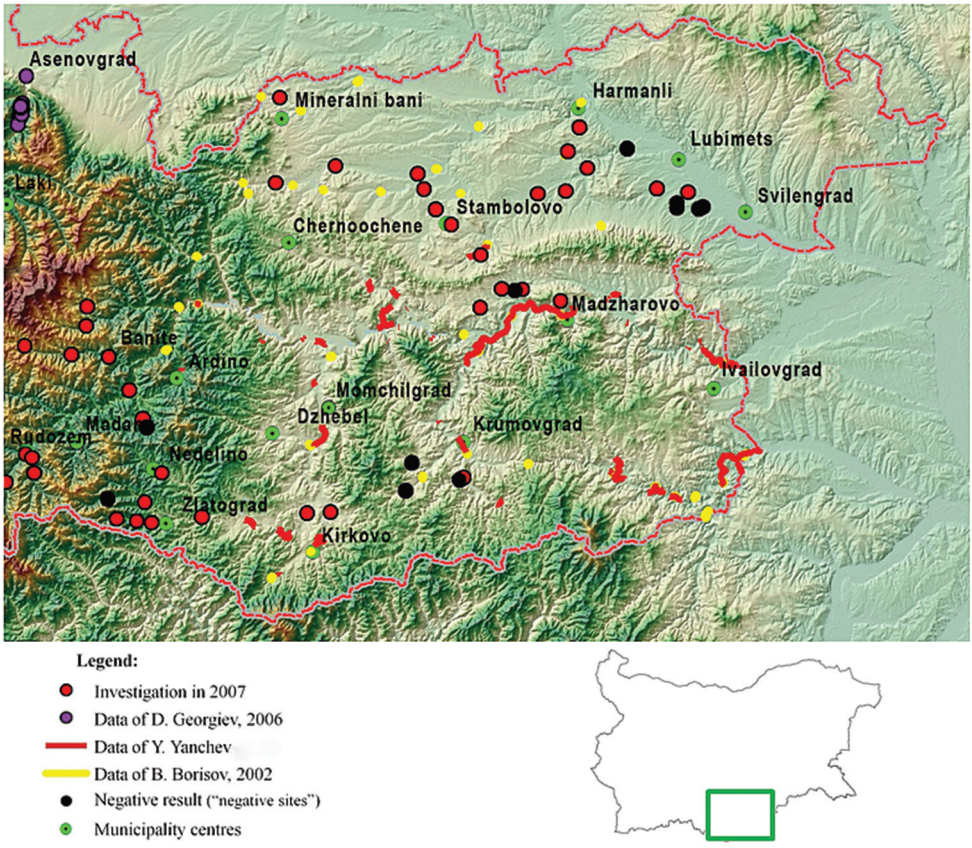

Fig. 1. Distribution of the otter in the Eastern (and partly Central) Rhodopes. The results from the present study are marked with red line (Y. Yanchev). The other data were established by Borisov (2002), Georgiev and Stoycheva (2006b) and Georgiev (2007).

Received during the field trips data suggested that the diet of otters in the studied areas includes 10 fish species (7 species from the family Cyprinidae, 2 from Percidae and 1 from Centrarchidae), 1 frog species, 1 crab species and a water beetle from the family Dytiscidae. Specimens of the Cyprinidae family were the major prey also in the study of Geidezis (1996), as in other studies in eutrophic lakes and streams (Wise et al. 1981, Jacobsen and Hansen 1996, Hofmann and Butzeck 1992). The cyprinids seem to be preferred by the otter in cold seasons probably due to their lower activity, which makes them an easy prey (Georgiev 2004).

The lack of some typical for the basins in the area fish species, found in specialised ichthyological studies (Kodzhabashev et al. 2009), enforces further purposive studies clarifying the specific causes which may be natural or resulting from the anthropogenic changes.

The results of the analysis are presented in Table 2 as for the fishes there are included the age, average weight and average size (body length). The percentage of the preys (as number of individuals) in the otters' spraints is demonstrated on Figure 2.

Table 2. Composition of the otter's diet.

Species	Section	BR1	BR2	BR3	A1	A2	K
Rutilus rutilus (Linnaeus, 1758) Roach (Cyprinidae)	Specimens	-	-	-	5	3	4
	Age, years	-	-	-	3	4	3
	Weight, g	-	-	-	28	32	30
	Length, cm	-	-	-	10–12	11–13	11–12
Squalius orpheus Kottelat & Economidis, 2006 Orpheus chub (Cyprinidae)	Specimens	10	17	7	4	5	11
	Age, years	3	3	3	4	3	3
	Weight, g	60	60	40	100	65	72
	Length, cm	13–15	12–16	12–13	14–17	13–16	14–16
Chondrostoma vardarense Karaman, 1928 Vardar nase (Cyprinidae)	Specimens	7	-	-	4	-	6
	Age, years	2	-	-	2	-	3
	Weight, g	70	-	-	70	-	90
	Length, cm	14–16	-	-	14–16	-	15–16
Barbus cyclolepis Heckel, 1837 Round-scaled barbel (Cyprinidae)	Specimens	9	10	5	7	11	12
	Age, years	3	3	2	2	2	2
	Weight, g	40	40	31	26	31	31
	Length, cm	12–14	12–14	12–13	11–13	9–12	15–16
Alburnus alburnus (Linnaeus, 1758) Common bleak (Cyprinidae)	Specimens	-	7	6	-	4	7
	Age, years	-	3	3	-	3	3
	Weight, g	-	17	16	-	17	17
	Length, cm	-	10–11	9–10	-	11–13	10–12
Carassius gibelio (Bloch, 1782) Silver Prussian carp (Cyprinidae)	Specimens	-	-	-	5	-	5
	Age, years	-	-	-	3	-	3
	Weight, g	-	-	-	105	-	65
	Length, cm	-	-	-	12–20	-	14–17

Species	Section	BR1	BR2	BR3	A1	A2	K
Rhodeus amarus (Bloch, 1782) European bitterling (Cyprinidae)	Specimens	-	9	-	-	-	-
	Age, years	-	3	-	-	-	-
	Weight, g	-	8	-	-	-	-
	Length, cm	-	5–7	-	-	-	-
Perca fluviatilis Linnaeus, 1758 European perch (Percidae)	Specimens	-	-	-	32	7	7
	Age, years	-	-	-	3	3	3
	Weight, g	-	-	-	42	45	40
	Length, cm	-	-	-	12–15	13–15	13–14
Gymnocephalus cernua (Linnaeus, 1758) Eurasian ruffe (Percidae)	Specimens	-	-	-	19	-	-
	Age, years	-	-	-	3	-	-
	Weight, g	-	-	-	24	-	-
	Length, cm	-	-	-	8–12	-	-
Lepomis gibbosus (Linnaeus, 1758) Pumpkinseed sunfish (Centrarchidae)	Specimens	-	-	-	7	5	-
	Age, years	-	-	-	3	3	-
	Weight, g	-	-	-	21	20	-
	Length, cm	-	-	-	7–11	8–10	-
Pelophylax ridibundus (Pallas, 1771) Marsh frog (Amphibia: Ranidae)	Number of specimens	2	-	1	2	2	-
Potamon ibericum (Bieberstein, 1809) Iberian crab (Malacostraca: Potamonidae)	Number of specimens	3	2	2	1	1	-
Coleoptera (Dytiscidae) Diving beetle	Number of specimens	1	-	-	-	-	-

The predominance of fish prey is normal and had been shown in the literature and sometimes exceeds more than 80 % of the otters' diet (Erlinge 1968, Webb 1975, Harna 1993, Geidezis 1996, Ruiz-Olmo and Palazon 1997, Taastrøm and Jacobsen 1999, Lanszki and Molnar 2003, Georgiev 2004, Reid et al. 2013, Juhász et al. 2014). Sidorovich (1995) divides water basins in terms of the percentage of fish in the otter menu. In the large and medium-sized rivers and lakes the fish represents on average 70 % of its dietary spectrum. In the small rivers it decreases to 50 %. In fish breeding ponds and micro dams designed for intensive fish farming it is averaging 73 % (sometimes up to 93 %) and in low-water rivers and drainage channels it is 38 %.

However, otters often use other groups of animals as secondary prey or even as their main food (Kruuk 1995, Adrian and Delibes 1987, Brzeziński et al. 1993, Geidezis 1996, Georgiev 2004, Lanszki et al. 2006, Miranda et al. 2008, Remonti et al. 2008, Poledníková et al. 2013, Juhász et al. 2014, Roos et al. 2015, Krawczyk et al. 2016, etc.). These include aquatic insects, reptiles, amphibians, birds, small mammals, crustaceans. It is known that

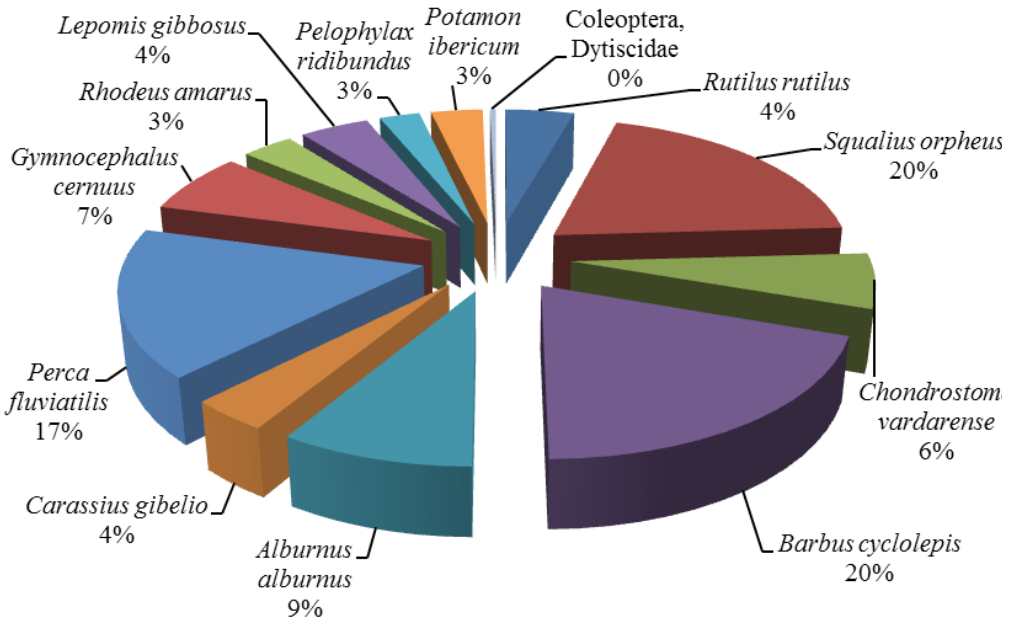

Fig. 2. Composition of the otter diet (as number of prey individuals in the spraints).

the otter can act as a highly specialised piscivorous predator in temperate freshwater ecosystems, while Mediterranean otters are more generalist predators, relying less on fish, and more on aquatic invertebrates and reptiles (Adrian and Delibes 1987, Clavero et al. 2003). There are also seasonal variations in otter diet (Adrian and Delibes 1987, Brzeziński et al. 1993, Geidezis 1996, Georgiev 2004, Miranda et al. 2008, Smiroldo et al. 2009). Fish consumption might decrease during winter, while the importance of alternative prey taxa increases (Juhász et al. 2014) or, on contrary, the share of the fish might be grater in the cold seasons when other food is hard to obtain (Georgiev 2004).

The data analysis from the different sampling transects demonstrated some particular features resulting mainly from the location of the station, water flow in the water body and the degree of anthropogenic influence.

The three sections located on Byala Reka River are very identical in terms of environment and naturalness, and any differences might be only resulting from the specific characteristics related to the biological and ecological requirements of the fishes or the features in terrain structure and river body. The analysis of otters' spraints collected along Byala Reka River showed the permanent and greatest percentage presence in all three transects of chub (34 % on average). In all three transects were found also barbel and Iberian crab, but they had a slightly lesser percentage presence, respectively – an average of 24 % and 6 %. In two of the sections we established bleak (an average of 22 %) and Marsh frog (an average of 5 %), and in only one of them – nase and bitterling. In all three sections the main part of the pray (by number of specimens) was almost thoroughly (over 75 %) formed by the three dominant spe-

cies in the river (chub, barbel and bleak). A similar significance was also found in relation to the distribution of relative biomass of the species in otters' menu. Size of the fishes (TL) ranged from 5 to 16 cm for the different species, and the weight – from 8 to 70 g. The specimens with age 3 years dominated and single individuals were 2-year-old.

The absence of invasive fish species in all three investigated sections is probably originating from the lack of human interventions and the relative remoteness of the area from anthropogenically affected stretches of the riverine system. The occurrence of bitterling in the third section located in the lower river stream was logical, given the silt deposit on the bottom, which is a necessary component for the existence of river mussels – a breeding substrate for this fish.

An interesting finding from the analysis of the sample from stretch BR1 is the fact that in the menu we found an insect from order Coleoptera, family Dytiscidae. Although rare, information for established insects in otters' diet is present in literature (Adrian and Delibes 1987, Sidorovich 1995, Georgiev 2004, Juhász et al. 2014), and in some cases the share of Dytiscidae might reach up to 9 % of the biomass taken by otters in spring and summer (Brzeziński et al. 1993).

The feeding with crabs was noted in other studies, as their rate could constitute a significant share and even dominate in the diet (e.g. Adrian and Delibes 1987, Chanin 2003a, Chanin 2003b, Georgiev 2004, Poledníková et al. 2013). In Bulgaria, Iberian crab is the most common species found so far in otter's diet (Georgiev 2004, Georgiev 2006, Georgiev and Stoycheva 2006a). It is also proved that amphibians, namely frogs, may consist up to 49 % of it (Poledníková et al. 2013).

The analysis of the spraints collected from the stretches of the rivers of Arda and Krumovitsa showed that the highest average presence in all three sections had the perch (22 %). In the first section (A1) it occupied 37 % of otter's food. Perhaps this was due to the higher stocks of this species in standing waters, in our case Ivailovgrad Dam. The perch is usually eaten more frequently by otters in pond areas (Geidezis 1996, Juhász et al. 2014). In all transects were presented the barbel (20 %), chub (13 %) and roach (7 %).

The greatest was the diversity of species in the first section (A1) – 10 species, as in addition to the above mentioned we also found nase, silver carp, ruffe, sunfish, marsh frog, Iberian crab. This variety is probably resulting from section size (it is the biggest of all) and the various conditions – the presence of a river and a large dam (Ivailovgrad Dam). The results of the analysis demonstrated increased presence (with around 75 %) of the invasive species, both as number of specimens and relative biomass significance in the otter diet as well.

Data from section A2 included a total of 8 food components – 6 fish species, marsh frog and Iberian crab. In species composition of fish-preys, this section is distinguished by the absence of two invasive species – silver carp and ruffe, and by the presence of bleak. By number of specimens in the diet predominated the typical river species – chub, barbel and bleak, and the invasive perch and sunfish had a secondary importance. Similar relative biomass ratios in the otter diet had the chub, barbel and perch. In this sector the river is relatively preserved, but through the direct link with Kardzhali Dam, invasive species such as perch, sunfish and roach penetrate in it, and they probably trophically, spatially and generatively com-

pete with the autochthonic ichtyocoenose.

The results of the dietary analysis in the section near the mouth of the river Krumovitsa (K) differed significantly from those in Arda River, due to the relative naturalness of the habitat and absence of human interventions. The presence of two invasive species (perch and silver carp) was probably due to the connection of the river with the affected section of Arda River below the wall of Studen Kladenets Dam. Qualitatively and quantitatively the diet of the otter at maximum approached the natural for the area food resources.

The established preys of the otters were characterised by different frequency in the studied areas. Only two species (barbel and chub) have been found in all transects. It was interesting that, although they made a small proportion in otter diet, marsh frog and Iberian crab were present in 5 out of the 6 analyzed plots. It is entirely possible that they occupy a significant part of the otter menu in the Eastern Rhodopes, especially in the winter (in overwintering clusters of amphibians, etc.) (observed by Juhász et al. 2014), but due to the short collection period and the only few sections that could not be established. The availability of alternative prey might decrease the chance of disturbing fish species during hibernation, which is of great importance especially for fish farming.

The length of fishes' body (TL) varied within the individual sections and species – from 7 to 20 cm, and the weight was in the range 20–100 g. Figure 3 shows the minimum, maximum and average body lengths. The age of the majority of the fishes caught by the otters was 3 years (rarely 2 and 4 years). These data about the otters' feeding largely overlap with the data published by other authors (Peshev et al. 2004).

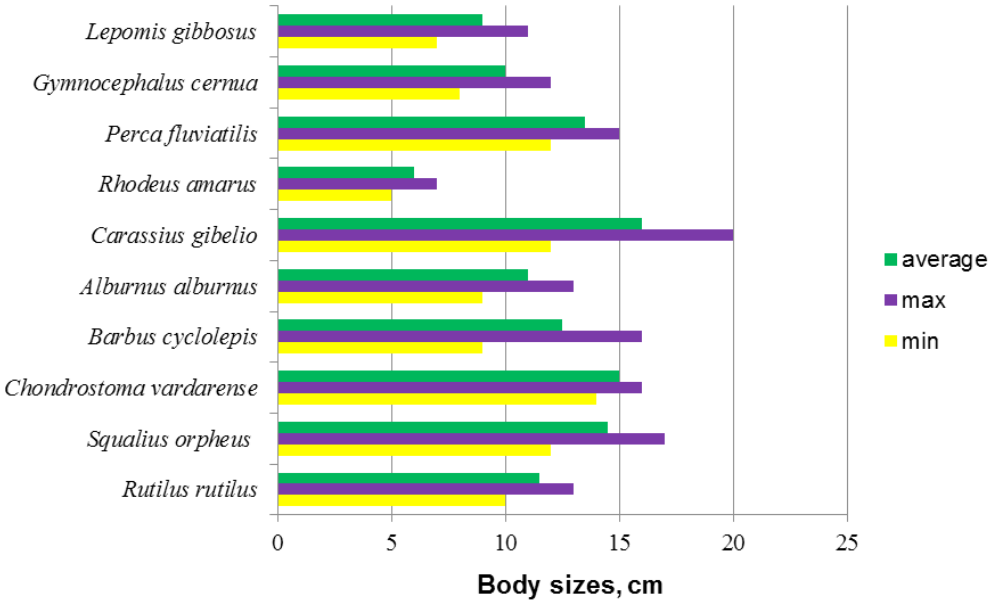

Fig. 3. Body size of the fishes in otters' diet.

In our study the most common sizes of the fish preys were from 8–10 to 12–14 cm, regardless of the species belonging. Most of them had a weight of 30–40 to 80–90 g. Larger by size and mass were relatively few individuals of nase, silver carp and chub. Less weight was found in bitterling and bleak, but their dimensions were close to the typical for the otter preys. It is known that the Eurasian otter is capable of taking fish as large as 9 kg (Chanin 2003a), however, many studies in Europe have revealed that the fishes consumed by the otters are relatively small with a median length of 13 cm (Kruuk 1995, Roos et al. 2015), which is in accordance with our results vice versa. In Denmark otters' showed a tendency for selecting individuals between 9–21 cm (Taastrøm and Jacobsen 1999). In Poland, 35 % of the fishes in otters spraints were within the same limits (10–15 cm) and 50 % were even smaller (7–10 cm) (Brzeziński et al. 1993). Larger fishes were preferred in artificial wetlands in Hungary (Juhász et al. 2014).

The ratio of various fish species in the otter diet is presented in Figure 4. The main fish species in the studied area were the chub, barbel and nase, and additional were the bleak, perch, roach, silver carp, bitterling, sunfish, ruffe. The perch and roach were among the most common prey in Czech Republic representing respectively up to 49 % and up to 31 % of the diet (Poledníková et al. 2013).

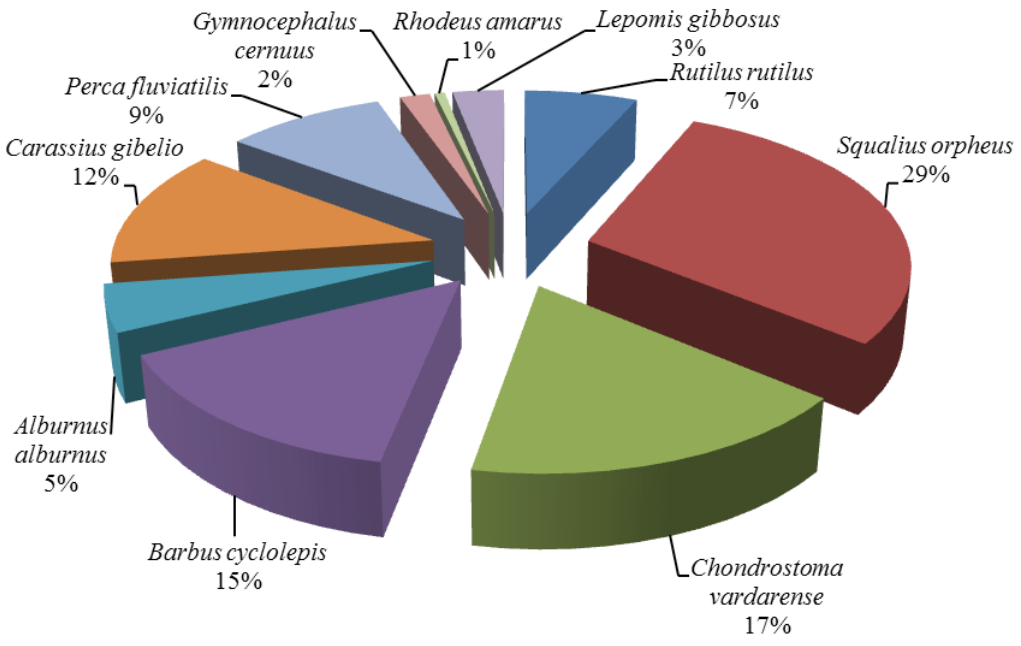

Fig. 4. Percentage partition of the fishes in otter's diet in the Eastern Rhodope Mts., calculated according to their weight, g.

Large fish species were mainly 3-year-old and rarely 4-year-old. Small fishes were around 7 cm long and weighing up to 20 g, and the maximum dimensions of the fishes were 20 cm in length and 100–150 g in weight.

The otter is an important factor in the natural selection of fish populations, destroying mostly ill, physiologically weak and lagging in development preys. Accounting the weight of this predator (6–8 kg for females and 8 to 10 kg for males), the average weight is about 8 kg. For the maintenance of the normal vital functions during the year the otter needs to consume daily about 10 % of its own weight, or 10 fishes weighing 80 g or 20 fishes weighing 40 g (an average of 15 fishes) (Kruuk and Carss 1996). This hypothesis completely eliminates the portion of other food objects, which for the large rivers normally are 30 %, and for the small and poor in fish – up to 50 % and even more.

For maximum accuracy in assessing the status and capacity of a water basin in relation to the otter density, it is necessary in parallel with the analysis of the diet to conduct a specialized study of the ichthyofauna and ichthyocoenose, accounting the exact realization of the species in accordance with the available food supply, and its main population parameters – density, age and sex structure. For defining and achieving optimal accuracy on the capacity of given habitat for otter's density it is necessary to examine in detail gender and age structure of the animals, and to evaluate afterwards the distribution along the concrete coastal transect.

In ideal conditions for river sections of medium large rivers, such as in this particular area, the individual stretch varies depending on the trophic capacity on average from 2 to 6 km for an adult male otter, which most often overlaps with two females. If we assume that, on average, the female raises 3 cubs, then for the feeding of these 9 individuals it will be needed daily the following maximum quantity of fish: 1.5 kg for the male, 2 kg for the females (1 kg each), and 0.5 kg for each cub. It makes a total of about 6.5–7 kg per day, about 210 kg per month and approximately 2500 kg per year, if we consider that juveniles stay with their mothers during the winter period. Averaging the data of the hypothetical model allows us to consider that normally the otters eat about 500 kg per kilometre from the medium-size river valley or an average of 10,000 fishes with medium size 15 cm and weight of 50 grams. Calculated per hectare of the river surface this densities are respectively 20/500 m = 10,000 m^2 for Arda River and 10/1000 m = 10,000 m^2 for the rivers of Krumovitsa and Byala Reka.

The research of the fish stocks in Arda River and other rivers of the Aegean catchment area showed stocks of an average 10,000 individuals with average fish biomass of 150–350 kg/ha (Dikov et al. 1994). According to this, for the normal distribution of the otter individuals is needed three times longer feeding stretch in Arda River, which means that for the combination of one male and two females with three cubs a stretch of around 12–15 km will be needed.

The rivers of Krumovitsa and Byala Reka are characterized with relative unaffected and natural coastal habitats. Therefore, in spite of their twice smaller size, it could be considered that their fish stocks per hectare are not smaller than those of Arda River and their potentials are not insufficient for the otter, and it is also very likely that with expected supply of 50,000–100,000 individuals and biomass from 300 to 500 kg per hectare, a stretch with length of about 5 km would be fully adequate for the maintenance of an optimal otter density. Such biotic parameters of relatively small but well preserved rivers in Bulgaria were measured repeatedly (Dikov et al. 1994).

Differences in the prevailing prey species are primarily originating from the differences in the structure of water basins and the conditions of hunting. In the otter's diet usually the benthic, but mostly inhabiting the coastal areas, preys predominate (e.g. Kruuk and Moorhouse 1990). This fact was confirmed by the absence of preys like the sheat-fish and carp, as well as the increased percentage of species like the perch, barbel and chub. According to Juhász et al. (2014) common carp predation is present more frequently in winter and spring.

The study of Krawczyk et al. (2016) demonstrated that the plasticity of the feeding behaviour might be explained by the various habitats occupied by otters, and habitat differences reflected in otter's diets might have importance for the maintenance and conservation of local populations of this species.

However, different studies seem to show that otters do not always feed on the most abundant prey (fish) but are selective. Probably behaviour (flight behaviour, catchability), distribution (pond or river) and/or even nutrient value of the potential prey influences the otter's choice (Geidezis 1996). According to Miranda et al. (2008) non-native fish species occurred relatively rarely or not at all in otter spraints. The same was established also for introduced crustaceans (Beja 1996). Therefore, the maintenance of indigenous prey should be considered a major issue in conservation strategies, even in areas with abundant populations of introduced animals.

Another important issue is the destruction of natural habitats (via pollution, water acidification, canalization of rivers, removal of bank side vegetation, dam construction, draining of wetlands, aquaculture activities and associated anthropogenic impacts on aquatic systems) though seriously affecting the otter populations (Reuther and Hilton-Taylor 2004, Roos et al. 2015, Pandakov et al. 2017).

Furthermore, most of the people in the surveyed area perceive the otter entirely as a hunting object. This undoubtedly means that there is a poaching pressure over the studied species, which even thou currently not severely affecting the population, in the future might manifest. Another alarming fact is the conflict between the otter and fish poachers (Georgiev 2007). Human-wildlife conflicts often arise between humans and large protected vertebrates when they compete for the same biological resources or when wildlife cause damage, especially in case of farmed resources (Kloskowski 1999, Vaclavikova et al. 2011). In many cases the otter eats fish straight from the nets of the poachers seriously damaging them. At the same time, there are data on drowned otters (Georgiev 2007), as a result of entanglement in poachers' fishing nets (Studen Kladenets Dam).

Conclusion

As result of this study we analysed and evaluated the dietary preferences of the otters on the territory of the Eastern Rhodope Mts., as well as their importance to the hydrobionts in a concrete habitat. We investigated the feeding plasticity of the species, depending on the habitat type and available food base. For complete elucidation of otters' dietary composition, however, additional specialized research is needed.

Otter in the region is trophically dependent on the specific characteristics of the feeding water basins. The most common preys are fishes inhabiting coastal

areas of the standing waters and relatively shallow stretches of the rivers. Fish preys are with medium body size 10–12 cm and weight 80–90 g.

The main fish species in the studied area are chub, barbel and nase, and additional are bleak, perch, roach, silver carp, bitterling, sunfish and ruffe. Very often in the otter diet are established frogs and crabs that are particularly common in the basins and easy to catch preys. The analysis of the relative share in the diet biomass showed a strong dependence on the density of the prevailing size-weight prey group and relatively weak preference of particular preyed fish species, either natural or invasive.

Deterioration and destroying of natural habitats, reduction of the food base, disturbance during the breeding season of the species and poaching are serious threats to the otter in the Eastern Rhodopes. For their overcoming are needed multitude efforts and resources, but as a first and essential condition for starting of the conservation activities it is necessary an Action plan for conservation of the otter in Bulgaria to be developed and approved. It will represent the beginning of the real conservation measures for this species in the country.

Studies of the diet of the otter by spraints and other food remnants can be successfully used for mapping and monitoring of the ichthyofauna and ichthyocoenoses in different sections of water basins, for assessment of the current state and for prognosis about the development of otter populations in a given area as well. Such investigations contribute to the recording, mapping and paspotisation of the ichthyofauna and ichthyocoenoses as a component of the otter's diet, and such data may be used for the purposes of the conservational monitoring.

References

Adrian M.I., Delibes M. 1987. Food habits of the otter (*Lutra lutra*) in two habitats of the Doñana national Park, SW Spain. Journal of Zoology 212(3): 399–406.

Almeida D., Copp G.H., Masson L., Miranda R., Murai M., Sayer C.D. 2012. Changes in the diet of a recovering Eurasian otter population between the 1970s and 2010. Aquatic Conservation–Marine and Freshwater Ecosystems 22: 26–35.

Beja P. 1996. An analysis of otter *Lutra lutra* predation on introduced American crayfish *Procambarus clarkii* in Iberian streams. Journal of Applied Ecology 33: 1156–1170.

Borisov B. 2002. Distribution and frequency of the Otter in the Eastern Rhodopes. Unpublished report (in Bulgarian).

Brzeziński M., Jędrzejewski W., Jędrzejewska B. 1993. Diet of otters (*Lutra lutra*) inhabiting small rivers in the Białowieża National Park, eastern Poland. Journal of Zoology 230(3): 495–501.

Chanin P. 2003a. Ecology of the European Otter. Conserving Natura 2000 Rivers Ecology Series No 10, English Nature, Peterborough. 64 p.

Chanin P. 2003b. Monitoring the Otter *Lutra lutra*. Conserving Natura 2000 Rivers Monitoring Series No 10, English Nature, Peterborough. 43 p.

Clavero M., Prenda J., Delibes M. 2003. Trophic diversity of the otter (*Lutra lutra* L.) in temperate and Mediterranean freshwater habitats. Journal of Biogeography 30(5): 761–769.

Dikov Tz., Jankov J., Jochev S. 1994. Fish stocks in rivers of Bulgaria. Polskie archiwum hydrobiologii 41(3): 377–391.

Geidezis L. 1996. Food availability versus food utilization by Otters (*Lutra lutra* L.) in the Oberlausitz pondland in Saxony, Eastern Germany. IUCN Otter Specialist Group Bulletin 13(2): 58–70.

Georgiev D. 2004. Material on the diet of otter (*Lutra lutra* L., 1758) from Bulgaria. Trav. Sci. Univ. Plovdiv, Animalia 40(6): 165–172 (in Bulgarian).

Georgiev D. 2006. Diet of the otter *Lutra lutra*

in different habitats of southeastern Bulgaria. IUCN Otter Specialist Group Bulletin 23(1): 4–10.

Georgiev D. 2007. Otter (*Lutra Lutra* L.) Mortalities in Southern Bulgaria: A Case Study. IUCN Otter Specialist Group Bulletin 24(1): 36–40.

Georgiev D., Koshev Y. 2006. A report on the distribution and the habitats of the otter (*Lutra lutra*) in Bulgaria, and taking a part in the preparing of a conception of its conservation in the country in the Natura 2000 network. Ministry of the Environment and waters, Bulgaria. 17 p. (in Bulgarian).

Georgiev D., Stoycheva S. 2006a. Freshwater crabs preyed on by the Eurasian otter *Lutra lutra* in a river habitat of Southern Bulgaria. Hystrix It. J. Mamm. (n.s.) 17(2): 129–135.

Georgiev D., Stoycheva S. 2006b. Habitats, distribution and population density Otter survey in the Western Rhodopes Mountains (Southern Bulgaria). IUCN Otter Specialist Group Bulletin 23(1): 35–43.

Erlinge S. 1968. Food studies on captive otters (*Lutra lutra* L.). Oikos 19: 259–270.

Harna G. 1993. Diet composition of the otter *Lutra lutra* in the Bieszczady Mountains, south-east Poland. Acta Theriologica 38: 167–174.

Hofmann T., Butzeck S. 1992. Beitrag zur Ernährung des Fischotters *Lutra lutra* (L., 1758) im Spreewald. In: Semiaquatische Säugetiere, Wiss. Beitr. Univ. Halle 1992: 436–450.

Jacobsen L., Hansen H.-M. 1996. Analysis of otter (*Lutra lutra*) spraints: Part 1: Comparison of methods to estimate prey proportions; Part 2: Estimation of the size of prey fish. Journal of Zoology 238(1):167–180.

Juhász K., Végvári Z., Perpék M., Lukács B.A., Nagy S.A. 2014. Main versus alternative prey of Eurasian otters in an East-European artificial wetland system. North-Western Journal of Zoology 10(1): 1–9.

Kloskowski J. 1999. Otter *Lutra lutra* predation in cyprinid dominated habitats. Zeitschrift fur Saugetierkunde 64: 201–209.

Kodzhabashev N., Kolev V., Gruychev G. 2009. Study of the ichthyofauna of Ivailovgrad Dam. Forestry Ideas 1(37): 212–225.

Krawczyk A.J., Bogdziewicz M., Majkowska K., Glazaczow A. 2016. Diet composition of the Eurasian otter *Lutra lutra* in different freshwater habitats of temperate Europe: a review and meta-analysis. Mammal Review 46(2): 106–113.

Kruuk H. 1995. Wild otters: Predation and populations. First edition. Oxford University Press, Oxford. 304 p.

Kruuk H., Carss D.N. 1996. Costs and benefits of fishing by a semi-aquatic carnivore, the otter *Lutra lutra*. In: Greenstreet S.P.R., Tasker M.L. (Eds.). Aquatic predators and their prey. Fishing New Books, London: 10–16.

Kruuk H., Moorhouse A. 1990. Seasonal and spatial differences in food selection by otters (*Lutra lutra*) in Shetland. Journal of Zoology, Lond. 221: 621–637.

Lanszki J., Molnár T. 2003. Diet of otters living in three different habitats in Hungary. Folia Zoologica 52(4): 378–388.

Lanszki J., Molnár M., Molnár T. 2006. Factors affecting the predation of otter (*Lutra lutra*) on European pond turtle (*Emys orbicularis*). Journal of Zoology 270(2): 219–226.

LBD 2002. Law for the Biological Diversity, 2002 (prom. SG. 77/2002, amend. SG. 88, 105/2005, amend. SG. 29, 30, 34/2006, amend. SG. 52, 64, 94/2007, amend. SG. 43/2008, amend. SG. 19, 80, 103/2009, amend. SG. 62, 89/2010, amend. SG. 19, 33/2011, amend. and suppl. SG. 32/2012, amend. and suppl. SG. 59/2012, amend. SG. 77/2012, amend. SG. 15/2013, amend. and suppl. SG. 27/2013, amend. SG. 66/2013, amend. SG. 98/2014, amend. SG. 61/2015).

Mason C.F., Macdonald S.M. 1983. The otter *Lutra lutra* in Southern Italy. Biological Conservation 25: 95–101.

Mason C.F., Macdonald S.M. 1986. Otters: Ecology and Conservation. Cambridge University Press, Cambridge. 236 p.

