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FORESTRY IDEAS, 2013, vol. 19, No 1 (45): 3–17

THE QUALITY OF LIFE OF INHABITANTS IN THE CITY OF IOANNINA: THE CONTRIBUTION OF LAKE PAMVOTIDA

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Received: 24 November 2012 Accepted: 03 March 2013

Abstract

Lake Pamvotida is inseparably linked to the life and history of the inhabitants of the city of Ioannina. This research records the views and beliefs of the inhabitants of the city of Ioannina with regard to the lake. The majority of the citizens believe that Lake Pamvotida plays an important role in their lives since the mere presence of the lake contributes to improving their psychology. In addition, Lake Pamvotida contributes to the aesthetics of the city and helps with regard to opportunities for recreation and sport. In general, the citizens declare satisfied from the quality of their life. They also believe that if there are opportunities for them to stay in their homeland, they will do so. It seems that 50 percent of the citizens do not wish to participate in public matters. In addition, the percentage of citizens which do not participate in any environmental program is significant. However, it is encouraging that the percentage of those who would participate voluntarily in a lake protection program is quite big.

Key words: Lake Pamvotida, City of Ioannina, views of citizens, personal interviews, loglinear analysis.

Introduction

Lake Pamvotida, also known as the lake of Ioannina, is located in the northwestern part of Greece. The lake covers a small part of the Ionnina basin. Lake Pamvotida as it is today is a left-over of a wider ecosystem which included Lake Lapsista which was drained in the 1950s. It is worth-noting that the health of the first lake depended on the health of the second and vice versa (Management Agency 2013). Geological research has shown that lake Pamvotida is more than 1 million years old (Kagkalou 1990). Lake Pamvotia covers an area of 23 square kilometers. The depth of the lake is on average 4–5 meters (Vrigka 2003). The lake was always important to people because it provided their food and because it was a refuge against enemies and the harsh conditions of the surrounding mountains (Barba 2008).

Today the population in the wider area of Lake Pamvotida is 100,000 individuals. To a greater or lesser extent these people use the lake as a source of living either directly or indirectly. At the same time the state of the natural environment has a direct influence on the life of the population (Management Agency 2013).

The development of the city of Ioannina and the wider area in recent years disturbed the harmonious co-existence of city and lake. Stock-breeding, industrial and agricultural production increased with fast rates something which increased the quality of life of people in the area on the one hand but which also simultaneously created ecological problems both with regard to the lake and the wider area (Lambrou 1998).

Today, lake Pamvotida suffers from serious eutrophication problems which are linked with the decreased transparency of its waters, the distinctive scent, the death of fishes, the lessening of fish catches, the excessive increase of aquatic vegetation, etc. The increased values of phosphorus, nitrogen and chlorophyll-*α* are indicative of the existence of eutrophication in the lake (Albanis et al. 1986).

In the past many well-intended interventions took place but in the long-run all had negative consequences on the ecosystem of the lake (Panou 2011). Interventions such as the drying of Lapsista, the construction of sea roads and low walls around the lake functioned as hydro dams which blocked some sources and prevented the entry of clean water to the lake. Filling areas with rubble in order to create public facilities (stadiums, squares) in the long term contributed to the changing of the natural seashore, the reduction of the lake's size and its total water volume and also restricted the possibilities for cleaning the lake. However, filling areas with rubble mainly changed society's views towards the lake.

The aim of this paper is to find out how important the lake is to the inhabitants of the city of Ioannina and why. Though examination of the views and behavior of the inhabitants with regard to the protection and promotion of the lake is done, the paper attempts to find out what people know about the lake and how sensitive they are towards issues which are related with the lake.

The views of the citizens regarding the quality of life which their homeland offers to them are analyzed but also the opportunities for work which exist mainly for young people as well the prerequisites which are created with the purpose of encouraging people to stay in the area. Also, the paper investigates if the inhabitants are keeping themselves informed about the public affairs of their region.

Research Methods

This research was carried out through the use of personal interviews. The research area of the paper was the Municipality of Ioannina (Fig. 1).

Satellite image of coastal part of the town is shown in Fig. 2, where it is obvious that the development of the Ioannina City is parallel with the western zone of the lake. The sampling method applied was simple random sampling. This choice was made on the basis of the simplicity of this method (Damianos 1999, Kalamatianou 2000, Matis 2001).

The proportion of the population which is the impartial estimation of population p and the estimation of the standard error of the proportion of the population s_p, without the correction of finite population since the sampling fraction is small, was done via the aid of the formulas of simple random sampling.

In order to calculate the size of the sample we needed to carry out pre-sampling, with the size of the sample being 50 individuals. The size of the sample was calculated on the basis of the formulas of simple random sampling (where t=1.96 and e=0.048) (Kalamatianou 2000, Matis 2001). Although we used simple random sampling, the correction of finite population can be ignored because the size of the sample n is small in relation to the size of the population N (Pagano and Gauvreau 2000). In this case the size of the sample was calculated to be 417 individuals.

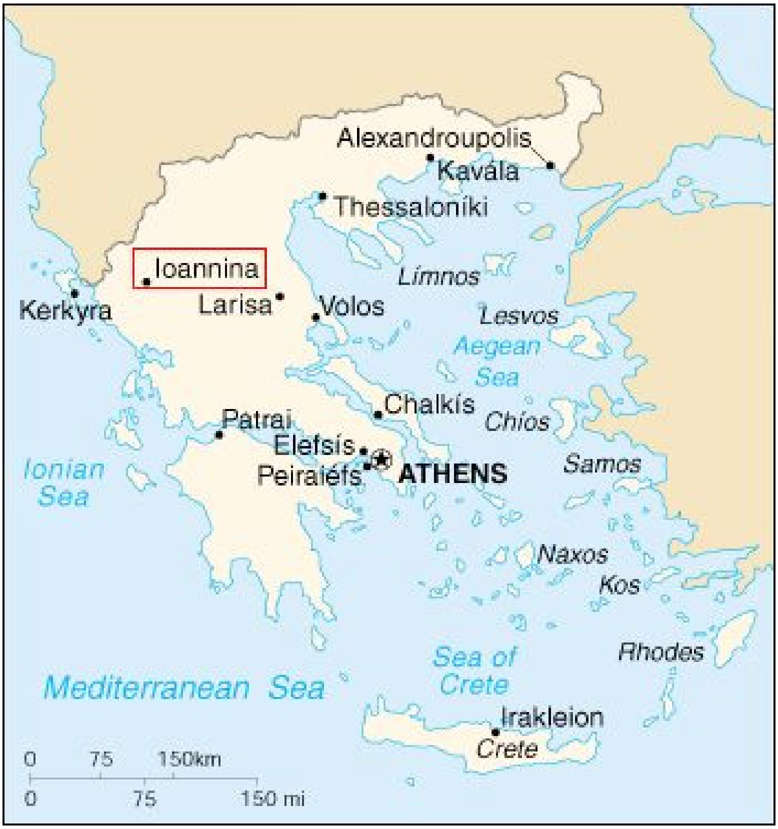

Fig. 1. Map of Greece depicting the investigation area (by Science and Society 2008).

The collection of the data was done in the last six months of 2009. The individuals were then located precisely. The next step was to carry out personal interviews. When this was not possible we used the same process to choose new sampling units.

For the variables “quality of life”, “following the public affairs of the municipality”, “voluntary participation in programs of protection of the lake” and “age” we carried out analysis of frequencies for more than two criteria. Prior to the carrying out of loglinear analysis, it was decided to examine the expected frequencies in the contingency table (Siardos 1999). A large number of expected frequencies (more than 20 %) of less than 5 but not lower than 1, possibly lead to a loss in the effectiveness of the applied analysis (Tabachick and Fidell 1989). Classes were grouped together in order to satisfy the above criteria.

