RESEARCH ARTICLE

Violeta Dimitrova [1]
Dimitar Dimitrov [2]
Emiliya Velizarova [2]

Biomass and carbon content in undergrowth from areas affected by fires

Authors' addresses:
[1] University of Forestry – Sofia, Kliment Ohridski Bvd. 10, 1756 Sofia
[2] Forest Research Institute, Bulgarian Academy of Sciences, Kliment Ohridski Bvd. 132, Sofia

Correspondence:
Violeta G. Dimitrova
University of Forestry – Sofia,
Kliment Ohridski Bvd. 10,
1756 Sofia
e-mail: vilydi@abv.bg

ABSTRACT

The assessment of natural regeneration in forests is an important criterion in determination the viability, status and their productivity. The future development of the communities depends on the amount and composition of undergrowth. Nowadays we are witnessing more frequent forest fires in various parts of the country. They can cause various problems such as destruction of large quantities of wood, habitats, death of many plants and animal species, soil biota, overall deterioration of the functions of the forest ecosystem, one of which is the reduction of the ability to absorb carbon dioxide.

The high frequency of the fires can drastically change the structure and composition of aboveground biomass and affect the carbon cycle in the ecosystem. The undergrowth is one of the fuel components of the ground biomass destructed by fire, and also is a factor that can be used for controlling and managing fires and has a role as a carbon storage in forest ecosystems.

The study aims to establish the quantity and composition of the aboveground phytomass of undergrowth from different forest tree species in areas affected by fires and an assessment of its role as a carbon storage.

Key words: undergrowth, biomass, carbon, fires

Introduction

The assessment of natural regeneration in forests is an important criterion in determining the viability, the status and their productivity. The future development of the communities depends on the amount and composition of undergrowth. The biomass is one of the main indicators for assessment of the functional status of the communities. The determinination and analyzing of the phytomass of forest communities, which are major producers of organic matter is of great importance to the overall understating of the processes in the biosphere. The undergrowth is one of components of biosphere which is limited studied. Data about biomass and carbon content in the undergrowth can be found in publications of Lyubenova & Bondev, 1998; Vulchev & Nikolov, 1999; Dimitrova et al., 2005; Dimitrova & Zhiyanski, 2011; Dimitrova et al., 2014; Helmisaari et al., 2002; Samran, 2005 and others.

On the other hand, in the recent years we are witnessing of more frequent forest fires in various parts of both the country and the world. They can cause various problems such as destruction of large quantities of wood, destruction of habitats, death of many plant and animal species, soil biota and overall deterioration of the functions of the forest ecosystems, one of which is reduction of the ability to absorb carbon dioxide from atmosphere. The high frequency of fires can drastically change the structure and composition of aboveground biomass and affect the carbon cycle in the ecosystem.

The fires usually occur during droughts, accompanied by high temperatures. The causes of the fires are often anthropogenic. The fallen leaves are the main fuel component in forest communities. The composition of biomass burning on the ground include also litter, twigs, grass species and undergrowth. The intensity of the fire depends on the amount of ground level biomass, which will burn and the amount of pollutants that will be released. The intensity of the fire depends on the amount of biomass, on the altitude, the moisture content of litter, humidity and the temperature.

The forest fires not only directly affect ground biomass, i.e undergrowth, litter and branches, but also affect soil properties and processes taking place in it, and food dynamics (Wanthongchai et al., 2008; Molla et al., 2014). However, the heat from the fire can activate natural regeneration and growth of undergrowth (Suthivanit, S., 1989). Survival of the species depends on the diameter of the stem at the base. It has been found that the undergrowth with the base diameter less than 1 cm would be completely dead in string fire (Suthivanit, 1989).

The forests have a high potential for absorbing carbon dioxide from the atmosphere through photosynthesis (Weber, 1990). However, information on the absorption of carbon dioxide in forests affected by fire are still insufficient studied.

The undergrowth is one of the fuel components of ground biomass under fire, and also is a factor that can be used for controlling and managing fires and has a role as a carbon storage in forest ecosystems.

Thus, the study aims establishing the aboveground phytomass of undergrowth from the important forest tree species for the country and their carbon content in forest fire affected areas.

Materials and Methods

The investigations were conducted in Osogovska mountain on the territory of Nevestino Government Forestry Enterprise (GFE) (Figure 1).

Osogovska mountain is known with its localities of black pine with natural origin. They are an important genetic bank for black pine in our country. Often self-afforesting of black pine from crops or from natural stands near Nevestino has been seen over 1100 m.