Mason C.F., Macdonald S.M. 2004. Growth in Otter (*Lutra lutra*) populations in the UK as shown by long-term monitoring. Ambio 33: 148–152.

Miranda R., Copp G.H., Williams J., Beyer K., Gozlan R.E. 2008. Do Eurasian otters *Lu-*

tra lutra (L.) in the Somerset Levels prey preferentially on non-native fish species? Fundamental and Applied Limnology / Archiv für Hydrobiologie 172(4): 339–347.

Pandakov P., Teofilova T., Kodzhabashev N. 2017. Theoretical bases and typification of the anthropogenic impacts on the river systems and their effect on the ichthyofaunas and ichthyocoenoses in Bulgaria. Proceedings of the Fifth student scientific conference 'Ecology and environment', 21 April 2017, Vol. 4, Konstantin Preslavsky University Press, Shumen: 8–18.

Peshev Ts., Peshev D., Popov V. 2004. Fauna of Bulgaria, vol. 27, Mammalia. Academic publishing house 'Marin Drinov', Sofia: 511–514 (in Bulgarian).

Poledníková K., Kranz A., Poledník L., Myšiak J. 2013. Otters causing conflicts. The fish farming case of the Czech Republic. In: Klenke R.A. et al. (Eds). Human-Wildlife Conflicts in Europe. Environmental Science and Engineering. Springer-Verlag Berlin Heidelberg: 81–106.

Putman R.J. 1984. Facts from faeces. Mammal Review 14: 79–97.

Reid N., Thompson D., Hayden B., Marnell F., Montgomery W.I. 2013. Review and quantitative meta-analysis of diet suggests the Eurasian otter (*Lutra lutra*) is likely to be a poor bioindicator. Ecological Indicators 26: 5–13.

Remonti L., Prigioni C., Balestrieri A., Sgrosso S., Priore G. 2008. Trophic flexibility of the otter (*Lutra lutra*) in southern Italy. Mammalian Biology 73: 293–302.

Reuther C., Hilton-Taylor C. 2004. *Lutra lutra*. The IUCN Red List of Threatened Species. Available at: www.iucnredlist.org.

Roos A., Loy A., de Silva P., Hajkova P., Zemanová B. 2015. *Lutra lutra*. The IUCN Red List of Threatened Species 2015: e. T12419A21935287. Available at: http://dx-.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T12419A21935287.en. Downloaded on 31 May 2017.

Ruiz-Olmo J., Palazon S. 1997. The diet of the European otter (*Lutra lutra* L., 1758) in Mediterranean freshwater habitats. Journal of Wildlife Research 2(2): 171–181.

Ruiz-Olmo J., Lopez-Martin J., Palazon S. 2001. The influence of fish abundance on the otter (*Lutra lutra*) populations in Iberian Mediterranean habitats. Journal of Zoology 252: 325–336.

Sidorovich V. 1995. Minks, otters, weasel and other mustelids, 'Uradzhay', Minsk. 190 p. (in Russian).

Smiroldo G., Balestrieri A., Remonti L., Prigioni C. 2009. Seasonal and habitat-related variation of otter *Lutra lutra* diet in a Mediterranean river catchment (Italy). Folia Zoologica 58: 87–97.

Spassov N., Spiridonov G. 1985. Otter (*Lutra lutra* L. 1758). Red Book of Bulgaria. Vol. 2. Animals. BAS Press, Sofia: 137 (in Bulgarian).

Spiridonov G., Spassov N. 1989. The otter (*Lutra lutra* L, 1785) in Bulgaria, its status and conservation. Historia Naturalis Bulgarica 1: 57–64.

Spiridonov G., Spassov N. 1998. Large mammals (Macromammalia) of Bulgaria: Bulgaria`s Biological Diversity: Conservation Status and Needs Assessment. Vol. I and II. (Meine C. Ed.). Washington D. C.: Biodiversity Support Program: 467–483.

Spiridonov G., Spassov N. 2015. Otter (*Lutra lutra* Linnaeus, 1758). Red Data Book of the Republic of Bulgaria. Vol. 2. Animals. BAS & MOEW, Sofia. 383 p. (in Bulgarian).

Taastrøm H.-M., Jacobsen L. 1999. The diet of otters (*Lutra lutra* L.) in Danish freshwater habitats: comparisons of prey fish populations. Journal of Zoology 248(1): 1–13.

Vaclavikova M., Vaclavik T., Kostkan V. 2011. Otters vs. fishermen: Stakeholders' perceptions of otter predation and damage compensation in the Czech Republic. Journal for Nature Conservation 19: 95–102.

Tariff for compensation in causing persistent damage to protected natural objects 1980. Adopted with Decree No 71 of the Council of Ministers of the Republic of Bulgaria since 19 Dec. 1980 (prom. SG. 11/6.02.1981, amend. SG. 57/24.07.1987, c. SG. 116/9.12.1997).

Webb J.B. 1975. Food of the Otter (*Lutra lutra*) on the Sommerset levels. Journal of Zoology, Lond. 177: 486–491.

Webb J.B. 1976. Otter spraint analysis. Occasional Publication. London.
Wise M.H., Linn I.J., Kennedy C.R. 1981. A comparison of the feeding biology of mink *Mustela vison* and otter *Lutra lutra*. Journal of Zoology 195: 181–213.

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CONSUMER'S PREFERENCES AND FACTORS AFFECTING THE URBAN DEMAND FOR BAOBAB (*ADANSONIA DIGITATA* L.) FRUITS IN SUDAN

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Abstract

The objective of the study was to recognize the baobab fruit consumers' preferences and factors affecting the urban demand. For this purpose, data was collected in 2015 from 100 and 150 fruit consumers in Elobeid and Khartoum markets, respectively, using structured questionnaire. Descriptive statistics (frequency and percentages) were used for data analysis. The study results reveal that there is demand for the baobab fruit and its secondary products, and thus substantial fruit pulp commercialization exists in Sudan. The most important attraction factor for the consumer is the nutritional value (vitamins) of the fruit pulp. The study suggests a need for promoting fruits processing, and this could further create a desire for domesticating and managing baobab trees in private farms and rural livelihoods improvement.

Key words: consumer preferences, demand determinants, NTFPs, tree fruits.

Introduction

Baobab (*Adansonia digitata* L.) grows naturally and is a typically scattered tree in the savannah, in fields and fallows, and is often associated with human settlements (Schreckenberg 1999, Duvall 2007). The tree, of which many parts can be used as food (Gebauer et al. 2002), has an important role in contributing to family nutrition and food security, as well as to cash income generation particularly for marginalized rural communities (Jamnadass et al. 2011, Adam et al. 2012, Adam et al. 2013, Adam et al. 2015, Venter and Witkowski 2013). The fruit pulp is of high nutritional value, particularly for calcium and vitamin C (Stadlmayr et al. 2013, Bamalli et al. 2014), has pre-biotic and antioxidant functions and high dietary fiber contents (Gebauer et al. 2002). It has been also mentioned in different African pharmacopoeias to treat malaria, ulcer, skin problems, fever, diarrhea and anemia (Diop et al. 2005, Caluwe et al. 2009), which is considered as the most important public health problems in Africa (FAO/WHO 2005).

The naturally low water content of the fruit pulp allows its long-term storage and later consumption in times of need and makes its transport to domestic and international markets easy (Gruenwald and Galizia 2005). Since 2008, dried baobab fruit pulp has been accepted as a novel food ingredient in the European Union,

as well as for the US market (CEC 2008, Wilkinson 2006, Jones 2007, FDA 2009). However, in many countries, fruits consumption is below recommended levels of the world. Wild fruits provide promising solutions for the so-called 'hidden hunger', which is currently affecting about 2 billion people over the world (IFPRI 2015). Wild fruits consumption in Sub-Saharan Africa range from about 100 g/person/day in Guinea, 71 g in Kenya, 64 g in Ghana, 55 g in Tanzania, 34 g Uganda, 30 g in Malawi, and 23 g in Mozambique (Ruel et al. 2005). These intake quantities are below the recommended daily amount of 200 g of fruits per person or 400 g of fruits and vegetables combined (WHO 2003). Nevertheless, studies on wild fruits consumption are limited (Keding et al. 2017). Thus, the objective of this paper was to investigate the baobab fruit consumers' preferences and factors affecting the consumer's urban demand.

Materials and Methods

Study area

The present study about *Adansonia digitata* fruits consumers' preferences, behavior and factors affecting the demand was conducted in Sudan (15° N and 30° E), which is situated in northeast Africa, with an area of 1,861,484 km^2 and total population of 35,482,233. It is bounded on the north by Egypt, on the northeast by the Red Sea, on the east by Eritrea and Ethiopia, on the south by South Soudan, Kenya, and Uganda, on the west by the Central African Republic and Chad, and on the northwest by Libya. In the northern plains and desert region, average temperatures range from 32 °C in winter (November to February) to 42 °C in summer (March to June); the hottest months are May and June. In the central and southern regions, average temperatures are 27 °C to 29 °C. Rainfall decreases from south to north, the annual average varying from 1200 mm in the south to less than 10 mm in the north; the rainy season is from July to September. The acacia desert shrub and acacia short-grass shrub grow in the northern desert and the grasslands – in the west. The broad-leaved tropical woodland and forest region is in the most part in the southwest, where areas of luxuriant growth and closed forests are found; grass covers much of the steppe area of the southeast.

The principal study cities are Elobeid and Khartoum. Elobeid (13° 18′ N and 30° 22′ E) is located in the dry zone of central Sudan, North Kordofan state. The total population is about 340,940 (UNDP 2010). The city is approximately 600 km from the capital Khartoum. The city has one of the most important agricultural gum Arabic markets in Sudan. Khartoum (15° 33′ N and 32° 32′ E) is the capital of the country with total population of 4,286,000. The selected study cities provide contracting cases in terms of their socio-economic and other characteristics. Khartoum has higher population (12 %) of the national figure while Elobeid constitutes 0.96 % of the total country population. In addition, these cities were chosen because there are markets for baobab fruits.

Data collection and analysis

A consumer survey was conducted in two cities each in different state (Elobeid and Khartoum) to investigate fruits consumed including priorities, purpose of consuming, consumer's preferences (fruit attributes), consuming form and desired products, attitude to consumption of the fruit pulp, and

problem experienced by fruit consumers. A total of 250 consumers (100 in Elobeid and 150 in Khartoum) were randomly selected using structured questionnaire in 2014. The questionnaire was pre-tested and redesigned before use. Pre-testing involved five consumers in each city market on a convenience basis but from among the target group. To ensure ethical issues, effective communication, and improve reliability of the study results, a consumer was informed in advance about the study objectives, the voluntary nature of her/him in the research, what expected from her/him if she/he participates, and how her/his privacy will be respected. The study focused on consumer as a unit of analysis because findings at consumer level were expected to have stronger influence on the design of interventions on trading the fruits than perceptions at either collector or trader levels. Consumers are the primary architects of an industry through the decisions they make about products on market (Kohls and Uhl 1998).

Data analysis involved the process of arranging data into computer readable form for statistical analysis (coding), checking for mistakes and entering data into computer. Data was coded to obtain a limited set of attributes for a variable composition. Descriptive and inferential statistics involving frequency tables, and percentages were used for data analysis using SPSS and Microsoft Excel Programs.

Results

Socioeconomics characteristics of the respondents

The results show that sixty percent (60 %) of the consumers (*n*=150) are females in both study areas. The mean age for a consumer of fruit is 45 years. Consumers' age distribution ranges from 18 to 65 years. The majority of the consumers are married. The average consumer household consists of five persons. The education level for the consumers ranges from no formal education (35.5 %) through primary school (30.4 %), higher secondary school (20.7 %) to university education (13.4 %). The annual average income for the consumer is SDG 12,000 (US$ 2,068).

Consumers' preferences

A number of different types of wild fruits are traded and consumed in both Elobeid and Khartoum. At least 8 wild fruits are consumed. Table 1 shows the consumers' ranking of the wild fruits in the two market places, baobab fruit is the most commonly consumed. Consumers ranked *Adansonia digitata* fruit among the wild fruits with an overall mean ranking/score of 2.00 and 2.10 for Elobeid and Khartoum markets, respectively. It is followed by *Grewia tenax* (Forssk.) Fiori. fruit in both market places. The respondents said they like *A. digitata* fruit because it is easy to process into several products (e.g. juice). *G. tenax* fruit is the second most popular fruit in Elobeid and Khartoum. Based on the rankings, it seems that consumers use *A. digitata* and *G. tenax* fruits for similar purposes. Therefore, *G. tenax* fruit might be considered a competing fruit to *A. digitata*. For instance, in Khartoum the retailers observed that they can sell *G. tenax* fruit and *A. digitata* and still be able to satisfy the market. They mentioned the following fruits as the potential close substitutes for *A. digitata* fruit: *G. tenax* and *Tamarindus indica* L. in Khartoum. However, in Elobeid the retailers and consumers report no close substitutes to *A. digitata* fruit as it has historical and cultural uses in the region.

Table 1. Ranking of preferred wild fruits for consumption (*n*=250).

Name of fruit tree		Rank			
		Mean Score*		Position based on Mean (score/rank)	
Scientific	Local	Elobeid (*n*=100)	Khartoum (*n*=150)	Elobeid (*n*=100)	Khartoum (*n*=150)
Adansonia digitata L.	Gongles	2.00	2.10	1	1
Ziziphus spina-christi (L.) Desf.	Nabag	3.75	3.81	4	5
Blanites aegyptiaca (L.) Delile	Lalob	4.50	4.00	6	6
Grewia tenax (Forssk.) Fiori	Guddeim	3.00	2.71	2	2
Sclerocarya birrea (A. Rich.) Hochst.	Humeid	4.00	5.00	5	8
Hyphaene thebaica (L.) Mart.	Dom	3.20	3.70	3	4
Tamarindus indica L.	Aradeib	4.56	3.21	7	3
Borassus aethiopum Mart.	Deleib	5.00	4.90	8	7

Note: * – calculated by adding the individual ranking by the respondent and dividing by total number of respondents. This means that the lower the mean the more popular the fruit is (a fruit positioned as 1 is more popular than one positioned 2 or 3 in ranking).n presents number of respondents.

Reasons for fruit consumption

Reasons for consuming the fruits are generally the same for the two study areas as reported by the respondents during the market survey. In both study areas, nutritional value (vitamins) and sweetness are the most popular reasons. In Elobeid, reasons for fruit consumption include vitamins (75 %), sweetness (20 %), cultural value (3 %), and snack value (2 %). In Khartoum, the chief purposes for fruit consumption are vitamins (90 %), sweetness (9 %), and sank value (1 %). The consumers in Khartoum didn't mention cultural value as reason for consuming the fruit. The fruit nutritional value is reported by the respondents as important reason behind the consumption of the fruit in both study areas.

Raw *versus* processed fruits

Based on study results, there is processing of *A. digitata* fruit in both study areas. The fruit is consumed both in raw and processed form. The majority of consumers in Elobeid (67 %) and in Khartoum (80 %) consume the processed fruit, while only 30 % and 20 % indicated that they consume it raw in Elobeid and Khartoum, respectively (Table 2). When consumers are asked in which of the two forms they would want to consume the fruit, the majority prefer processed fruit. Table 2 shows different consumer consumption desires in the study areas. The majority of consumers would like to have rather processed fruits than raw.

Some respondents want raw fruit for reasons of safety and health, while the respondents who prefer processed fruit are for reasons of food security and value addition and having better products than raw on the market. The desired processed products for the consumers are juice, fine powder, jam and ice cream. A segment of the consumers is knowledgeable about the benefits of processing the *A. digitata* fruit into other products. Juice and jam are the most preferred in Khartoum, while consumers in Elobeid prefer only juice.

Table 2. Current and desired consumption by study markets.

Market (*n*=250)	Scenario	Consumption form			Total, %
		Raw, %	Processed, %	Raw & processed, %	
Elobeid	Current	30	67	3	100
(*n*=100)	Desired	20	70	10	100
Khartoum	Current	20	70	10	100
(*n*=150)	Desired	1	97	2	100

Factors influence fruit consumers' behavior

Table 3 explains ten attributes of *A. digitata* fruit and marketing environment the consumers consider when making decisions to purchase the fruit. The two attributes mostly valued by consumers are taste and cleanness of the fruit. About 90 % of the consumers in Elobeid and 88.5 % in Khartoum mentioned taste of the fruit as the strongest factor considered. Cleanness of the fruit is considered strongly by 80 % of the consumers in Elobeid and 77 % of the consumers in Khartoum.

Table 3. Comparison of factors considered by consumers when buy *Adansonia digitata* fruit.

Attributes	Respondents, % (*n*=250)					
	Strongly considered		Considered		Not considered	
	Elobeid (*n*=100)	Khartoum (*n*=150)	Elobeid (*n*=100)	Khartoum (*n*=150)	Elobeid (*n*=100)	Khartoum (*n*=150)
Taste of the fruit	90.00	88.50	9.00	10.50	1.00	1.00
Color of the fruit	60.00	30.00	38.50	55.00	1.50	15.00
Maturity of fruit	77.00	56.43	23.00	43.57	10.00	0.00
Price of the fruit	25.34	20.00	74.66	60.00	0.00	20.00
Selling site	50.56	66.00	40.00	42.00	10.00	2.00
Packing of the fruit	22.36	40.00	20.00	50.00	56.64	10.00
Source of the fruit	76.13	50.00	23.87	22.34	0.00	20.66
Cleanness of the fruit	80.00	77.00	20.00	32.00	0.00	1.00
Size of the fruit	45.65	30.33	50.35	60.00	4.00	9.67
No pests	100.00	100.00	00.00	00.00	0.00	0.00

Factors affecting the demand for *Adansonia digitata* fruits

The consumers of *A. digitata* fruit in the two study areas experience a number of problems such as fruits having different taste (20 %), spoilage of the fruits (13.5 %), seasonality of the fruits (12.9 %), high fruit price (5.5 %), and unhygienic selling environment (2.6 %). Less common problems were stomach pains after eating the fruits (0.5 %), inconsistent supply of the fruit (0.5 %), no fruit grading system (0.3 %), raw fruit being the only competition from available on market (0.2 %), and fruit contains too many seeds (0.2 %). About 43.8 % of the respondents said they did not experience any problems as consumers of the fruits. Related to the general problems consumers face with the fruit is the preferred form in which the fruit should be marketed. The consumers' preference

is having packed fruit (50 %), grade the fruit based on size and taste (43.1 %), and processed fruits into juice, jam and fine powder (90.5 %).

Discussion

The study results reveal that married respondents formed the majority of the consumers of the *A. digitata* fruits. Ramadhani and Schmidt (2008) also reported that in Zimbabwe the purchasing behavior for *Uapaca kirkiana* Müll. Arg. and *Strychnos cocculoides* Baker fruits is correlated with the gender, marriage status, education and market sites for the respective fruit. Their study further revealed that educated people were more likely to buy the fruits than less educated categories. The findings suggested that there might have been a family influence in purchasing behavior of indigenous fruits (Ramadhani and Schmidt 2008). One possible explanation for such influence could be a higher level of appreciation of the nutritional and other value because of the knowledge about *A. digitata* fruit. These findings, including that of this study, identify and stress the importance and need to educate (sensitize/raise awareness) population on the nutritional value and benefits of consuming the fruit. In this regard, strategic extension services and/or events would be appreciated.

In the study areas, the current findings show *A. digitata* fruit as the most preferred and popular fruits followed by *Grewia tenax* fruit. The current study also has shown that *A. digitata* fruit was preferred both raw and processed fruit product for several reasons, including sweetness and nutritional value. Nutrition and taste are popular reasons for choosing the fruit among consumers. Study findings suggested that consumers can increase their nutritional well-being by utilizing the fruit tree products. Foods from trees and forests such as fruits, vegetables and bushmeat are rich in micronutrients (Chivandi et al. 2015) and can often be acquired cheaply and easily without the need for significant capital investment (Awodyin et al. 2015). Ensuring access to nutritionally important foods such as fruits, vegetables and animal source foods is particularly important for preventing micronutrient deficiencies (Stadlmayr et al. 2013) but the widespread usage of wild foods focuses primarily on knowledge, use and nutritional composition of wild foods, and not on contributions to human nutrition (Buchmann et al. 2010).

Some fruit demand drivers were based on fruit characteristics and market environment. Based on the study results there were ten attributes of fruit and marketing environment the consumers considered when making decisions to purchase the fruit. Most of the consumers value taste and cleanness of the fruit. Taste was the most strongly considered. This finding shows that consumers of the fruit regarded quality measures (taste, cleanness, etc.) of the important when selecting fruit for consumption. In some studies on indigenous tree fruits (ITFs) consumers also regarded quality measures (texture, taste and flavors) more than price (Harker et al. 2003). Buying behavior for *A. digitata* fruit was also influenced among others by price, size, pest infection, color, maturity, packing, and source of the fruit. These in order to increase the sales and income generation, collectors and traders must provide fruits with the characteristics identified by the consumers. These might be addressed in two major ways to expand the fruit demand. One way would be through marketing strategies which

such attributes as pricing, fruit maturity, packing, selling site and cleanness could be addressed. The other way is scientific research. Matters of size of fruit, pest and taste may require genetic improvement (Assogbadjo et al. 2008). Different tastes may result substantially from tree-to-tree variation in fruit characteristics and thus a lack of uniformity in quality. Gebauer and Luedeling (2013) report the existence of a high morphological diversity in baobab stands in Sudan.

The consumers experience seasonality supply of the fruit by the traders. The fruit is available at most only a quarter of the year due to their seasonality nature (Adam et al. 2012). More tree fruits have seasonal production and demand patterns that also influence their marketing (Adam 2015), suggesting that there are among the important constraints in the trade of the fruit (Adam et al. 2013). However, the availability of *A. digitata* fruit at a time when most agricultural crops are not harvested improves nutrition and secures income generation especially for rural people (Adam 2015). The reason for consuming the fruit was generally same for the two study areas with sweetness and nutritional value/vitamins as the most popular reasons. The fruit was consumed both in raw and processed form. Referring to the Indian scenario, Haq et al. (2008) reported that the higher nutritional value and medicinal properties of some fruits could be exploited by producing products for niche markets, such as health foods and natural products. They observed that many of indigenous tree fruits have considerable marketing potential. Adam (2015) made similar observation whereby *A. digitata* fruits are eaten raw or processed in the form of fine powder, juice and other products with processed and unprocessed fruits being occasionally sold to urban markets for cash income. As indicated by this study, low levels of processing might be because of limited technology to add value to the product. Unlike Khartoum (1 %), in Elobeid 20 % of consumers preferred raw to processed fruit. The reason for the differences in consumption from preference is not clear or certain but could be about awareness level. The Khartoum market might be more exposed to processed fruit product than Elobeid market. For Elobeid the indication of preference was based on the knowledge that exists among the consumers of what was possible to produce. In Khartoum, it appeared that the people were more aware of the potential products into which the fruit could be processed. This could have been due to the Food Research Center (FRC) in Khartoum which disseminates and scales up baobab fruit products development technologies. Studies have also shown that effective utilization of indigenous knowledge and community preferences were a key to domestication of *A. digitata* tree (Assogbadjo et al. 2008) and trading of its products (Adam 2015). Most of the foregoing reasoning for consuming and preferring raw to processed fruit products seems to revolve around limited knowledge of the alternative utility forms of the fruit. It seems the fruit has not been rigorously promoted especially with the support of FRC in Khartoum. A side from increasing the income for the rural collectors and traders, promoting the processing of the fruit would encourage fruit tree domestication and management to satisfy expanded market demand including people who have apprehension for unfamiliar products. It is however, important to note that knowledge exists about the importance of processing the fruit and could be investigated further.

Conclusions

This study has shown that the demand for baobab fruit is propelled by desire for vitamins and sweetness among others. Such desires are addressed by consuming the fruit in basically two utility forms. The raw form in the market place is the commonest followed by the processed form. Very few people consume the fruit in both the raw and processed form at the present. Analysis of the responses revealed that some of the consumption preferences were due to the limited knowledge on possible utility options on the part of the consumers. Processing of the fruit is welcomed by consumers for various purposes including health, value added and better products. Consequently, a number of potential products and opportunities for product development have been identified in this study comprising, fine powder, juice, etc.

Recommendations

The raw fruits should be processed into other finished products desired by the consumers. There is also a need for disseminating the appropriate information/ knowledge to the various actors in the *A. digitata* fruit commercialization. In this regard, research should therefore work to strengthen communication among all stakeholders especially collectors/traders who have limited access to information like potential utility forms of the fruit. For instance, consumption in only raw form is a result of ignorance about processing. Equally, information about the nutritive value of the fruit can help improving demand and enable it compete with other exotic fruits. Therefore, this study is recommending public awareness and education by extension methods among all actors including formal, private, and agribusiness sectors to accord them an opportunity to made enlightened choices about the fruit. The strategic extension/ education intervention packages may be to systematically promote the consumption of the fruit in addition forms either unknown or currently unacceptable to the majority of the consumers. This could expand the fruit demand which can create an incentive for tree species domestication and management on private farms.

References

Adam Y.O. 2015. Contribution of some tree fruits to rural development in Sudan. LAP LAMBERT Academic Publishing, ISBN: 978-3-659-35980-4. 180 p.

Adam Y.O., Eisa M.A., Ahmed D.M. 2012. Role of *Adansonia digitata* L. fruits in development and forest conservation in Rashad locality, Nuba Mountains, Sudan. University of Khartoum Journal Agricultural Sciences 20(3): 314–328.

Adam Y.O., Jürgen P., Pettenella D. 2013. Contribution of non-timber forest products livelihood strategies to rural development in drylands of Sudan: Potentials and Failures. Agricultural Systems 117: 90–97.

Assogbadjo A.E., Kakai R.G., Chadare F.J., Thomson L., Kyndt T., Sinsin B., Van Damme P. 2008. Folk classification, perception, and preferences of baobab products in West Africa: consequences for species conservation and improvement. Economic Botany 62(1): 74–84.

Awodoyin R.O., Olubode O.S., Ogbu J.U., Balogun R.B., Nwawuii J.U., Orji K.O. 2015. Indigenous fruit trees of tropical Africa: Status, opportunity for development and biodiversity management. Agricultural Sciences 6: 31–41.

Bamalli Z., Mohammed A.S., Ghazali H.M., Karim R. 2014. Baobab (*Adansonia digitata* L.) parts: Nutrition, application in food and uses in ethno-medicine- A review. Ann Nu-

tral Disorder & Therpy 1(3): 1–9.

Buchmann C., Prehsler S., Hartl A. Vogl C.R. 2010. The importance of Baobab (*Adansonia digitata* L.) in rural west African subsistence – Suggestion of a cautionary approach to international market export of Baobab fruits. Ecology of Food and Nutrition 49: 145–172.

Caluwe E.D., De Smedt S.A., Assogbadjo E., Samson R., Sinsin B., Van Damme P. 2009. Ethinc differences in use value and use pattern of baobab (*Adansonia digitata* L.) in northern Benin. Afracan Journal of Ecology 47: 433–440.

CEC 2008. Commission Decision of 27 June 2008 authorizing the placing on the market of Baobab dried fruit pulp as a novel food ingredient under Regulation (EC) No 258/97 of the European Parliament and of the Council (notified under document number C(2008) 3046) (2008/575/EC). Official Journal of the European Union. 11/7/2008. Available at: http://www.food.gov.uk/mul/t/imedia/pdfs/commdec2008575ec.pdf [last accessed on 08/09/2015].

Chivandi E., Mukonowenzou N., Nyakudya T., Erlwanger K.H. 2015. Potential Indigenous fruit-bearing trees to curb malnutrition, improve household food security, income and community health in Sub-Saharan Africa: A review. Food Research International. Available at: http://dx.doi.org/10.1016/j.foodres.2015.06.015.

Diop A.G., Sakho M., Dornier M., Cisse M., Reynes M. 2005. African baobab (*Adansonia digitata* L.): Principal characteristics and utilisation. Fruits 61: 55–69.

Duvall C.S. 2007. Human settlement and baobab distribution in south-western Mali. Journal of Biogeography 34: 1947–1961.

FAO/WHO 2005. Fruit and vegetables for health. In Proceedings of a Joint FAO/WHO Workshop on Fruit and Vegetables for Health, 1–3 September 2004, Kobe, Japan, 46 p. FAO – Food and Agriculture Organization of the United Nations, Rome, Italy and WHO – World Health Organization, Geneva, Switzerland.

FDA 2009. Agency response letter GRAS notice No GRN000273, 25/July/2009. US Food and Drug Administration. Available at: http://www.fda.gov/Food/FoodIngredientsPackaging/GenerallyRecognizedasSafeGRAS/GRASListings/ucm174945.htm [last accessed on 08/06/2015].

Gebauer J., El-Siddig K., Ebert G. 2002. Baobab (*Adansonia digitata* L.): a review on a multipurpose tree with promising future in the Sudan. Gartenbauwissenschaft 67: 155–160.

Gebauer J., Luedeling E. 2013. A note on baobab (*Adansonia digitata* L.) in Kordofan, Sudan. Genetic Resoure Crops Evolution 60: 1587–1596.

Gruenwald J., Galizia M. 2005. Market Brief in the European Union for selected natural ingredients derived from native species, *Adansonia digitata* L. Baobab. United Nations Conference on Trade and Development, Geneva. Available at: http://www.biotrade.org/ResourcesPublications/Biotradebriefbaobab.pdf [last accessed on 23/05/2014].

Haq N., Bowe C., Dunsiger Z.E. 2008. Challenges to stimulating the adoption and impact of indigenous fruit trees in tropical agriculture. In: Akinnifesi F.K., Leakey R.B., Ajayi O.C., Sileshi G., Techoundjeu Z., Matakala P., Kwesiga F.R. (Eds.). Indigeous fruit trees in the tropics domestication, utilization and commercialization. Wallingford: CABI Publishing: 50–69.

Harker F.R.; Gunson F.A., Jaeger S.R. 2003. The case for fruit quality: An interpretive review of consumer attitudes and preferences for apples. Postharvest Biology and Technology 28: 333–347.

International Food Policy Research Institute (IFPRI) 2015. Global Nutrition Report 2015: Actions and accountability to advance nutrition and sustainable development. Washington, DC. 168 p. http://dx.doi.org/10.2499/9780896298835

Jamnadass R.H., Dawson I.K., Franzel S., Leakey R.R., Mithöfer D., Akinnifesi F., Tchoundjeu K.Z. 2011. Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallholders' agroforestry systems. A review. International Forestry

Review 13: 1–17.

Jones C. 2007. Initial opinion: baobab dried fruit pulp. Food Standards Agency. Available at: http://www.food.gov.uk/multimedia/pdfs/baobabinitialopinion.pdf [last accessed on 30/05/2014].

Keding G.B., Kehlenbeck K., Kennedy G., McMullin S. 2017. Fruit production and consumption: Practices, preferences and attitudes of women in rural western Kenya. Food Security 9(3): 453–469.

Kohls R.L., Uhl J.N. 1998. Marketing of agricultural Products. Eighth edition. Upper Saddle River Prentice Hall. 560 p.

Ramadhani T., Schmidt E. 2008. Marketing of indigenous fruits in Southern Africa. In: Akinnifesi F.K., Leakey R.B., Ajayi O.C., Sileshi G., Tchoundjeu Z., Matakala P., Kwesiga F.R. (Eds.) Indigenous fruit trees in the tropics domestication, utilization and commercialization. Wallingford: CABI Publishing: 224–236.

Ruel M.T., Minot N., Smith L. 2005. Patterns and determinants of fruit and vegetable consumption in sub-Saharan Africa: a multicountry comparison. Paper presented at the joint FAO/WHO workshop on fruit and vegetables for health, 1–3 Sept 2004. Kobe, Japan. International Food Policy Research Institute. Washington DC, USA. 45 p. Available at: http://cdrwww.who.int/dietphysicalactivity/publications/f&v_africa_economics.pdf [last accessed on 05/11/2017]

Schreckenberg K. 1999. Products of a managed landscape: Non-timber forest products in the parklands of the Bassila region, Benin. Global Ecology and Biogeography 8: 279–289.

Stadlmayr B., Charrondiere U., Eisenwagen R.S., Jamnadass R., Kehlenbeck K. 2013. Nutrient composition of selected indigenous fruits from sub-Saharan Africa. Journal of the Science of Food and Agriculture 93: 2627–2636.

UNDP 2010. Socio-economic and opportunity mapping assessment report for North Kordofan State. Joint mission (NSD-DRC-SC/ UNDP). 38 p.

Venter S.M., Witkowski E.T.F. 2011. Baobab (*Adansonia digitata* L.) fruit production in communal and conservation land-use types in Southern Africa. Forest Ecology and Management 261: 630–639.

Wilkinson J. 2006. Baobab dried fruit pulp- An application for novel foods approval in the EU as a food ingredient. The Seed Bed Centre, Langston road, Loughton, UK. Available at: http://www.food.gov.uk/multimedia/pdfs/baobabapplicationfinal.pdf [last accessed on 30/06/2015].

WHO 2003. WHO fruit and vegetable promotion initiative – report of the meeting. 25–27 August 2003, Geneva, Switzerland, World Health Organization. 29 p. Available at: http://www.who.int/dietphysicalactivity/publications/f&v_promotion_initiative_report.pdf [last accessed on 05/11/2017]

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NATURAL REGENERATION UNDER PINE STANDS IN FRESH PINE FORESTS OF ZHYTOMYR POLISSYA AREA (UKRAINE)

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Abstract

Under unfavourable ecological and climatic factors pine plantations preserve the seeding abilities on forest plots. Provision of soil moisture (that directly depends on regular precipitations) during vegetative period is decisive for the appearance and preservation of young generation. Successful natural regeneration of more than ¾th of area is possible due to the pine undergrowth of even less than 10-year-old trees, accounting their vitality.

Key words: density of undergrowth, frequency, natural losses, pine undergrowth, vitality.

Introduction

The largest forest areas in Zhytomyr district during last several years alongside with the biggest (among other districts of Ukraine) total cuttings (total cuttings of main utilization forests and total sanitary cuttings) are being regenerated. About 2/3 of forest plots are regenerated artificially, the rest are left for natural regeneration (Statistic … 2014).

The plots with excess moisture growing conditions are most often left for natural regeneration. Under moist and wet conditions often occurs together with the change of valuable tree species for con-comitant species, which is a negative phenomenon in forestry. Under these conditions the regenerative potential of valuable species in favourable for natural regeneration types of forest growing conditions is of little utilization (Mehalinskyy 1968, Maurer and Kolodiy 2005, Maurer et al. 2008), for example, Scots pine under the conditions of fresh and moist pine forest that prevail in the region (Turko et al. 2015, Fuchylo et al. 2011). According to the current normative documents (Felling rules 2009) less than 8 thousand trees per ha with height up to 0.5 m of vital pine undergrowth is considered to be sufficient under the condition of its even distribution. Although, according to the successful natural regeneration scale Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky (URIFFM) the estimation of the quantity of vital undergrowth depends foremost on its age. For 4- – 8-year-old trees 6 thousand trees per ha is considered sufficient and for 2- – 3-year-old trees – 12 thousand per ha (Pasternak et al. 1990).

In recent years the pine tree stands in Ukraine as well as in Europe (in Poland and Belarus in particular) have been found in extremely unsatisfactory state. Most scientists and practitioners consider it to be the result of deterioration of ecological and climatic conditions of the mentioned areas (Anonimous 2016, Anonimous 2017a, Anonimous 2017b, Chudak 2014). The lowering of groundwater level is one of the decisive factors affecting the drying out of pine plantations.