Our data are classified in accordance with 4 criteria and expressed in terms of frequencies. The null hypothesis, Ho, is that the 4 criteria are fully independent from each other. It is unlikely that this

Fig. 2. Satellite image of coastal part of Ioannina (from www.map.google.gr).

assumption will be accepted, but the analysis will give information on the strength of various interrelations and this will be included in a model that expresses the interrelations between the data (Frangos 2004).

Results

The contribution and importance of the lake

Lake Pamvotida is interwoven with the life of the inhabitants of the city of Ioannina. The inhabitants regard the lake as a refuge for relaxation from the modern way of life and at the same time as a natural park in which the visitor comes into contact not only with water but also with several kinds of flora and fauna (Barba 2008). Thus, with regard to the question on how important the lake is for the city, it is worth adding that 78.7 % (s_p=0.0201) of the inhabitants declared very much, 16.3 % (s_p=0.0226) much, while 4.6 % (s_p=0.0102) declared fairly. The percentage of those who think of the lake as not important at all is smaller, i.e. 0.2 % (s_p=0.0024). The same percentage applies to those who did not answer.

Ioannina is a picturesque city with many traditional elements all related to the history of the city. The history of the city is interwoven with the lake. For this reason and with regard to the question on the extent of correlation of the history of the city with the lake, the vast majority of those asked, i.e. 71.7 % (s_p=0.0221) answered very much. 20.9 % (s_p=0.0199) of the inhabitants answered much and 6 % (s_p=0.0116) fairly. The percentages of the rest of the categories are small. The percentage of those who did not want to answer was 1 % (s_p=0.0048), of those who said little was 0.2 % (s_p=0.0024) and not at all 0.2 % (s_p=0.0024). 1 % (s_p=0.0048) of the inhabitants did not answer the question.

An important incentive for the protection of the cultural and natural resources of an area is tourism (Gunce 2003). When tourism and natural environment are interwoven they create a system which is ecologically healthy, economically sustainable and socially and culturally appropriate and humanitarian (Farrel and McLellan 1987). The majority of the inhabitants agree with this opinion since 64.3 % believe that the lake has a very positive impact on tourist development (Table 1).

The area inside and around Lake Pamvotida has been declared a protected area (Environment DG – European Commission 2001). In these areas the local inhabitants have to adopt land use practices which would be friendly to the environment (Lassen and Panagopoulos 2008).

Local communities generally welcome the establishment of protected areas something which is particularly true in developing countries since their income depends on such areas (Rodgers 1989). Improvements in the quality of life are intimately related with the creation of sustainable economic activities and the real participation of the local population in decision making processes (Seixas et al. 2012).

The next question is about the influence of tourist development on the lake itself. 41.2 % (s_p=0.0241) declared that tourism has affected the lake positively, 37.2 % (s_p=0.0237) is neither positive nor negative on the issue, while 13.7 % (s_p=0.0168) assessed this influence as negative. 7.9 % (s_p=0.0137) of the citizens did not answer the question (Fig. 3).

The lake also offers to the inhabitants of Ioannina opportunities for recreation. On this issue a quite large percentage of the citizens replied positively: 36.2 % replied very much and 33.6 % much. Regarding opportunities for sports the majority of the inhabitants also expressed positive views (Table 1).

Table 1. Evaluation by the citizens of the city of Ioannina regarding the positive contribution of Lake Pamvotida.

Positive contribution	Very much		Much		Fairly		Little		Not at all		No answer	
	p, %	s_p	*p*, %	s_p	*p*, %	s_p	*p*, %	s_p	*p*, %	s_p	*p*, %	s_p
Touristic development	64.3	0.0235	28.3	0.0221	5.5	0.0112	1.7	0.0063	0.2	0.0024		
Opportunities for recreation	36.2	0.0235	33.6	0.0231	19.7	0.0195	9.8	0.0146	0.7	0.0041		
Opportunities for sports	31.9	0.0228	34.5	0.0233	24.7	0.0211	6.7	0.0123	1.4	0.0058	0.7	0.0041
Beauty for the city	79.1	0.0199	17	0.0184	1.9	0.0067	1.0	0.0048	0.5	0.0034	0.5	0.0034
Better psychology	42.9	0.0242	26.4	0.0216	22.5	0.0205	6.0	0.0116	1.9	0.0067	0.2	0.0024
Better quality of life	32.1	0.0229	33.1	0.023	19.2	0.0193	12.5	0.0162	2.9	0.0082	0.2	0.0024

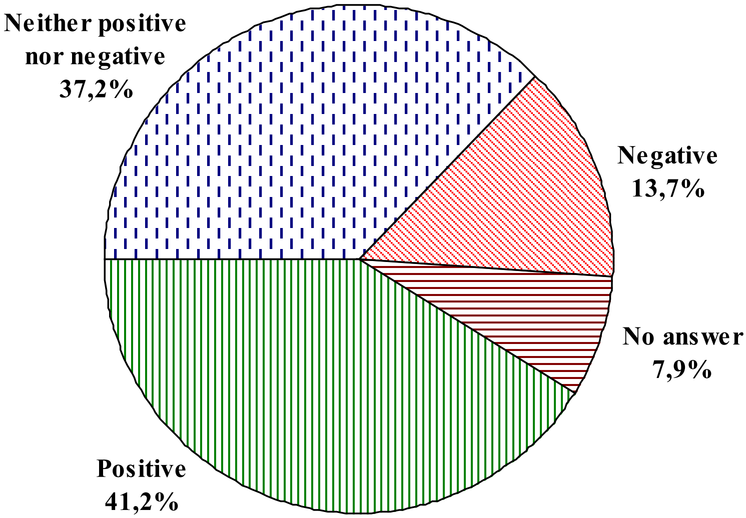

Fig. 3. The opinion of the inhabitants regarding the influence of tourist development on the lake.

Among the most beautiful cities of Greece are those which have water near them. One of these cities is the city of Ioannina. Regarding the question on how much the lake makes the city beautiful a high percentage of the citizens (79.1 %) replied very much. Almost all of the inhabitants think that to a larger or a lesser extent the lake influences positively the psychology of the people. This is logical since the life of the inhabitant is interwoven with water. This is also supported by psychologists who think of water as the most precious element of the aesthetics of lanscape (Kaplan and Kaplan 1989). Also there was a high

Table 2. Evaluation by the citizens of the city of Ioannina regarding the negative contribution of the Lake Pamvotida.

Negative contribution	Very much		Much		Fairly		Little		Not at all		No answer	
	p, %	s_p	*p*, %	s_p	*p*, %	s_p	*p*, %	s_p	*p*, %	s_p	*p*, %	s_p
Source of pollution	14.1	0.0171	20.1	0.0196	28.8	0.0222	26.4	0.0216	10.1	0.0147	0.5	0.0034
Reproduction of mosquitos	21.6	0.0201	21.1	0.0200	31.4	0.0227	21.8	0.0202	3.8	0.0094	0.2	0.0024
Source of undesirable scents	13.9	0.0169	19.9	0.0196	30.2	0.0225	29.0	0.0222	6.2	0.0118	0.7	0.0041
Danger for children	7.4	0.0128	9.4	0.0143	23.3	0.0207	36.5	0.0236	23.5	0.0208		
Negative microclimate (humidity)	29.0	0.0222	26.4	0.0216	32.9	0.0230	9.8	0.0146	1.4	0.0058	0.5	0.0034

percentage of acceptance regarding the beneficial influence of water on the psychology of the people (42.9 % replied very much and 26.4 % much) Finally the quality of life is important for the local population of a city or a village with lake or river nearby and its improvement is a challenge for the further development of the area (Tsiadikoudis et al. 2012). Finally on the question if the inhabitants are satisfied from the quality of life in their area 32.1 % said very much and 33.1 % much.