The sample plots in this study are situated in plantations at a lower altitude at oak habitats, that is why it was observed a large amount of oak undergrowth on their territory. The studies were conducted in 2013. The sample plots were established in close proximity to the border of areas in which during 2012 there was affected by intensive surface fire with anthropogenic origin and low intensity. The five sample plots are covered different stands with typical species for the Nevestino GFE. Their characteristics are presented in Table 1.

Methods

The aboveground biomass was investigated through classical methods (Rodin et al., 1968; Lyubenova, 2009). Ten individuals of each investigated species from each sample plots were collected. Their height and diameter were measured. The age was determined through counting up the age rings. The density was determined through counting the individuals in five experimental plots per 1 m^2 located in each SP. Aboveground plant mass was divided into stem and leaves and was dried at 85°C for 48 h until constant weight was reached and then the dry mass was measured. The studies were conducted at the end of the growing season (October 2013), when the accumulation of biomass has reached its final stage for the year.

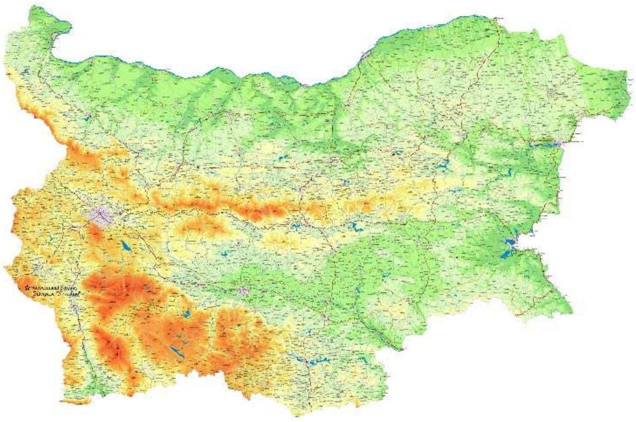

Figure 1. *Location of the investigated stands.*

Carbon content was calculated according to Larcher's ratio (Larcher, 1978; Lyubenova, 2009).

The data were analysed with Statistica 7 (McGarigal et al., 2000). The standard errors and the representative of the average values was calculated at the level of significance 0.05.

Results and Discussion

As a result of the investigation within the sample plot (SP) 1 it was calculated beech undergrowth with density 5.6 n/m^2. The average diameter is 4.6 mm, the average height is 27.7 cm, and age – 3 years. On the territory of SP 2 it was established undergrowth of Turkey oak with a density of 1.4 n/m^2. The average diameter is 2.5 mm, the average height is 13.25 cm, and age – 2 years. On the territory of SP 3 undergrowth of two types of trees was established: Turkey oak – a density of 1.6 n/m^2, average diameter 2.6 mm, average height 20.4 cm, avg. age – 2 years and black pine – a density of 4 n/m^2, avg. diameter 4.9 mm, avg. height 29.6 cm, avg. age – 3 years. On the territory of SP 4 was established the undergrowth of black pine density of 2.2 n/m^2, avg. diameter 4.1 mm, avg. height 22.3 cm, avg. age – 3 years and Turkey oak – with a density of 3.8 n /m^2, avg. diameter 2.6 mm, avg. height 18.7 cm, avg. age – 2 years. On the territory of SP 5 it was established

Table 1. *Characteristics of the sample plots.*

Sample plots	Altitude, m	Exposition	Slope	Composition/ tree species	Origin	Age, years	Canopy	Site index	Average height, m	Average $D_{1.30}$, cm
SP 1	850	W, NW	27	beech 10	seed	130	0.6	III	21	34
SP 2	920	E, NE	11	Scots pine 10	plantations	40	1.0	IV	14	14
SP 3	980	S, SW	15	black pine 10	plantations	65	1.0	III	18	26
SP 4	950	E	18	black pine 10, Turkey oak	plantations	65	0,7	III	19	26
SP 5	600	E	21	black pine 10	plantations	50	0,7	IV	14	18

undergrowth of black pine with a density of 1.2 n/m^2, avg. diameter 2.9 mm, avg. height 22.6 cm, avg. age – 2 years and Turkey oak with a density of 4 n/m^2, avg. diameter 3.5 mm, avg. height 34 cm, avg. age – 2 years