On the account of deterioration of sanitary conditions, because of the changes in Sanitary Rules (Sanitary rules … 2016) that allow thinning out the density up to rare growing trees by selective sanitary cutting, the question of regeneration of disturbed plantations is especially sharp. With the view of the above, extremely important is the formation of new forest generation from the undergrowth. So as occurrence and preservation of natural regeneration is a variable phenomenon that depends on ecological and climatic factors and on the farming activity of humans (Turko 1995), the goal of this research is to study the state of undergrowth of plantations free from any forestry activity during several years. Alongside with it, the research is aimed at the extent to which pine plantations weakened because of deterioration of ecological and climatic conditions are able to regenerate.

The goal of the research was to discover the following:

1. To research the level of mature and premature pine tree stands provision with reliable advanced growth of aimed species, Scots pine, in particular;

2. To determine the height, age structure and vitality of pine undergrowth;

3. To study the dynamics of occurrence and natural losses of Scots pine shoots.

Material and Methods

To perform the above tasks we carried out the accounting of natural regeneration on 20 experimental plots. All objects were in Levkiv Forestry SE ‘Zhytomyr Forestry’, so as the largest areas of pine plantations growing under pine forest conditions were concentrated in this forestry.

In general, the criteria of selecting experimental plots were composition, age, origin, type of forest and vegetative conditions, density and absence of forestry measures for the last 3 years. Because of substantial volumes of carried out forestry measures in this enterprise (sanitary cuttings in particular) only 20 plots meeting the criteria have been chosen for the research. All plots were represented by premature and mature pure pine tree stands with stand density from 0.6 to 0.8. The type of forest is fresh fairly poor with oak and pine of artificial origin.

Among living above soil litter dominates green moss (*Dicranum polysetum* Sw., *Pleurozium schreberi* (Willd. ex Brid.) Mitt.), red bilberries (*Rhodococcum vitis-idaea* (L.) Avror.), heather (*Calluna vulgaris* (L.) Hull), and cereal vegetation (*Agrostis vinealis* Schreb., *Festuca ovina* L., *Festuca rubra* L. s. str., *Calamagrostis epigeios* (L.) Roth, *Poa pratensis* L.). The underbrush is sporadically represented by rowan tree (*Sorbus aucuparia* L.), hawthorn (*Crataegus monogyna* Jacq.) and sweetbrier (*Rosa canina* L.). The compositiont of living top soil litter and underbrush in every experimental plot was similar. In each experimental plot the accounting of natural regeneration was held along the merchantable lines that were made along the centre of spots. 100 m^2 of area at each spot were under calculations (Anonimous 2006). The calculations were exercised

on accounting sites of 0.5×0.5 m (Siruk et al. 2016) in size that were located along the merchantable line, the total length of which within every spot amounted 400 m. The accounting was held during August-September in 2016 and 2017 on the attached transects. The natural composition, vitality and size category were taken into account in calculations.

The estimation of vitality condition of Scots pine was made by applying the relative index – relative accretion (Saltykov and Tkach 2007). The investigation of its spectrum has been set into the basis of this method. This condition was reflected in the quantitative correlation of undergrowth of different rate of reliability (Zlobin 1976).

The analysis of vitality state spectrum of undergrowth predicts its grouping on the example of annual increment (accretion) of central axis. The correlation of crown increment for the last year and average increment of height (relative accretion of height) was used as index, allowing to estimate increment. The application of index permits (with certain subjective attitude) to single out the specimen with extinguished increment (to 0.5), progressive (0.5–1.5) and perspective. In the last group crown increment is 1.5 and more times higher than average increment of height for the whole growing period.

Results and Discussion

The accounting of advanced growth on the experimental plots was carried out during 2016–2017. These years were essentially different, as to the weather conditions that greatly affected the occurrence and natural losses of understory. A very dry, without precipitations, vegetative period was observed in 2016 from July to October. It should be mentioned that a year preceding the research was similar in weather conditions. While 2017, on the contrary, was marked with great precipitations and moderate temperature during vegetative period. The accounting results of all experimental plots confirmed the shortage of advanced growth by 28 % averagely (min – 7 %, max – 59 %). The biggest losses were noticed in pine forests with shallow undergrowth up to 0.5 m of height prevailing. The losses of 1- – 3-year-old trees on some experimental plots amounted 60 %. As to the older trees of 4- – 8-year-old the losses were not significant (about 5 %). The density of natural regeneration as well as its distribution worsened. If in 2016 the average frequency of pine undergrowth amounted – 34 %, in 2017 this index decreased to 25 %. As to the composition, on almost 19 plots it was represented by pine underwood with separate specimen of oak and birch. Only one plot revealed natural regeneration of ordinary oak alongside with pine under the canopy of parent stand (Table 1).

If we take into account only the number of pine undergrowth not accounting the height, structure and viability, ¾th of experimental plots were provided with more than 8 thousand trees per ha in 2017. But so far as the main value represents fine (shallow) undergrowth of 0.5 m height, the amount of this category regeneration will exceed the stated limit on 10 out of 20 plots. According to the methods URIFFM (Pasternak et al. 1990) as to the age of undergrowth, regeneration on 17 out of 20 plots may be considered successful.

Table 1. Characteristic of viable natural regeneration on experimental plots.

No sample plot	2016		2017		Composition of regrowth*
	Density, thousand pcs. ha^{-1}	Frequency, %	Density, thousand pcs. ha^{-1}	Frequency, %	
1	32.8	44	27.2	37	10Ps
2	56.8	74	39.4	54	10Ps
3	43.2	48	31.8	43	10Ps
4	20.0	30	8.3	16	10Ps
5	37.6	50	29.5	44	10Ps
6	21.0	30	13.2	22	10Ps
7	30.8	50	24.8	37	10Ps
8	29.0	44	12.3	21	10Ps
9	14.2	28	11.2	18	10Ps
10	17.6	30	8.9	16	10Ps
11	29.8	44	25.6	38	10Ps
12	13.6	28	7.3	14	10Ps
13	8.2	13	6.3	12	10Ps
14	25.2	39	17.3	30	10Ps
15	28.8	37	25.3	35	10Ps
16	14.1	24	10.1	17	10Ps
17	2.1	5	1.8	4	10Ps
18	9.3	21	7.4	13	10Ps
19	1.4	3	1.3	3	6Ps 4Qr
20	15.8	29	13.2	22	10 Ps

*Legend: Ps – *Pinus sylvestris* L.; Qr – *Quercus robur* L.

Within the period of 2 years, the height structure of undergrowth experienced some changes. These changes on all experimental plots depended as on the ability of undergrowth to regenerate so on the ability to transfer from one size category to another. So as in 2016 the average part of shallow (fine) underwood amounted about 86 %, middle and large 13 % and 1 % respectively, in 2017 these accounting plots showed 58 % of shallow, 38 % of middle and 14 % of large underwood (Table 2).

As to the annual young seeding, that were not included into general accounting, it should be stated that they wer not noticed at all during the survey in September 2016, because of two months draught. Consequently, the part of shallow (fine) undergrowth was not affected by young seeding of previous year. In 2017 the moisture supply of top soil (due to regular precipitations) during vegetative period made it possible to observe young seeding of pine from 100 to 12,200 trees per ha on experimental plots (Fig. 1). However, the character of young seeding location is mostly uneven (average frequency 4 %).

Table. 2. Height structure of underwood, %.

No sample plot	2016			2017		
	< 0.5 m	0.51–1.50 m	>1.50 m	< 0.5 m	0.51–1.50 m	>1.50 m
1	98.8	1.2		95.2	4.8	
2	93.3	6.7		82.4	17.6	
3	96.3	3.7		91.5	8.5	
4	95.5	4.5		86.8	13.2	
5	96.8	3.2		67.5	32.5	
6	79.1	17.6	3.3	21.2	67.4	11.4
7	92.9	7.1		75.8	22.2	2.0
8	96.2	3.8		88.7	11.3	
9	74.3	23.2	2.5	27.7	65.2	7.1
10	89.8	10.2		65.2	34.8	
11	95.6	4.4		81.7	18.3	
12	64.7	33.8	1.5	2.8	80.8	16.4
13	92.7	7.3		49.2	50.8	
14	91.7	8.3		57.2	42.8	
15	99.0	1.0		93.3	6.7	
16	100.0	0.0		95	5.0	
17	61.9	38.1		0.0	94.4	5.6
18	34.4	37.6	28.0	0.0	55.4	44.6
19	78.8	21.2		23.1	76.9	
20	81.6	18.4		57.8	42.2	

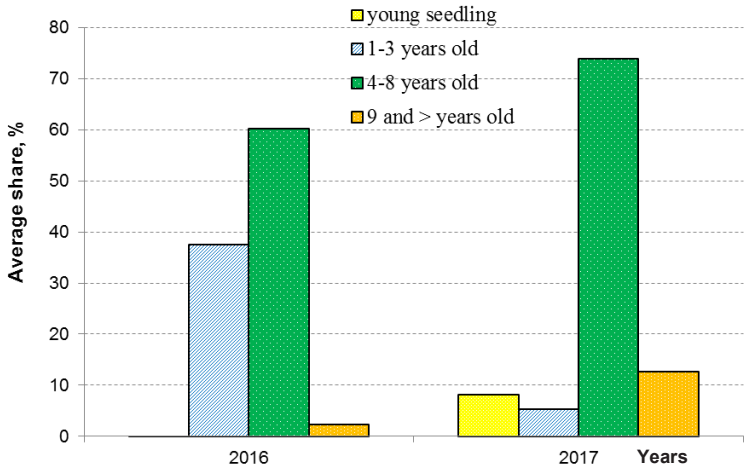

Fig. 1. Advanced growth for age groups.

The viability of shallow 1- – 3-year-old pine undergrowth was estimated visually. It should be noted, that the majority of shallow natural regeneration was viable with explicit increment and normal conifer sprouts at the moment of accounting. As to the medium and large undergrowth – the situation was more variable – part of it had a tendency to current increment reduction, though the conifer state of sprouts showed the signs of sound trees.

With the aim of determining viability of medium (0.5–1.5 m) and large (>1.5 m) pine undergrowth, the measuring of current medium increment of 30 pine specimen of each size category have been carried out. The specimen on the experimental plot were chosen accidentally, their number was connected with the level of probability (95 %) and with the variety of average undergrowth and height within size categories (on the level of 14 %) (Horoshko et al. 2004). For every pine tree the height, average and current increment (as to the height) has been determined (Table 3).

Table 3. Average values of biometric measures of pine advanced growth.

No sample plot	Height gradation of undergrowth, m	Medium height of undergrowth X±m	Increment in height, cm		Relative
			Medium, X±m	Current, X±m	
6	0.5–1.5	0.68±0.02	0.12±0.01	0.13±0.01	1.08
	>1.5	1.63±0.07	0.18±0.01	0.12±0.01	0.67
7	0.5–1.5	0.59±0.02	0.11±0.01	0.10±0.01	0.91
	>1.5	1.57±0.06	0.19±0.01	0.14±0.01	0.74
9	0.5–1.5	0.63±0.02	0.14±0.01	0.09±0.01	0.64
	>1.5	1.61±0.07	0.15±0.01	0.13±0.01	0.87
12	0.5–1.5	0.87±0.04	0.21±0.01	0.24±0.01	1.14
	>1.5	1.65±0.08	0.20±0.01	0.17±0.01	0.85
17	0.5–1.5	0.73±0.03	0.18±0.01	0.18±0.01	1.00
	>1.5	1.60±0.12	0.23±0.01	0.19±0.01	0.83
18	0.5–1.5	0.92±0.04	0.21±0.01	0.26±0.01	1.24
	>1.5	1.77±0.09	0.24±0.01	0.22±0.01	0.92

Because of the existence of Scots pine undergrowth of different regeneration waves we have conducted calculations as to relative increment for medium undergrowth (4- – 8-year-old) and large (from 9-year-old) on the experimental plot.

Judging from the calculated medium values of relative increment for undergrowth of different size categories on experimental plots, it should be stated, that this index exceeded for medium undergrowth on all plots. The relative increment index for regrowth of 0.5–1.5 m of height fluctuated between 0.64 and 1.24. This index showed the perspectives of natural regeneration of this size on 4 from 6 experimental plots. The average values of relative increment for large undergrowth comparing to the medium turned to be somewhat smaller (from 0.67 to 0.92). The relative increment of medium undergrowth on 6 experimental plots was 19 % higher in general than the corresponding index of large undergrowth. This fact testifies to the decrease of pine viability with time under the canopy of parent stand.

According to the applied methods of viability estimation as to pine underwood,

populations are divided into prosperous, balanced and depressed (Zlobin 1976). In the first case the next condition should be present: half amount of frequently perspective (perspective increment) and medium depressed (progressive increment) are more frequent than heavily depressed (extinguished increment). In the second case – half amount of frequency of specimen without depression (perspective increment) and medium depressed (progressive increment) are equal to the frequency of heavily depressed specimen. The domination of heavily depressed specimen is typical for depressed cenopopulation.

The given below table (Table 4) confirms that the majority of medium and large undergrowth is perspective on the experimental plots. The progressive advanced growth of pine obviously prevails in the spectrums of experimental plots No 12, 17 and 18. Consequently. according to the applied methods, these populations' undergrowth can be called 'prosperous'. The research results for large undergrowth constitute close correlation of specimen with extinguished, progressive and perspective indices of relative increment, allowing to estimate the population state on experimental plot as 'balanced'. As to the average undergrowth of this sample, it is mostly perspective.

Table 4. Fraction of advanced growth of various viability within size category, %.

No sample plot	Height gradation, m	Class of relative increment		
		Extinguished (0–0.49)	Progressive (0.5–1.49)	Perspective (≥1.5)
6	0.5–1.5	16.7	70.0	13.3
	>1.5	30.0	63.3	6.7
7	0.5–1.5	13.3	70.0	16.7
	>1.5	36.7	40.0	23.3
9	0.5–1.5	40.0	50.0	10.0
	>1.5	23.3	53.3	23.3
12	0.5–1.5	10.0	70.0	20.0
	>1.5	23.3	50.0	26.7
17	0.5–1.5	6.7	90.0	3.3
	>1.5	-	96.7	3.3
18	0.5–1.5	6.7	53.3	40.0
	>1.5	-	93.3	6.7

Estimating the advanced growth of Scots pine on experimental plot 7 (only for large undergrowth) and on experimental plot 9 (only for medium undergrowth) as to the viability state, the populations of young generation under the canopy of mature stand could be called 'depressive', so as the part of 'extinguished' specimen of undergrowth exceeded half of the sum of progressive and perspective specimen.

Conclusions

In spite of the enfeebled state of pine plantations, they preserve not bad ability to natural regeneration which is proved by the availability of young seeding of the current year (up to 12 thousands per ha in number). The occurrence and preservation of young seeding is directly connected with weather conditions during vegetative

period. The absence of precipitations for 2 and more months (example of 2016) under high temperatures led to perishing of seeding and one-year undergrowth. The losses of pine undergrowth of 3-year-old trees may reach 60 % a year, and older – up to 10 %.

In estimating the successful natural regeneration of Scots pine under the stand canopy, the methods of URIFFM seem to be appropriate, as they take into account undergrowth losses depending on its age.

Considering the viability of medium and large undergrowth the index of vitality should be applied. It is based on using the index of relative increment by height. Reliable is considered undergrowth when this index isn't lower than 1.

Over ¾th of investigated plots could be considered acceptable for natural reforestation being provided with necessary for natural regeneration measures.

References

Anonimous 2006. The sampling plots for forest management. The method of laying. Normative document, Ministry of Agrarian Policy of Ukraine. 32 p. (in Ukrainian).

Anonimous 2016. Drying out destroys Scots pine forests. (in Polish). Available at: http://www.lasy.gov.pl/pl/informacje/aktualnosci/susza-niszczy-sosny (Accessed on 13 June 2016).

Anonimous 2017a. Mass drying out of pine plantations. (in Russian). Available at: http://forestlife.by/ru/massovoe-usyhanie-sosnovyh-nasazhdeniy (Accessed on 22 September 2017).

Anonimous 2017b. Pine drying out caused by bark beetles expanding geography. (in Russian). Available at: http://lesgazeta.by/economy/nauka--proizvodstvu/koroednoe-usyhanie-sosny-rasshirjaet-geografiju (Accessed on 25 May 2017).

Chudak V. 2014. The information concerning forest condition of Ukrainian Polissya and Podillya: dated June 2. 2014. (in Ukrainian). Available at: http://dklg.kmu.gov.ua/forest/control/uk/publish/article;jsessionid=53B192DA48758B029DA0AE592D6B1DD0.app2?art_id=118307&cat_id=81209.

Felling Rules 2009. State Forestry Committee of Ukraine. Order No 364 dated December 23, 2009 (in Ukrainian). Available at:http://zakon3.rada.gov.ua/laws/show/z0085-10.

Fuchylo Y., Ryabukhin O., Sbytna M. 2011. The perspectives of formation of native Scots pine forests which was formed as a result of gradual felling in Kiev-Chernihiv Polissya. Scientific Herald of Ukrainian National Forestry University. Issue 21.10. Lviv: 15–19 (in Ukrainian).

Horoshko M., Myklush S., Khomyuk P. 2004. Biometric. Lviv. 236 p. (in Ukrainian).

Maurer V., Gordienko M., Brovko F., Fuchylo J., Pinchuk A., Kychylyuk A., Ivanyuk I. 2008. Theoretical and technological bases of reproduction of forests in environmentally oriented forestry principles. Scientific information center of forest management. 60 p. (in Ukrainian).

Maurer V., Kolodiy Yu. 2005. Reforestation based on environmentally oriented forestry as the basis of biological stability of forests. Naukoviy visnik NAU 83: 52–58 (in Ukrainian).

Mehalinskyy P. 1968. Natural regeneration in pine forests of central Polissya Ukrainian SSR. The increasing forest productivity, Kiev: 44–57 (in Ukrainian).

Pasternak P., Molotkov P., Patlay I., Polyakov V., Mihovich A., Avramenko I., Ananiev P., Berezhnoy M., Voron V., Gavrilenko A., Gavrilov V., Davydova N., Kiselevsky R., Krasnov V., Kuchma N., Ladeyshchikova E., Lebedev V., Lesovsky A., Lokhmatov N., Medvedev L., Molotkova I., Moroz V., Polupan A., Prikhodko N., Romashov N., Smolyaninov I., Teleshek Yu., Torosov A., Fedets I., Tsyganenko L., Chernyavsky N., Shinkarenko I. 1990. Forester's Handbook, Kiev. 296 p. (in Russian).

Saltykov A., Tkach L. 2007. Assessment of the vital state of pine undergrowth. Forestry and hunting: the current state and development prospects. Volume II. State Agro-

ecological University, Zhytomyr: 159 (in Russian).

Sanitary rules in the forests of Ukraine 2016. Ukrainian Government Regulation No 756 dated October 26, 2016. (in Ukrainian). Available at: http://zakon3.rada.gov.ua/laws/show/555-95-%D0%BF.

Siruk Yu., Pechenyuk E., Chernyuk T. 2016. The methodical peculiarities of determining the density of pine regrowth according to the index of frequency under conditions of fresh Pine forests. Scientific Bulletin of UNFU. Issue 26.8, Lviv: 159–165 (in Ukrainian).

Statistic Annual Book of Ukraine for Year 2014. 2015. State Statistics Service of Ukraine, Kiev. 585 p. (in Ukrainian).

Turko V. 1995. The peculiarities of natural renewal, preservation in the process of felling and formation of young pine trees in pine forests of Ukrainian Polissya. Abstract of PhD thesis. URIFFM, Kharkiv: 12 p. (in Ukrainian).

Turko V., Siruk Yu., Chernyuk T. 2015. Characteristics of volumes reforestation in forestry companies of Zhytomyr region. Agricultural science, education, production: European experience for Ukraine. Zhytomyr National Agroecological University, Zhytomir: 183–186 (in Ukrainian).

Zlobin K. 1976. Estimation of the quality of cenopopulations of wood species undergrowth. Lesovedenie [Forest Science] 6: 72–79 (in Russian).

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RELATIONSHIP BETWEEN FOREST ABOVEGROUND BIOMASS GROWTH AND TREE SPECIES RICHNESS, IDENTITY, AND STRUCTURE

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Abstract

The effects of stand structure and species composition on the forest diversity-productivity relationship have received much attention during the last few decades. The objective of this study was to compare dry live aboveground biomass (AGB) growth among species structures (pure hardwood, mixtures of hardwoods, mixtures of pines, mixtures of pines with hardwoods, and pure pine) for different stand age, stand stocking, and site productivity classes. We also examined the relationship between AGB growth and the predictors species richness, quadratic mean diameter, height, compacted crown ratio, relative density, slope, aspect, precipitation, and elevation. We used data from 2554 USDA Forest Inventory and Analysis (FIA) plots in Alabama. Tukey-Kramer procedure with multiplicity adjustment was applied to compare AGB growth among the five species structures. Species richness was 1–17 and AGB growth was 0.01–15.68 Mg ha^{-1} yr^{-1} across the plots. For the pooled data, there was a weak overall correlation between AGB growth and species richness (r=0.07, p=0.001). The AGB growth of pure and mixed stands was statistically the same. In high-stocked stands productivity (AGB growth) was statistically the same in the different structures. There was no difference between the AGB growth rate of pure pine stands and mixtures that contained pine. However, pure pine stands outperformed mixed stands that did not contain pines in the mix. Species identity was an important factor for AGB growth in pure and mixed stands. As stocking increased, species structure became less important for the AGB growth rate. Among stands with high-stocking, pure stands were as productive as mixtures with no overall growth benefit of monocultures. If high or medium stocking level is maintained, there is no obvious growth benefit from monocultures or mixtures. In stands with low-stocking however, there appeared to be a benefit to having multiple species in the composition.

Key words: aboveground biomass growth; FIA; species richness; species structures; stand stocking.

Introduction

The quantitative relationship between biodiversity and ecosystem function has been investigated for decades (Huston et al. 2000, Nadrowski et al. 2010). The question of whether plant diversity promotes aboveground biomass productivity has been a matter of much interest and experimentation (Vilà et al. 2003, Paquette and Messier 2011). Grassland studies, conducted as controlled manipulative experiments, have found conclusive evidence that plant diversity increases and

stabilizes productivity (Tilman and Downing 1994, Tilman et al. 1996, Tilman 1999, Cardinale et al. 2006), nutrient retention, stability of multiple functions such as soil microbial activity and nutrient cycling, and soil carbon sequestration (Nadrowski et al. 2010). There are no such rigorous experiments showing whether a positive diversity-productivity relationship is also present in naturally regenerated forests, where the relationship is not necessarily the same as in plantations (Firn et al. 2007).

Several studies of naturally regenerated forests found species diversity as a significant factor for aboveground biomass productivity (Caspersen and Pacala 2001, Liang et al. 2007, Vilà et al. 2007, Paquette and Messier 2011, Ojha 2015, Liang et al. 2016), while others showed stronger effects of species identity (referring to which (set of) species are in the community) than diversity (Nadrowski et al. 2010). The mechanisms explaining patterns of diversity-productivity relationships in many ecosystems depend on complex interactions between spatial covariance and ecological parameters (Belote et al. 2011). Several factors can have an influence on the species diversity-productivity relationships in forests, such as plant density (He et al. 2005, Potter and Woodall 2014), site quality (Rodríguez-Loinaz et al. 2008, Thoms et al. 2010, Paquette and Messier 2011, Potter and Woodall 2014), environment (Hooper et al. 2005, Vilà et al. 2005, Ma et al. 2010, Paquette and Messier 2011), seed dispersal limitation (Pärtel and Zobel 2007), evolutionary history and latitude (Pärtel et al. 2007), successional status (Caspersen and Pacala 2001, Vilà et al. 2003), anthropogenic disturbances (Lorimer and White 2003, Tenzin and Hasenauer 2016), and spatial scales (Chase and Leibold 2002, Belote et al. 2011).

In forest dynamics, the biotic tree-to-tree interactions (competitive or facilitative) are important structural mechanisms that have been found to vary across environmental gradients and tree growth stages (Fichtner et al. 2015). Many processes, such as competition reduction or facilitation, take place due to interspecific differences in physiology, phenology, or morphology. These and other interspecific interactions among species may influence the diversity-productivity relationships in forests (Forrester and Bauhus 2016).

Mixed species forests have sometimes been found more productive than monocultures due to the complementarity interactions among species, but the important factors that influence the diversity-productivity relationships are stand structural attributes, resource availability, resource uptake, and resource use efficiency (Forrester and Bauhus 2016). While the relationship between species diversity and productivity has received a lot of attention in many recent studies, we found far less information about the effects of stand and site characteristics and of species structures (e.g., pine, hardwood, mix) on aboveground biomass productivity.

Our knowledge of the diversity-productivity relationships in forest ecosystems is essential for the sustainable management and conservation of biodiversity (Mittelbach et al. 2001).There are several studies that used a large number of permanent plots in stands of all ages to study the relationships between tree species diversity and productivity (Caspersen and Pacala 2001, Liang et al. 2007, Vilà et al. 2007, Moser and Hansen 2009, Paquette and Messier 2011, Woodall et al. 2011, Potter and Woodall 2014). However, there is a lack of studies that compared pure and mixed stands consisting of various species structures (confers, hardwoods,

mixtures of conifers and hardwoods) for different age classes, stand stocking classes, and site productivity classes.

Understanding the relationship between stand structure, species composition, and aboveground biomass productivity, as well as its relation to ecosystem function, are crucial for management, so that we can manipulate the number of species to achieve greater aboveground biomass production and carbon sequestration (Woodall et al. 2011) while maintaining other important ecosystem services and functions.

Our study aimed to evaluate dry live aboveground biomass (AGB) growth among species structures (pure hardwood, mixtures of hardwoods, mixtures of pines, mixtures of pines with hardwoods, and pure pine). The study objectives were to investigate if 1) there is a difference in AGB growth among the species structures, 2) there is a difference in AGB growth among species structures for a range of species richness levels in different stand age, stand stocking, and site productivity classes, and 3) there is a difference in AGB growth between pure and mixed stands of the two most dominant tree species. We also examined the bivariate correlation between AGB growth, species richness, quadratic mean diameter, height, compacted crown ratio, relative density, slope, aspect, precipitation, and elevation.

Materials and Methods

Study area

The study area was the state of Alabama in the United States. The state represents a southeastern humid subtropical climate under the Köppen climate classification (Zifan 2016). There are about 200 tree species and 4000 species of vascular plants including trees, shrubs, vines, grasses, legumes, and ferns in Alabama (Alabama Forestry Commission 2010). The forests in the state cover 9.2 million ha, approximately seventy percent of the land area. It consists of forty-six forest types with the loblolly pine (*Pinus taeda* L.) type being the most common forest type and covering one third of all forested area (Alabama Forestry Commission 2010). Hardwood or mixed pine-hardwood forests comprise fifty-seven percent of the state's forestland. The most common hardwood species of the state are northern red oak (*Quercus rubra* L.), southern red oak (*Quercus falcata* Michx.), white oak (*Quercus alba* L.), hickories (*Carya* spp.), sweetgum (*Liquidambar styraciflua* L.), and yellow poplar (*Liriodendron tulipifera* L.). Ninety-four percent of the forest is owned by private landowners, and plantations occupy about thirty percent of the forest area of the state (Hartsell and Cooper 2013).

The major physiographic areas of Alabama are the Interior Plateau (Highland Rim), Southwestern Appalachians (or Cumberland Plateau), Piedmont, Ridge and Valley, and the East Gulf Coastal Plain (Alabama Department of Conservation and Natural Resources 2006). The average summer temperatures range from 21 to 32 °C, and average winter temperatures range from -1 to 10 °C (Alabama Department of Conservation and Natural Resources 2006). The humid and mild climate of the state is favorable for the growth of many plant species.

Data

We used forest inventory data from the US Forest Service Forest Inventory and Analysis (FIA) database, which is publicly available. The FIA uses a national

standard sampling procedure with a quasi-systematic sampling design and a sampling intensity of one plot for every 2428 hectares (Bechtold and Patterson 2005). The FIA standard plot (size 0.067 ha) consists of four 7.3 m radius subplots (approximately 0.0168 ha) spaced 36.6 m apart in a triangular arrangement with three plots at each corner and one subplot in the center of the triangle. The data from the subplots included all trees of at least 12.7 cm in diameter at breast height (dbh, 1.37 cm above the ground).

We used plots that were measured during the most recent periodic inventory cycle between 2005 and 2012 in the state of Alabama. There were a total 2554 plots, all of which were classified as forest land with at least ten percent cover by trees and with no visible disturbance since the last measurement or within the last five years due to natural causes. The approximate location of the selected plots in Alabama map is shown on Figure 1.

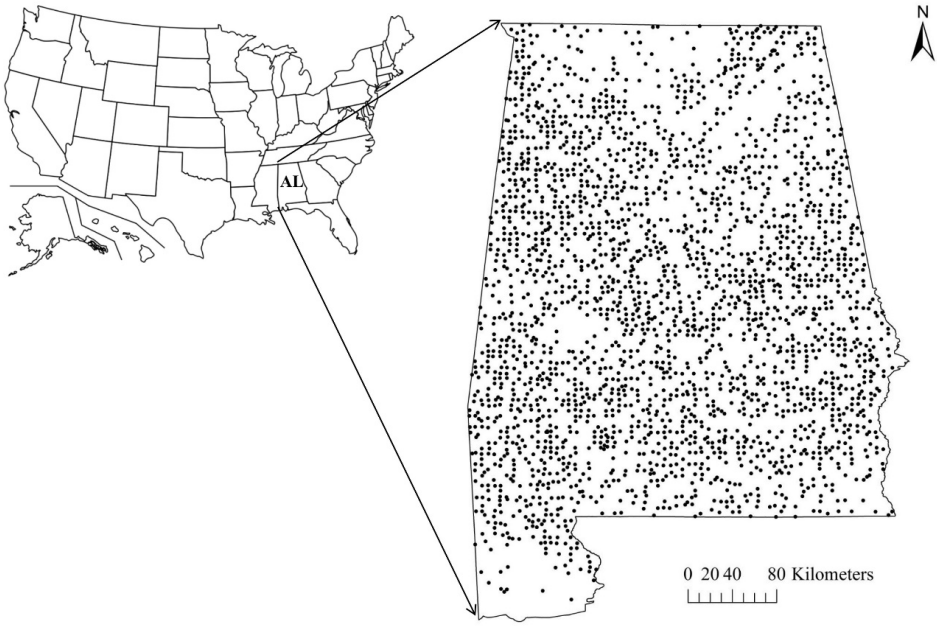


Fig. 1. Map with approximate location of the 2554 FIA plots in Alabama and an inset map of the USA.

About two thirds out of the 2554 plots were naturally regenerated and the remainder were plantations. Almost 98 % of the plots were classified as two-storied stands (two distinct layer of the tree crowns), 1 % were in multistoried stands (three or more canopy layers), and 1 % were in single-storied stands (single canopy layer). The plots were located in natural stands and plantations under various ownership (private, public (both federal and state government ownership), industrial, and others). About 20 % of the plots experienced management activities such

as clear cut, partial harvest, shelterwood harvest, commercial thinning, timber stand improvement, and salvage cutting since the last measurement.

We used the following variables from the FIA database: species, dbh, height, compacted crown ratio, stand age, slope, aspect, elevation, and site productivity class. We generated the plot level variables species richness, quadratic mean diameter (QMD), dry above ground biomass of live-trees, relative stand density, stand age class, stand stocking class, and species structure class. We use the terms plot and stand interchangeably. Precipitation data were extracted from spatial datasets with resolution of 800 m (PRISM Climate Group 2016). Precipitation value was the 30 year average for the period of 1981 to 2010.

We used primarily species richness (number of species in the plot) among the taxonomic diversity indices to characterize species diversity. To express the average tree diameter, we calculated the QMD for each plot. The mean height of the trees in a plot is the average height of all individual trees in the subplots with dbh of at least 12.7 cm. Compacted crown ratio (CCR) is the percent of the tree bole supporting live, healthy foliage on all sides of the stem (Woudenberg et al. 2010). The mean CCR of a plot is the average CCR of all individual trees in the subplots with dbh of at least 12.7 cm. We used FIA calculated stand age that is an average of the ages of dominant and codominant crown class trees (Stevens et al. 2016), where the age of individual live trees is determined from counting of tree rings on increment cores from breast height. The stand age ranged from 1 to 125 years.

The AGB of a live tree was calculated as the sum of the biomass of the merchantable bole, top of the tree, and tree stump (Woudenberg et al. 2010). We used the FIA method for estimating AGB (in mega grams per hectare, Mg ha^{-1}) that was based on the published Jenkins biomass equations (Jenkins et al. 2003) with adjustment factors of the tree components (Woudenberg et al. 2010). We define forest productivity as the mean annual increment of AGB, referred hereafter as the 'AGB growth', and expressed it in mega grams per hectare per year (Mg ha^{-1} yr^{-1}). We computed mean annual AGB growth (Y) of each plot as follows:

$$Y = \frac{\sum_{i=1}^{n} b_i}{t} \quad (1),$$

where b is the biomass of i_{th} tree of a plot that contains n trees, and t is the mean stand age on the plot.

The FIA manual notes that stand age may have large measurement errors. However, as these errors are likely random, such an error would add noise to the data, which should not conceal a trend or a pattern in the data. In addition, the estimate of AGB growth is likely to be below its true value because similar to other studies (Vilà et al. 2007, Moser and Hansen 2009, Paquette and Messier 2011, Potter and Woodall 2014), we did not account for the biomass that may have been removed since stand establishment – this was impossible to do with the available data.

The Gaussian distribution of AGB growth was left skewed, so a square root transformation was applied to satisfy the normality and homogeneity assumptions (Legendre and Legendre 2012). Thus, the transformed AGB growth is referred hereafter as 'square root AGB growth' which was used only in the Pearson correlation analysis.

The aspect was transformed by modifying the azimuth from 0–360° to values ranging from 0 to 2 (Beers et al. 1966).

A value of 2 corresponds to northeast facing slopes (mesic) and a value of 0 to southwest facing slopes (xeric). We used arcsine transformation for slope and CCR as it is considered an appropriate normalizing transformation for percentages and fractions (Legendre and Legendre 2012).

Relative stand density was calculated by dividing the current stand density index (SDI) by the maximum SDI (Woodall et al. 2005). We used a published regression equation (Woodall et al. 2005) based on wood specific gravity (Miles and Smith 2009) of each tree species in the plot to estimate maximum SDI of each plot. Relative stand density is the stand stocking, defined as the number equivalent of 25-cm diameter trees per unit area in a stand relative to the potential maximum number of trees in the same stand (Woodall et al. 2011). We estimated SDI of each plot based on Reineke (1933) but after a slight modification that is useful for uneven-aged stands, called summation method (Long and Daniel 1990). The equation is expressed as:

$$SDI = \sum tph_i \left(\frac{DBH_i}{25} \right)^{1.6} \quad (2),$$

where tph_i is number of trees per hectare for the i^{th} tree in the stand, and DBH_i is the diameter of the i^{th} tree in the stand (cm).

We evaluated the AGB growth among species structures at various stand stocking, stand age and site productivity classes. The categorical variables stand stocking, stand age, site productivity and stand structures were generated as described below.

All the plots were divided in three stand stocking classes, similar to Long (1985): low stocked (relative density (RD<0.3), medium stocked (RD of 0.3–0.6), and high stocked (RD>0.6). Out of 2554 plots, about 45 % were less than 25 years old and over 95 % of the plots were under 75 years old. Thus, we formed three stand age classes with adequate sample size in each class: age class I (stand age less than or equal to 25 years), age class II (26 to 50 years), and age class III (more than 50 years).