Negative aspects of the lake

Lakes do not only influence the lives of those who live in the nearby areas positively but negatively, too (Tsiadikoudis et al. 2012). Therefore, Pamvotida lake may often be the source of pollution or reproduction of mosqitoes or undesirable scents. The lake may also contribute negatively to the microclima of the area (by increasing humidity) and may also contstitute an additional danger for small children. So, regarding the question if the lake constitutes a negative contribution for the city of Ioaninna the effect of the microclima, especially humidity, is the most important problem for the inhabitants (29.0 % replied very much and 26.4 % much) (Table 2).

The negative contribution of the reproduction of mosquitoes seems to be another important problem for the residents (21.6 % answered very much and 21.1 % much). Other negative contributions are: the lake as a source of pollution for their area (14.1 % very much and 20.1 % much) and reproduction of undesirable scents (13.1 % very much and 19.9 % much). Less important is the lake as a danger for the children (36.5 % little and 23.5 % not at all).

The impact of the lake on the quality of life of the inhabitants

Water constitutes one of the most important attributes of the environment which influences the demand for houses and in this way is increasing their market value In the Netherlands such an increase may fluctuate from 12–18 % (Luttik 2000). On the question how much extra money the inhabitants of Ioannina would give in order to buy a house with a view to the lake 37.6 % (s_p=0.0237) would give from 0–20 % extra, 23.3 % (s_p=0.0207) 21–40 %, 9.4 % (s_p=0.0143) 41–60 %, 5 % (s_p=0.0107) from 61–80 %, 3.1 % (s_p=0.0085) 81–100 % and 2.2 % (s_p=0.0071) more than 100 % while the same percentage applies to those who did not give an answer. Finally, 17.3 % (s_p=0.0185) of the inhabitants replied that they would not give any extra money for a house with a view to the lake (Fig. 4).

Quality of life is multidimensional inconstruct including physical, emotional, mental, social, and behavioural components (Janse et al 2004). The recognition of the relationship between quality of life and environmental problems is a recent phenomenon in contemporary literature. The human sciences and environmental sociology in particular have only recognized an intimate relationship between these two themes. This has probably come about because of the effects that environmental degradation has imposed on the lives of populations in different regions of the planet (Seixas et al. 2012). Studies also show that improvements in the quality of life are intimately related with the creation of sustainable economic activities and the real participation of the local population in decision making processes (Pacione 2003, Seixas et al. 2012).

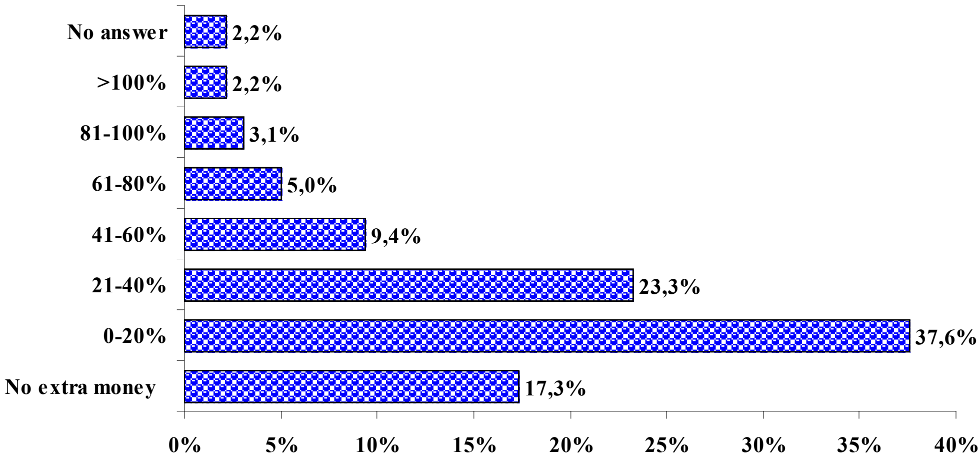

Fig. 4. Resident's view about extra money given for a house with view to the lake.

Lakes have often been characterized as the eyes of landscape. They can provide a spiritual value to those who want to look deep inside themselves (Klessig 2001).

The issue quality of life constitutes an important factor for the local population of an area. Improving the quality of life of the population, for purposes of further development of the area these people live in, is something which is certainly considered a challenge. Regarding the general question if the inhabitants are satisfied from the quality of life in their area the answers are the following: 16.3 % (s_p=0.0181) declared absolutely satisfied and (51.6 %, s_p=0.0245) very satisfied. 27.6 % (s_p=0.0219) said they were a little satisfied while 4.3 % (s_p=0.0100) declared not at all satisfied. Finally, 0.2 % (s_p=0.0024) of the inhabitants did not give an answer (Fig. 5).

Opportunities for work are especially important for young people and constitute decisive factors for the young to remain in their home land. Possible failure regarding exploitation of these opportunities for the completion of the necessary infrastructure of an area constitutes a real danger which could lead to isolation and social decay. From this research we concluded that 53.5 % (s_p=0.0244) of the inhabitants believe that their area provides sufficient incentive and is capable of creating the pre-requisites for the young to stay in the area. On the other side, 35 % (s_p=0.0234) believe that there are not enough choices and for this reason the young cannot remain in the area. 11.5 %, (s_p=0.0156) of the inhabitants declared that they do not have a clear opinion on this issue.

Participation, regular meetings and effective discussions between inhabitants and the various departments of the municipality of Ioannina constitute a first step so that each side can learn from the other which could then have a positive impact on the development of the area. This is so because the principles of democracy could be better applied if decision making processes were to take place via dialogue with all interested parties. Therefore, on the question if the inhabitants follow

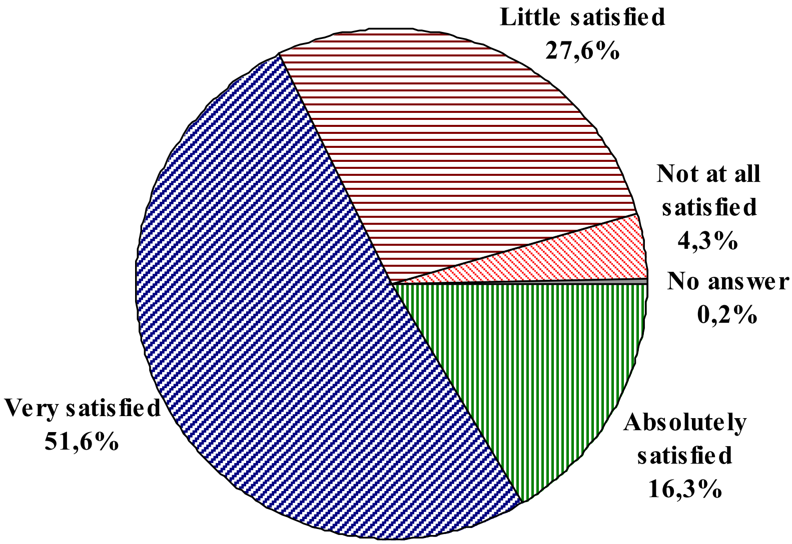

Fig. 5. Satisfaction of the population regarding quality of life.

public affairs in their area (46 %, s_p=0.0244) of those asked replied positively and are willing to participate in the processes and events with regard to their municipality, while 40.5 % (s_p=0.0240) of the inhabitants were negative regarding the issue of their participation. It is worth noting that 13.4 % (s_p=0.0167) of the inhabitants had not formed an opinion on this issue.

Environmental programs can give knowledge to the people who attend them but also make them more sensitive on environmental issues. Environmental programs for the protection of the lake could constitute an important factor and incentive for the citizens of Ioannina 68.1 % (s_p=0.0228) of whom have never been involved in such programs. 23.3 % (s_p=0.0206) have had experience with some environmental program while 8.6 % (s_p=0.0140) did not express a view.