On the territory of SP 1 the undergrowth only from edificator species – common beech (*Fagus sylvatica* L.) was observed. On the territory of the three sampling plots (SP 2, 4 and 5) the prevalence of undergrowth of Turkey oak (*Quercus cerris* L.), was observed regardless that the composition of the tree floor, consists from black pine (*Pinus nigra* J.F.Arnold) and Scots pine (*Pinus sylvestris* L.). The presence of undergrowth from Turkey oak and the lack of undergrowth of coniferous species (SP 2) within the plantations of Scots pine shows that the forest in this SP is in poor condition and probably could not be regenerated. It is expected that coniferous plantation will be replaced by oak stand. On the territory of SP 3 the undergrowth was presented mainly by black pine however the presence of Turkey oak was also observed. The presence of the undergrowth from these 2 species shows that in the future this plantation would most probably consists of mixed composition.

The age of undergrowth within the all sampling plots was 2 – 3 years old. The mean diameter ranged between 2.5 and 5 mm, as for Turkey oak it is smaller, while for beech and black pine undergrowth it was in the higher range. The average height varied from 13 cm for Turkey oak to 37 cm. The density ranged from 0.2 to 5.6 n/m^2.

As a result of the studies data on stocks of aboveground phytomass of undergrowth were obtained. The data are presented in Table 2.

The total (for all available tree species) aboveground biomass of undergrowth varies from 1.3 g.m^{-2} (SP 2) to 21.2 g.m^{-2} (SP 3). The leaves biomass vary between 21 and 33% for the undergrowth of deciduous species, while for the undergrowth of pine this percentage is higher – 40-45%. The stem of deciduous species is between 67 and 79% of the total aboveground phytomass, while conifers it is 55-60% respectively.

The collected undergrowth phytomass was analysed concerning amounts of carbon content. The results are presented in Table 3.

The variation in the of carbon content reflects the differences in the quantities of phytomass. The calculated content of carbon is highest in black pine from SP 3 (10.3 g.m^{-2}) and is the least for Turkey oak in SP 2 (0.6 g.m^{-2}). The calculated amount for undergrowth of common beech is 6 g.m^{-2} (SP 2). The amount of carbon in stems slightly exceeds that in the leaves.

Table 2. *Biomass stocks of undergrowth (g.m^{-2} abs.dry.m).*

Sample plots	SP 1	SP 2	SP 3		SP 4		SP 5	
Tree species	Common beech	Turkey oak	Turkey oak	Black pine	Black pine	Turkey oak	Black pine	Turkey oak
Stem	**8.809**	**0.864**	**1.387**	**10.384**	**2.822**	**2.895**	**1.107**	**9.038**
SD*	4.58	0.257	1.005	4.153	0.971	1.339	0.669	0.512
SE**	0.76	0.128	0.251	1.038	0.324	0.223	0.084	0.256
Leaves	**2.355**	**0.41**	**0.942**	**8.466**	**1.899**	**2.334**	**1.018**	**4.076**
SD	2.07	0.018	0.589	2.367	0.265	0.903	0.689	0.814
SE	0.34	0.009	0.147	0.592	0.088	0.15	0.086	0.407
Total	**11.163**	**1.274**	**2.329**	**18.85**	**4.72**	**5.229**	**2.124**	**13.114**
SD	6.64	0.239	1.594	6.52	1.236	2.242	1.358	1.227
SE	1.11	0.119	0.399	1.63	0.412	0.373	0.169	0.663

Legend: SD* - standard deviation; SE** - standard error

Table 3. *Carbon stores of undergrowth (g.m^{-2}).*

Sample plots	SP 1	SP 2	SP 3		SP 4		SP 5	
Tree species	Common beech	Turkey oak	Turkey oak	Black pine	Black pine	Turkey oak	Black pine	Turkey oak
Stem	**4.809**	**0.476**	**0.757**	**5.669**	**1.541**	**1.581**	**0.604**	**4.937**
SD	2.5	0.141	0.549	2.671	0.53	0.731	0.365	0.279
SE	0.42	0.07	0.137	0.668	0.171	0.122	0.046	0.139
Leaves	**1.286**	**0.224**	**0.515**	**4.622**	**0.895**	**1.275**	**0.556**	**2.225**
SD	1.13	0.009	0.322	1.293	0.017	0.492	0.376	0.445
SE	0.19	0.005	0.08	0.323	0.002	0.082	0.047	0.222
Total	**6.095**	**0.696**	**1.271**	**10.292**	**2.435**	**2.855**	**1.16**	**7.16**
SD	3.63	0.15	0.871	3.964	0.548	1.224	0.741	0.724
SE	0.6	0.075	0.218	0.991	0.179	0.204	0.093	0.362

Conclusion

The future composition of the stands, proven by the species composition of the undergrowth showed an increase of deciduous instead of coniferous species. Thus the fire danger in the future stand is expected to decrease as the black pine, one of the most combustible species, was observed to be shifted by Turkey oak. Moreover the studied plantations of black pine are in apparently poor condition (III, IV site index). They have a lot of dead, fallen and standing trees, which further increase the risk of the rapid spread of a fire.