The FIA uses site index trees to classify the plots based on the productivity of the site in terms of its capacity to grow crops of industrial wood (Woudenberg et al. 2010). The FIA uses seven productivity classes, with class 1 being the most productive. We had plots from all classes except 7. We grouped the FIA site productivity classes into three groups: 1) low (FIA site productivity classes 5 and 6 with wood growth potential less than 5.9 $m^3\ ha^{-1}\ yr^{-1}$), 2) medium (FIA site productivity classes 3 and 4 with wood growth potential between 5.9 and 11.5 $m^3\ ha^{-1}\ yr^{-1}$), and 3) high (FIA site productivity classes 1 and 2 with wood growth potential greater than 11.5 $m^3\ ha^{-1}\ yr^{-1}$).

We first divided all plots into two broad species structures, pure (species richness (SPR) =1) and mixture (SPR>1) and tested whether the AGB growth of pure and mixed stands differ significantly from each other. Secondly, based on species richness, species composition and species taxonomic identity, all the plots were then classified into five separate species structures, namely, 1) pure hardwood (plot contains single hardwood species; SPR=1), 2) mixtures of hardwoods (plot comprises two or more hardwood species; SPR≥2), 3) mixtures of pines (plot comprises of two or more pine species; SPR≥2), 4) mixtures of pines with hardwoods (plot comprises two or more pine and hardwood species; SPR≥2), and 5) pure pine (plot contain single pine species; SPR=1). It should be noted that the amount of non-pine coni-

fers in the data was insignificant, so we refer to the structures containing conifers as simply pine structures.

The AGB growth across the plots consisting of the two most dominant species, loblolly pine and sweetgum, was examined to determine whether it was different in pure stands and in stands where these species grow in mixtures. Three kinds of species composition groups for each species were examined – for loblolly pine: pure loblolly pine (SPR=1), loblolly pine and hardwoods (SPR≥2), and loblolly pine and other pines and hardwoods (SPR≥3), and similarly for sweetgum, pure sweetgum (SPR=1), sweetgum and hardwoods (SPR≥2), and sweetgum and other hardwoods and pines (SPR≥3).

Data analysis

To assess the dominancy of the species across the plots, we calculated importance value percent (IVP) of each species by averaging relative frequency percent, relative density percent, and relative dominance percent (Curtis and McIntosh 1951). Importance values rank species and give an estimate of influence of a plant species in the community. The benefit of using importance value is that a large size tree or a large number of small trees from a particular species do not influence excessively the importance value of the species (McCune and Grace 2002).

The relationship between AGB growth and stand age as well as between species richness and stand age across the plots was examined using loess smoothing curve fitted with tricube weighting and polynomial regression using 50 % of the data points. Loess is a non-parametric smoothing procedure that displays functional dependencies between the variables (Jacoby 2000). The loess fitting procedure produces parsimonious graphical summary of the bivariate data and is a fairly direct generalization of traditional least-squares methods for data analysis that tracks the most concentrated areas of data points and ignores the outliers (Jacoby 2000).

We performed analysis of variance (ANOVA) to test whether there were any differences among groups for a given variable. When ANOVA showed an overall significant difference among group means, we ran post hoc tests to check where the differences occurred.

As we divided plots into five species structures that resulted in five unequal group sizes, we used a modified Tukey-Kramer procedure for pairwise comparisons of unequal size samples, as it better addresses the variance heterogeneity of the groups. To handle unequal group sizes and any possible unequal group variances, i.e., data heteroscedasticity, multiplicity adjustments are necessary to take into account the denominator degrees of freedom that are not constant across estimates. Both the Satterthwaite and Kenward-Roger degree of freedom are designed for use in models with unbalanced designs and more complex covariance structures (Bell et al. 2013). They were selected to estimate the degrees of freedom in Tukey-Kramer mean separation. Among them, the Kenward-Roger method adjusts the covariance matrix with a small-sample bias (Bell et al. 2013) and therefore, it was applied when one of the group sizes was too small compared to other group sizes. The estimation method for the covariance parameter in the model was based on residual (restricted) maximum likelihood (REML). SAS® PROC mixed procedure with multiplicity adjustment for Tukey was executed to check whether AGB growth least square (LS)

means of the species structures differ significantly.

We used Pearson bivariate correlation to assess the linear relationship between the dependent variable transformed AGB growth and the predictor variables species richness, quadratic mean diameter, mean height, compacted crown ratio, relative density, slope, aspect, precipitation, and elevation.

The descriptive statistics, ANOVA, and multiple comparisons of the means were performed using the IBM SPSS® 21 and SAS® 9.3 statistical packages. Species richness and species IVP were calculated using PC-ORD® Version 6.12.

Results

The forests across the study area were highly diverse with a total of 113 woody species. At the plot level, species richness ranged from 1 to 17. The current AGB ranged from 0.10 to 403.5 Mg ha^{-1}, while AGB growth was from 0.01 to 15.7 Mg ha^{-1} yr^{-1} (Table 1).

Based on IVP, the three most important species were loblolly pine (31.58 %), sweetgum (7.97 %), and water oak *(Quercus nigra* L., 4.78 %*),* all of which are shade intolerant species. The next three most important species were yellow-poplar, white oak, and red maple (*Acer rubrum* L.), with IVP values from 3.08 % to 4.32 %.

The only hardwood species growing as pure stands on more than one plot were sweetgum, water oak, red maple, black gum (*Nyssa sylvatica* Marsh.), mockernut hickory (*Carya alba* Mill.), and sweetbay (*Magnolia virginiana* L.). The other species that were in pure stands, but occurring on only a single plot each were Florida maple (*Acer barbatum* Michx.), sugarberry (*Celtis laevigata* Willdenow), flowering dogwood (*Cornus florida* L.), common persimmon (*Diospyros virginiana* L.), yellow-poplar (*Liriodendron tulipifera* L.), sourwood (*Oxydendrum arboreum* (L.) DC), southern red oak (*Quercus falcata* Michx.), chestnut oak (*Quercus prinus* L.), post oak (*Quercus stellata* Wangenh.), black willow (*Salix nigra* Marshall), winged elm (*Ulmus alata* Michx.), and the non-

Table 1. Mean, standard deviation, minimum and maximum values of the variables across 2554 FIA plots in Alabama.

Variables	Mean	SD	Minimum	Maximum
Quadratic mean diameter, QMD (cm)	23.1	5.73	12.6	94.1
Basal area (m^2 ha^{-1})	16.2	9.14	0.19	58.96
Height (m)	16.7	3.83	6.1	32.6
Density (stems ha^{-1})	392	229	15	1324
Relative stand density	0.4	0.15	0	0.83
Compacted crown ratio	0.39	0.10	0	0.99
Stand age (yr)	34	22	1	125
Total AGB (Mg ha^{-1})	82.8	60.4	0.10	403.5
Mean annual AGB growth (Mg ha^{-1} yr^{-1})	2.7	1.8	0.01	15.7
Species richness (SPR)	5.8	3.36	1	17
Precipitation (cm)	142	8.4	121	172.7
Slope (percent)	12	12	0	85
Elevation (m)	138	90.45	0	677

native chinaberry (*Melia azedarach* L.). The trees recorded in the pure hardwood plots were most likely residuals from a previous rotation, considering that the mean stand age in these plots was only 6 years, the mean density was 29 stems ha^{-1}, but the diameter of the residual trees was over 12.7 cm.

It was surprising that the AGB growth in the very young plots (less than about 5 years) was fairly high. The dbh of the trees in these plots ranged between 12.7 cm and 42.4 cm, suggesting that even in the recently regenerated stands, there was a large amount of unharvested residual trees remaining on site. Stand age of these plots was determined by the FIA based on a large number of small size seedlings and saplings, likely without taking into account the age of the much fewer large-size residual trees (e.g., maximum dbh 42.4 cm at stand age 3) that were present in the plots. Furthermore, the seedlings, saplings, and small trees in these young plots were dominated by loblolly pine, pignut hickory (*Carya glabra* Mill.), sourwood (*Oxydendrum arboreum* L. DC), white oak, scarlet oak (*Quercus coccinea* Muenchh.), and yellow poplar, whereas the residual large trees were primarily loblolly pine, American beech (*Fagus grandifolia* Ehrh.), chestnut oak (*Quercus prinus* L.), red maple, yellow poplar, and water oak. The AGB growth of some young plots is therefore somewhat artificially inflated because the stand age was recorded as being quite low, but there was actually a rather small number of much older trees present. Therefore, the loess smoothing curve fitting using tricube weight and 50 % of the observations was used to show the relationship between stand age and AGB growth, as well as between stand age and species richness, without the influence of such outliers. The AGB growth rate increased with increasing stand age up to the age of 19 years, and after that, decreased gently with increasing stand age (Fig. 2a). Similarly, species richness increased rapidly with increasing stand age up to the age of 50 years and then slowed down (Fig. 2b).

There was no significant relationship between AGB growth and species richness across the plots (Fig. 3a and 3b).

Moreover, there was no significant AGB growth difference between pure stands (SPR=1) and mixtures (SPR>1, $t_{1,\ 365.39}$=0.016, p=0.99, Fig. 4a). The amount of AGB (not growth), however, of pure and mixed stands was significantly different, with the mixtures containing about twice as much biomass ($t_{1,\ 563.57}$=-18.59, p<0.001) (Fig. 4b), where stand age was a confounding factor. The pure stands ranged from 1 to 78 years and about 91 % of the plots were under the age of 25 years, while the mixed stands ranged from 1 to 125 years and about 61 % of the plots had stand age over 25 years. Pure stands were relatively younger than mixed stands.

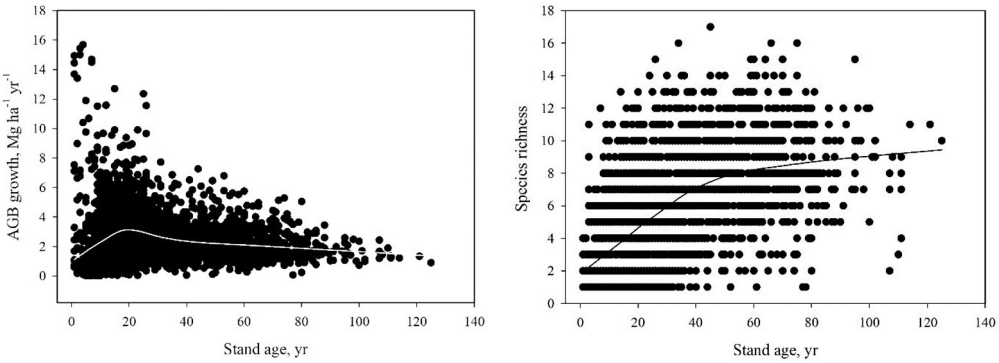


Fig. 2. Scatterplots for (a) AGB growth and stand age, and (b) species richness and stand age, across 2554 FIA plots in Alabama. The loess smoothing curve is fitted with tricube weighting and polynomial regression using 50 % of the data points.

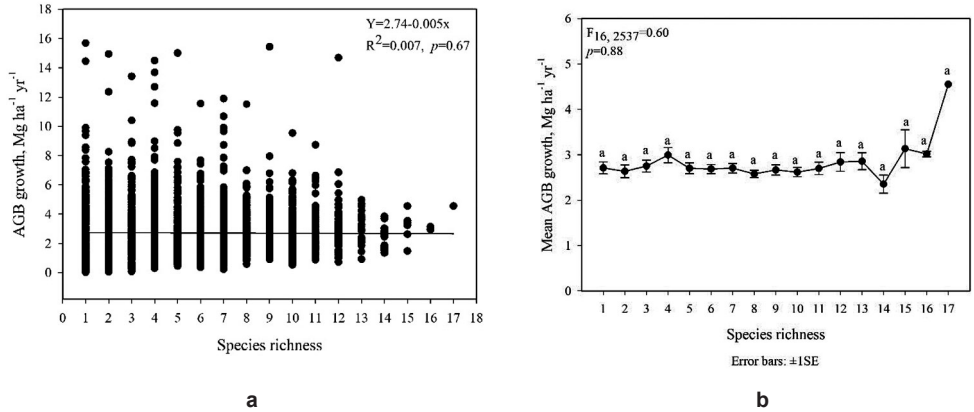
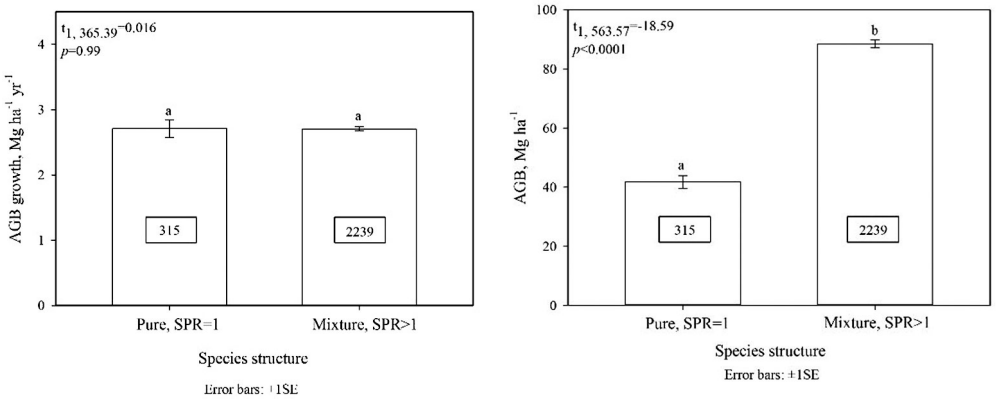


Fig. 3. Relationship between (a) AGB growth and species richness and (b) mean AGB growth and species richness across 2554 FIA plots in Alabama. Means with the same letter are not significantly different at α=0.05. The best fitted trendline, equation, R^2, and *p*-values show the linear association between the variables.



a **b**

Fig. 4. Welch-Satterthwaite t-test between (a) AGB growth means of pure (species richness (SPR)=1) and mixed species structures (SPR>1), and between (b) current AGB (not growth) of pure and mixed species structures across the 2554 FIA plots in Alabama. Age is confounded with species structure, as the mixtures were generally older than the pure species stands. Means with the same letter are not significantly different at α=0.05. The number of plots for each species structure is shown inside each bar.

Species structure and AGB growth

Plots that contained mixture of hardwoods had species richness of 2 to 17 (average 7), while the plots that contained mixtures of pines and hardwoods had richness of 2 to 16 (average 7; Table 2). The mean stand age (6 years) and stand density (29 stems ha^{-1}) of the pure hardwood stands were very low compared to other stand structures.

We found significant difference in AGB growth among the five species structures ($F_{4,2549}$=14.65, p<0.001, Fig. 5). The AGB growth was greatest in pure pine (SPR=1), mixtures of pines with hardwoods, and mixtures of pines. The AGB growth of these three species structures was not significantly different. AGB growth was lowest in pure hardwoods (SPR=1), whose growth was significantly smaller than the growth in the other four groups (Fig. 5). However, it is important to note that the plots with pure hardwoods had at least ten times fewer stems per hectare than any of the other species structures and their mean stand age was only 6 years, compared to 16 to 45 years for the other groups (Table 2).

Table 2. Stand characteristics of the species structure classes across the 2554 FIA plots in Alabama. Minimum and maximum values are in parenthesis.

Variables	Species structure				
	Pure hardwood	Mixtures of hardwoods	Mixtures of pines	Mixtures of pines with hardwoods	Pure pine
Plots	38	458	44	1737	277
Quadratic Mean diameter (cm)	19.4(13.0,94.1)	26.2(12.6,48.0)	20.9(13.8,34.0)	23.1(13.2,56.2)	19.3(12.6,45.2)
Mean stems per ha	29(15,89)	283(30,1100)	379(30,981)	412 (30,1219)	502 (15,1324)
Mean basal area (m^2ha^{-1})	0.97(0.21,10.43)	16.31(0.38,53.7)	12.55(0.48,30.91)	17(0.41,58.96)	14(0.19,41)
Mean height (m)	13(7.6,32.6)	18.7(7.9,29.4)	14.2(7.7,26)	16.9(7.2,28.8)	13.6(6.1,31.4)
Mean compacted crown ratio	0.48(0,0.95)	0.39(0.14,0.83)	0.44(0.22,0.75)	0.39(0.16,0.8)	0.44(0.17,0.99)
Relative stand density	0.1(0,0.5)	0.3(0,0.8)	0.3(0,0.7)	0.4(0,0.8)	0.3(0,0.8)
Mean stand age (yr)	6(1, 23)	45(1,114)	21(3,74)	34(1,125)	16(1,78)
Species richness (SPR)	1(1,1)	7(2,17)	2(2,3)	7(2,16)	1(1,1)
Mean AGB growth (Mg ha^{-1} yr^{-1})	1.02(0.04,14.44)	2.37(0.07,15.43)	2.54(0.11,8.25)	2.8(0.05,15)	2.94(0.01,15.68)

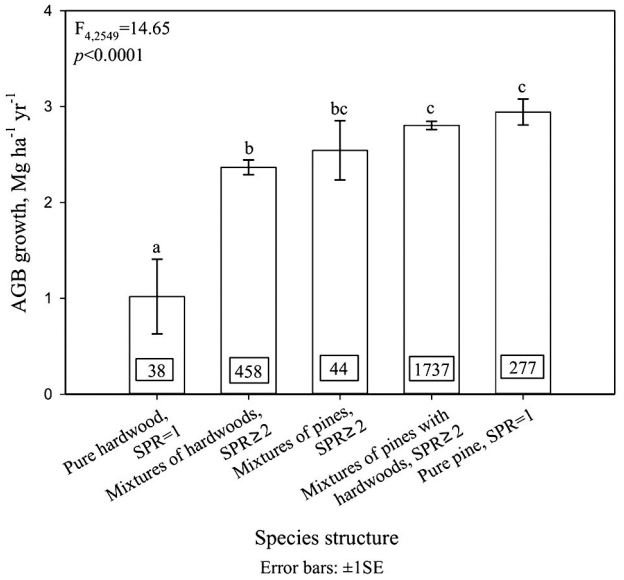


Fig. 5. Multiple comparisons (Tukey-Kramer test) of the AGB growth LS-means among the species structures and species richness (SPR) across the 2554 FIA plots in Alabama. LS-means with the same letter are not significantly different at α=0.05. The number of plots for each species structure is shown inside each bar.

Species structure, stand age, and AGB growth

We found significant differences in AGB growth among the five species structures for age class I ($F_{4,1156}$=14.10, p<0.001), and for age class III ($F_{3,578}$ =4.73, p=0.0029), but not for age class II ($F_{3,807}$=0.42, p=0.73, Table 3). The majority of the plots (83 %) in age class I were mixtures of pines with hardwoods (SPR≥2) and pure pine (SPR=1), whereas the plots in age classes II and III were mostly mixtures of pines with hardwoods (SPR≥2) and mixtures of hardwoods (SPR≥2).

Table 3. Multiple comparisons (Tukey-Kramer test) between the AGB growth LS-means of the species structures in different stand age, stand stocking, and site productivity classes across the plots in Alabama.

Species structure	Plots	LS-mean	95 % CL		Plots	LS-mean	95 % CL		Plots	LS-mean	95 % CL	
			LB	UB			LB	UB			LB	UB
Stand age class		Age class I				Age class II				Age class III		
Pure hardwood	38	1.02^{c}	0.30	1.74								
Mixtures of hardwoods	127	2.40^{b}	2.00	2.79	136	2.60^{a}	2.38	2.83	195	2.18^{a}	2.05	2.32
Mixtures of pines	35	2.80^{ab}	2.05	3.56	5	2.05^{a}	0.86	3.23	4	0.88^{b}	-0.07	1.83
Mixtures of pines with hardwoods	713	3.38^{a}	3.22	3.55	646	2.57^{a}	2.47	2.68	378	2.11^{ab}	2.01	2.20
Pure pine	248	3.00^{ab}	2.72	3.28	24	2.76^{a}	2.22	3.30	5	1.00^{b}	0.15	1.85
Stand stocking class		Low stocked				Medium stocked				High stocked		
Pure hardwood	36	1.05^{b}	0.47	1.63	2	0.39^{de}	-1.84	2.62				
Mixtures of hardwoods	180	1.82^{ab}	1.56	2.08	254	2.60^{ce}	2.40	2.80	24	3.96^{a}	3.06	4.86
Mixtures of pines	27	1.84^{ab}	1.17	2.51	15	3.70^{abc}	2.88	4.51	2	3.38^{a}	0.27	6.50
Mixtures of pines with hardwoods	523	2.16^{a}	2.00	2.31	1130	3.00^{bd}	2.91	3.10	84	4.16^{a}	3.68	4.64
Pure pine	149	1.69^{b}	1.41	1.98	118	4.35^{a}	4.06	4.64	10	4.98^{a}	3.59	6.37
Site productivity class		Low				Medium				High		
Pure hardwood	23	0.76^{b}	0.12	1.39	15	1.42^{c}	0.44	2.40				
Mixtures of hardwoods	248	2.18^{a}	1.98	2.37	181	2.60^{bc}	2.32	2.88	29	2.54^{b}	1.87	3.21
Mixtures of pines	24	1.97^{ab}	1.35	2.59	19	3.30^{ab}	2.43	4.18	1	1.89^{ab}	-1.71	5.50
Mixtures of pines with hardwoods	694	2.37^{a}	2.25	2.48	894	3.01^{ab}	2.88	3.13	149	3.62^{a}	3.32	3.91
Pure pine	85	1.93^{a}	1.60	2.25	160	3.25^{a}	2.95	3.55	32	4.11^{a}	3.47	4.75

Note: LS – least square, LB – lower bound, and UB – upper bound. Blank spaces where data was not available. LS-means with the same letter are not significantly different.

In age class I, the AGB growth of pure hardwood (SPR=1) was significantly lower than the AGB growth of the other four groups. While the plots with mixed hardwoods had slower AGB growth than the plots with a mixture of pines with hardwoods, the pure pine plots had similar productivity to all other groups (except the pure hardwoods). Unlike age class I, in age class III the AGB growth of the pure pine (SPR=1) was significantly smaller than the AGB growth of the mixtures of hardwoods (SPR≥2).

Species structure, stand stocking, and AGB growth

We found significant differences in AGB growth among the five species structures in plots with low stand stocking ($F_{4,910}$ =5.07, p<0.001) and medium stand stocking ($F_{4,1514}$ =26.40, p<0.001), but not in plots with high stand stocking ($F_{3,116}$ =0.59, p=0.62, Table 3).

In the low stocked plots, the mixtures of pines with hardwoods (SPR≥2) had significantly greater growth than both pure hardwoods and pure pine (Table 3). In the medium stocked plots, the AGB growth of pure pine (SPR=1) was the greatest and was significantly more than AGB growth of all other groups, except mixtures of pines with hardwoods (SPR≥2). However, in high stocked plots all groups had statistically equal rates of growth.

Species structure, site productivity, and AGB growth

We found significant differences in AGB growth among the five species structures in all three site productivity classes (Table 3). On the low productivity sites, the plots with only pure hardwoods in the composition were again the least productive, and less productive than all but the mixtures of pines. On medium and high productivity sites, the AGB growth of pure pine was greater than the growth of the species structures that did not contain conifers in the composition. On all three productivity sites, the AGB growth of pure pine (SPR=1) was not significantly different than the AGB growth of mixtures of pines (SPR≥2), and mixtures of pines with hardwoods (SPR≥2, Table 3).

Dominant species, species composition, and AGB growth

The AGB growth of pure loblolly pine (SPR=1) was not different from the growth of the other two groups (Table 4). The growth of sweetgum, however, was significantly lowered when it grew in pure stands compared to when it grew in any of the two types of mixtures (Table 4).

Table 4. Multiple comparisons (Tukey-Kramer test) between the mean AGB growth among pure (species richness (SPR)=1) and mixed (SPR>1) loblolly pine and sweetgum stands across the plots in Alabama.

Species compositions	Plots	LS-mean	LB	UB
Pure loblolly pine vs. mixtures				
Pure loblolly pine (SPR=1)	256	3.06^{ab}	2.83	3.28
Loblolly pine and hardwoods (SPR≥2)	804	3.05^{a}	2.92	3.17
Loblolly pine and other pines and hardwoods (SPR≥3)	632	2.75^{b}	2.60	2.89
Pure Sweetgum vs. mixtures				
Pure sweetgum (SPR=1)	8	0.45^{c}	-0.68	1.57
Sweetgum and other hardwoods (SPR≥2)	248	2.57^{b}	2.37	2.77
Sweetgum and other hardwoods and pines (SPR≥3)	960	2.92^{a}	2.81	3.02

Note: LS – least square, LB – lower bound, and UB – upper bound. LS-means with the same letter are not significantly different.

Correlation of AGB growth with species richness, stand- and environmental variables

We found a stronger association of square root AGB growth with the stand variables than with the environmental variables (Table 5). Square root AGB growth had an extremely weak association with species richness (r=0.07, p=0.001, Table 5). Square root AGB growth had high and significant correlation with relative stand density, height, compacted crown ratio, and quadratic mean diameter. Compacted crown ratio, slope, and precipitation had a significant negative correlation with square root AGB growth, but the correlation with slope and precipitation was very weak (Table 5). The aspect and elevation had no correlation with the square root AGB growth.

Table 5. Pearson bivariate correlation between the square root transformed aboveground biomass growth (AGBG) and other variables across the 2554 FIA plots in Alabama.

	AGBG	QMD	SPR	RD	HT	CCR	SL	AS	PPT	ELEV
AGBG	1	0.25**	0.07**	0.46**	0.36**	-0.36**	-0.07**	0.03	-0.08**	-0.02
QMD		1	0.32**	0.15**	0.82**	-0.23**	-0.02	0.06**	-0.04*	0.03
SPR			1	0.39**	0.40**	-0.23**	0.26**	-0.06**	-0.06**	0.19**
RD				1	0.28**	-0.33**	0.09**	-0.01	-0.02	0.12**
HT					1	-0.53**	0.04	0.06**	-0.03	0.04*
CCR						1	-0.01	-0.04	-0.06**	-0.003
SL							1	-0.42**	-0.07**	0.43**
AS								1	0.06**	-0.21**
PPT									1	-0.08**
ELEV										1

Note: The ** and * indicate that the correlation is significant at α=0.01 at α=0.05 level, respectively. QMD – quadratic mean diameter (cm); SPR – species richness; RD – relative stand density; HT – height (m); CCR – compacted crown ratio; SL – slope (arcsine transformed); AS – aspect (Beers transformed); PPT – mean precipitation (Z-score transformed); ELEV – elevation (Z-score transformed).

Discussion

The results have to be interpreted with these three important considerations: 1) stand age range was fairly large (1 to 125 years) and only trees over 12.7 cm in dbh were used for calculating the AGB growth. Because the plots with stand age of 5 years or younger also contained some large trees (likely residuals from the previous stand), and because stand age was likely determined by the FIA from the age of the seedlings and saplings only, it is likely that there is an overestimation of AGB growth in the plots with stand age 5 years or less; 2) past management could not be taken into account, so it is possible that the rather common and degrading practice of selectively harvesting the largest trees of the most valuable species (often referred to as highgrading), would have resulted in underestimation of the growth in the mixed stands; and last, but certainly not least, 3) the pine stands were generally younger than the hardwood stands, as they are often harvested at a younger age.

When species structure was not taken into account, there was no significant difference between the AGB growth of

pure stands (2.71 Mg ha^{-1} yr^{-1}) and mixed stands (2.70 Mg ha^{-1} yr^{-1}). We observed an increase in AGB growth with the change in species structure from pure hardwoods to mixed hardwoods and to a mix of pines with hardwoods, but the pure pines and mixed pines were as productive as the hardwood-pine mixes. Hardwood stands had greater species diversity (up to 17 species) than mixed pine stands (up to only 3 species) and they also contained species with a larger variety of shade tolerances than the pine stands. Facilitation, or resource partitioning due to diversified functional trait variation of the species, should have been stronger in the mixed hardwood stands than in the mixed pine stands. The observed AGB growth rate in our study does not support this hypothesis however – AGB growth of the mixed hardwoods (usually containing shade tolerant and intolerant species) and mixed pines (usually only intolerant species) were not different from each other, even after taking into account stand age, stocking, and site productivity. There was only one exception – at age class III (more than 50 years old) the mixed pine stands grew much slower than the mixed hardwoods, but this result is based only on 4 mixed pine plots (and 195 mixed hardwood plots) and therefore the result is not particularly convincing. Pangle et al. (2009) similarly found nearly identical aboveground net primary productivity (ANPP) in late successional secondary mixed hardwood forests (11.5 Mg ha^{-1} yr^{-1}) and in mature 50 year old white pine (*Pinus strobus* L.) plantations (10.2 Mg ha^{-1} yr^{-1}) in the southern Appalachian Mountains. Vilà et al. (2007), however, reported that the dominant tree species were an important determinant for wood production in forests across Catalonia, Spain. The identity of the species in the mixture sometimes determines whether mixed stands are more productive than monospecific stands of similar age, tree density, soil characteristics, and management. In boreal forests for example, the mixture of birch (*Betula* spp.) with spruce (*Picea abies*) exhibits greater productivity than pure spruce stands, but mixture of birch with Scots pine (*Pinus sylvestris*) is less productive than pure pine stands (Vilà et al. 2005). Similar to the total biomass, stemwood production also increased with increasing species richness in *sclerophilous* and conifer forests in Catalonia, Spain, where production increased 19.6 % and 45.8 % in four and five species mixtures, respectively, than in monospecific, two or three species mixtures (Vilà et al. 2005).

Successional stage can have significant effect on forest productivity. The association between species diversity and productivity can be stronger in early successional forests than in late successional forest communities (Caspersen and Pacala 2001) when early successional forest contains multilayered trees with greater species richness than late successional communities that contain monolayered structure with lower species diversity (Sprugel 1985). In our case, at age class I (less than or equal to 25 years), the pure pine stands were as productive, but not more productive, than any of the structures containing a mixture of species (mixed hardwoods, mixed pines, mixed pine-hardwoods). The same was true for the older stands of age class II (26 to 50 years), while for the oldest stands (more than 50 years) this could not be determined with much confidence, as there were too few plots for two of the structures. This was likely due to the high probability of invasion over time by more shade-tolerant species in the pure stands. Thus, in our study, there was no clear importance

of successional stage on productivity of the different types of stands, but it should be noted that the age range was not particularly wide.

At high stocking all structures were equally productive, whereas at low stocking the pure pines were less productive than pine-hardwood mixes. The mixed pines were as productive as pure pines at all stocking levels. Weaker interspecific competition in mixed stands than intraspecific in pure stands has been proposed by others as a possible reason for increased productivity with increasing species diversity (Amoroso and Turnblom 2006). On the other hand, a facilitative-competitive interactions study in old-growth European beech (*Fagus sylvatica* L.) forests reported that the growth rates of trees do not necessarily depend on the density of potential competitors at the intraspecific level, but on the conspecific aggregation of large diameter trees and their functional role (Fichtner et al. 2015). The effects of species mixtures on productivity may vary considerably depending upon the type of mixture and site conditions (Pretzsch 2005). A positive relationship between diversity and productivity is sometimes particularly pronounced in less productive site conditions (Potter and Woodall 2014). The low species richness is commonly found at high resource environments because of the presence of less environmental heterogeneity and fewer niches (Chisholm et al. 2013). Fast growing and highly productive species can dominate and compete well in more productive habitats where the positive association between tree diversity and aboveground biomass may be weaker (Potter and Woodall 2014). Stress-gradient hypothesis is used in many forest studies to explain that complementarity increases with harsher environmental conditions or along gradients of declining site productivity in forests (del Río et al. 2014, Toïgo et al. 2015, Forrester and Bauhus 2016). The low species richness is commonly found at high resource environments because of the presence of less environmental heterogeneity and fewer niches (Chisholm et al. 2013). Fast growing and highly productive species can dominate and compete well in more productive habitats where the positive association between tree diversity and aboveground biomass may be weaker (Potter and Woodall 2014). The low functional trait variation in such cases may lead to competitive exclusion rather than facilitation in pine forests and consequently diversity is not an important factor for productivity.

Our findings showed that, in general, the AGB growth of the pure pine or even pure loblolly pine (the most commonly grown species in the state) stands was not significantly different than the growth of mixed stands that contained pine species. Research in intensive silviculture has shown that the growth of pure stands can increase substantially as a result of various treatments. However, we did not take account of such treatments, which may have been applied in the pure pine stands to increase the productivity. Even though some of these stands may have indeed been fertilized or subjected to early competition control, the overall productivity of pure loblolly pine was still not greater than that of the mixtures. The productivity of some stands that are already near the physiological optimum does not increase with the increase in species or structural diversities because these stands would have already benefitted from management inputs, such as fertilizing or control of pests and invasive species (Forrester and Bauhus 2016). The combined effect of fertilizer and weed control treatments enhanced aboveground

dry biomass growth on average 2 and 2.8 fold for slash and loblolly pine respectively (Jokela et al. 2004).

Sometimes, the beneficial interactions between the species in mixtures do not occur in enough magnitude, or do not even exist, to produce more yield than the monoculture of a highly productive species (Kelty 1992). We found no relationship between diversity and productivity in pine dominated stands where no hardwoods were present. Thus, the pure pine stands were as productive, although not more productive, than the stands with other species in the mix. On the other hand, mixed hardwood stands, as well as pine-hardwood mixtures, were either more productive than or as productive as pure hardwood stands. Moreover, the relationship between species richness and aboveground biomass growth was not significant across the loblolly pine containing plots, but was positive across the sweetgum containing plots. The associations of pines and hardwood species may sometimes help the utilization of limiting resources efficiently, despite the negative effect of interspecific competition, resulting in equal or increased AGB productivity with increasing species richness.

Based on the bivariate correlations, the stand variables density and height, had the greatest association with AGB growth among the selected predictors. The weak correlation of AGB growth with precipitation, slope, aspect, or elevation indicates that environmental factors explain little variation of stand AGB growth, which may be because of relatively low environmental and climatic heterogeneity in the study area. Stand density can significantly affect diversity-productivity relationships, and the complementarity effect increases or decreases with increasing stand density depending on the limiting resources (or climatic conditions) (Forrester and Bauhus 2016). In a review of large inventory data set studies, Forrester and Bauhus (2016) found stand density to be a stronger determinant of productivity than tree species richness and pointed out the importance of accounting for stand density while analyzing diversity-productivity relationships, as we have done in this paper.

Our study contributes towards the understanding of the relationship between stand composition, structure, and aboveground biomass growth, particularly in southeastern US forests, where loblolly pine is a dominant choice in forestry for commercial wood production. The study results are of significance to forest management strategic planning and biodiversity conservation. Maintaining high productivity is also vital for carbon sequestration and climate change mitigation. If the objective is to maintain both species diversity and optimal aboveground biomass production, maintaining mixed species is crucial.

Conclusion

The dynamics of heterospecific forests are much more complex and difficult to predict than that of conspecific forests, because productivity is related to both population dynamics of the dominant species and differences in resource use among species. In the case of forest ecosystems, higher species diversity may not always or everywhere associate with greater productivity due to the effect of certain environmental, ecological and management factors in the ecosystem processes.

When all data were pooled, species richness was not a significant factor for aboveground biomass growth across the forests of Alabama. The area has little

variability in climatic condition and represents only humid subtropical climate and was dominated by pine stands, particularly loblolly pine. The overall comparison between the five species structures showed that pure pine stands were not more productive than mixed pine stands and pine-hardwood mixtures, but were more productive than mixed hardwoods and pure hardwood stands. If the stands are grown at high stocking however, then all structures (pure, mixed, with or without pine in the composition) were equally productive.