Interest for voluntary participation in a lake protection program, e.g. cleaning the lake from garbage etc., is particularly high and this is an optimistic message for the lake and the area near it, since 73.9 % (s_p=0.0215) of the inhabitants would involve themselves with such a program if such opportunity presented itself. 16.1 % (s_p=0.0180) said they would not take part in such activities and 10.1 % (s_p=0.0146) did not give an answer (Fig. 6).

Before the application of loglinear analysis it was tested that there is no problem with low expected frequencies. Applying hierarchical loglinear analysis, after the removal of the correlation term of fourth and third class, it was established that the most appropriate model was the one which includes the impact and the interaction of the variables in pairs. We have

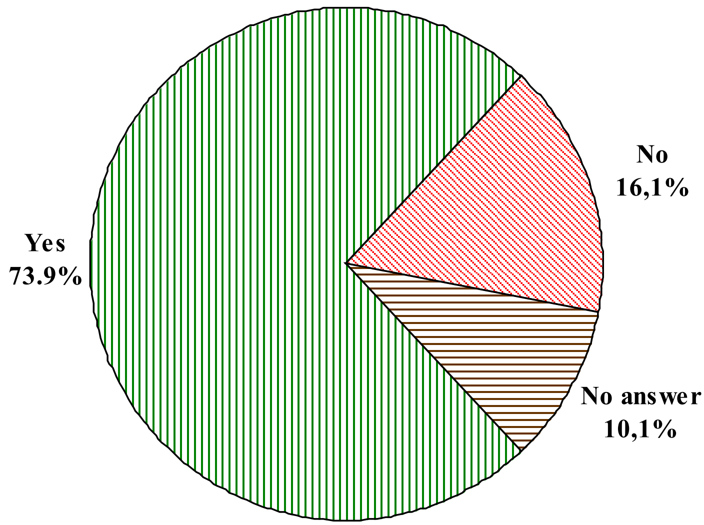

Fig. 6. Opinion given about voluntary participation in a lake protection program.

erase interaction per 4 and 3 criteria, because the X^2 for the Pearson test is 4.021 with probability p=0.855 and because the X^2 likelihood ratio is 4.264 with probability p=0.833. The above are confirmed by the "null" controls for the interaction of k terms and terms of higher degree, as well as the "null" controls for the interaction of k terms (Norusis 1994). As shown in Table 3, there exists no interaction per 4 criteria

Table 3. Nullity tests.

k	*df*	$L{\cdot}R{\cdot}X^2$	Probability	Pearson X^2	Probability	Iteration
Tests that *k*-way and higher order effects are zero						
4	1	0.053	0.8180	0.053	0.8180	3
3	5	2684.000	0.7490	263.400	0.7560	3
2	11	39832.000	0.0000	42.109	0.0000	2
1	15	302438.000	0.0000	357.154	0.0000	0
Tests that *k*-way effects are zero						
1	4	262606.000	0.0000	315.045	0.0000	0
2	6	37148.000	0.0000	39.475	0.0000	0
3	4	2631.000	0.6210	2.581	0.6300	0
4	1	0.053	0.8180	0.053	0.8180	0

k – the number of effects being zero; *df* – degrees of freedom.

because the value of probability p=0.8180. In addition, there exists no interaction per 3 criteria because the value of probability p=0.6300. However, there exists interaction per 2 criteria because the probability p<0.05. Indeed, regarding the three pairs of variables "following the public affairs of the municipality" – "voluntary participation in a program of lake protection", "following the public affairs of the municipality" – "age" and "quality of life" – "voluntary participation in a program of lake protection" there is significant statistical interaction.

Table 4. Table of cross tabulation of the variables "following the public affairs of the municipality" and "voluntary participation in a program of lake protection".

Following the public affairs of the municipality	Indicator	Voluntary participation in a program		Total
		Yes	No or they did not answer	
Yes	Count	157	35	192
	Expected count	141.8	50.2	192
	Residual	15.2	–15.2	
No or they did not answer	Count	151	74	225
	Expected count	166.2	58.8	225
	Residual	–15.2	15.2	
Total	Count	308	109	417
	Expected count	308	109	417

In order to interpret the interactions, we should first present all the data in the form of three-dimensional tables (Crosstabs). Through the aid of Table 4 we see that the inhabitants of the city of Ioannina who follow the public affairs of their municipality are positive on the issue of their participation in lake protection programs, while those who declare that they do not participate in public affairs or do not answer, are negative or do not provide an answer regarding their participation in lake protection programs.

Through the aid of Table 5 we see that the inhabitants who follow the public affairs of their municipality are more than 30 years old, while those who declare that they do not participate in the public affairs of their municipality or who do not give an answer are 18–30 years old.

Finally, we see (Table 6) that the inhabitants who declare fully or very

Table 5. Table of cross tabulation of the variables "following the public affairs of the municipality" and "age".

Following the public affairs of the municipality	Indicator	Age, years		Total
		18–30	>30	
Yes	Count	33	159	192
	Expected count	48.8	143.2	192
	Residual	–15.8	15.8	
No or they did not answer	Count	73	152	225
	Expected count	57.2	167.8	225
	Residual	15.8	–15.8	
Total	Count	106	311	417
	Expected count	106	311	417

Table 6. Table of cross tabulation of the variables "quality of life" and "voluntary participation in a program of lake protection".

Quality of life	Indicator	Voluntary participation in a program		Total
		Yes	No or they did not answer	
Fully satisfied – very satisfied	Count	223	60	283
	Expected count	208.8	74.2	283
	Residual	14.2	–14.2	
Satisfied – not at all satisfied	Count	84	49	133
	Expected count	98.2	34.8	133
	Residual	–14.2	14.2	
Total	Count	307	109	416
	Expected count	307	109	416

satisfied from the quality of their life are positive regarding the issue of their participation in programs related to the protection of the lake, while those who declare that they are satisfied or not at all satisfied are negative or they do not give an answer regarding their participation in programs of lake protection.

Demographic attributes

The demographic attributes of the people who participated in the research are given in (Table 7).

Conclusions – Discussion

Lake Pamvotida constitutes an inseparable part of the city of Ionnina and of the life of the people who live there.

The human factor has affected the city negatively. It is only in the recent years that the proper attention was given to the problems created and to efforts to deal with these problems. The ignorance of the inhabitants of Ioannina regarding the negative consequences which were to follow as well as their greed for more arable land led to the draining of the Lapsistas. The consequences from this ecological destruction are obvious even today. The impact on the flora and fauna of the ecosystem was a negative one and the quality of the lake·s water was degraded. This happened because some underground tunnels closed which, in turn, prevented the renewal of the lake's waters.

The role of the lake was always important for the inhabitants of the area and it is for this reason that its uses are many which means that they include recreation, water sports, tourism, etc. In addition, the lake is encroached both by local bodies and by individuals who engage in activities around the lake. The result is the deterioration of the lake through time. The human factor is responsible for the increase of the pollutants which enter the lake and which worsen significantly the phenomenon of eutrophication. The reduction of the level and body of water as well as the non-renewal of its waters make necessary the enrichment of the lake with water. However, no action has been taken in order to deal with the problem.

We must point out that the lake has many problems and many drastic measures should be taken for the restoration

Table 7. Socio-demographic profile of the inhabitants of the city of Ioaninna.