In case of fire occurance, the investigated communities would lose aboveground biomass of undergrowth in the amount of respectively 8.8 g.m^{-2} for black pine, 5.5 g.m^{-2} for Turkey oak and 11.2 g.m^{-2} for common beech. This undergrowth biomass has an average carbon stocks respectively for undergrowth of pine – 4.6 gm^{-2}, for Turkey oak – 3 g.m^{-2} and 6.1 g.m^{-2} for beech.

Acknowledgement

The study was realized with the financial support of National Scientific Fund at the Ministry of Education, Youth and Science of Bulgaria through project entitled: Simulation of the behaviour of forest and field fires. BNSF No I 01/0006 from 28.11.2012.

References

Dimitrova VD, Zhiyanski M. 2011. Phytomass of Herbaceous Floor in Urban Forest Parks of Sofia, Bulgaria. Journal of BE, 14(2): 187-195.

Dimitrova V, Lyubenova M, Dimitrov D. 2014. Biomass of young tree saplings of main forest species in Bulgaria and its role as a carbon depot. Silva Balkanica, 15(2): 35-42.

Dimitrova V, Lubenova M, Bratanova-Doncheva Sv. 2005. Aboveground phytomass and production in the shrub layer of the chestnut (*Castanea sativa* Mill.) communities in the Belasitsa mountain. Balkan scient. conf. of biology. 19-21.05.2005, Plovdiv, 443-451.

Helmisaari H-S, Makkonen K, Kellomaki S, Valtonen E, Malkonen E. 2002. Below and aboveground biomass, production and nitrogen use in Scots pine stands in eastern Finland. For. Ecol. Manag., 165: 317-326.

Larcher V. 1978. Plant ecology. – M., Mir, 381p. (In Russian).

Lyubenova M, Bondev I. 1998. Overground annual production and biomass of oak forests in the Balkan mountains. Ecologie, 29 (1-2): 389-392.

Lyubenova M. 2009. Functional biocoenology. – An-Di, Sofia, Bulgaria (in Bulgarian).

McGarigal K, Cushman S, Stafford S. 2000. Multivariate Statistics for Wildlife and Ecology Research. – Springer-Verlag New York, Berlin, Heidelberg.

Molla I, Velizarova E, Malcheva B, Bogoev V, Hadzhieva Y. 2014. Forest fire impact on the soil carbon content and stock on the north slopes of Rila Mountain (Bulgaria). Ecologia Balcanica, 5: 81-88.

Rodin L, Remezov N, Bazilevich N. 1968. Methodological Instructions for Study Dynamics and Biological Cycle in Phytoceanosis. – Science Publisher, Leningrad, 9-24.

Vulchev V, Nikolov V. 1999. Primary production and reserves of the above-ground phytomass of two *Pinus sylvestris* L. communities in the Malyovitsa Divide of the Rila Mountains. Phytologia Balcanica, 5(1): 75-84.

Samran S. 2005. Effect of forest fire on change above ground biomass in the Maeklong mixed deciduous forest, Kanchanaburi province, Thailand. – In: Proceedings of the Conference on Climate Change in Forest: The Potential of Forest in Support of the Kyoto Protocol, Bangkok, Thailand, 45: 351-362

Suthivanit S. 1989. Effects of fire frequency on vegetation in dry dipterocarp forest at Sakarat, Changwat Nakornratchasima. M. Sc. Thesis, Forest Resource Administration, Kasetsart University, Bangkok, Thailand (in Thai).

Wanthongchai K, Bauhus J, Goldammer J. 2008. Nutrient losses through prescribed burning of aboveground litter and understorey in dry dipterocarp forests of different fire history. Catena, 74: 321-332.

Weber M. 1990. Forest soil respiration after cutting and burning in immature Aspen ecosystems. For. Ecol. Manag., 31: 1-14.