Based on the results for age class I, we conclude that for biomass production on a short rotation, pure pine forests may be as productive as mixed forests, but without the ecological benefits, as well as the economic benefits (but sometimes processing disadvantages) of greater tree species diversity. Further studies need to increase spatial scale to observe the diversity-productivity relationship on a broader geographic scale and in stands that have not experienced harvesting since establishment. Besides the environmental conditions, forest disturbances and management activities have a great influence on forest composition and productivity and they should be accounted for in future studies, analyses, and experimental designs.

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References

Alabama Department of Conservation and Natural Resources 2006. Alabama's comprehensive wildlife conservation strategy. Chapter 2. Wildlife Habitat – Alabama's Ecological Framework. Alabama Department of Conservation and Natural Resources. Available at: http://www.outdooralabama.com/sites/default/files/Chapter2.pdf. (Accessed on 4 February 2016).

Alabama Forestry Commission 2010. Forests at the Crossroads – Alabama Statewide Forest Assessment and Resource Strategy. Available at: http://www.forestry.alabama.gov/PDFs/Forests_at_the_Crossroads-AL-State_Assessement.pdf. (Accessed on 12 July 2016).

Amoroso M.M., Turnblom E.C. 2006. Comparing productivity of pure and mixed Doug-

las-fir and western hemlock plantations in the Pacific Northwest. Canadian Journal of Forest Research 36: 1484–1496.

Bechtold W.A., Patterson P.L. (Ed.) 2005. The enhanced forest inventory and analysis program-national sampling design and estimation procedures. General Technical Report SRS–80. USDA Forest Service, Southern Research Station: 98 p. Available at: http://www.treesearch.fs.fed.us/pubs/20371. (Accessed on 17 November 2016).

Beers T.W., Dress P.E., Wensel L.C. 1966. Aspect transformation in site productivity research. Journal of Forestry 64: 691–692.

Bell B.A., Smiley W., Ene M., Sherlock JR.P.R., Blue G.L. 2013. An Intermediate Primer to Estimating Linear Multilevel Models using SAS® PROC MIXED. SAS Institute Inc. Available at: http://analytics.ncsu.edu/sesug/2013/SD-14.pdf. (Accessed on 23 October 2016).

Belote R.T., Prisley S., Jones R.H., Fitzpatrick M., De Beurs K. 2011. Forest productivity and tree diversity relationships depend on ecological context within mid-Atlantic and Appalachian forests (USA). Forest Ecology and Management 261: 1315–1324.

Cardinale B.J., Srivastava D.S., Emmett Duffy J., Wright J.P., Downing A.L., Sankaran M., Jouseau C. 2006. Effects of biodiversity on the functioning of trophic groups and ecosystems. Nature 443: 989–992.

Caspersen J.P., Pacala S.W. 2001. Successional diversity and forest ecosystem function. Ecological Research 16: 895–903.

Chase J.M., Leibold M.A. 2002. Spatial scale dictates the productivity-biodiversity relationship. Nature 416: 427–430.

Chisholm R.A., Muller-Landau H.C., Abdul Rahman K., Bebber D.P., Bin Y., Bohlman S.A., Bourg N.A., Brinks J., Bunyavejchewin S., Butt N., Cao H., Cao M., Cárdenas D., Chang L.-W., Chiang J.-M., Chuyong G., Condit R., Dattaraja H.S., Davies S., Duque A., Fletcher C., Gunatilleke N., Gunatilleke S., Hao Z., Harrison R.D., Howe R., Hsieh C.-F., Hubbell S.P., Itoh A., Kenfack D., Kiratiprayoon S., Larson A.J., Lian J., Lin D., Liu H., Lutz J.A., Ma K., Malhi Y., Mcmahon S., Mcshea W., Meegaskumbura M., Mohd. Razman S., Morecroft M.D., Nytch C.J., Oliveira A., Parker G.G., Pulla S., Punchi-Manage R., Romero-Saltos H., Sang W., Schurman J., Su S.-H., Sukumar R., Sun I.-F., Suresh H.S., Tan S., Thomas D., Thomas S., Thompson J., Valencia R., Wolf A., Yap S., Ye W., Yuan Z., Zimmerman J.K. 2013. Scale-dependent relationships between tree species richness and ecosystem function in forests. (Ed.) D. Coomes. Journal of Ecology 101: 1214–1224.

Curtis J.T., Mcintosh R.P. 1951. An Upland Forest Continuum in the Prairie – Forest Border Region of Wisconsin. Ecology 32(3): 476–496.

Del Río M., Schütze G., Pretzsch H. 2014. Temporal variation of competition and facilitation in mixed species forests in Central Europe. Plant Biology 16: 166–176.

Fichtner A., Forrester D.I., Härdtle W., Sturm K., von Oheimb G. 2015. Facilitative-Competitive Interactions in an Old-Growth Forest: The Importance of Large-Diameter Trees as Benefactors and Stimulators for Forest Community Assembly. Plos One 10: e0120335.

Firn J., Erskine P.D., Lamb D. 2007. Woody species diversity influences productivity and soil nutrient availability in tropical plantations. Oecologia 154: 521–533.

Forrester D.I., Bauhus J. 2016. A review of processes behind diversity – productivity relationships in forests. Current Forestry Reports 2: 45–61.

He J.-S., Wolfe-Bellin K.S., Schmid B., Bazzaz F.A. 2005. Density may alter diversity – productivity relationships in experimental plant communities. Basic and Applied Ecology 6: 505–517.

Hooper D.U., Chapin III F.S., Ewel J.J., Hector A., Inchausti P., Lavorel S., Lawton J.H., Lodge D.M., Loreau M., Naeem S., Schmid B., Setala H., Symstad A.J., Vandermeer J., Wardle A. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological monographs 75(1): 3–35.

Huston M.A., Aarssen L.W., Austin M.P., Cade B.S., Fridley J.D., Garnier E., Grime J.P.,

Hodgson J., Lauenroth W.K., Thompson K., Vandermeer J. H., Wardle D. A. 2000. No consistent effect of plant diversity on productivity. Science 289: 1255–1255.

Jacoby W.G. 2000. Loess: a nonparametric, graphical tool for depicting relationships between variables. Electoral Studies 19: 577–613.

Jenkins J.C., Chojnacky D.C., Heath L.S., Birdsey R.A. 2003. National-scale biomass estimators for United States tree species. Forest Science 49: 12–35.

Jokela E.J., Dougherty P.M., Martin T.A. 2004. Production dynamics of intensively managed loblolly pine stands in the southern United States: a synthesis of seven long-term experiments. Forest Ecology and Management 192: 117–30.

Kelty M.J. 1992. Comparative productivity of monocultures and mixed-species stands. In: Kelty M.J., Larson B.C., Oliver C.D. (Eds.). The Ecology and Silviculture of Mixed-Species Forests: Forestry Sciences 40. Springer Netherlands: 125–141.

Legendre P., Legendre L.F.J. 2012. Numerical Ecology, Volume 24. Third. Amsterdam: Elsevier. 1006 p.

Liang J., Buongiorno J., Monserud R.A., Kruger E.L., Zhou M. 2007. Effects of diversity of tree species and size on forest basal area growth, recruitment, and mortality. Forest Ecology and Management 243: 116–127.

Liang J., Crowther T.W., Picard N., Wiser S., Zhou M., Alberti G., Schulze E.-D., McGuire A.D., Bozzato F., Pretzsch H., de-Miguel S., Paquette A., Herault B., Scherer-Lorenzen M., Barrett C.B., Glick H.B., Hengeveld G.M., Nabuurs G.-J., Pfautsch S., Viana H., Vibrans A.C., Ammer C., Schall P., Verbyla D., Tchebakova N., Fischer M., Watson J.V., Chen H.Y.H., Lei X., Schelhaas M.-J., Lu H., Gianelle D., Parfenova E.I., Salas C., Lee E., Lee B., Kim H.S., Bruelheide H., Coomes D.A., Piotto D., Sunderland T., Schmid B., Gourlet-Fleury S., Sonke B., Tavani R., Zhu J., Brandl S., Vayreda J., Kitahara F., Searle E.B., Neldner V.J., Ngugi M.R., Baraloto C., Frizzera L., Ba Azy R., Oleksyn J., Zawi a-Nied Wiecki T., Bouriaud O., Bussotti F., Finer L., Jaroszewicz B., Jucker T., Valladares F., Jagodzinski A.M., Peri P.L., Gonmadje C., Marthy W., Obrien T., Martin E.H., Marshall A.R., Rovero F., Bitariho R., Niklaus P.A., Alvarez-Loayza P., Chamuya N., Valencia R., Mortier F., Wortel V., Engone-Obiang N.L., Ferreira L.V., Odeke D.E., Vasquez R.M., Lewis S.L., Reich P.B. 2016. Positive biodiversity-productivity relationship predominant in global forests. Science 354: aaf8957–aaf8957.

Long J.N. 1985. A practical approach to density management. The Forestry Chronicle 61: 23–27.

Long J.N., Daniel T.W. 1990. Assessment of growing stock in uneven-aged stands. Western Journal of Applied Forestry 5: 93–96.

Lorimer C.G., White A.S. 2003. Scale and frequency of natural disturbances in the northeastern US: implications for early successional forest habitats and regional age distributions. Forest Ecology and Management 185: 41–64.

Ma W., He J.-S., Yang Y., Wang X., Liang C., Anwar M., Zeng H., Fang J., Schmid B. 2010. Environmental factors covary with plant diversity-productivity relationships among Chinese grassland sites: Diversity-productivity relationships in Chinese grassland. Global Ecology and Biogeography 19: 233–43.

McCune B., Grace J.B. 2002. Analysis of Ecological Communities. MjM Software Design Gleneden Beach, Oregan USA. 304 p.

Miles P.D., Smith B.W. 2009. Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America. Research Note NRS-38. Newtown square PA 19073-3294: United States Department of Agriculture Forest Service Northern Research Station. 39 p. Available at: http://www.nrs.fs.fed.us/pubs/rn/rn_nrs38.pdf. (Accessed on 9 February 2017).

Mittelbach G.G., Steiner C.F., Scheiner S.M., Gross K.L., Reynolds H.L., Waide R.B., Willig M.R., Dodson S.I., Gough L. 2001. What is the observed relationship between species richness and productivity? Ecology 82: 2381–2396.

Moser W.K., Hansen M. 2009. The relation-

ship between diversity and productivity in selected forests of the Lake States Region (USA): relative impact of species versus structural diversity. In: McRoberts R.E., Reams G.A., Deusen P.C.V., McWilliams W.H. (eds.) Proceedings of the Eighth Annual Forest Inventory and Analysis Symposium: 414. Monterey, CA: USDA, Forest Service, General Technical Report, WO-79.

Nadrowski K., Wirth C., Scherer-Lorenzen M. 2010. Is forest diversity driving ecosystem function and service? Current Opinion in Environmental Sustainability 2: 75–79.

Ojha S.K. 2015. Tree diversity-productivity relationships in the forests of Alabama and the eastern United States (PhD). Alabama Agricultural and Mechanical University, Alabama, United States.

Pangle L., Vose J.M., Teskey R.O. 2009. Radiation use efficiency in adjacent hardwood and pine forests in the southern Appalachians Forest. Ecology and Management 257: 1034–1042.

Paquette A., Messier C. 2011. The effect of biodiversity on tree productivity: from temperate to boreal forests. Global Ecology and Biogeography 20: 170–180.

Pärtel M., Laanisto L., Zobel M. 2007. Contrasting plant productivity–diversity relationships across latitude: the role of evolutionary history. Ecology 88: 1091–1097.

Pärtel M., Zobel M. 2007. Dispersal limitation may result in the unimodal productivity-diversity relationship: a new explanation for a general pattern. Journal of Ecology 95: 90–94.

Potter K.M., Woodall C.W. 2014. Does biodiversity make a difference? Relationships between species richness, evolutionary diversity, and aboveground live tree biomass across U.S. forests. Forest Ecology and Management 321: 117–129.

Pretzsch H. 2005. Diversity and Productivity in Forests: Evidence from Long-Term Experimental Plots. In: Scherer-Lorenzen M., Körner C., Schulze E.-D. (Eds.). Forest Diversity and Function, 176. Ecological Studies. Springer Berlin Heidelberg: 41–64.

Prism Climate Group 2016. Northwest Alliance for Computational Science & Engineering. Available at: http://www.prism.oregonstate.edu/normals/. (Accessed on 28 April 2016).

Reineke L.H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research 46: 627–638.

Rodríguez-Loinaz G., Onaindia M., Amezaga I., Mijangos I., Garbisu C. 2008. Relationship between vegetation diversity and soil functional diversity in native mixed-oak forests. Soil Biology and Biochemistry 40: 49–60.

Sprugel D.G. 1985. Natural Disturbance and Ecosystem Energetics. In: Pickett S.T.A., White P.S. (Eds.). The Ecology of Natural Disturbance and Patch Dynamics. Academic Press Inc. San Diego, California 92101: 335–352.

Stevens J.T., Safford H.D., North M.P., Fried J.S., Gray A.N., Brown P.M., Dolanc C.R., Dobrowski S.Z., Falk D.A., Farris C.A., Franklin J.F., Fulé P.Z., Hagmann R.K., Knapp E.E., Miller J.D., Smith D.F., Swetnam T.W., Taylor A.H. 2016. Average Stand Age from Forest Inventory Plots Does Not Describe Historical Fire Regimes in Ponderosa Pine and Mixed-Conifer Forests of Western North America. PLoS ONE 11: 1–20.

Tenzin J., Hasenauer H. 2016. Tree species composition and diversity in relation to anthropogenic disturbances in broad-leaved forests of Bhutan. International Journal of Biodiversity Science, Ecosystem Services & Management 12(4): 274–290.

Thoms C., Gattinger A., Jacob M., Thomas F.M., Gleixner G. 2010. Direct and indirect effects of tree diversity drive soil microbial diversity in temperate deciduous forest. Soil Biology and Biochemistry 42(9): 1558–1565.

Tilman D. 1999. The ecological consequences of changes in biodiversity: A search for general principals. Ecology 80: 1455–1474.

Tilman D., Downing J.A. 1994. Biodiversity and stability in grasslands. Nature 367: 363–365.

Tilman D., Wedin D., Knops J. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature 379: 718–720.

Toïgo M., Vallet P., Perot T., Bontemps J.-D., Piedallu C., Courbaud B. 2015. Overyield-

ing in mixed forests decreases with site productivity. Journal of Ecology 103: 502–512.

Vilà M., Inchausti P., Vayreda J., Barrantes O., Gracia C., Ibáñez J.J., Mata T. 2005. Confounding Factors in the Observational Productivity-Diversity Relationship in Forests. In: Scherer-Lorenzen M., Körner C., Schulze E.-D. (Eds.). Forest Diversity and Function- Temperate and Boreal Systems, 176. Ecological Studies. Springer: 65–86.

Vilà M., Vayreda J., Comas L., Ibáñez J.J., Mata T., Obón. B. 2007. Species richness and wood production: a positive association in Mediterranean forests. Ecology Letters 10: 241–250.

Vilà M., Vayreda J., Gracia C., Ibáñez J.J. 2003. Does tree diversity increase wood production in pine forests? Oecologia 135: 299–303.

Woodall C.W., D'Amato A.W., Bradford J.B., Finley A.O. 2011. Effects of stand and inter-specific stocking on maximizing standing tree carbon stocks in the eastern United States. Forest Science 57: 365–378.

Woodall C.W., Miles P.D., Vissage J.S. 2005. Determining maximum stand density index in mixed species stands for strategic-scale stocking assessments. Forest Ecology and Management 216: 367–377.

Woudenberg S.W., Conkling B.L., O'Connell B.M., Lapoint E.B., Turner J.A., Waddell K.L. 2010. The Forest Inventory and Analysis Database: Database description and users manual version 4.0 for Phase 2. 344 p. Available at: http://www.treesearch.fs.fed.us/pubs/37446. (Accessed on 10 February 2017).

Zifan A. 2016. USA map of Köppen climate classification. Available at: https://commons.wikimedia.org/wiki/File:USA_map_of_K%C3%B6ppen_climate_classification.svg. (Accessed on 20 February 2017).

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PLANTS FOR LIVER AND JAUNDICE TREATMENT: A CASE STUDY FROM FOREST FRINGE COMMUNITIES IN NORTH BENGAL, INDIA

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Abstract

The traditional utilization of ethno-medicinal plants used for the treatment of jaundice and other liver disorder is commonly known among ethnic groups. The present study was carried out among the forest fringe villages of Chilapatta Reserve Forest in foothills of the eastern Sub-Himalayan mountain belts of West Bengal. The aim of the study was to document the traditionally used ethno-medicinal plant resources against jaundice and other liver disorders. A total of 19 plant species belonging to 15 families and 17 genera were documented. These 19 species were dominated by trees (07), herbs (05), shrubs (03) and four species of climbers. The plant families dominating the list were Apiaceae, Dioscoreaceae, Euphorbiaceae and Moraceae with 2 species each. Fruits (08) were the most dominant plant parts used for the treatment followed by leaves of 07 species. The plant parts are employed by the inhabitants in the form of infusion, decoction, paste, juice, etc., either as a sole drug species or in combination with other species. The documented plants and their procedure for utilization can be a useful tool for scientific community for further evaluation and recommendations to the practicing communities.

Key words: ethno-medicine, formulations, liver disorder, orally.

Introduction

Medicinal plant use evolved into an art and a science, practiced according to the experience, traditions and disease theory of the healer (Van der Merwe et al. 2001). The traditional system of health care has been significantly used for over two thousand years to treat illnesses (Tripathi et al. 2013). Traditional medicinal use of plants is strongly related to physiological and pharmacological activity of active plant ingredients (Fourie et al. 1992). Jaundice is one of the commonest liver disorders affecting the citizens of both rural and urban Indians and is treated by both cultivated and wild plants. Yellowing of eyes and vomiting yellowish fluid are the initial external symptoms of hepatitis (Bernard and Knipe 1996, White and Fenner 1994). Jaundice is indicated by the yellowish staining of skin and sclera that is caused by high levels of bilirubin in blood. It may result from various diseases or conditions that affect the liver including Hepatitis A, Hepatitis B, Hepatitis C, Hepatitis D, Autoimmune hepatitis, liver cirrhosis, liver cancer, haemolytic anaemia and malaria (Wahab et al. 2004). The disorder is commonly observed in new borns because

there is some haemolysis during delivery and the new born's liver is immature and may not be fully matured to handle the task of bilirubin for a few days (Wahab et al. 2004). Jaundice becomes visible when the bilirubin level is about 2 to 3 mg/dl (Hall et al. 2005).

Due to varied climatic and geographical features, India alone holds large number of medicinal plants used in indigenous systems of medicine (Shah et al. 2013, 2014; Pala et al. 2012; Debbarma et al. 2017). A large number of plants and formulations have been claimed to have hepatoprotective activity. Nearly 160 phyto-constituents from 101 plants have been claimed to possess liver protecting activity (Handa et al. 1986). There have been several studies and reports from the northern part of West Bengal regarding the use of ethno-medicinal plants to treat various diseases (Biswakarma et al. 2015, Sarkar et al. 2015, Shukla and Chakravarty 2012). However, a study completely pertaining to the treatment of jaundice through the use of orally transmitted traditional knowledge has not been reported yet from this study area. Therefore, the present study was carried out among forest fringe communities of Chilapatta forest from northern part of West Bengal with the aim to document the plant resources used for the treatment of liver and jaundice disorder and the traditional knowledge they possess about these plant resources.

Material and Methodology

The study area is located around Chilapatta Reserve Forest spreading over 41 km^2 that lies within the forests of Cooch Behar Wildlife Division of Alipurduar district (recently separated out from Jalpaiguri district) of West Bengal withlatitude 26°32.85′N and longitude 89°22.99′E. The villages included in the present study are Uttar Simlabari, Uttar Chaukakheti, Andu Basty, Bania Basty, Dakshin Mendabari, Uttar Mendabari, Kodal Basty and Kumarpara. The forest is inhabited by the divergent communities with Indo-Mongoloid tribes consisting of Raj Bangshis, Mech, Ravas, Totos, Limbus, Lepchas, Nageshias, Uraons and Mundas dependent directly or indirectly on its forest resources and are mainly agrarian subsistently growing paddy, jute and maize. The study was conducted from December 2014 to May 2016 with purposive sampling method used for selection of area. To obtain the information, both old aged and middle aged groups were approached for interview. A total number of 100 respondents including traditional medicinal practitioners were selected randomly for personal interview schedule through open ended questionnaire. Majority of the respondents were literate (71 %), i.e. have attended school up to primary level or more, while rest of them were illiterate or not attended school at all. The livelihood of the respondents centred on non-timber forest products and subsistence rain-fed farming on forest adjacent lands.

The schedule was administered to the respondent in local language and the responses were recorded in English on the schedule. The questionnaire covered aspects like plant species used as ethno-medicines against stomachand liver disorder, plant parts used, procedure for dosage and therapy (Pala et al. 2012, Shah et al. 2014, Shukla and Chakravarty 2012). The ethno-medicinal plant species were identified mostly in the field with their local names and also by consulting available secondary literature. However few unidentified specimens were mounted on herbarium sheets and identified with

the available herbarium of Department of Forestry Uttar Banga Krishi Viswavidyala, Pundibari.

Result and Discussion

The present study is an effort to scrutinize the resources with respect to medicinal plants used by the ethnic people for treating the liver disorder and jaundice. The study reported 19 species belonging to 15 families and 17 genera for curing of various liver and jaundice disorder. Our study revealed that the families like Apiaceae, Dioscoreaceae, Euphorbiaceae and Moraceae were represented by maximum of two species each, while rest of the families were having single species (Table 1). These reported plant species are represented by 7 species of trees (*Averrohoa carambola* L.*, Emblica officinalis* Gaertn., *Ficus hispida* L., *Mangifera indica* L., *Morus alba* L.*, Oroxylum indicum* (L.) Benth. ex Kurz*, Terminalia chebula* Retz.), 5 species of herbs (*Centella asiatica* (L.) Urban*, Andrographis paniculata* (Burm. f.) Wall. ex Nees*, Centella* spp.*, Musa* L. spp.*, Rauvolfia serpentine* (L.) Benth. ex Kurz), 3 species of shrubs (*Ricinus communis* L.*, Cajanus cajan* (L.) Mill.*, Abroma augusta* (L.) L. f. etc.) and 4 species of climbers (*Cuscuta europaea* L.*, Dioscorea belophylla* L.*, Dioscorea* L. spp.*, Luffaae gyptiaca* Mill.). The most dominant parts of the plants to prepare phyto-medicine were fruits found to be used in 8 formulations followed by leaves in 7, root in 5, whole plant in 4, bark in 3, tubers in 2 and stem and flowers from one species each. The reports of plant species used for jaundice and liver treatment has also been reported by Mulay and Sharma (2013) from Ahmednagar district of Maharastra, and Kumar et al. (2017) from Hathras district of Uttar Pradesh, India. In majority of cases, the herbal drugs were prepared in the form of juice, decoction, paste and powder and method of drug administration was oral. Some of the plant species documented in the present study have been reported earlier from other areas and for different treatments. *Abroma augusta* were used to treat jaundice in Tamil Nadu and Bangladesh by using its leaves (Maruthupandian et al. 2011, Chowdhury and Rahmatullah 2012), but in our study we found its root and bark is effectively used for the same treatment by using its different mode of application. Rahim et al. (2012), Gupta et al. (2010) and Debi et al. (2016) also reported *Cajanus cajan, Ricinus communis* and *Centella asiatica* in the treatment of jaundice. We also observed that *Dioscorea belophylla* tuber and fruit are used to treat jaundice but according to Srivastava and Nyishi (2010) they are used for the treatment of fever, malaria, headache and dysentery. Kumar et al. (2017) also reported the use of *Andrographis paniculata* for the treatment of jaundice. Fruit decoction of *Terminalia chebula* is also reported by Amiri et al. (2014) used to treat jaundice in Iran.

Conclusion

The indigenous communities have rich traditional knowledge system about the ethnobotanical plants. The documentation of the plant species and their traditional procedure indicates the community consciousness on the conservation values of these ethnobotanical species used against liver and jaundice. There could be possibility of presence of more species of this value in the area and needs to be identified through further research and can be of commercial and livelihood importance

Table 1. Reported species, parts used and their applications.

Scientific name	Common name	Family	Habit*	Uses	Parts used	Therapy/procedure of use
Abroma augusta (L.) L. f.	Ulatkambal	Malvaceae	S	Jaundice	bark, root	Root bark paste along with misri (local sweet) is used to prepare juice.
Andrographis paniculata (Burm. f.) Wall. ex Nees	Kalmegh, Chirawta	Acanthaceae	H	Liver problems	whole plant	Leaves and immature stem of *Andrographis paniculata*, roots of *Rauvolfia serpentina* and fruits of *bistifal* is taken in powdery form. Whole plant parts in the form of tablets are taken to cure liver problems.
Averrohoea carambola L.	Kamringa, Charpatay	Oxalidaceae	T	Jaundice and liver problems	fruits	Fruits juice is taken for curing jaundice and liver problem.
Cajanus cajan (L.) Mill.	Rahar, Raheri	Fabaceae	S	Jaundice and liver problem	leaves, root	10–12 leaves along with talmisri (local sweet) and sadhamisri (local sweet) of 100 g juice is used for curing jaundice. Roots juice with addition of water is also used for curing jaundice.
Centella asiatica (L.) Urban	Bang Sag, Thankuni, Gortapre	Apiaceae	H	Jaundice	leaf, roots	*Centella asiatica*, bamboo, *Ocimum sanctum* leaf and earthworm is boiled and juice is taken for curing jaundice. Roots are eaten simply or else by cooked with potato (fried) and taken to cure jaundice. Besides this *Centella asiatica, Piper nigrum,* cardamom (2–3 nos.) is taken as tea for curing jaundice.
Centella sp. Linn.	Mana-muni	Apiaceae	H	Liver problem	whole plant	Whole plant is chewed or juice is taken to cure liver problems.
Cuscuta europaea L.	Kankor, Pahelolahara	Convolvulaceae	C	Jaundice	whole plant	The whole plant is boiled and taken bath with light warm water for curing jaundice. Also the boiled water with salt is taken to cure jaundice.
Dioscorea belophylla (Prain) Voigt ex Haines	Janglialu, Ban alu, Gichikanda, Ghetuallu	Dioscoreaceae	C	Jaundice	fruits, tubers	Cut fruits is boiled and taken as food to cure jaundice by removing its bitter taste. Excess eating is poisonous and not good for health. It's bitter in taste. Tubers in powdery form are massaged on the whole body for curing jaundice.
Dioscorea sp.	Kowatumbil	Dioscoreaceae	C	Jaundice	tubers	Tubers soaked in water for 5–10 minutes are taken to cure jaundice.

Emblica officinalis Gaertn.	Amlai, Amla, Amloki	Euphorbiaceae	T	Liver problem	fruits	Fruits of *Emblica officinalis* along with fruits of *Terminalia chebula* and *Terminalia bellirica* is formed into powder and taken to cure liver problem.
Ficus hispida L. f.	Kuchuli	Moraceae	T	Jaundice, liver problems	fruits	Fruits are edible which helps in curing jaundice and liver problem.
Luffaae gyptiaca Mill.	Gongra, Dhudol, Gherawla	Cucurbitaceae	C	Liver disorder	fruits, leaves	Immature fruits and leaves are consumed as vegetables which also resulted in treating liver disorder.
Mangifera indica L.	Amba	Anarcardiaceae	T	Jaundice	bark	Bark juice with water is taken in empty stomach for curing jaundice.
Morus alba L.	Neel, Tuth	Moraceae	T	Jaundice	root, leaves	Small piece of root is enclosed and tied on neck on Tuesday and Saturday with their traditional belief for 12 days and thrown where he or she doesn't pass by for curing jaundice. Also 10–12 boiled leaves are cooled and taken facing eastward direction in one breath (about 200–300 g).
Musa sp.	Kola	Musaceae	H	Liver problem	leaves	Juice of leaves is taken in empty stomach to cure liver problem.
Oroxylum indicum (L.) Benth. Ex Kurz	Kanaidingi, Totola, Surimala	Bignoniaceae	T	Jaundice, liver problem	flowers, bark, leaves	Fallen flowers are cooked and taken to cure jaundice. Bark soaked in water used for taking bath also cures Jaundice. Bark juice and leaves eaten as vegetables in empty stomach cures jaundice and liver problem.
Rauvolfia serpentine (L.) Benth ex Kurz.	Nakbail, Sarpaganda	Apocynaceae	H	Jaundice	whole plant	Whole plant or any other plant part is powdered (bitter in taste) and used to cure jaundice.
Ricinus communis L.	Aranda,Varenda, Rahari	Euphorbiaceae	S	Jaundice	leaves, fruits	Leaf with sugar is consumed to cure jaundice. Fruits are boiled with fruits of *Cajanus cajan* and consumed to cure jaundice.
Terminalia chebula Retz.	Haritaki, Harra	Combretaceae	T	Jaundice, liver problem	fruits	Dried fruit solution of *Terminalia chebula, Terminalia bellirica*, and *Emblica officinalis* (one each) is taken in empty stomach to cure jaundice and makes liver strong.

*Legend: T – tree; S – shrub; H – herb; C – climber.

to local communities. The communities should be encouraged with improved cultivation techniques of commercially viable ethnobotanical species through capacity building, timely policy intervention along with strong market linkage. This will ensure income generation and livelihood improvement and ultimately conservation of these species.

References

Amiri Md.S., Joharchib Md.R., Yazdi Md.E.T. 2014. Ethno-Medicinal Plants Used to Cure Jaundice by Traditional Healers of Mashhad, Iran. Iranian Journal of Pharmaceutical Research 13(1): 157–162.

Bernard F., Knipe D.M. 1996. Virology. 3rd Edition, Lippincott Raven Philadelphia: 2739–2789.

Biswakarma S., Sarkar B.C., Shukla G., Pala N.A., Chakravarty S. 2015. Traditional application of ethnomedicinal plants in Naxalbari area of West Bengal, India. International Journal of Usufruct Management16: 36–42.

Chowdhury A.R., Rahmatullah M. 2012. Ethnomedicinal plants for treatment of jaundice by the folk and tribal medicinal practitioners of several districts in Bangladesh and review of their scientifically reported hepatoprotective activity. American-Eurasian Journal of Sustainable Agriculture 6(4): 360–370.

Debbarma M., Pala N.A., Kumar M., Bussmann R.W. 2017.Traditional knowledge of medicinal plants in tribes of Tripura in northeast, India. African Journal of Traditional, Complement Alternative Medicine 14(4): 156–168.

Debi D., Datta B.K., Debbarma J., Deb S. 2016. Ethno-medicinal plants used for herbal medication of jaundice by the indigenous community of Tripura. India biodiversity 1: 256–259.

FourieT.G., Swart I., Snyckers F.O. 1992. Folk medicine: a viable starting point for pharmaceutical research. South African Journal of Science 88: 190–192.

Gupta R., Vairale M.G., Deshmukh R.R., Chaudhary P.R., Wate S.R. 2010. Ethnomedicinal uses of some plants used by Gondtribe of Bhandara district, Maharashtra. Indian Journal of Traditional Knowledge 9(4): 713–717.

Hall J., Guyton A., Hall J. 2005. Textbook of Medical Physiology. 11th Edition, eBook, Saunders. 1152 p.

Handa S.S., Sharma A., Chakraborty K.K. 1986. Natural products and plants as liver protecting drugs. Fitoterapia 57: 307–351.

Kumar S., Singh B.S., Singh R.B. 2017. Ethnomedicinal plants to cure diabetes and jaundice diseases among the rural and tribal peoples of Hathras district (U.P.). International Journal of Botany Studies 2(2): 19–20.

Maruthupandian A., Mohan V.R., Kottaimuthu R. 2011. Ethnomedicinal plants used for the treatment of diabetes and jaundice by Palliyartribals in Sirumalai hills, Western Ghats, Tamil Nadu, India. Indian Journal of Natural Products and Resources 2(4): 493–497.

Mulay J.R., Sharma P.P. 2013. Plants Used in Treatment of Jaundice by Folklore of Ahmednagar district, Maharashtra, India. Science Research Reporter 3(2): 216–222.

Pala N.A., Negi A.K., Gokhale Y., Razvi S., Todaria N.P. 2012. Medicinal plant resources in sacred forests of Garhwal Himalaya. Journal of Non-Timber Forest Products 19(4): 291–296.

Rahim Z.B., Rahman M.M., Saha D., Hosen S.M.Z., Paul S., Kader S. 2012. Ethnomedicinalplants used against jaundice in Bangladesh and its economical prospects. Bulletin of Pharmaceutical Research 2(2): 91–105.

Sarkar B.C., Biswakarma S., Shukla G., Pala N.A., Chakravarty S. 2015. Documentation and utilization pattern of ethnomedicinal plants in Darjeeling Himalayas, India. International Journal of Usufruct Management 16: 3–11.

Shah S., Ram J., Pala N.A., Tripathi P. 2013. Ecological status of medicinal plants in Oak

and mixed Oak forests of Nainital Catchment, Uttarakhand. Journal of Non-Timber Forest Products 3: 171–178.

Shah S., Ram J., Pala N.A., Tripathi P., Kumar M. 2014. Medicinal plant wealth of Oak dominated forests in Nainital Catchment Area of Uttarakhand. Academia Journal of Medicinal Plants 2(1): 006–013.

Shukla G., Chakravarty S. 2012. Ethnobotanical Plant use of Chilapatta Reserve Forest in West Bengal. Indian Forester 138: 1116–1124.

Srivastava R.C., Nyishi C. 2010. Traditional knowledge of Nyishi (Daffla) tribe of Arunachal Pradesh. Indian Journal of Traditional Knowledge 9: 26–37.

Tripathi S., Ray S., Mondal A.K., Verma N.K. 2013. Rare ethnomedicinal plants of south-west Bengal, India with their different medicinal uses; needs conservation. International Journal of Life Sciences Biotechnology and Pharma Research 2(2): 114–122.

Van der Merwe D., Swan G.E., Botha C.J. 2001. Use of ethnoveterinary medicinal plants in cattle by Setswana-speaking people in the Madikwe area of the North West Province of South Africa. Journal of South African Veterinary Association 72(4): 189–196.

Wahab M.A., Yousaf M., Hossain M.E. 2004. Some indigenous medicinal knowledge for treating jaundice in Chittagong hill tracts Bangladesh. Hamdard Medicus XLVII(4): 55–58.

White D., Fenner F. 1994. Medical Virology. 4th Edition, eBook, Academic Press. 603 p.

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ANALYSIS OF AIR TEMPERATURE AND POLLUTANT VARIATIONS IN SOFIA

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Abstract

Urban climate is the most modified by humans among local climates. Industry, traffic and heating emit artificial heat, water vapor and pollution to the atmosphere. Air pollution and air temperature are becoming ones of the major factors for the quality of life of urban dwellers. The aim of present paper is to analyze the temperature conditions in Sofia, Bozhurishte and Bankya. For this purpose long term (1961–2011) meteorological data of their stations were used. The amendment of certain atmospheric pollutants, observed in southwestern areas of Sofia city – Hipodruma and Pavlovo, where there is high urbanization, intensive traffic and industrial activity is studied too. The relationship between pollutants and the temperature has been examined.

Key words: air pollutants, climate, temperature extremes, threshold.