1. Gender					
Male	Female				
49.9 % (s_p =0.0245)	50.1 % (s_p=0.0245)				
2. Age					
18–30 years	31–40 years	41–50 years	>50 years		
25.4 % (s_p=0.0213)	29.7 % (s_p=0,0224)	24.2 % (s_p=0,0210)	20.6 % (s_p=0,0198)		
3. Marital status					
unmarried	married	divorced	widowed	did not answer the question	
39.3 % (s_p=0.0239)	53.5 % (s_p=0.0244)	4.6 % (s_p=0.0102)	1.7 % (s_p=0.0063)	1.0 % (s_p=0.0048)	
4. Childhood					
without children	one child	two children	three children	more than three children	
48.2 % (s_p=0.0245)	12.2 % (s_p=0.0160)	28.1 % (s_p=0.0220)	7.9 % (s_p=0.0132)	3.6 % (s_p=0.0091)	
5. Educational level					
primary school	lower secondary school	technical school	upper secondary school	technological education	university
7.7 % (s_p=0.0130)	9.8 % (s_p=0.0146)	7.2 % (s_p=0.0127)	40.3 % (s_p=0.0240)	14.4 % (s_p=0.0172)	19.9 % (s_p=0.0196)
6. Profession					
private employee	public servants	self-employed	students	unemployed	housewives
27.6 % (s_p=0.0219)	19.2 % (s_p=0.0193)	16.8 % (s_p=0.0183)	8.9 % (s_p=0.0139)	7.2 % (s_p=0.0127)	7.4 % (s_p=0.0128)
farmers or stock-breeders		pensioners		did not answer the question	
5.0 % (s_p=0.0107)		5.8 % (s_p=0.0114)		2.2 % (s_p=0.0071)	
7. Annual income					
<5,000 euro	5,000–10,000 euro	10,001–20,000 euro	20,001–30,000 euro	>30,000 euro	no answer
6.7 % (s_p=0.0123)	9.4 % (s_p=0.0136)	27.1 % (s_p=0.0218)	19.4 % (s_p=0.0194)	8.4 % (s_p=0.0143)	29.0 % (s_p=0.0222)

of the lake. Taking into account the answers given by those asked we are led to some important conclusions.

The majority of the inhabitants claim that the lake plays an important role in their lives since the mere presence of the lake is important for the improvement of their psychology. This is something which is also proved by their desire to give more money for the purpose of buying a house with a view to the lake. In addition, Pamvotida contributes positively to the aesthetics of the city and provides opportunities for recreation and sport. Everybody agrees that the inhabitants are satisfied from the quality of life in their area something which is confirmed by them admitting that there are many opportunities and incentives which can create prerequisites for the young to stay home.

Despite all this an important percentage of the inhabitants thought that there was a need for stronger support regarding opportunities for work in the area.

On the one hand a big part of the inhabitants declares that it participates and follows the public affairs of their area and on the other hand another big part of the inhabitants replied that it has never participated in an environmental program. However, the fact that there is a large percentage of people who would participate voluntarily in an environmental protection program is encouraging. The large percentage of abstinence regarding the question on problems facing the area is particularly worrying since it shows ignorance on behalf of the inhabitants and inertia for taking measures for solving these problems. Indeed, the inhabitants who are positive regarding their participation in environmental protection programs are the ones who follow the public affairs of their municipality and declare fully or very satisfied from the quality of their life.

The participation of the citizens in environmental decision making processes mainly refers to decisions the results of which can in some way affect the local community. The participation of the public includes the right of the local society to information and access to decision making processes. The education and sensitization of citizens to issues of social, cultural and environmental sustainability is one more important factor for the development of sustainable societies and by extension of sustainable tourism (McNeely 1994).

Many studies view the preservation of water and natural resources as a result of minimal influence of human activity, but only a small percentage of studies has considered including population as a dynamic force which can shape and sustain an environment which helps the coming generations with a healthier future (Lassen and Panagopoulos 2008).

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FORESTRY IDEAS, 2013, vol. 19, No 1 (45): 19–26

APPLICATION POSSIBILITIES OF DOUGLAS-FIR IN EROSION CONTROL

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Received: 06 February 2013 Accepted: 11 March 2013

Abstract

Erosion should be controlled with the programme of the National Strategy, which includes the use of biotechnology and afforestation. Protective afforestation should primarily provide quick establishment of plantation canopy. This prevents the direct influence of erosion agents on land surface. The establishment of forest canopy simultaneously results in the establishment of full hydrological function of forests, by reducing the probability of occurrence of surface runoff and extending the period of water concentration from the basin to the channel. Douglas-fir, as a fast-growing species, meets all requirements, which should be met by a species used in protective afforestation. Different Douglas-fir provenances under the same site and stand conditions in Serbia do not use the habitat production potential in the same way, i.e. the rates of canopy establishment are not the same in all Douglas-fir provenances. This means that the rate of establishing the protection and hydrological functions of Douglas-fir plantations depends largely on the provenance. In order to test the potential of fast-growing conifer Douglas-fir, experimental fields of this tree species were founded in Serbia. The test represented a variety of provenance from the natural range in North America. The insufficient research and the lack of reliability in the introduced tree species result in the fact that exotic species are rarely applied in such circumstances, for fear of their difficult adaptation to the changes of site conditions. To be able to meet the demands, the planting material should be: adequately chosen, correctly selected species at the level of the provenance, capable of providing the long-term stabilization of degradation processes, reproductively invasive, widely adaptive, with developed root system, more effective, less expensive and, of course, popular in the market. The paper presents the results of long term investigations of Douglas-fir value for erosion control in Serbia.

Key words: Douglas-fir, introduction, provenances, erosion control.

Introduction

It is widely accepted that soil erosion under forests is much less than under other forms of vegetation cover such as pasture, as trees have deeper stronger root systems (Knowles 2006).

Douglas-fir [*Pseudotsuga menziesi* (Mirb.) Franco], which originates from North America, is the most frequently introduced species in Europe and New Zealand, one of the most important and most quality conifers (Little 1979, Bradley et al. 2005). Germany is the leading country in the percentage of the introduction, establishment of the plantations and number of researches, followed by France and New Zealand (where Douglas-fir is the second most common conifer, and *Pinus radiata* D.Don is the most common). The introduced species have to prove by their high quality that they were rightly introduced. Douglas-fir is the fast-growing, easily adaptable conifer, since it thrives on the degraded sites and meets the advertising requirements of the market. Douglas-fir is very important for the erosion control, but it is rarely used owning to the insufficient knowledge on species' biology and poor selection of the provenance. Douglas-fir is the tree which can be very efficiently used as the windbreak on the adaptable site, and it is the excellent species for the regeneration of eroded soil, watershed management, and mine soil reclamation (USDA-NRCS 2002). The value of the vegetation and reforestation in the erosion control is reflected in the long-term stabilization of the area. If the autochthonous species cannot meet the requirements of the protection programme, they can be very effectively replaced by the fast-growing species, which are ecologically adaptable. However, best results are achieved if in the first phase introduced species are combined with autochthonous ones, since the associations of Douglas-fir and broadleaved and conifer species are very effective.

Douglas-fir provenance in test plantations are subject to long-term research in Serbia in many aspects: ecological adaptation, erosion control, anatomy, physiology, dendrometry ... (Lavadinović et al. 2001, 2011a, 2011b; Lavadinović and Isajev 2005).

In Serbia, judging from the multiannual researches conducted by Miletić (2004), on the open pit mines of the Mining-Energy-Industrial Complex "Kolubara", the effect of the Douglas-fir monoplantations on the mine soil characteristics was much better than the effect of other conifer plantations. The dense canopy, which is formed by this mesophilic species, completely provides the hydrological and protective functions of the forest, and Douglas-fir litter fall has a favourable effect on the fertility and productivity of the mine soil. Also, as a result of the decomposition of its litter fall, the characteristics of the mine soil on which the erodibility, i.e. the ability of soil to resist the eroding agents, improve. The humus content and stability of the microstructural aggregates increase, which during the occurrence of the surface runoff prevents the mobility of the soil substances and their transformation into the suspension. On the clay mine soil in the differential soil porosity, under the influence of Douglas-fir, the percent of the coarse gravitation pores increases. As a result, the infiltration of precipitated water in the soil is accelerated and there is less likelihood of the occurrence of the surface runoff.

The influence of the Douglas-fir plantations of soil characteristics, upon which its ability to resist the eroding agents depends, is conditioned by the initial soil characteristics, prior to the reforestation by this species. In addition, the intensity of the influence of the Douglas-fir on the soil depends on the general site conditions, which determine the conditions for the activity of the soil microorganisms and rate of the decomposition of the soil organic litter. The chemical nature of the products of decomposition, which affect the soil, also depends on the site conditions and type of the saprophytic microorganisms which decompose the nutrients.

Thirty years after the substitution of mountain beech forests in Jelova gora, Douglas-fir did not cause the important changes in the soil, i.e. the erodibility under Douglas-fir plantations was similar as under the original beech forests (Miletić et al. 2003). Nevertheless, on Hungarian and Turkey oak sites with hornbeam in Bogovaća under Douglas-fir plantation somewhat greater soil erodibility than under the original forest was reported (Miletić et al. 2010).

Douglas-fir adapts to the wide range of soil types and structures, but it thrives best on the soil of clay and powdery texture (Washington State University. 1979). The depth of soils, on which it adapts best, ranges from very shallow on the steep slopes and ridges to the deep colluvial sediments. The variance *menziesii* thrives best on the well-aerated (loose) deep soils, with the pH values from 5 to 6.

Douglas-fir is characterised by the great horizontal range on its natural site (Campbell 1979). Generally speaking, variety *glauca* is located at much higher altitudes than the sea variance at the respective latitudes. The altitudinal limit of Douglas-fir in central British Columbia is 760 meters above the sea level, whereas it is located at 1250 meters above the sea level in the Vancouver Island. In Washington and Oregon, this species generally ranges from the sea level up to 1520 meters, but it can occupy much higher altitudes at some places. In South Oregon Cascades and Sierra Nevada, the altitudinal zone ranges from 610 to 830 meters. In river valleys and canyons, this species is mainly located at altitudes ranging from 240 to 270 meters.

At the border southern parts of the altitudinal zone in Sierra Nevada, this species is located at 2,300 meters above the sea level. The continental variance is located at altitudes ranging from 550 to 2,400 in the northern part of the zone. In the central part of the Rocky Mountains, Douglas-fir is mainly found at the altitudes ranging from 1830 to 2590 meters, and in the southern Rocky Mountains at the altitudes ranging from 2440 to 2900 meters. At some sites of south and central Arizona, Douglas-fir can be found in the canyons, located at 1550 meters. The highest altitude where Douglas-fir grows in the Rocky Mountains is at 3260 meters, on the ridge of Graham Mountain in southeastern Arizona (Hermann1985, 1987).

The high adaptability of Douglas fir to the different soil and bedrock is also the result of the well-developed root system. Although Douglas-fir is a species with deep root system, its root morphologically varies, depending on the type of the bedrock and soil. If there are no obstacles, Douglas-fir first forms taproot, which enables the fast growth in the early youth. It was reported that on the deep soils (from 69 to 135 cm) the root system reaches about 50 % of its final depth, over first 3 to 5 years, and even 90 %, from the age of 6 to the age of 8. However, rocks or hard bedrock on the soil surface leads to the fast proliferation (extension) of the original taproot. When Douglas-fir develops on the shallow or extremely wet soils, the plate-shaped root system is developed.

Material and Method

Erosion is the gradual wearing away of the land surface as a result of uncontrolled wind and water energy. Sedimentation is the result of transport and delivery of eroded soil particles, deposited at some point. Erosion and sediment control is a complex interaction of soils, engineering water management, agronomic and horticultural practices (Gaffney and Dickerson 2005).

The protective function of forest is reflected in the decrease of erodibility of the eroding agents, i.e. in the reduction of their mobility and ability to move the soil material. In the case of pluvial erosion, this function is performed by the vegetation canopy (Djorović et al. 2003). Douglas-fir is mesophilic species of the very dense canopy and the closed plantations completely provide the protective function. The rate of the canopy formation is crucial for the fast reduction of the effects of eroding agents on the soil and on the decrease of their erodibility. Height, as the element of estimation of forests, is the most reliable indicator of the effectiveness of the species on certain site, as well as of the rate of the canopy formation. In order to test the adaptability and ecological capability of the introduced species, two provenance tests in central and eastern Serbia were set. The sample plot “Juhor” is located in the management unit “Juhor I” of the forest district Jagodina, between 660 and 700 meters above the sea level.

The sample plot in Juhor is located in the association of mountain beech (Ass. *Fagetum submontanum* Rud.) on acidic brown soil.

Sample plot Tanda is in the management unit Stol of the forest district Bor, on the site of Hungarian oak and Turkey oak (*Quercetum frainetto-cerris* Rud.).

The material for the experiment originates from the collection of seeds from 27 Douglas-fir provenances collected by the Centre for Forest Seed in Georgia (USA) from the entire natural area of the species (Table 1).

At the age of fifteen, in the provenance test, plant heights were measured as indicator of the rate of canopy formation and protective function of forests. Sample plot Tanda is located on the site of Hungarian oak and Turkey oak (*Quercetum frainetto-cerris* Rud.), at elevation of 370 m, south-east exposure.

Results of Research

At the age of fifteen, plantations of all provenances on both sample plots formed the dense canopy (0.9–1), and, thereby, completely provided the protective function of forest and decrease of the eroding agents on the soil. The height of trees of observed provenances reflects on the rate of canopy formation.

Average plant height of all provenances in Tanda is 4.00 m, standard deviation 0.94 m, and the coefficient of variation 23.5 %. Provenance 19 (Washington 204-09) has lowest height (2.11 m), and trees of provenance 31 (Washington 205-02) are the highest (5.47 m). There are significant differences between tree heights (Lavadinović and Isajev 2005).

Average plant height in all provenances on Juhor was 4.65 m, standard deviation 0.86 m, and coefficient of variation 18.5 %. The lowest height (2.82 m) was that of provenance 9 (Washington 204-07), and provenance 3 (Oregon 202-27) was the highest (5.58 m). There are significant differences in the attained heights between the provenances. (Lavadinović et al. 2001).

The measurement of height of Douglas-fir (at the age of fifteen) of different provenances, in the experiment in eastern and central Serbia, showed significant differences.

Mean height of Douglas-fir in Tanda varies from 2.11 m (prov. 19, Washington 204-09) to 5.47 m (prov. 31 Washington

205-02). Mean height is 4.00 m, standard deviation is 0.94 m, and the coefficient of variation 23.5 %.

Mean plant height in all provenances in Juhor varied between 2.82 m (provenance 9, Washington 204-07) and 5.58 m

Table 1. Geographic characteristics and plant height of tested Douglas-fir provenances.

Provenance		Our sign	Latitude, °	Longitude, °	Altitude, m	Plant height, m	
						Tanda	Juhor
Oregon	205-15	1	43.7	123.0	750	3.90	5.16
Oregon	205-14	2	43.8	122.5	1200	4.01	5.17
Oregon	202-27	3	45.0	122.4	450	4.81	5.58
Oregon	205-38	4	45.0	121.0	600	4.77	4.99
Oregon	204-34	6	45.0	121.0	1050	4.95	-*
Oregon	205-16	7	44.0	123.0	150	4.87	-*
Washington	205-31	8	48.8	121.5	450	4.93	-*
Washington	204-07	9	49.0	119.0	1200	2.53	2.82
Oregon	205-13	10	43.8	122.5	1050	4.20	5.06
Oregon	205-18	11	44.2	122.2	600	4.63	5.24
Oregon	202-22	12	42.5	122.5	1200	3.91	4.72
Oregon	202-21	14	42.4	123.7	300	3.99	-*
Washington	202-17	15	47.6	121.7	600	4.31	5.16
Oregon	201-10	16	44.5	119.0	1350	2.98	3.53
Washington	204-06	17	49.0	120.0	750	2.82	3.48
Oregon	202-19	18	45.3	123.8	300	4.84	5.37
Washington	204-09	19	49.0	119.3	900	2.11	-*
Oregon	205-11	20	45.0	123.0	150	4.75	5.10
Oregon	205-45	21	44.0	122.0	900	4.48	-*
Oregon	202-31	24	44.3	118.8	1500	2.39	2.86
Oregon	205-29	26	42.6	122.8	900	3.98	4.86
Oregon	205-08	27	42.7	122.5	1050	3.46	4.63
Oregon	205-22	28	45.0	121.0	750	4.49	-*
Oregon	204-18	29	44.5	119.0	1500	2.24	-*
Oregon	204-04	30	45.0	121.5	900	3.67	4.69
Washington	205-02	31	47.7	123.0	300	5.47	5.29
Oregon	205-17	32	44.0	124.0	450	4.59	-*

* Provenances which are not included in experiment on Juhor.