Aims and Background

Urban climate is the most modified by humans among local climates. Industry, traffic and heating emit artificial heat, water vapor and pollution to the atmosphere. Air pollution and air temperature are becoming ones of the major factors for the quality of life of urban dwellers, posing a risk both to human health and to the environment (Berlyand 1985, Vassilev et al. 1989, Batchvarova et al. 1996, Dimitrova 2001, Zujic et al. 2005, Doncheva-Boneva and Koleva-Lizama 2013, Kadinov et al. 2014). The anthropogenic impact on climate is unique in Sofia (Blaskova et al. 1983, Blaskova and Lingova 1991). After 1965 the city has been expanding, increasing the number of floors of buildings, formation of new residential neighbourhoods, increasing industrial and other areas. Sofia is the largest city and industrial center in Bulgaria, in which territory there are operating a number of industrial enterprises, half of which are among the residential areas or adjacent to them. From the industry activities directly in the air are discharged sulphur, nitrogen and carbon monoxide, dust and carcinogenic substances. The number of vehicles that emit large amounts of harmful gases is increasing. The peripheral low-rise neighbourhoods of the city are using inefficient domestic heaters. These various sources concentrated in a relatively small area lead to changes in weather elements and

the formation of the 'urban environment'. The aim of the study is to investigate the characteristics of temperature conditions in Sofia, their changes under the influence of urbanization and the amendment of certain atmospheric pollutants in the central part of town.

Object and Methods

The city of Sofia is situated in the central and southern parts of Sofia hollow with mean altitude of about 580 m. Sofia hollow valley itself consists of two parts: the bottom (often called 'field') and the surrounding mountain slopes. The climate in this region of Bulgaria has a continental character (Stanev et al. 1991). Meteorological data from 'Vasil Levski' Square station (1), Meteorological Observatory (2) and Central Meteorological Station (3), situated in Sofia city, are used. Data from suburban stations – Bozhurishte and Bankya are used too. In order to investigate the temperature changes methods of complex climate science and mathematical statistics are used (Koleva-Lizama and Rivas 2004). In addition, the amendment of certain atmospheric pollutants, observed in southwestern areas of Sofia city – Hipodruma and Pavlovo, where there is high urbanization, intensive traffic and industrial activity is studied too. Analysis and assessment of air pollution in the selected area is made based on validated data provided by the Executive Environment Agency (EEA). Information includes 1-hour concentrations of the measured pollutants and meteorological elements for the period 2009–2013. The temperature and air pollutants database are systematized for each year. The average annual concentrations, maximum daily average and number of exceedances per year are determined. The evaluation of the database was performed using the existing regulations, lower limit values and overall assessment thresholds. The relationship between pollutants (SO_2, NO_2, PM10) and the temperature has been studied.

Results and Discussion

In the region of Sofia and its surroundings are situated several weather stations, with which the local temperature of the city and surrounding area can be characterized (Fig. 1). The coldest month is January with an average monthly temperature of minus 1.7 °C. In the early spring and mainly in March in line with the increase of day and the solar height occurs an increase in the radiation sheet. The spring conditions in the region are relatively cooler that autumn ones. The average annual temperature of the spring (March, April,

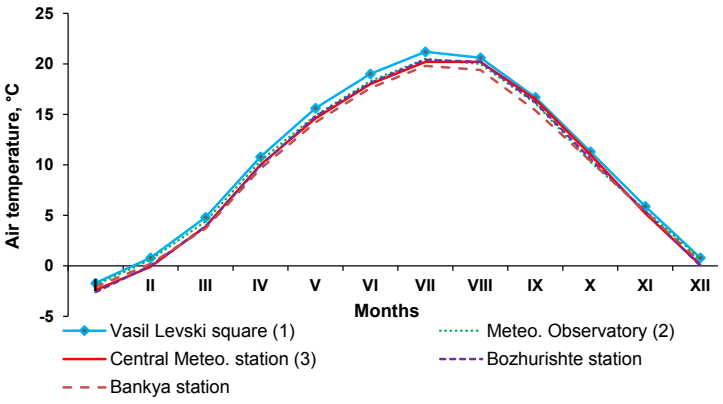

Fig. 1. Mean monthly air temperature.

May) is about 1 °C lower than that for the autumn (September, October, November). The warmest month of the year is July, but sometimes it is August. The annual temperature range in Sofia is 23 °C. The measured lowest and highest temperatures were minus 31.1 °C (abs. min) and 40.2 °C (abs. max).

The largest difference between urban and suburb stations can be seen in the warm part of the year.

The statistical parameters of annual air temperature in studied meteorological stations are shown in Table 1.

Table 1. Statistical parameters of annual air temperature (1961–2011).

Station	Latitude	Longitude	H, m	Mean, °C	Min, °C	Max, °C	σ	As	Es	Cv
Sofia Central Meteostation	42°39'13.16"	23°22'58.43"	584	10.2	8.9	11.7	0.62	0.44	-0.23	0.061
Bankya	42°42'17.94"	23°9'3.10"	640	9.5	8.5	10.8	0.49	0.30	0.01	0.052
Bozhurishte	42°45'12.46"	23°12'24.09"	554	9.8	8.4	11.4	0.63	0.31	-0.29	0.064

The average annual temperature in Sofia Central meteorological station is 10.2 °C, in Bozhurishte – 9.8 °C and in Bankya – 9.5 °C. The average annual temperature of the city is higher than the surrounding areas with 0.4 °C to 0.7 °C, demonstrating the differences in temperature inside and outside the city. The greatest difference between the city and its environs is in the minimum temperatures (Fig. 2). Their values are negative from December to March. The average monthly minimum temperature during the period for Sofia (1) and Sofia (3) varies from -4.8 °C to -6.2 °C. The highest minimum temperatures are in July. The weather is warmest in the city center near 'Vasil Levski' Square (Sofia 1). The decisive factor determining the higher minimum temperatures in the city during the winter months are significantly reduced effective radiation and resulting from anthropogenic activity in the city.

The analysis of temperature conditions is essential to study the maximum values that determine the evaporation and superheating of enclosed spaces in the central parts of the urban environment (Fig. 3).

During the cold part of the year, the lowest maximum temperatures were measured in January, and the average monthly values were within 1.3 °C and 1.6 °C. The highest values of maximum temperatures were recorded in July and August. The average monthly maximum of air temperatures in urban stations in Sofia was between 26.5 °C and 27.2 °C in August and in the outskirts was between

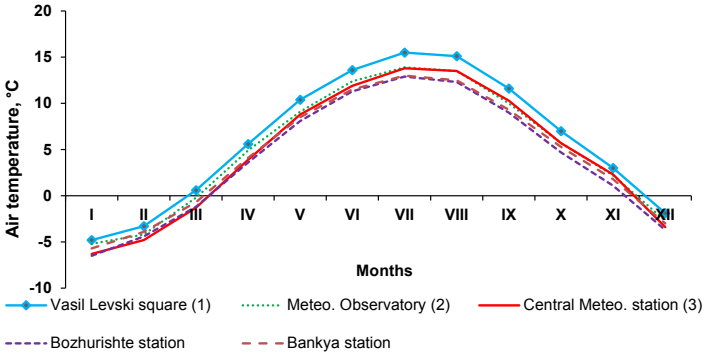

Fig. 2. Average monthly minimum air temperature.

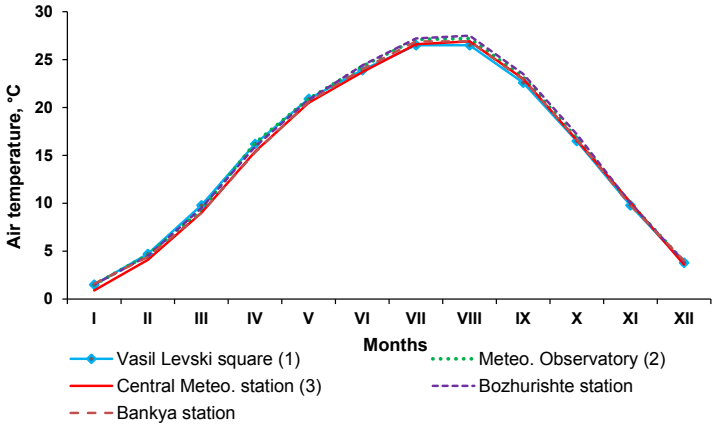

Fig. 3. Average monthly maximum air temperature.

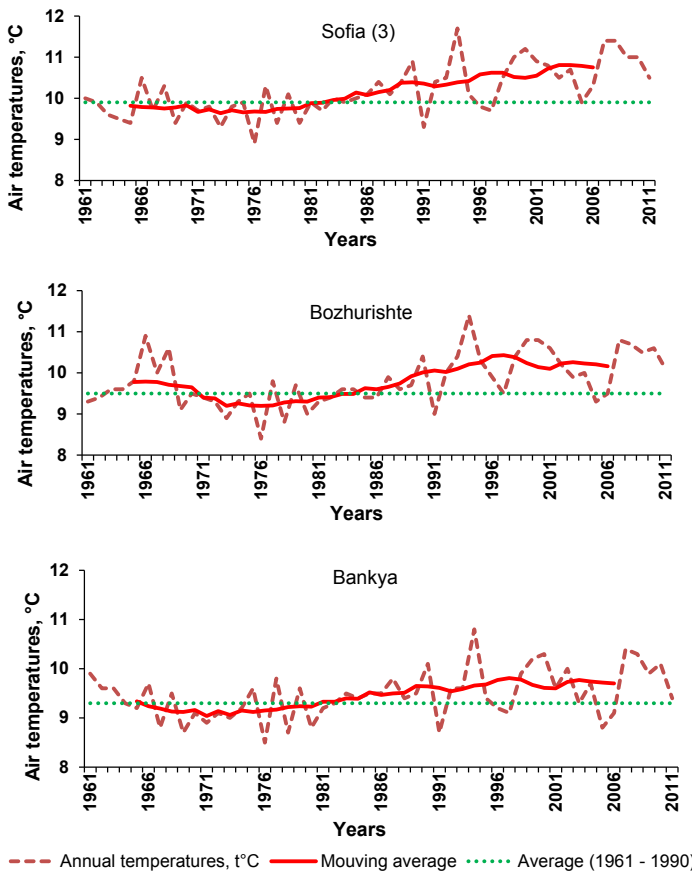

Fig. 4. Mean annual temperatures and their mouving average at Sofia 3, Bozhurishte and Bankya stations.

26.9 °C and 28.1 °C. The lowest maximum of temperatures in July and August were observed in the city center – Station 'Vasil Levski' Square. The main reason for this is that in the afternoon region is located in the shade of large trees. The winter season does not affect the maximum temperature.

The dynamics of annual temperatures and their moving average values observed in the region of Central Meteorological station, Bozhurishte and Bankya is shown in Figure 4.

The annual temperature tends to increase after 1982. The temperature increase in the last decade is most pronounced.

In this study amendment of the annual concentrations of some pollutants in the selected areas of Sofia city – Hipodruma and Pavlovo were examined. The average annual sulphur dioxide concentration is shown in Figure 5. It varies in the range of 7.4 mg/m^3 to 13.4 mg/m^3 without pronounced difference between the two districts. The highest values were observed in 2011, and the lowest – in 2013.

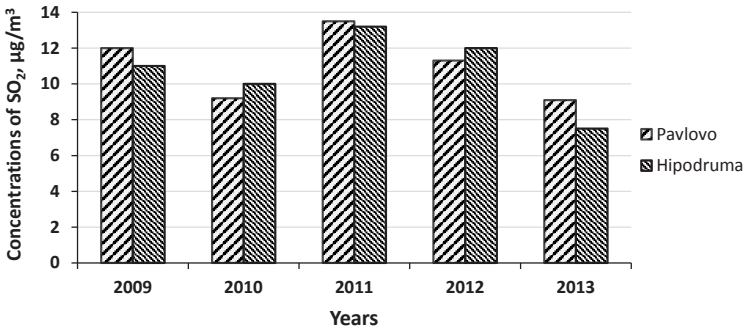

Fig. 5. Average annual concentrations of SO_2.

The higher concentration of SO_2 can be explained by the cold winter.

The annual average concentration of NO_2 ranged from 28.94 µg/m^3 to 43.00 µg/m^3 in the area of district Hipodruma and from 32.55 µg/m^3 to 41.78 µg/m^3 in the district Pavlovo (Figs 6 and 7). The values of annual average

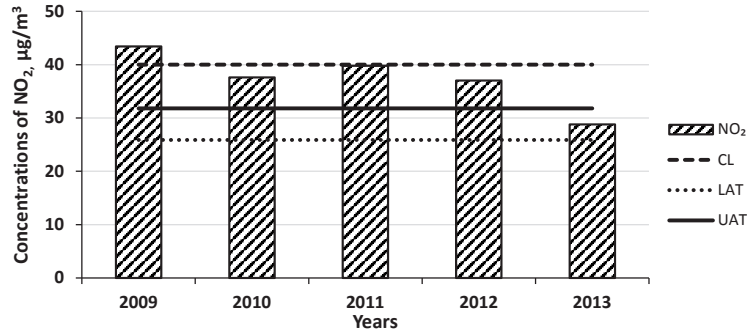

Fig. 6. Average annual concentrations of NO_2 – Hipodruma.
Legend: CL – Critical levels for the protection of health; LAT – Lower assessment threshold; UAT – Upper assessment threshold.

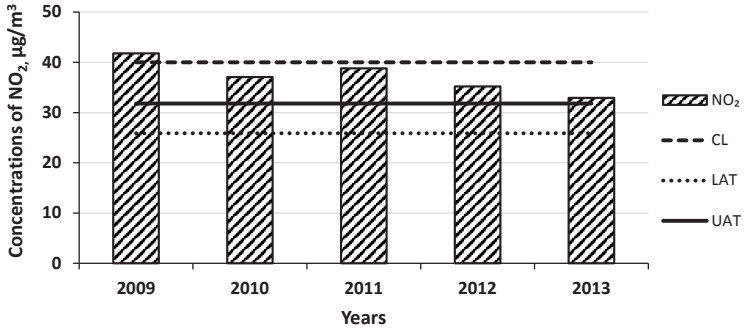

Fig. 7. Average annual concentrations of NO_2 – Pavlovo.
Legend: CL – Critical levels for the protection of health; LAT – Lower assessment threshold; UAT – Upper assessment threshold.

concentrations exceed the assessment thresholds in all years.

The average annual concentration of PM10 (particulate matter < 10 micrometers) are shown in figures 8 and 9.

The average annual concentration of PM10 ranged from 41.53 μg/m^3 to 62.81 μg/m^3 in the district Hipodruma (Fig. 8) and from 43.17 μg/m^3 to 59.73 μg/m^3 in Pavlovo (Fig. 9). There were increases in 2011. Exceedances of the limit value (40 μg/m^3) are observed in all years. The assessment of temperature influence on contaminants is conducted by means of correlation analysis. The values of obtained correlation coefficients between daily concentrations of major pollutants with data of diurnal air temperature in areas of Pavlovo and Hipodruma station are shown on Table 2.

In Pavlovo region (Table 2) air temperature have relatively little impact on nitrogen oxides (r = -0.29 – -0.45) and particulate matter (r = 0.25 – 0.44). More significant influence of air temperature is on sulphur dioxide (r = -0.44 – 0.70) and ozone (r = 0.45 – 0.79). In Hipodruma region (Table 2) air temperature have relatively little impact on nitrogen oxides (r = -0.23 – -0.38) and particulate matter

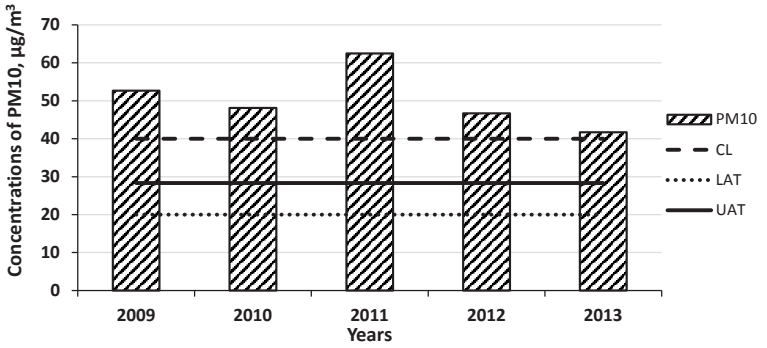

Fig. 8. Average annual concentrations of PM10 in Hipodruma.
Legend: CL – Critical levels for the protection of health; LAT – Lower assessment threshold; UAT – Upper assessment threshold.

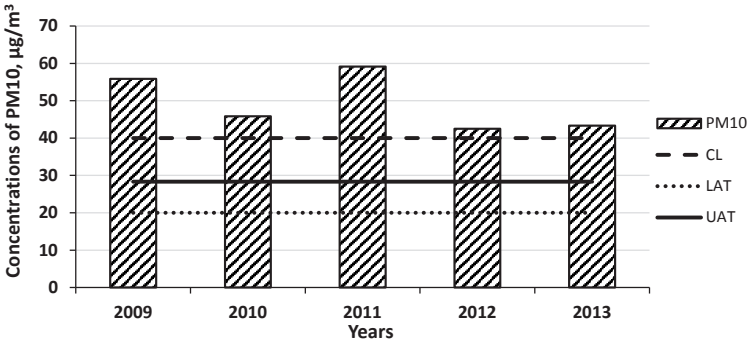

Fig. 9. Average annual concentrations of PM10 in Pavlovo.
Legend: CL – Critical levels for the protection of health; LAT – Lower assessment threshold; UAT – Upper assessment threshold.

Table 2. Correlations between daily concentrations of air pollutants and temperature in the area of Pavlovo and Hipodruma.

Air pollutants	Years				
	2009	2010	2011	2012	2013
		Pavlovo			
NO, mg/m^3	-0.291	-0.292	-0.452	-0.360	-0.345
NO_2, mg/m^3	-0.125	-0.236	-0.461	-0.282	-0.289
NOx, ppb	-0.254	-0.285	-0.466	-0.343	-0.334
O_3, mg/m^3	0.454	0.520	0.795	0.649	0.662
SO2, mg/m^3	-0.436	-0.583	-0.704	-0.613	-0.557
PM10, mg/m^3	-0.251	-0.272	-0.439	-0.338	-0.353
		Hipodruma			
NO, mg/m^3	-0.280	-0.230	-0.383	-0.308	-0.342
NO_2, mg/m^3	-0.231	-0.269	-0.370	-0.269	-0.359
NOx, ppb	-0.275	-0.246	-0.389	-0.305	-0.366
O_3, mg/m^3	0.565	0.449	0.611	0.432	0.525
SO_2, mg/m^3	-0.354	-0.588	-0.612	-0.525	-0.325
PM10, mg/m^3	-0.258	-0.246	-0.404	-0.314	-0.347

PM10 (r = 0.25 – 0.40).

More significant influence of air temperature is on sulphur dioxide (r = -0.32 – 0.61) and ozone (r = 0.43 – 0.61).

Conclusion

The obtained results showed that:

• The average annual temperature in the city is higher than in the surrounding areas with 0.4 to 0.7 °C approximately. In recent years, temperatures in Sofia have increased on average with about 1.2 °C, being more expressed in 1996 and over the past 3 years.

• Air quality in Sofia is poor, as the main reason for this is the high concentration of PM10. The average annual concentrations of PM in Pavlovo and Hipodruma exceed acceptable norm for the entire period (2009–2013). The highest rates were recorded in 2011 and 2009 as a result of lower temperatures during those years.

• In the studied areas of Sofia city air temperature have relatively little impact on nitrogen oxides and PM10. More significant influence of air temperature is on concentration of sulphur dioxide and ozone.

References

Batchvarova E., Syrakov D., Tzenkova A. 1996. Air pollution characteristics of a region of Sofia and data from field experiments (1992–1993). In: Urban Air Pollution. Monitoring and control strategics. Allegrini I. and Sanus F.De. (Eds.). NATO ASI Series, 2. Environment vol. 8: 235–242 (in Bulgarian).

Berlyand M. 1985. Air pollution forecasting and

regulation. Gidromcteoizdat, Leningrad. 272 p. (in Russian).

Blaskova D., Lingova S. 1991. Urban influence on climate. The climate of Bulgaria. BAS, Sofia: 438–450 (in Bulgarian).

Blaskova D., Zlatkova L., Lingova S., Modeva Zh., Subev L., Teneva M. 1983. Climate and microclimate of Sofia. BAS, Sofia. 154 p. (in Bulgarian).

Dimitrova R. 2001. Air flows and pollution transport in the Sofia valley under highly stable background conditions. Bulgarian Geophysical Journal 27(1/2): 114–123 (in Bulgarian).

Doncheva-Boneva M., Koleva-Lizama I. 2013. Study on the influence of some meteorological factors on the dust pollution of Veliko Tarnovo. Journal of Environmental Protection and Ecology 14(3): 825–835.

Kadinov G., Doncheva-Boneva M., Bezlova D. 2014. Ozone accumulation in mountainous regions in Bulgaria. Journal of Environmental Protection and Ecology 15(4): 1526–1535.

Koleva-Lizama I., Rivas B.L. 2004. Study on variability of temperature and precipitation conditions in the south eastern Bulgaria. Proceedings of International Conference on Water Observation and Information System for Decision Support, 25–29 May 2004, Ohrid, FYRepublic of Macedonia: 308–315.

Stanev S., Kyuchukova M., Lingova S. 1991. Climate of Bulgaria. BAS, Sofia. 499 p. (in Bulgarian).

Vassilev I., Andreev V., Godev N., Spasova T. 1989. A synoptic-statistical method for air pollution forecast in the towns, situated in mountainous areas. Proceeding XIV International Conference on Carpathian Meteorology, September 25–30, Sofia: 374–378 (in Russian).

Zujic A., Gopcanin D., Miljevic N. 2005. Air quality parameters in Belgrade. Journal of Environmental Protection and Ecology 6(3): 505–512.

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A NEW PSILOPEZIOID FUNGI RECORD ON RELICT ENDEMIC *LIQUIDAMBAR ORIENTALIS* IN TURKEY

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Abstract

In the current study, *Psilopezia nummularia*, which known as psilopezioid fungi, is a new record at genus level in Turkey. In addition, this is the first report that relict endemic *Liquidambar orientalis* is a host of this species. Macro- and microphotographs of the taxon are given together with a description.

Key words: Ascomycota, new record, new host, oriental sweetgum, taxonomy.

Introduction

The majority of Turkey has a unique biodiversity consisting of rare and endemic species. Among them *Liquidambar orientalis* Mill., generally known as oriental sweetgum, is very important by being used economically by local people. In addition, oriental sweetgum forests act as hosts for other animals, plants and mushrooms. Especially, it encourages interesting macro- and microfungal species by moisture structures of its forests (Öztürk et al. 2008, Işıloğlu et al. 2011, Çolak et al. 2015, Güngör and Allı 2016, Kaygusuz et al. 2016).

Psilopezioid fungi are recognized with several genera of operculate discomycetes. As mentioned above these interesting fungi are generally growing on wet, submerged wood or other decayed plant debris. The most of psilopezizoid members are belonging to *Pachyella* Boud. and *Psilopezia* Berk. (Pfister 1973a,b,c; Hosoya and Maruyama 2004; Hansen and Pfister 2006).

The genus *Psilopezia* is a member of cup fungi in the family Pyronemataceae Corda (Pezizales, Ascomycota) (Anonymous 2017a). It was circumscribed by Miles Berkeley in 1847 (Pfister 1973b). It includes approximately 14 taxa throughout the world (Kirk et al. 2008, Anonymous 2017b, Wijayawardene et al. 2017). However, there is not any report of the members related to genus *Psilopezia* in Turkey (Sesli and Denchev 2008, Solak et al. 2015).

Members of the genus are mainly characterized by sessile and ascomata broadly attached to the substrate. They are 0.3–3 cm in diameter, flat and disc-shaped, sometimes it becomes convoluted, with dark colours of blackish, brown or greenish. Asci are operculate, cylindrical, with prominent croziers and generally 8-spored. Ascospores are generally more than 25 µm long, ellipsoidal, hyaline, with

two guttules at maturity, smooth, with a perispore which loosens in cotton-blue, lactic acid or in Melzer's reagent (Seaver 1942; Pfister 1973a,b).

The purpose of this study was to contribute knowledge to the mycobiota of Turkey.

Materials and Methods

In the autumn of 2017, some fungal samples were collected from sweetgum forest protected area in Burdur Province. In the field, the specimens were photographed on the substrates. The morphological and ecological characteristics were recorded. Microstructural data were observed with a light microscope magnification, trade using Congo Red and Melzer's reagent. 20 asci, ascospores and paraphyses from each ascoma were measured, length and width ranges were recorded. Identification of the samples was conducted according to Pfister (1973b) and Breitenbach and Kränzlin (1984). The dried samples were conserved in the personal fungarium of the first author at Süleyman Demirel University.

Results

A new psilopezioid fungi record for Turkey

Pyronemataceae Corda

Psilopezia nummularia Berk. [as 'nummularis'], London J. Bot. 6: 325 (1847) SYN.: *Peziza nummularia* (Berk.) Morgan [as 'numularia'], J. Mycol. 8(4): 190 (1902) (Figs 1 and 2).

Ascomata 1–2 cm in diameter, sessile, disc shaped, initially flat but with undulating surface or somewhat convoluted as it get age, **hymenium** smooth and shiny when wet, from chestnut to greenish-light brown, becomes blackish with time, **outer surface** lighter, almost whitish beige and often invisible. **Asci** 340–425 × 19–22 µm, cylindrical, operculate, non-amyloid, with

Fig. 1. *P. nummularia*: a and b – fresh ascomata developed on wood of *L. orientalis*.

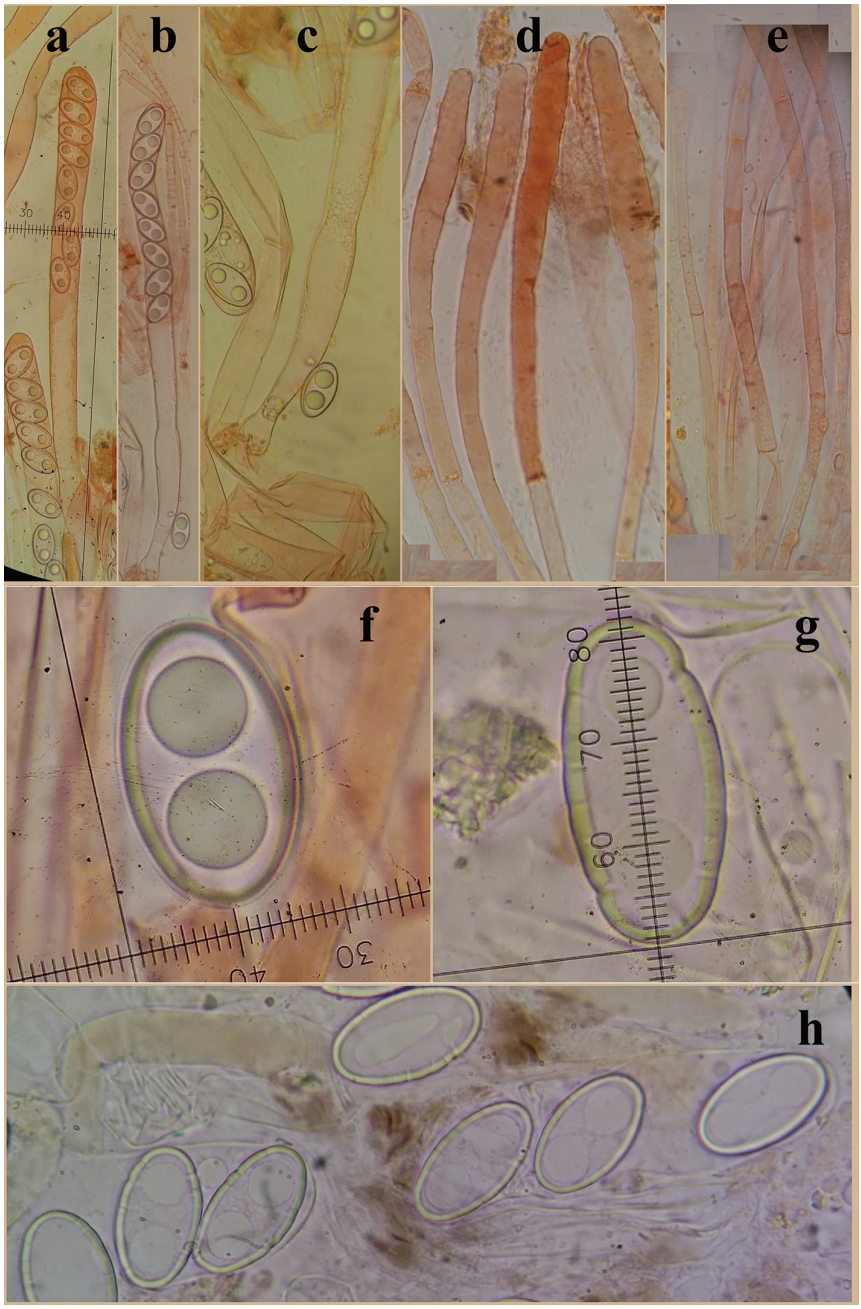

Fig. 2. ***P. nummularia*****: a – asci in Congo red; b – asci in Congo red, with croziers and eight uniseriate spores; c – asci in Congo red, with croziers; d – paraphyses upper part in Congo red, with brownish amorphous material; e – paraphyses down part in Congo red, with septate; f – ascospores in Congo red; g and h – ascospores, with an outer spore wall which loosens in Melzer's reagent (magnification: a–e: 40×, f–h: 100×).**

evident croziers and eight uniseriate spores. **Ascospores** (23-)24–30(-31.5) × (13-)14–17(-19) µm, ellipsoidal, hyaline and smooth surface, 2-guttulate, with an outer spore wall which loosens in Melzer's reagent. **Paraphyses** 10 µm wide in the upper part, septate and cylindrical, with brownish amorphous material.

Habitat: On water-soaked rotten branches of *L. orientalis*.

Specimen examined: Turkey. Burdur Province, Bucak district, Kargı village, Sweetgum forest protected area, 200–250 m above sea level, 15 October 2017, leg. & det. Ö.F. Çolak (ÖFÇ 1311).

Discussion

P. nummularia has been reported so far from North America (USA), South America (Trinidad), the Caribbean, Europe (Germany, Italy, France, Great Britain, Switzerland) and Asia countries (Seaver 1942, Beller 1972, Pfister 1973b, Breitenbach and Kränzlin 1984, Moyne et al. 2014).

P. nummularia is barely distinguishable macroscopically from *Pachyella babingtonii* (Berk. & Broome) Boud. (Breitenbach and Kränzlin 1984). Unlike *Psilopezia*, *Pachyella*, a member of the family Pezizaceae Dumort. (Pezizales, Ascomycota), is characterized by asci without prominent croziers; usually less than 25 µm ascospores, lacking a loosening outer spore wall in Melzer's reagent, cotton-blue or lactic acid (Pfister 1973a,b,c; Hosoya and Maruyama 2004; Hansen and Pfister 2006).

Although the ascomata of *P. nummularia* is dark coloured, *P. aquatica* (Lam. & DC.) Rehm is yellow or orange. Also the ascomata of *P. nummularia* and *P. juruensis* Henn. is larger than 1 cm diameter while *P. deligata* (Peck) Seaver is smaller than 1 cm diameter. *P. nummularia* and *P. juruensis* are distinguished by spores' lengths (length is greater than 30 µm or smaller) and apothecia shapes. Ascospores of all these species are smooth while ascospores of *P. trachyspora* Ellis & Everh are rough (Seaver 1942, Pfister 1973b).

P. nummularia has previously been reported growing on various wet dead wood (Seaver 1942, Beller 1972, Pfister 1973b, Breitenbach and Kränzlin 1984, Moyne et al. 2014). In this study *L. orientalis* is found as a new host substrate for this species found here.

Detailed descriptions of *P. nummularia* have been provided in previous studies (Seaver 1942, Beller 1972, Pfister 1973b, Breitenbach and Kränzlin 1984, Van Vooren 2006, Moyne et al. 2014). A comparative analysis of Turkish specimens and data provided by other authors is presented in Table 1: it shows that the size of macroscopic and microscopic structures of our samples are compatible with previous findings.

Conclusions

According to current mycobiota checklists (Sesli and Denchev 2008, Solak et al. 2015) and the recent contributions regarding Ascomycetes in Turkey (Güngör et al. 2015, Acar and Uzun 2016, Akata et al. 2016, Akçay and Uzun 2016, Güngör et al. 2016, Şen at al. 2016, Çolak and Kaygusuz 2017, Kaygusuz and Çolak 2017, Uzun et al. 2017), it could be concluded that *Psilopezia nummularia* is a new record at genus level for the mycobiota of Turkey. According to recent studies, twenty four genera belonging to Pyronemataceae family have so far been reported in Turkey (Sesli and Denchev 2008, Solak et

Table 1. Comparison of *P. nummularia* features.

Size of ascomata, cm	Size of asci, µm	Size of ascospores, µm	Width of paraphyses at the top, µm	References
1–5	200–250 × 15–18	20–25 × 12	10	Seaver (1942)
3–4	270–310 × 15–18	19–21 × 9–11	8	Beller (1972)
3	275–300 × 20–27	(25)29–40 × 14–20	12	Pfister (1973b)
0.5–2	300–350 × 18–26	25–37 × 15–18.5	10	Breitenbach and Kränzlin (1984)
0.8–1	370–390 × 17–23	24–28 × 14–16	8–10	Van Vooren (2006)
2	380–500 × 16–23	25–30 × 14–16	12	Moyne et al. (2014)
1–2	**340–425 × 19–22**	**23–31.5 × 13–19**	**10**	**This study**

al. 2015, Çolak and Kaygusuz 2017). In the present study, *Psilopezia* is reported as the 25th member of the family Pyronemataceae in the country.

Acknowledgment

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References

Acar İ., Uzun Y. 2016. *Peziza granularis* Donadini, a New Record for Turkish Mycobiota. Journal of the Institute of Natural & Applied Sciences 21(1): 39–42 (in Turkish).

Akata I., Kaya A., Uzun Y. 2016. Two new genus records for Turkish Helotiales. Kastamonu University Journal of Forestry Faculty 16(1): 131–134.

Akçay M.E., Uzun Y. 2016. *Belonidium mollissimum* (Lachnaceae): A new record for the mycota of Turkey. The Journal of Fungus 7(2): 118–121 (in Turkish).

Anonymous 2017a. MycoBank. Available at: www.mycobank.org

Anonymous 2017b. Index Fungorum. Available at: www.indexfungorum.org

Beller J. 1972. *Psilopezia nummularia* Berkeley. Documents mycologiques 3: 1–4 (in French).

Breitenbach J., Kränzlin F. 1984. Fungi of Switzerland, Vol. 1. Verlag Mykologia, Luzern: 310 p.

Çolak Ö.F., Kaygusuz O. 2017. *Octospora leucoloma* (Pyronemataceae): A new bryoparasitic genus record for Turkish mycobiota. Phytologia Balcanica 23(3): 345–348.

Çolak Ö.F., Şen İ., Alkan N., Işiloğlu M. 2015. A new and interesting *Peziza* record from sweet gum forest in Turkey. The Journal of Fungus 6(1): 10–12.

Güngör H., Alli H. 2016. Macrofungi associated with relict endemic *Liquidambar orientalis* Mill. Bangladesh Journal of Botany 45(3): 589–595.

Güngör H., Çolak Ö.F., Yaratanakul Güngör M., Solak M.H. 2015. New Ascomycete (*Geoglossum umbratile, Peziza lobulata*) records for Turkey. Biological Diversity and Conservation 8(2): 1–3.

Güngör H., Solak M.H., Alli H., Işiloğlu M., Kalmış E. 2016. Contributions to the macrofungal diversity of Muğla province (Turkey). Mycotaxon, Link Page 131: 256.

Hansen K., Pfister D.H. 2006. Systematics of the Pezizomycetes – the operculate Discomycetes. Mycologia 98(6): 1029–1040.