(provenance 3, Oregon 202-27). Mean height in all Douglas fir provenances was 4.65 m, standard deviation 0.86 m, and coefficient of variation 18.5 %. It is interesting that the height of 50 % of the provenances is greater than 5.00 m.

Based on the observed heights on both sites, provenances 31 (Washington 205-02) in Tanda and provenance 3 (Oregon 202-27) in Juhor can be singled out as promising ones.

Almost all studied provenances on mountain beech site are characterized by faster growth, since at the age of fifteen they are higher than the provenances on the oak site in Tanda (Fig. 1). It implies that majority of studied Douglas fir provenances, used in the protective reforestation, is more favourable for the beech sites than for the oak ones.

The exception to the rule is the provenance Washington 205-02, which is higher on the oak site. As a result, it is more favourable for the protective reforestation on oak sites.

Conclusion

The key to successful afforestation is well and carefully selected plant material. The fast-growing species have the aims to connect complex forming soil structure and help to control erosion of endangered habitats. The goal of the introduced fast-growing species is to "occupy" habitat and stop erosion process in short term.

A combination of superior wood quality and high productivity has made Douglas-

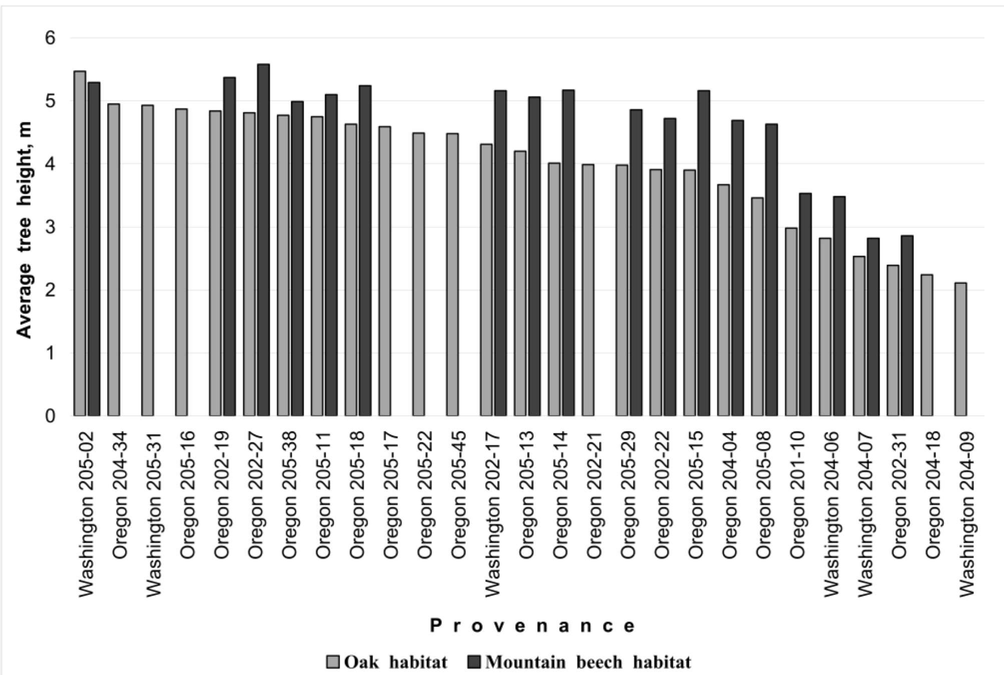

Fig. 1. Height of tested Douglas-fir provenances.

fir [*Pseudotsuga menziesii* (Mirb.) Franco] one of the premier timber trees in the world (Hermann and Lavender 1999).

Douglas-fir is the fast-growing species, whose plantations form complete canopy shortly after reforestation and thereby decrease the erodibility of the eroding agents.

Plant height is one of the reliable dendrometric parameters for assessing the productivity of provenances.

The mean height of the tree of studied provenances of the same age reflects on the rate of growth and canopy formation, thereby the rate of the establishment of protective and hydrological functions of the forest. Almost all studied provenances on beech site (*Fagetum submontanum* Rud.) establish the protective and hydrological functions of the forest faster than the forests on oak site (*Quercetum frainetto-cerris* Rud.).

In contrast to the influences on the decrease of the erodibility of the eroding agents, which is completely reflected in the canopy formation, the influence of Douglas-fir on soil erodibility can vary to a great extent. It depends on the general site conditions, and mainly from the initial characteristics of the soil, before reforestation. Genecological variations, which are most often reflected in the introduced material, as the modification variability of the quantitative and qualitative characteristics, are the result of interactions between introduced material and environmental conditions, in the place where the transfer was made. The range of variation of characteristics are conditioned by climate, edaphic and coenological characteristics of the sites to which the trees are introduced, as well as by the influence of altitude and geographic co-ordinates of the original origin of the population, from which the introduced material originates. The possibilities and future directions of the intensive use of introduced material depend on the knowledge on the interaction of the above mentioned elements. The results obtained by this paper contribute to:

Determination of the ecological parameters, which are important for the selection of Douglas-fir provenances for its transfer from North America to the sites in Serbia;

Gaining knowledge on the range of variation of economically important quantitative characteristics, as the selection criterion for the ranking of adaptive and productive provenances for growing in Serbia;

Reliable selection of Douglas-fir provenances for its directed use in Serbia during the establishment of special purpose plantations, in the erosion control activities.

Douglas-fir is an excellent tree species for restoring eroded lands, watershed management, and strip-mined areas reclamation.

Acknowledgment

This paper was realized as a part of the project "The development of technological processes in forestry in order to realize the optimal forest cover" (TR31070) financed by the Ministry of Education and Science of the Republic of Serbia within the framework of integrated and interdisciplinary research for the period 2011–2014.

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FORESTRY IDEAS, 2013, vol. 19, No 1 (45): 27–40

EFFECT OF HIGH-INTENSITY DIRECTED FIRE IN DIFFERENT SEASONS ON SURVIVAL AND SPROUTING OF ROYAL PAULOWNIA (*PAULOWNIA TOMENTOSA* (THUNB.) STEUD.)

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Received: 20 December 2012 Accepted: 30 March 2013

Abstract

Invasive plant species are widely recognized as a serious environmental threat. They can cause local extinction or a vast decline in some native species populations by increasing competition and through modifications of their habitat. The currently used control measures commonly involve herbicides that can be toxic to other plants, people, and wildlife. Some of the undesired side effects include reduction of nutrients to non-target species, mortality in tadpoles, deformation of fish, and reduced fertility and sexual development in frogs. There is a need for new methods for invasive species removal that do not use herbicides, but whose efficiency is similar to that of herbicide-based techniques. In this study we tested the effectiveness of high-intensity fire directed at the base of the stem. We used external fuel source and applied the fire to royal paulownia trees to examine the effects of tree diameter, length of time of fire application, and season of application. Overall, greatest mortality occurred when the studied treatments were applied in the summer and when the exposure to fire continued for 30 s in diameters from 3.8 cm to 20.1 cm and for 60 s in diameters from 20.2 cm to 68.6 cm. The season of burning had no effect on sprouting. Post-burn sprouting was greater following longer fire exposure. Additional treatment of the sprouts may be necessary using this or other methods. Nevertheless, the percent of trees that sprouted was relatively low. The tested treatment can be scaled up and its cost decreased by employing already available flaming equipment currently used in agriculture.