Hosoya T., Maruyama K. 2004. *Pachyella globispora* sp. nov. (Pezizaceae) from Japan. Mycoscience 45(2): 112–115.

Işiloğlu M., Alli H., Güngör H., Candar S. 2011. Macrofungi of *Liquidambar orientalis*

Mill. forests in Muğla (Turkey). XVI. Congress of European Mycologists, Halkidiki, Greece: 160.

Kaygusuz O., Çolak Ö.F. 2017. New records of Helotiales in Turkey. ScienceAsia 43(4): 217–222.

Kaygusuz O., Gezer K., Şeker M. 2016. Four new records of *Pluteus* Fr. from interesting habitats in the Aegean region of Turkey. Botany Letters 163(3): 251–259.

Kirk P.F., Cannon P.F., Minter D.W., Stalpers J.A. 2008. Dictionary of the fungi, 10th ed. CAB International, Wallingford, UK. 575 p.

Moyne G., Sylviane M.J.M., Chaillet P. 2014. Un Petit Ruisseau Bien Sympathique Ou Quelques Ascomycètes Brun-Purpurin Croissant Sur Le Tuf. Mycologia Montenegrina 17: 105–117 (in French).

Öztürk M., Çelik A., Güvensen A., Hamzaoğlu E. 2008. Ecology of tertiary relict endemic *Liquidambar orientalis* Mill. forests. Forest Ecology and Management 256(4): 510–518.

Pfister D.H. 1973a. The psilopezioid fungi. I. History, nomenclature, and delimitation of the psilopezioid genera. Mycologia 65(2): 321–328.

Pfister D.H. 1973b. The psilopezioid fungi. III. The genus *Psilopezia* (Pezizales). American Journal of Botany 60(4): 355–365.

Pfister D.H. 1973c. The psilopezioid fungi. IV. The genus *Pachyella* (Pezizales). Canadian Journal of Botany 51(11): 2009–2023.

Seaver F.J. 1942. The North American Cup-Fungi (Operculates). Lancaster Press, New York. 377 p.

Şen İ., Alli H., Civelek H.S. 2016. Checklist of Turkish Truffles. Turkish Journal of Life Sciences 1(2): 103–109.

Sesli E., Denchev C.M. 2008. Checklists of the Myxomycetes, larger Ascomycetes, and larger Basidiomycetes in Turkey. Mycotaxon 106: 65–67. + [complete version, 1–145, new version uploaded in January 2014].

Solak M.H., Işiloğlu M., Kalmiş E., Alli H. 2015. Macrofungi of Turkey, Checklist, Vol. 2. University Ofset, Izmir. 280 p.

Uzun Y., Kaya A., Karacan İ.H., Yakar S. 2017. New additions to Turkish Hyaloscyphaceae. The Journal of Fungus 8(1): 13–19.

Van Vooren N. 2006. Ascomycètes, saison 2005. Bulletin mycologique et botanique Dauphiné-Savoie 183: 11–24 (in French).

Wijayawardene N.N., Hyde K.D., Rajeshkumar K.C., Hawksworth D.L., Madrid H., Kirk P.M., et al. 2017. Notes for genera: Ascomycota. Fungal diversity 86(1): 1–594.

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VERIFICATION OF VERY HIGH RESOLUTION LOCAL COMPONENT PRODUCTS WITH THE LACO-WIKI OPEN ACCESS ONLINE PORTAL

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Abstract

Very High Resolution local component products provide information on specific land cover characteristics, which are necessary for land cover/land use mapping. The main objectives of this study are the Natura 2000 areas on the territories of the Natural Park Rusenski Lom and the protected area Lomovete. A Dataset and a Sample collection are created and a Validation exercise is provided, using the open access online portal LACO-Wiki. A specific land cover/land use nomenclature is used which is fully compatible with the MAES (Mapping and Assessment of Ecosystems and their Services) nomenclature.

Key words: LACO-Wiki software, land cover/land use, Natura 2000 nomenclature, Mapping and Assessment of Ecosystems and their Services.

Introduction

The aim of the network Natura 2000 (N2K) is to assure the long-term survival of Europe's most valuable and threatened species and habitats. Extracted through Very High Resolution (VHR) satellite images information for land cover/land use (LC/LU) of selected N2K sites is applied for supporting biodiversity monitoring and mapping and assessment of ecosystems and their services. The classes follow the pre-defined nomenclature on the basis of the Mapping and Assessment of Ecosystems and their Services (MAES) typology of ecosystems (Level 1 to Level 4) (Richter et al. 2015) and Corine Land Cover (CLC) nomenclature (Bossard et al. 2000, Büttner and Kosztra 2007). The production of the Natura 2000 updates is coordinated by the European Environment Agency (EEA) in the frame of the EU Copernicus program (Anonymous 2017).

The main aim of this study is to present the verification methodology for very high resolution local component product Natura 2000 on the territory of the Natural Park Rusenski Lom and the protected area Lomovete. As validation method the visual semi-automatic classification of VHR satellite data is used (Anonymous 2015a). The methodology is applied by means of the open access online portal LACO-Wiki (Anonymous 2016b).

Very High Resolution Local Component Products

The VHR local component products 2012, finalized by the end of 2015 are available at http://land.copernicus.eu/local portal.

The local component products do not cover the complete Pan-European territory, but only selected areas of interest, with a specific challenge in terms of either environmental pressures and problems or spatial management (Table 1). Examples are: cities above a given number of inhabitants (Urban Atlas 2012) (Anonymous 2016), protected areas under the Natura 2000 instrument (N2K 2006–2012), Riparian zones along the hydrographic network or coastal zones etc. (Riparian Zones 2012) (Anonymous 2015). The products are based on very high resolution imagery (2.5 × 2.5 m pixels).

Table 1. Total area covered by the Very High Resolution local component products.

Product	Total Area, km^2
Urban Atlas 2012	1,015,000
Riparian Zones 2012	525,000
N2K 2006–2012	160,000

The Natura 2000 product offers a detailed land cover/land use map for a selection of Natura 2000 sites and a surrounding 2 km buffer zone. The mapping was conducted for 2006 and 2012 and change analysis is available.

In general this layer is designed for the needs of biodiversity monitoring as developments within N2K can be traced reliably. The nomenclature is designed according to feasibility of production and MAES ecosystem types, a high degree of comparability with other LC/LU products, such as the Urban Atlas and the Riparian zones is ensured.

The LC/LU classification is based on the MAES typology of ecosystems (level 1–4) and includes grassland-rich sites (5 grassland habitats types 6210, 6240, 6250, 6510 and 6520). The mapping extends 2 km beyond site boundaries The Minimum Mapping Unit (MMU) is 0.5 ha, the Minimum Mapping Width (MMW) is 10 m (Anonymous 2016a).

Verification of Local Component Data

The aims of the country verification of local component data are to provide complementary information to the systematic quantitative validation results provided by the European scale validation exercise and support the best possible familiarization with the VHR land cover data by national actors while performing systematic technical and thematic quality assessment on the dataset. Verification includes 4 steps: Data preparation; Stratified random sampling of LC/LU polygons; Visual inspection of selected samples, including the possibility to provide comments / feedback and Evaluation of results.

The LACO-Wiki Software

The LACO-Wiki Online Tool (Fig. 1) is an open access online portal for land cover validation.

This software allows data management and sharing functionality because every data uploaded or generated in LACO-Wiki can be managed by the owner and shared with other users which could provide a valuable resource for building improved hybrid land cover maps. (Anonymous 2016b).

Features:

– LACO-Wiki offers a single online access point for the complete map validation

Fig. 1. The LACO-Wiki Online Tool.

process;

– a user-friendly environment to upload new maps and create sampling designs;

– state-of-the-art accuracy reports generated with just a few clicks;

– easy access to shared datasets and validations sessions, allowing users to share the workload with other people in their team and have multiple people validate datasets at once.

Natura 2000 LC/LU Nomenclature

In the frame of the Natura 2000 project, a specific LC/LU nomenclature was used which is fully compatible with the MAES nomenclature on Level 1 and as far as possible compatible to the Riparian Zones project's MAES nomenclature on Levels 1–3, but tailored to the particular needs of a biodiversity monitoring on Level 4 (Richter et al. 2015).

Of special interest is a discrimination of semi-natural/species-rich grassland classes in terms of decrease/increase as well as qualitative changes, which shall be reflected in the class definition on Level 4.

This LC/LU nomenclature ensures compatibility to other European established LC/LU products such as CLC and Urban Atlas as well as Riparian Zones, to a high degree. Natura 2000 LC/LU nomenclature contents the following MAES Level 4 classes (Table 2).

This Nomenclature for the LC/LU dataset is in accordance with the MAES levels 1 (Table 3).

Table 2. MAES Level 4 classes.

Level 2	Level 4
1.1 Urban fabric, industrial, commercial, public, military and private units	1.1.1.1 Urban fabric
	1.1.1.3. Industrial or commercial units
1.2 Transport infrastructure	1.2.1.1 Road network and associated land
	1.2.1.2 Railways and associated land
	1.2.1.3 Port areas
	1.2.1.4 Airports
1.3 Mineral extraction, dump and construction sites, land without current use	1.3.1.1 Mineral extraction, dump and construction sites
	1.3.2.1 Land without current use
1.4 Green urban areas, sports and leisure facilities	1.4.1.1 Green urban areas and leisure facilities
2.1 Arable land	2.1.1.1 Arable irrigated and non-irrigated land
	2.1.2.1 Greenhouses
2.2 Permanent crops	2.2.1.1 Vineyards
	2.2.2.1 Fruit trees and berry plantations
	2.2.3.1 Olive groves
2.3 Heterogeneous agricultural area	2.3.1.1 Annual crops associated with permanent crops
	2.3.2.1 Complex cultivation patterns
	2.3.3.1 Land principally occupied by agriculture with significant areas of natural vegetation
	2.3.4.1 Agro-forestry
3.1 Broadleaved forest	3.1.2.1 Broadleaved swamp forest
	3.1.3.1 Other natural & semi-natural broadleaved forest
	3.1.4.1 Broadleaved evergreen forest
	3.1.5.1 Highly artificial broadleaved plantations
3.2 Coniferous forest	3.2.2.1 Coniferous swamp forest
	3.2.3.1 Other natural & semi-natural coniferous forest
	3.2.4.1 Highly artificial coniferous plantations
3.3 Mixed forest	3.3.2.1 Mixed swamp forest
	3.3.3.1 Other natural & semi-natural mixed forest
	3.3.4.1 Highly artificial mixed plantations
3.4 Transitional woodland and scrub	3.4.1.1 Transitional woodland and scrub
	3.4.1.2 Lines of trees and scrub
3.5 Damaged forest	3.5.1.1 Damaged forest
4.1 Managed grassland	4.1.1.1 Managed grassland

Level 2	Level 4
4.2 Natural & semi-natural grassland	4.2.1.1 Semi-natural grassland with trees (T.C.D. ≥ 30 %)
	4.2.1.2 Semi-natural grassland without trees (T.C.D. ≤ 30 %)
4.2.2 Alpine and sub-alpine natural grassland	4.2.2.1 Alpine and sub-alpine natural grassland
5.1 Moors and heathland	5.1.1.1 Heathland and moorlands
	5.1.1.2 Other scrub land
5.2 Sclerophyllous vegetation	5.2.1.1 Sclerophyllous vegetation
6.1 Sparsely vegetated areas	6.1.1.1 Sparsely vegetated areas
6.2 Bare soil, rock, perennial snow and ice	6.2.1.1 Beaches
	6.2.1.2 Dunes
	6.2.1.3 River banks
	6.2.2.1 Bare rocks and rocks debris
	6.2.2.2 Burnt areas (except burnt forest)
	6.2.2.3 Glaciers and perpetual snow
7.1 Inland marshes	7.1.1.1 Inland freshwater marshes
	7.1.2.1 Inland saline marshes
7.2 Peat bogs	7.2.1.1 Exploited peat bog
	7.2.1.2 Unexploited peat bog
8.1 Maritime wetlands	8.1.1.1 Salt marshes
	8.1.1.2 Salines
	8.1.2.1 Intertidal flats
8.2 Marine waters	8.2.1.1 Coastal lagoons
	8.2.2.1 Estuaries
9.1 Water courses	9.1.1.1 Interconnected running water courses
	9.1.1.3 Highly modified natural water courses and canals
	9.1.2.1 Separated water bodies belonging to the river system
9.2 Lakes and reservoirs	9.2.1.1 Natural water bodies
	9.2.1.3 Ponds and lakes with completely man-made structure
	9.2.1.4 Intensively managed fish ponds
	9.2.1.5 Standing water bodies of extractive industrial sites
10.1 Marine (other)	10.1.1.1 Marine (other)

Table 3. MAES Levels 1 Description.

MAES level 1	Description
1. Urban	The definition of urban areas in general is according to the Urban Atlas guidelines. The MAES level 2 separates the urban fabric from transportation network, construction & dump sites and green urban areas (including sports facilities). On MAES level 3, Industrial, commercial and military units are separated from urban fabric as well as land without current use from construction and dump sites. The MAES level 4 further differentiates the urban fabric (urban fabric or industrial, commercial and military units) and transport infrastructures (road network, port areas and airports), extraction mine, dump and construction sites and land without current use.
2. Croplands	On MAES Level 2, classes are defined according to the CORINE nomenclature. Three main classes are separated: – Arable Land: Land under a rotation system used for annually harvested plants and fallow lands, which are permanently or not irrigated. It includes flooded crops, such as rice fields and other inundated croplands. – Permanent crops: All surfaces occupied by permanent crops, not under a rotation system. They include ligneous crops of standard cultures for fruit production, such as extensive fruit orchards, olive groves, chestnut groves, walnut groves, shrub orchards, vineyards and some other specific low-system orchard plantation, espaliers and climbers. – Heterogeneous agricultural areas: Areas of annual crops associated with permanent crops on the same parcel, annual crops cultivated under forest trees, areas of annual crops, meadows and/or permanent crops which are juxtaposed, landscapes in which crops and pastures are intimately mixed with natural vegetation or natural areas. Class definitions on Level 3 are CORINE level 3 classes extended by the class ‘Greenhouses’. The CLC classes ’Rice fields’, ’Irrigated arable land’ and ’Non-Irrigated arable land’ are merged to one single class: ’Arable irrigated and non-irrigated land’.
3. Woodland and forest	MAES 2 differentiates main types of forests: – Broadleaved forest: Vegetation composed mainly of trees, including shrub and understories, where broadleaved species predominate and represent more than 75 % of the pattern. – Coniferous forest: Vegetation composed mainly of trees, including shrub and understories, where coniferous species predominate and represent more than 75 % of the pattern. – Mixed forest: Vegetation composed mainly of trees, including shrub and understories, where neither broadleaved nor coniferous species predominate. The share of coniferous or broadleaved species does not exceed 25 % in the canopy closure. Transitional woodlands scrub and damaged forest by fire are also included in MAES 2. The differentiation of Woodland and Forest on Level 3–4 is mainly oriented along aggregated EUNIS (the European Nature Information System habitat classes). Main classes are swamp forest, other natural and semi-natural forest and highly artificial forest (e.g. plantations), following the EUNIS classification scheme.

MAES level 1	Description
4. Grassland	MAES level 2 differentiates managed grasslands and natural grasslands. – Managed or agricultural grasslands are intensively managed areas (selection of grasses, intensive cutting and grazing, fertilization, etc.) for the production of grass. From a land use point of view, in this case, grass is a crop in the same way as cereals or others. – Natural grasslands include alpine meadows and other semi-natural grasslands included in Habitat Directive (except mountain and lowland hay meadows). Semi-natural grasslands are frequently associated with trees and scrubs (MAES 3 main differentiation). A distinction between semi-natural grasslands and alpine grasslands are included in MAES 4.
5. Heatland and scrub	The MAES level 2–3 separates Moors and Heathland from areas with sclerophyllous vegetation, following the CORINE Land Cover guidelines. The MAES level 4 further distinguishes Heathlands and Moorlands from Other scrub land.
6. Sparsely vegetated land	Differentiation of MAES Level 2 into two categories: 'Sparsely vegetated areas' and 'Bare soil, rock, perennial snow and ice' in order to separate vegetation classes from non-vegetated surfaces. On Level 3, a further split of non-vegetated surfaces into class 6.2.1 Beaches, dunes, sands and 6.2.2 Bare rocks, burnt areas, glaciers and perpetual snow is performed. Further differentiation in MAES level 4 into the classes 6.2.2.1 Bare rocks and rock debris, 6.2.2.2 Burnt Areas (except burnt forest) and 6.2.2.3 Glaciers and perpetual snow.
7. Wetland	Inland marshes and peat bogs are included in MAES Level 2. MAES Level 3 differentiates between inland freshwater marshes and inland saline marshes. On MAES Level 4 peat bogs are divided in exploited and unexploited peat bog.
8. Lagoons, coastal wetlands and estuaries	On MAES Level 2 Coastal waters are distinguished into maritime wetlands (coastal salt marshes according to the EUNIS habitat classification, salines and intertidal flats) and marine waters (coastal lagoons and estuaries). Maritime wetlands are divided in salt marshes and salines and intertidal flats in MAES level 3. Coastal lagoons and estuaries are also distinguished.
9. Rivers and lakes	'Water courses' (fresh running waters and constructed inland freshwater) and 'Lakes and reservoirs' is the division of MAES Level 2. On MAES Level 3 water courses are separated according to their morphology into interconnected running water courses and separated water bodies belonging to the river systems (oxbow lakes or dead side-arms, flood ponds, etc.) MAES Level 4 is based on: – Identification of highly modified natural water courses and canals (navigation, irrigation, water regulation, flood protection and land drainage); – Identification of main artificial or highly transformed water bodies: ponds and lakes with completely man-made structure for irrigation and water supply, intensively managed fish ponds and pools associated with extractive sites.
10. Marine (Other)	The coastal areas refer to coastal, shallow, marine systems that experience significant land-based influences (MAES Level 2, 3 and 4 Marine – other) not included in lagoons, coastal wetlands or estuaries.

The mapping of land cover and land use of selected areas has as main objective to support the MAES, as part of the EU Biodiversity Strategy to 2020.

Creating a Dataset and Sample Collection

LACO-Wiki currently supports three different land cover types for Dataset:

Categorical

Categorical data, also called thematic, discrete, or classified data, are used both for vector and raster data to represent discrete information. Examples of categorical data are land cover or land use maps like Pan-European CORINE land cover, Urban Atlas GlobCover etc.

Continuous

Continuous data, representing phenomena such as percentage, elevation data or density such as the Copernicus high resolution layers of imperviousness degree and forest density or population (density) maps.

Background

Background layers can be used additionally to Google and Bing maps base imagery in the validation step. Examples of such datasets would be an orthophoto of the study area.

Through LACO-Wiki software a new dataset named Lomovete is specified (Fig. 2). It covers entirely the Natura 2000 sites and a surrounding 2 km buffer zone in the Natural Park Rusenski Lom and the protected area Lomovete. The legend includes all MAES Level 4 classes.

The next step in the process is creating a sample collection based on the Dataset Lomovete.

There are different sampling methods for the collection. Depending on dataset's land cover type and the uploaded data type (vector or raster file) different sampling methods are available:

Random point

This approach creates a sample dataset with a definable number of points, which will be randomly distributed over the reference dataset.

Random pixel

This approach creates a sample dataset with a definable number of pixels which will be randomly selected from the reference dataset. Duplicates are not possible.

Random polygon

This approach creates a sample dataset with a definable number of polygons which will be randomly selected from the reference dataset. Duplicates are not possible.

Polygon at random point

This approach creates a sample dataset with a definable number of polygons, which will be randomly selected from the reference dataset, whereby the probability for selection will be influenced by the size of the polygons (i.e. higher probability of large polygons to be selected). Duplicates are not possible.

Stratified random point

This approach creates a sample data-

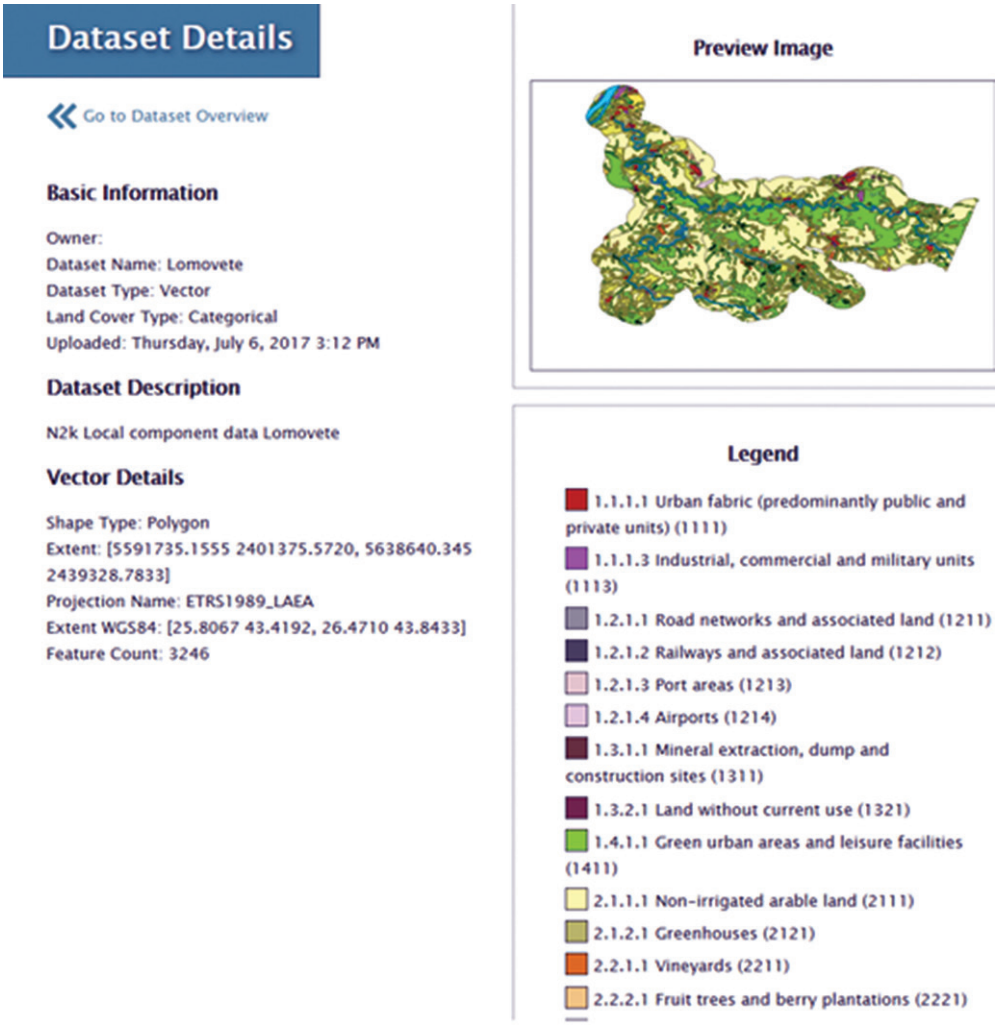

Fig. 2. Dataset Lomovete.

set with a definable number of points per class (e.g. land cover), which will be randomly distributed over the specified classes of the reference dataset.

Stratified random pixel

This approach creates a sample dataset with a definable number of pixels per class (e.g. land cover), which will be randomly selected from the specified classes of the reference dataset.

Stratified random polygon

This approach creates a sample dataset with a definable number of polygons per class (e.g. land cover), which will be randomly selected from the specified classes of the reference dataset.

Validation

The Validation exercise for Dataset Lomovete is created. As a validation Method from 3 possible (Fig. 3) is selected Enhanced Plausibility. The validation exercise makes the use of ESRI World imagery and national orthophoto as reference.

The process of validating can be paused and continued at any time. LACO-Wiki also allows you to split the workload by sharing the current validation session with other users and let them continue validating the same dataset.

Visual inspection of sample polygons

Selected sample polygons are displayed on the top of reference imagery one by one. Interpreters are asked to provide information about following characteristics for each sample:

- Correctness of LC/LU code around the sample point within the sample polygon, considering actual MMU value:
  - ✓ Correct (Fig. 4) / Non correct;
  - ✓ If the LC/LU code is found as non-correct, the interpreter is asked to suggest correct code (Fig. 5).

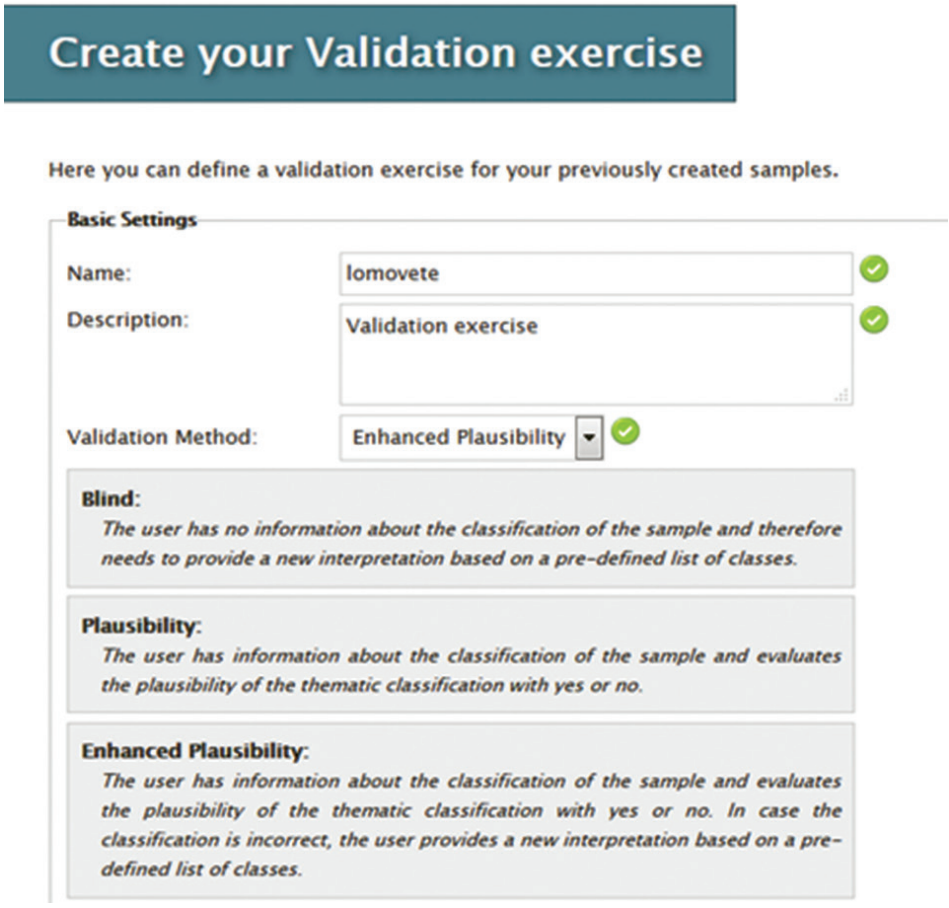

Fig. 3. Creating a Validation exercise for Dataset Lomovete.

- Correctness of delineation of the sample polygon:
  - ✓ Delineated area: Correct / Unnecessary parts included (Fig. 6) / Missing parts / Missing and Unnecessary parts included;
  - ✓ Detail of delineation: Correct / Too coarse / Too detailed;
  - ✓ Positional accuracy: Correct / Shifted.
- Characterizing the sample polygon through free text comment.

The correctness of LC/LU class should be checked around a random sample

Fig. 4. Correct codes about Airport Straklevo – Ruse and natural water body near Rusenski Lom River.

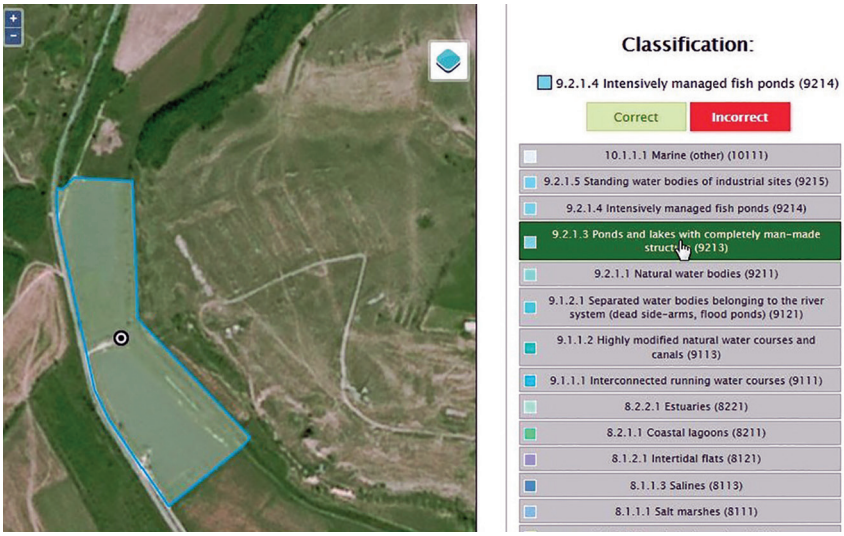

Fig. 5. An incorrect code and interpreter`s suggestion for the correct code.

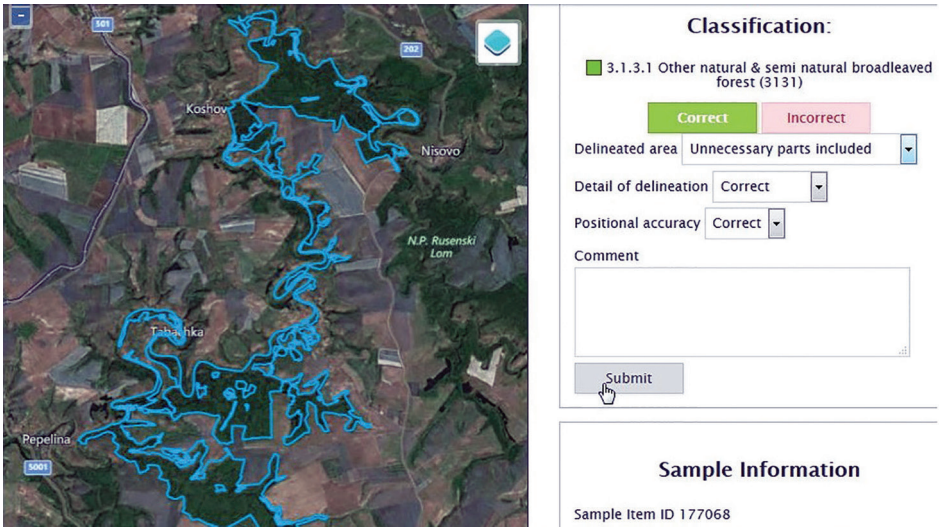

Fig. 6. A correct code with a note about unnecessary parts included in broadleaved forests on the territory of the Natural Park Rusenski Lom.

Classification Data

	1.1.1.1 Urban fabric (predominantly public and private units) (1111)	1.1.1.3 Industrial, commercial and military units (1113)	1.2.1.1 Road networks and associated land (1211)	1.2.1.2 Railways and associated land (1212)	1.2.1.3 Port areas (1213)	1.2.1.4 Airports (1214)	1.3.1.1 Mineral extraction, dump and construction sites (1311)	1.3.2.1 Land without current use (1321)	1.4.1.1 Green urban areas and leisure facilities (1411)	2.1.1.1 Non-irrigated arable land (2111)	2.1.2.1 Greenhouses (2121)	2.2.1.1 Vineyards (2211)	2.2.2.1 Fruit trees and berry plantations (2221)	2.2.3.1 Olive groves (2231)	2.3.1.1 Annual crops associated with permanent crops (2311)	2.3.2.1 Complex cultivation patterns (2321)
True	3	3	3	3	2	2	3	2	2	3	0	1	1	0	0	2
False	0	0	0	0	0	0	0	0	1	0	1	2	2	0	0	1
Column Total	3	3	3	3	2	2	3	2	3	3	1	3	3	0	0	3
Producer Accuracy	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	66,67%	100,00%	0,00%	33,33%	33,33%	0,00%	0,00%	66,67%

Overall Accuracy	0,780172
Geometric Agreement	
Delineated area	0,988636
Detail of delineation	1
Positional accuracy	1

25	9.2.1.3 Ponds and lakes with completely man-made structure	TRUE	Correct	Correct	Correct	
26	4.1.1.1 Managed grassland	FALSE	Correct	Correct	Correct	2.1.1.1 Arable irrigated and non-irrigated land
27	1.2.1.1 Road networks and associated land	TRUE	Correct	Correct	Correct	
28	2.1.1.1 Non-irrigated arable land	TRUE	Correct	Correct	Correct	
29	2.3.2.1 Complex cultivation patterns	FALSE	Correct	Correct	Correct	The larger part of this area is 2.1.1.1 Arable irrigated
30	9.1.1.2 Highly modified natural water courses and canals	TRUE	Correct	Correct	Correct	
31	6.2.1.3 River banks	TRUE	Correct	Correct	Correct	
32	3.4.1.2 Lines of trees and scrub	TRUE	Correct	Correct	Correct	
33	1.1.1.1 Urban fabric (predominantly public and private units)	TRUE	Correct	Correct	Correct	
34	2.1.1.1 Non-irrigated arable land	TRUE	Correct	Correct	Correct	
35	1.3.2.1 Land without current use	TRUE	Correct	Correct	Correct	
36	9.2.1.4 Intensively managed fish ponds	TRUE	Correct	Correct	Correct	
37	3.3.3.1 Other natural & semi natural mixed forest	TRUE	Correct	Correct	Correct	
38	3.3.3.1 Other natural & semi natural mixed forest	FALSE	Correct	Correct	Correct	3.1.3.1 Other natural & semi-natural broadleaved fo
39	6.1.1.1 Sparsely vegetated areas	TRUE	Correct	Correct	Correct	
40	2.3.3.1 Land principally occupied by agriculture with significant areas of natural vegetation	TRUE	Correct	Correct	Correct	
41	1.2.1.3 Port areas	TRUE	Correct	Correct	Correct	
42	9.1.1.2 Highly modified natural water courses and canals	TRUE	Correct	Correct	Correct	
43	6.2.2.1 Bare rocks and rock debris	TRUE	Correct	Correct	Correct	

Fig. 7. Parts of Local component verification report.

point within the sample polygon (Fig. 5), taking into account the MMU defined for the dataset – in this case 0.5 ha.

Local Component Verification Report

The harmonized evaluation of the results is created automatically and provided as an Excel file to download (Fig. 7). The report includes:

- Class specific accuracy parameters calculated automatically by LACO-Wiki tool:
  - ✓ User's accuracy by LC/LU class;
  - ✓ Producer's accuracy by LC/LU class;
  - ✓ Overall user's accuracy;
  - ✓ Uncertainty values will be provided for each accuracy value.
- Summary of the correctness of delineation by LC/LU class based on pre-defined attributes.
- All sample based comments listed by LC/LU class.

Conclusions

The Very High Resolution local component products are a part of the Pan-European component of the Copernicus Land Monitoring Services, managed by the European Environment Agency. The creation of many of the Copernicus information products and services provide an assessment of the thematic and positional accuracies. Extracted from VHR satellite data LC/LU information in a buffer zone of selected N2K sites provides supporting of the biodiversity monitoring, the mapping and assessment of ecosystems and their services. Based on the MAES nomenclature the validation allows implementation of these activities on the level of land cover/land use.

References

Anonymous 2015. Final nomenclature guideline Issue 3.0. 260 p. Available: http://land.copernicus.eu/user-corner/technical-library/RZ_CS3_17_Nomenclature_Guideline_I30.pdf

Anonymous 2015a. Natura2000 product specifications (short version). 10 p. Available: https://cws-download.eea.europa.eu/local/n2k/N2000_Product_Specifications_short%20version_20151104.pdf

Anonymous 2016. Mapping Guide v 4.7 for a European Urban Atlas. 42 p. Available: http://land.copernicus.eu/user-corner/technical-library/urban-atlas-2012-mapping-guide-new

Anonymous 2016a. Natura 2000. Available: http://land.copernicus.eu/local/natura

Anonymous 2016b. Quick start guide for the Laco-wiki online tool. 20 p. Available: https://laco-wiki.net/Content/Docs/LACO-Wiki_quickstart.pdf

Anonymous 2017. The Copernicus land monitoring service portfolio. 32 p. Available: epanet.pbe.eea.europa.eu/

Bossard M., Feranec J., Otahel J. 2000. CORINE land cover technical guide – Addendum 2000. EEA. Copenhagen. 105 p. Available: http://image2000.jrc.ec.europa.eu/reports/corine_tech_guide_add.pdf

Büttner G., Kosztra B. 2007. CLC2006 Technical Guidelines. EEA. Technical Report 17/2007. 70 p. Available: http://www.eea.europa.eu/publications/technical_report_2007_17

Richter R., Weingart U., Hermann S., Morera P., Nicolás M. 2015. Nomenclature guideline. München. 248 p.

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VERIFICATION OF THE NATURA 2000 LOCAL COMPONENT DATASET IN BULGARIA

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Abstract

The thematic accuracy is an important data quality element of land cover databases. For this reason it has been paid a considerable attention by researchers over years. The main aim of this article is the presentation of the results from verification of the Natura 2000 (N2K) local component dataset for Bulgaria, which is a part of a project, managed by the European Environmental Agency (EEA). Following the methodology proposed by EE, we apply a quantitative approach based on probability sampling at polygon level. Thus, we obtain scientifically rigorous estimate of the thematic accuracy of N2K layer and of some geometric characteristics as well. Based on local expertise and in situ data, an evaluation of the quality of this product is made and statistical results are obtained, comparable to the results in other countries. The results of the verification show that the overall thematic accuracy is higher than the 85 % level expected at Pan-European scale.

Key words: sampling, semi-automatic classification, thematic accuracy, VHR satellite image, visual interpretation.

Introduction

Image classification is a widely used technique for producing thematic maps of various resources. To make these maps useful it is necessary to have information about their accuracy. Assessment of the thematic accuracy of land cover databases is an important element of spatial data quality and therefore over years it has been paid a considerable attention by researchers (e.g., Congalton 1991), and for practical applications (Olofsson 2014). Proven approach for obtaining scientifically rigorous estimate of thematic accuracy is based on probability sampling (Cochran 1977). This is a sampling design in which: (1) Each potential sampling location receives its own non-zero probability of selection; (2) These so called inclusion probabilities are known in advance from the design; (3) The method for computing a unique estimate from every sample is stated.

Under the Land monitoring service of the Copernicus programme of the European Union, several land cover/land use (LC/LU) products have been produced (Anonymous 2017) within the frames of its Pan-European and Local components. Accuracy characteristics of the High Resolution Layers 2012 have recently been assessed applying qualitative (Dimitrov and Lubenov 2014) and quantitative (Congedo et al. 2015, Dimitrov 2016)

methodologies.

The main aim of this article is the presentation of the results from verification of the Natura 2000 (N2K) local component dataset for Bulgaria. The verification task is managed by EEA and is supported by Copernicus funds. All EEA member and cooperating countries are invited to participate. The EEA developed guidelines for the verification of the Local Component (Maucha et al. 2017), but member states are free to modify and improve the proposed methodology.

We apply a quantitative approach at polygon level to evaluate the thematic accuracy of N2K layer and of some geometric characteristics as well. Our goals are to provide statistical results comparable to the results in other countries and to make a quality evaluation based on local expertise and in situ data. Typical mistakes found by local teams could be used for technology improvements. Another goal is to raise the awareness on the local component products in this country to help in identifying potential use cases. The results of the verification show that the overall thematic accuracy is higher than the 85 % level expected at Pan-European scale. We also provide remarks and recommendations concerning LC/LU polygon content and delineation quality.

Overview of Natura 2000 Network

Natura 2000 protects about 18 % of the land in the EU countries (787,767 km^2) and is considered almost complete in the EU terrestrial environment. 251,564 km^2 have been designated as Natura 2000 in the marine environment.

Natura 2000 sites can vary considerably in character. They are not strictly protected in terms of how they are allowed to be used by people. Many sites are farmed, forested and located in urban areas. The other areas are wild and natural.

The European ecological network Natura 2000 is of the highest importance for the preservation of the natural habitats. It is a Pan-European system of protected areas and ecological corridors which identification is based on scientific criteria, thus putting into force the EU Directives 79/409 for the protection of birds and 92/43 for the conservation of the natural habitats and the habitats of the wild flora and fauna.

The establishment of the Natura 2000 network in Bulgaria is postulated by the Biodiversity Act, where the sites of this network are called “protected zones”. The process began in 2002 together with the accession of Bulgaria to the EU and finished in 2008 when the protected sites were accepted by the EC after the biogeographic seminar for Bulgaria and Romania. According to the two EU Directives 335 protected sites constitute the European Ecological Network Natura 2000 in Bulgaria (114 according to the Birds Directive and 231 according to the Habitats Directive). The total area is 3,901,084 ha that constitutes 34.3 % of the country’s territory (Gussev and Tzonev 2015).

The Bulgarian part of the European Ecological Network Natura 2000 encompass 90 habitat types, or 38.86 % of all 231 habitat types presently identified and designated in the EU Annex I of Directive 92/43/EEC.

LC/LU Product Description

Unlike the products of the Pan-European component, Copernicus’s local component only covers selected areas that are

particularly sensitive to environmental challenges or spatial management problems. Examples include Natura 2000 protected areas, riparian zones along the hydrographic or coastal areas, cities above a certain number of inhabitants, etc.

While the Pan-European component is hindered by relatively coarse spatial resolution (Corine land cover (CLC) – 25 ha Minimum Mapping Unit (MMU), High Resolution Layers (HRLs) – 1 ha grid) for national, regional or local applications, the local component provides a different level of spatial and thematic detail reducing the MMU from 1 ha to 0.25 ha. However, these products are mapped only for specific areas of interest from an environmental point of view.

The Natura 2000 product has been produced by a consortium of companies under a specific contract with EEA (Anonymous 2015b). They used a semi-automatic classification of very high resolution (VHR) satellite image data set with subsequently computer-assisted visual refinement. It offers a detailed LC/LU dataset for a selection of Natura 2000 sites and a surrounding 2 km buffer zone. The sites cover endangered semi-natural and species rich grassland habitats which will be assessed in order to investigate the effectiveness of the N2K network in halting the decline of certain grassland habitats (Richter et al. 2015). The LC/LU monitoring is implemented for a total of 160,444 km² of Natura 2000 area in 524 (buffered) sites at the two time steps 2006 and 2012 (Fig. 1).

The MAES (Mapping and Assessment of Ecosystems and their Services) nomenclature is LC/LU nomenclature which ensures compatibility to other European established LC/LU products such as CLC (Bossard et al. 2000, Büttner and Kosztra 2007), Urban Atlas (Anonymous 2016) and Riparian Zones (Anonymous 2015a). Detailed product specifications are presented in Table 1.

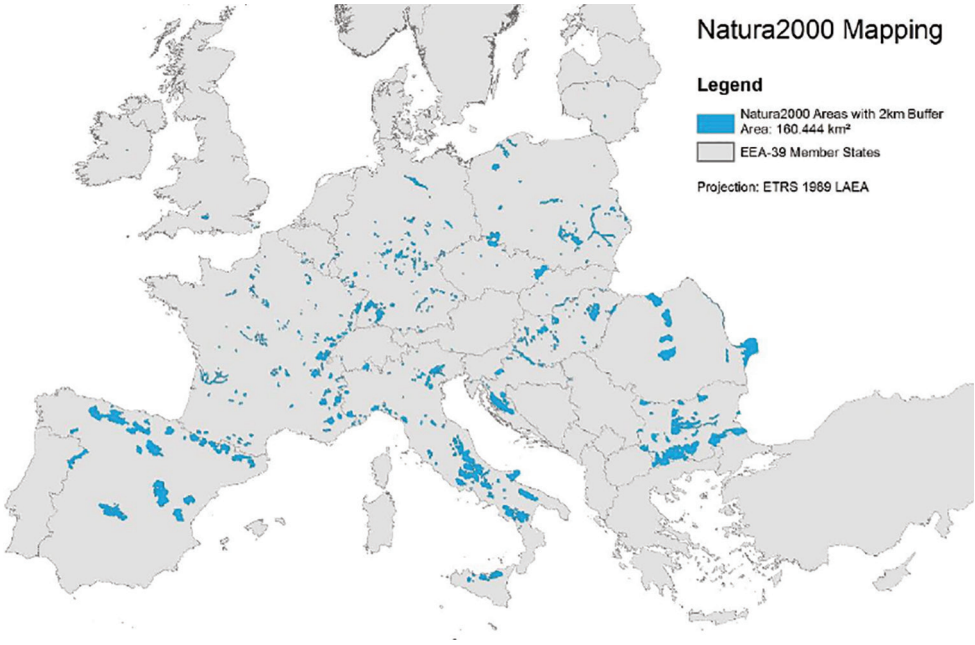

Fig. 1. Natura 2000 sites in Europe with 2 km buffer (Richter et al. 2015).

Table 1. Product Specifications of LC/LU Product (Richter et al. 2015).

Product Title / Content
Natura 2000: LC/LU mapping of a selection of N2K sites
Product Short Name
LCLU
Product Definition
The Natura 2000 product is providing a detailed LC/LU dataset for areas within buffer zone that comprises grassland habitats covering EEA28
Input Data Sources:
1) Selected Natura 2000 sites AOI with manual amendments: N2K_2kmBuff_2006_2012_80PcentCover_clipEU_ALL.shp
2) DWH_MG2b_CORE_03 / D2_MG2b_LOLA_011b – Optical VHR2 coverage over EU 2011–2013 and N2K Sites:
• 1045 SPOT-5 HRG (2.5 m); 71 SPOT-6 (1.5 m), 6 Pléiades (2.0 m)
3) DAP_MG2b_01 / N2K_data_procurement: Optical VHR2 coverage over EU 2004–2008 and N2K Sites:
• 476 SPOT-5 HRG (2.5 m)
Additional data:
• CLC 2006/2012
• Urban Atlas 2006/2012
• GIO HR Layer Forest
• DWH_MG2_CORE_01 – RapidEye (5 m)
• DAP_MG2b_CORE_02 – Image2006 (IRS / SPOT – 25 m)
• USGS – Landsat-8
• Numerous additional reference and in situ data sources

Natura 2000 LC/LU Product – Bulgaria

Summary statistics of Natura 2000 LC/LU product – Bulgaria is presented in Table 2. The total area for the country is 2,203,278 ha, i.e., 19.87 % of country's territory (Fig. 2).

Characterization of the dataset:

- Reference data provided centrally: IMAGE2012 VHR satellite image mosaic, Google Earth Imagery, Bing imagery and OpenStreetMap.
- In situ data used: National Orthophoto Map with spatial resolution 0.4 m, Land Parcel Identification System Land Cover data (LPIS LC), Forest management plans and a hydrography database.
- Reference years: 2009–2012 (partial coverages).
- MMU: 0.5 ha.
- Software used for verification: LACO-Wiki (Anonymous 2016a), Google Earth, ArcGIS 10.3, QGIS 2.18, etc.

Table 2. Summary statistics of Natura 2000 LC/LU product – Bulgaria.

N2K Class	Number of polygons	Area, ha	Share, %
1.1.1.1	3,400	39,763.09	1.80
1.1.1.3	2,349	9,663.99	0.44
1.2.1.1	253	3,320.11	0.15
1.2.1.2	55	612.39	0.03
1.2.1.3	2	16.22	0.00
1.2.1.4	5	211.81	0.01
1.3.1.1	464	1,951.44	0.09
1.3.2.1	31	103.01	0.00
1.4.1.1	528	2,673.46	0.12
2.1.1.1	5,403	260,438.21	11.82
2.1.2.1	92	220.60	0.01
2.2.1.1	531	11,523.72	0.52
2.2.2.1	1,034	14,076.94	0.64
2.3.1.1	3	14.70	0.00
2.3.2.1	945	14,044.72	0.64
2.3.3.1	658	7,478.35	0.34
3.1.2.1	2	6.77	0.00
3.1.3.1	13,084	768,140.55	34.86
3.1.4.1	1	4.60	0.00
3.1.5.1	1	5.10	0.00
3.2.2.1	2	2.06	0.00
3.2.3.1	13,243	394,401.54	17.90
3.3.3.1	3,949	96,005.80	4.36
3.4.1.1	14,733	90,423.27	4.10
3.4.1.2	273	344.62	0.02
3.5.1.1	8	98.24	0.00
4.1.1.1	7,558	123,191.24	5.59
4.2.1.1	9,301	68,838.43	3.12
4.2.1.2	21,763	238,961.06	10.85
4.2.2.1	92	16,507.59	0.75
5.1.1.1	1,091	6,832.22	0.31
5.1.1.2	90	4,138.15	0.19
5.2.1.1	136	2,694.59	0.12
6.1.1.1	2,168	8,151.33	0.37
6.2.1.1	33	107.99	0.00
6.2.1.3	329	811.69	0.04
6.2.2.1	742	2,749.75	0.12
6.2.2.2	4	40.51	0.00
7.1.1.1	134	713.62	0.03
9.1.1.1	375	4,027.21	0.18
9.1.1.3	25	120.73	0.01
9.1.2.1	17	42.99	0.00
9.2.1.1	903	9,232.63	0.42
9.2.1.3	18	215.21	0.01
9.2.1.4	16	94.09	0.00
9.2.1.5	33	196.57	0.01
1.0.1.1.1	5	65.19	0.00
Count 47	**Count 105,882**	**Sum 2,203,278.05**	**Sum 100.00**

Verification Methodology and Data Sets

The verification methodology we apply generally follows the methodology guidelines (Maucha et al. 2017) and consists in visual inspection of a stratified sample at polygon level against reference imagery of higher spatial resolution than the N2K layer. Several other in situ databases are involved in the decision making process as well. The stratification before sampling is based on the mapped classes. The reference data provided centrally and the in situ ones are described in the previous section.

The verification process includes the following steps:

- Preparation of input and reference data;

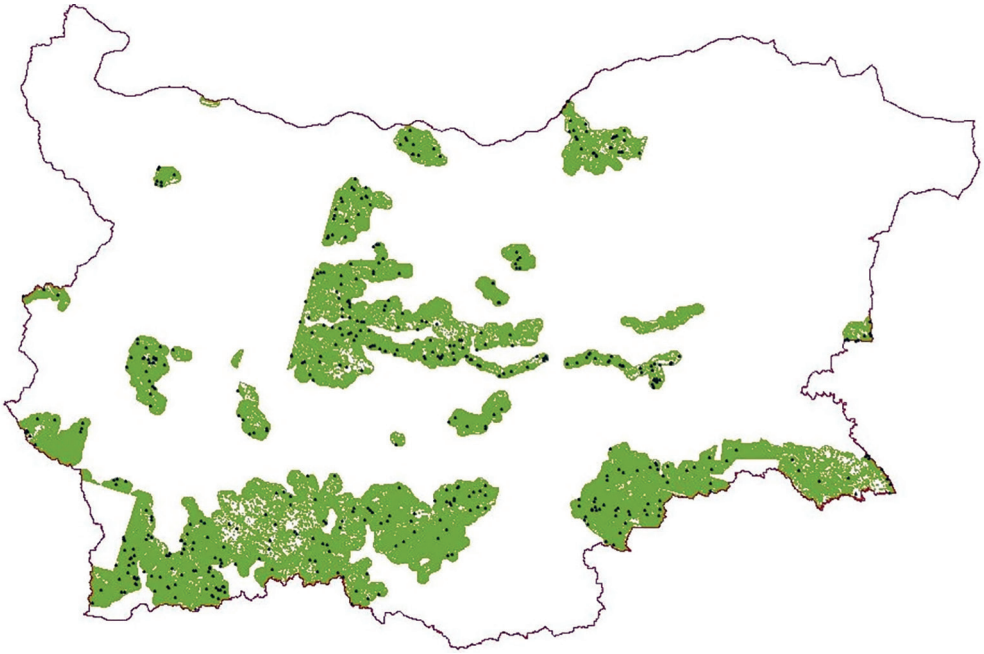

Fig. 2. Natura 2000 LC/LU product – Bulgaria.

- Creation of the sample set of LC/LU polygons;
- Visual interpretation of selected samples;
- Evaluation of results.

Preparation of input and reference data

The N2K data set is a single Pan-European layer of polygons in the EPSG: 3035 (ETRS89, LAEA) coordinate reference system. From the Pan-European LC / LU product, the part covering the territory of the country was clipped in order to serve as input for the verification. A total of 106,017 polygons along the border of Bulgaria were affected by the above operation. Of these, 136 polygons turned out to be smaller than MMU and were therefore eliminated by joining larger ones. The in situ image data are provided through a wms service and together with the vector ones organized in a local GIS working environment.

Creation of the sample set of LC/LU polygons

The number of samples is a trade-off between the minimum sample size requirements from a statistical point of view and the workload resources. Generally, the larger sample size ensures a better confidence of the assessment. One recommendation for stratified random sampling is to provide between 20 and 100 samples per stratum (Congalton and Green 2008). From the uncertainty of measurement point of view the lowest limit of number of measurements is accepted to be at least 10 (Anonymous 1999).

Here we have to mention that the N2K product currently is focused on several

valuable grassland types (Anonymous 2017). Thus, considering the goal of this study stated previously, we decide to provide at least 12 samples for each of non-grassland classes and 15 samples for the four grassland ones: 4.1.1.1, 4.2.1.1, 4.2.1.2 and 4.2.2.1. Taking also into account that several classes have less than 12 polygons the total number of samples is set to 500. The sample data set was generated within LACO-Wiki environment.

Visual interpretation of selected samples

The interpretation of LC/LU classes is performed according to the MAES nomenclature, levels 1 – 4. The polygons are displayed over LACO-Wiki reference imagery and the shown LC/LU class code of each sample is evaluated for correctness. In the LACO-Wiki tool this "not blind" approach is called "enhanced plausibility". For large polygons, that can be heterogeneous, the LC/LU class code is checked around a sample point, rendering an account of MMU size. These points have been generated in advance for all sample polygons as a separate layer. Other three characteristics can be set for the polygon evaluating its delineation and positional status: content of polygon's area, detail of delineation and positional accuracy. Finally, the expert can add a comment as a free text. In parallel to the work in the LACO-Wiki tool the expert carries out additional inspection of the same sample polygons in a local GIS environment using in situ image and vector databases. On-line open spatial databases like GoogleEarth and OpenStreetMap are intensively involved in the process as well.

Results and Discussion

As a result from the verification of LC/LU N2K product 465 sample polygons out of 500 have been assigned to the correct class. Therefore, the overall accuracy of 93.0 % is a result which is higher than the required 85 % level.

For 24 of the 47 classes typical for Natura 2000 sites in Bulgaria it was found that the code of all validated LC/LU samples was 100 % true (Table 3). For the most part, these are linear objects to which another code of the MAES nomenclature can hardly be attributed: Road networks and associated land, Railways and associated land, Lines of trees and scrub, River banks, Interconnected running water courses and Highly modified natural water courses and canals. This group also includes objects which have specific for the respective class interpretation features that cannot be found in another class of the nomenclature: Port areas, Airports, Green urban areas and leisure facilities, Greenhouses, Vineyards, Fruit trees and berry plantations and Marine (other).

Table 3. 100 % correctly interpreted samples.

N2K Class	Description	Number of samples
1.2.1.1	Road networks and associated land	12
1.2.1.2	Railways and associated land	12
1.2.1.3	Port areas	2
1.2.1.4	Airports	5
1.4.1.1	Green urban areas and leisure facilities	12
2.1.1.1	Non-irrigated arable land	13
2.1.2.1	Greenhouses	12
2.2.1.1	Vineyards	13

N2K Class	Description	Number of samples
2.2.2.1	Fruit trees and berry plantations	12
3.1.2.1	Broadleaved swamp forest	2
3.1.3.1	Other natural & semi-natural broad-leaved forest	13
3.4.1.1	Transitional woodland and scrub	13
3.4.1.2	Lines of trees and scrub	12
3.5.1.1	Damaged forest	8
4.2.2.1	Alpine and sub-alpine natural grassland	15
5.1.1.1	Heathland and Moorland	12
5.1.1.2	Other scrub land	12
5.2.1.1	Sclerophyllous vegetation	12
6.2.1.3	River banks	12
9.1.1.1	Interconnected running water courses	12
9.1.1.2	Highly modified natural water courses and canals	12
9.1.2.1	Separated water bodies belonging to the river system (dead side-arms, flood ponds)	12
9.2.1.1	Natural water bodies	13
10.1.1.1	Marine (other)	5
Count 24		

Typical Mistakes

Some typical and often recurrent errors have been detected in the validation process:

Incorrect classification

Twenty four erroneously classified polygons were found during the validation. The following examples are selected: Figure 3 shows the wrong code 6.2.2.1 Bare rocks and rock debris. In fact, the land cover in this polygon is no different from the surrounding forests. In situ data used – the stand characteristics from the forest management plan indicate that the outlined polygon includes coppice stands, Scots pine stands and coniferous plantations. Correct code has been proposed – 3.3.3.1 Other natural & semi-natural mixed forests.

In Figure 4 the code for polygon is 3.2.3.1 Other natural & semi-natural coniferous forest. After a careful review of the satellite and the ortho-images, of the retrospective images in Google Earth, as well as of the stand characteristics in the forest management plan, it was found that these are pure coniferous plantations and the code proposed by the interpreter is 3.2.4.1 Highly artificial coniferous plantations.

In Figure 5 the outlined polygon is classified as 3.1.4.1 Broadleaved evergreen forest. According to the forest inventory, these are coppice Turkey oak stands. The proposed code is 3.1.3.1 Other natural & semi-natural broadleaved forest.

In the following Figure 6 for the Eco-area Belite Skali, located in the Slavyanka reserve, the code 6.1.1.1 Sparsely vegetated areas is given. Perhaps the reason is that by 2006 this territory was a career. Because the area is rich in mineral springs it was decided the marble extraction to be terminated and this beautiful place to be created. By the reference year 2012, the correct code is 1.4.1.1 Green urban areas and leisure facilities.

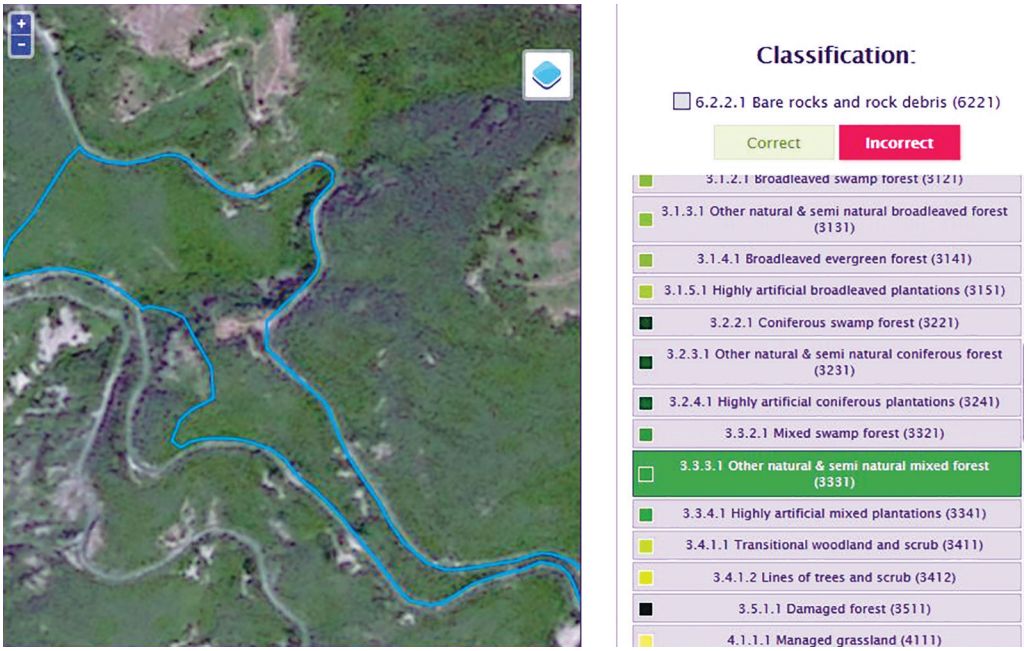

Fig. 3. Incorrect classification 6.2.2.1 Bare rocks and rock debris – Correct is 3.3.3.1 Other natural & semi-natural mixed forest.

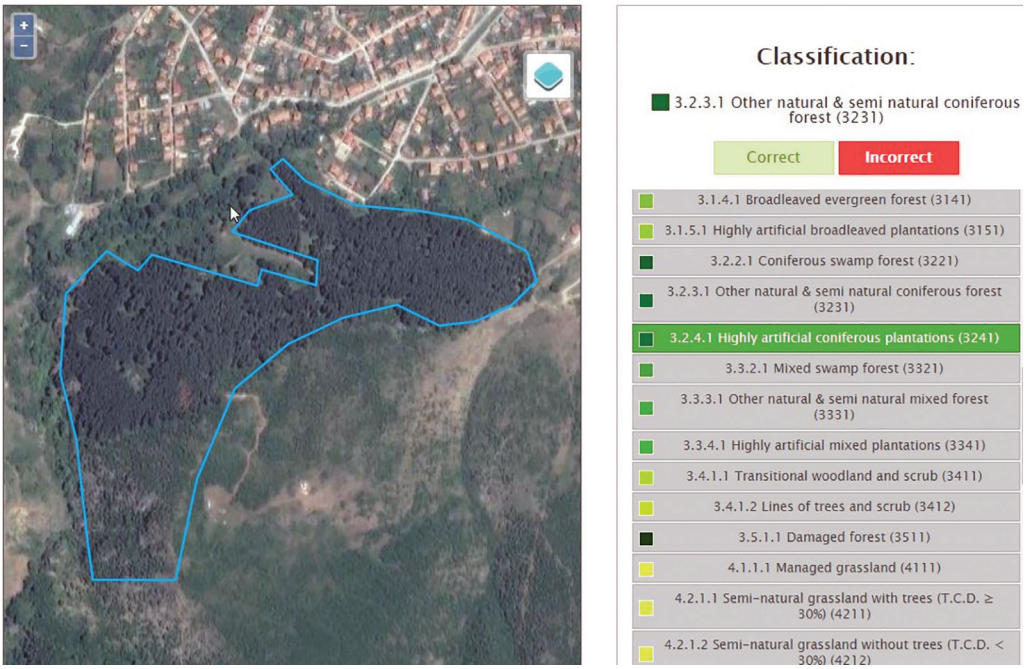

Fig. 4. Incorrect classification 3.2.3.1 Other natural & semi-natural coniferous forest – Correct is 3.2.4.1 Highly artificial coniferous plantations.

Fig. 5. Incorrect classification 3.1.4.1 Broadleaved evergreen forest – Correct is 3.1.3.1 Other natural & semi-natural broadleaved forest.

Fig. 6. Incorrect classification 6.1.1.1 Sparsely vegetated areas – Correct is 1.4.1.1 Green urban areas and leisure facilities – Eco-area BeliteSkali.

Incorrectly delineated areas

In many cases, the boundaries of the polygons are outlined too roughly; include unnecessary parts or there are missing parts, and often both. In other cases the boundaries have been shifted (Fig. 7).

Fig. 7. Delineation too coarse, missing and unnecessary parts, shifted borders.

Forest in Natura 2000 LC/LU Product

Over half of the Natura 2000 LC/LU products – Bulgaria areas (57.12 %) are occupied by forests. These are large-area polygons, and the overall impression is that in most cases the boundaries are delineated too roughly, with redundant or missing parts. Provided the MMU is 0.5 ha, separate polygons can be delineated in mixed forests – 3.1.3.1 Other natural & semi-natural broadleaved forest, 3.2.3.1 Other natural & semi-natural coniferous forest, 3.2.4.1 Highly artificial coniferous plantations, 3.1.5.1 Highly artificial broadleaved plantations, and in some cases also 3.4.1.1 Transitional woodland and scrub. Such is the example in Figure 8. The classification is correct – 3.3.3.1 Oth-

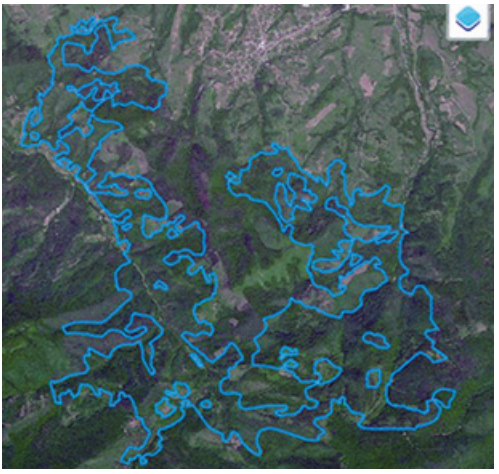

Fig. 8. Correct classification 3.3.3.1 Other natural & semi-natural mixed forest large polygons of 3.1.3.1, 3.2.3.1 and 3.2.4.1 should be separated.

er natural & semi-natural mixed forest, but large polygons of 3.1.3.1, 3.2.3.1 and 3.2.4.1 should be separated.

Damaged forest

Class 3.5.1.1 Damaged forest includes forest damaged by fire, storm, tornado or snow events as long as trees are lying on the ground and also forest damaged by pests like e.g. bark beetle as long as the damage is visible due to discoloration. In Figure 9 two examples are shown of forest stands affected by bark beetle in the Vitosha Nature Park.

Fig. 9. Damaged forest – forest stands affected by bark beetle in the Vitosha Nature Park.

Evaluation of Results of Verification

As a final step of the verification, the LACO-Wiki tool generates a report in the form of MS Excel file. It contains several sheets including a contingency matrix with user and producer accuracies and confidence intervals per class. As a whole, accuracies are good with user accuracies varying between 50 % and 100 % and producer accuracies falling into the range 76.47 % – 100 %. The overall accuracy is 93 % with confidence interval ±2.06 %. Favourable approaches applied, namely the polygon level of sampling and the plausibility interpretation probably have also given their contribution to these high results. Several summary accuracy characteristics taken from the report are shown in Table 4.

Table 4. Estimated accuracy characteristics.

Accuracy estimates	Value
Overall Accuracy	0.93
Overall Accuracy (CI)	**± 0.0206**
Kappa	0.928246
Kappa (CI)	**± 0.0229**
Geometric Agreement	
Delineated area	0.69
Detail of delineation	0.854
Positional accuracy	0.974

In the lower half of the table three geometric indicators are presented, calculated from the corresponding geometry attributes set up during the verification.

Using more detailed scores the geometric agreement indicators, describing the correctness of delineation can be presented as follows:

- Detail of delineation – 85.4 %;

Correct: 427; Too coarse: 73; Too detailed: 0;

- Correctness of delineated area – 69.0 %;

Correct: 345; Missing and unnecessary parts: 51; Unnecessary parts included: 62; Missing parts: 42;

- Positional accuracy – 97.4 %;

Correct: 487; Shifted: 13.

Conclusions

A quantitative approach to assessing the thematic accuracy of the LC/LU N2K product is applied that is statistically endorsed in view of the objectives pursued. It provides comparability of results between countries. The resulting 93.0 % overall accuracy, is higher than the required 85 % in the product specifications. Producer's accuracies for 24 out of 47 classes available in Bulgaria equal 100 %. Principally these are linear objects to which another code of the MAES nomenclature can hardly be attributed and also objects with typical and unique interpretation features.

The assessment of the quality of delineation shows that the boundaries of many polygons are outlined too roughly or shifted; include unnecessary parts or there are missing parts, and often both. In other cases the delineation is correct, but polygons can be separated into other MAES polygons with an area larger than the MMU of 0.5 ha.

The verification of the Natura 2000 local component dataset for Bulgaria provides statistical results and quality evaluation based on local expertise, reference data and in situ data used.

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References

Anonymous 1999. Expression of the Uncertainty of Measurement in Calibration. EA-4/02 M: 1999. 29 p. Available at: https://docs.google.com/document/d/ 1OK3X7bAW-DRJloOcmw9uwFXxNveDgZDFHlVHgnY-QU5zs/ edit#

Anonymous 2015a. Final nomenclature guideline Issue 3.0. 260 p. Available at: http://land.copernicus.eu/user-corner/technical-library/RZ_CS3_17_Nomenclature_Guideline_I30.pdf

Anonymous 2015b. Natura2000 PRODUCT SPECIFICATIONS (short version). 10 p. Available at: https://cws-download.eea.europa.eu/local/n2k/N2000_Product_Specifications_short%20version_20151104.pdf

Anonymous 2016. Mapping Guide v4.7 for a European Urban Atlas. 42 p. Available at: http://land.copernicus.eu/user-corner/technical-library/urban-atlas-2012-mapping-guide-new

Anonymous 2016a. Quick start guide for the Laco-wiki online tool. 20 p. Available at: https://laco-wiki.net/Content/Docs/LACO-Wiki_quickstart.pdf

Anonymous 2017. Copernicus programme. Available at: http://land.copernicus.eu/.

Bossard M., Feranec J., Otahel J. 2000. CORINE land cover technical guide – Addendum 2000. EEA. Copenhagen.105 p. Available at: http://image2000.jrc.ec.europa.eu/reports/corine_tech_guide_add.pdf

Büttner G., Kosztra B. 2007. CLC2006 Technical Guidelines. EEA. Technical Report 17/2007. 70 p. Available at: http://www.eea.europa.eu/publications/technical_report_2007_17

Cochran W. 1977. Sampling Techniques. 3rd edition, John Wiley. 428 p.

Congalton R. 1991. A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. Remote Sensing of Environment (37): 35–46.

Congalton R., Green K. 2008. Assessing the Accuracy of Remotely Sensed Data. Second edition. CRC Press. 192 p.

Congedo L., Sallustio L., Munafò M., Ottaviano M., Tonti D., Marchetti M. 2016. Copernicus high-resolution layers for land cover classification in Italy. Journal of Maps 12(5): 1195–1205.

Dimitrov V., Lubenov T. 2014. Verification and enhancement high resolution layers 2012 for Bulgaria. 40th COSPAR Scientific Assembly. Abstract A3.1-62-14. Available at: http://adsabs.harvard.edu/abs/2014cosp...40E.709D

Dimitrov V. 2016. Accuracy assessment of a thematic layer derived from satellite images. Geodesy, Cartography, Land management (1–2): 16–20 (in Bulgarian). Available at: https://www.joomag.com/magazine/Геодезия-Картография-Земеустройство-gkz-1-2-2016/0622277001462785928?short

Gussev Ch., Tzonev R. 2015. European Ecological Network NATURA 2000 in Bulgaria. Sofia. 10 p. Available at: http://e-ecodb.bas.bg/rdb/en/vol3/07natura2000.html

Maucha G., Pataki R., Lehoczki R., Kleeschulte S., Schröder Ch., Malak D.A., Perger Ch. 2017. Guidelines for verification of Local component products 2012. Wien. 43 p.

Olofsson P., Foody G., Herold M., Stehman S., Woodcock C., Wulder M. 2014. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment 148: 42–57.

Richter R.,Weingart U., Hermann S., Morera P., Nicolás M. 2015. Nomenclature guideline. München. 248 p.