Key words: invasive**,** *Paulownia tomentosa*, mortality, sprouting, burn.

Introduction

Most non-native species are often brought into new habitats for forage or for ornamental purposes, while others are brought accidently (Miller 2003). Some non-native species can become invasive in the absence of their main natural predators. This results in greater survival of the invasive species than the indigenous species. Non-native invasive woody species are of growing concern because of the negative impact they have on ecosystems including hindering forest use and management, and reduction of biodiversity and wildlife habitat (Burton et al. 2005). Control of non-native species is often needed in order to restore indigenous species.

Invasive species rank second, after habitat destruction, as a threat to biodiversity of imperiled groups of plants, mammals, invertebrates, fish, reptiles, and amphibians (Wilcove et al. 1998). Other threats include overharvest, pollution, and diseases. Not only do invasive species pose a threat to biodiversity and increase competition, but they are also expensive to control once established. The detrimental effects from invasive species are estimated to cost \$138 billion·year^{-1} in the United States (Pimentel et al. 1999). There is no direct way to assign monetary value to all the negative effects such as extinctions, losses in biodiversity, ecosystem services, and aesthetics, so the above cost estimate is rather conservative.

There are numerous management techniques for control of unwanted woody species which include herbicide use, mechanical control, prescribed fire, grazing, biological control, and soil solarization (Green and Newell 1982, Hartman and McCarthy 2004, Miller 2003, Tu et al. 2001). Each control method has advantages, but also disadvantages, e.g., there may be risks for damage to non-target species, or the method may be time consuming, labor intensive, or expensive to apply. Herbicide use, prescribed fire, and mechanical control are among the most common control methods.

The average yearly amounts of herbicide used in forestry over a period of a rotation are much smaller than in agriculture. Nevertheless, some herbicides have a number of negative effects on other plants, humans, and wildlife (Neumann et al. 2006, Acquavella et al. 2004). Herbicide application is also less desirable in valuable natural areas (Groves 1989).

Some of the commonly used herbicides in forestry have been glyphosate formulations commercialized as Roundup® by the Monsanto Company. Next we examine some of the issues with this widely used and relatively well studied herbicide.

The active ingredients of Roundup® have been detected in urine of applicators whether or not prevention was taken to minimize herbicidal contact (Acquavella et al. 2004). Glyphosate is also frequently found in non-target plant species after application (Neumann et al. 2006). The glyphosate overspray can reach the rhizosphere where it can reduce a non-target species ability to adequately absorb nutrients. In addition, glyphosate can be harmful to microorganisms and animals as well (Neumann et al. 2006).

Evidence for toxicity of the Roundup® formulations has been accumulating in the literature for over a decade. The toxicity of the active ingredient and especially of the inactive ingredients, adjuvants, and surfactants are now well known and documented (Peluso et al. 1998). Research demonstrated that Roundup® induced a dose-dependent formation of DNA adducts (a complex that forms when a chemical binds to the DNA) in the kidneys and liver of mice (Peluso et al. 1998). The formation of such adducts in the organs is considered damage to the DNA. The DNA adducts were related to some unknown compound in the mixture rather than to the active ingredient, isopropylammonium salt of glyphosate.

A study on a coastal microbial community showed that Roundup® modifies natural coastal microbial communities of prokaryotes and some pico-eukaryotes after a 7-day exposure (Stachowski-Haberkorn et al. 2008). Relyea (2005) showed that Roundup® and its surfactant Polyoxiethyleneamine (POEA) affect amphibians causing high mortality rates. Within three weeks, 98 % of tadpoles were killed, and within 24 hours 79 % of juvenile frogs and toads were killed. Roundup® starts to affect young and adult tilapia after approximately 96 hours of exposure (Jiraungkoorskul et al. 2002). The fish gills were found to have filament cell proliferation (a chain-like series of cells increasing at a fast rate), lamellar cell hyperplasia (abnormal increase of cells in the scale layer), and aneurysm. Kidney lesions consisted of dilation of Bowman's space and buildup of hyaline droplets in the tubular epithelial cells. This study showed clearly that the presence of Roundup® causes degenerative formation of organs in fish.

Roundup® also disrupts the expression of the steroidogenic acute regulatory (StAR) protein, inhibits steroidogenesis, and causes decrease in progesterone production (Walsh et al. 2000). Progesterone is a hormone involved in pregnancy (by supporting gestation) and in embryogenesis of animal species and humans. Therefore, Roundup® can impact fertility in wildlife and humans. Work by Paganelli et al. (2010) demonstrated that Glyphosate and Glyphosate based herbicides (GBH) impair the mechanisms needed for regulating early development in frog and chicken embryos when exposed at sub lethal levels, which leads to concerns about possible similar effects on human embryos.

Glyphosate is also toxic to human placental JEG3 cells and this toxicity was observed less than 18 hours after treatment (Richard et al. 2005). More importantly, this toxicity occurred at concentrations lower than the concentrations found in agricultural use. The observed toxic effect went up with the increases in concentration as well as in the presence of Roundup adjuvants.

The known negative effects for glyphosate-based herbicides listed above and the potential detrimental effects of less extensively studied herbicides create a need to consider other methods for control of invasive plants. Two widely used methods that do not rely of chemical applications are prescribed fire and mechanical control.

Some of the major disadvantages of implementing a prescribed burn are the impact on air quality and visibility, as well as possible lack of, or excess of, fuel on the forest floor. When fire has been suppressed for long and the fuel buildup is very large, a prescribed fire will burn too intensely and cause mortality in desired species (Stephens and Ruth 2005). It can indiscriminately kill non-target native species even at low intensity and often stimulates vigorous sprouting from the invasive species (Heffernan 1998). Prescribed burning requires a crew of qualified personnel, expensive equipment, construction of fire breaks, and can pose risk to property and human life, which raises liability and public concern (McCaffrey 2006).

Mechanical control methods are expensive, generally ineffective (Tu et al. 2001) and often disturb the soil (Evans et al. 2006). These methods of control have many advantages, but are often time consuming and not as effective when used without additional measures of control, such as herbicide application or burning (Miller 2003).

We explored a new and simple technique that poses minimal risk to the environment and may be effective at controlling the spread of invasive woody species. We examined the effectiveness of high-intensity fire directed at the base of the stem to kill and prevent stump resprouting. Unlike prescribed burning, this method requires one worker instead of a full crew, does not require the use of expensive fire control equipment, and can be applied anytime when there is no risk of starting a wildfire (i.e., during or soon after rain, snow, or when air humidity and fuel moisture are high). We used the method with the non-native (to North America) invasive plant species royal paulownia (P*aulownia tomentosa* (Thunb.) Sieb. & Zucc. ex Steud.). We investigated the effectiveness of the treatments when they are applied in different seasons (winter, spring, and summer), and we compared the effectiveness of the treatments for different lengths of exposure.

Materials and Methods

Species of study

Royal paulownia is a common invasive tree species in the eastern United States (Miller 2003). It is native of East Asia and belongs to the Scrophulariaceae family. It is fast growing and reaches heights of over 25 meters and diameters of over 70 cm. It is capable of growing up to 5.0 meters in one year, and reproduces from seeds, root sprouts (Bartlow et al. 1997), or stump sprouts (Miller 2003). Paulownia can invade a variety of different habitats including roadsides, cliffs, riparian areas, open woodlands, highway embankments, stream banks, forest edges, landslides, burned-over areas, rocky-outcroppings, mine spoils, old home sites, and other disturbed sites (Evans et al. 2006).

Royal paulownia was ranked as the twelfth most problematic invasive species by the National Environmental Research Park (Drake et al. 2003). Paulownia infestations occur in scattered and localized areas in managed forests, as well as in natural areas and parks (Alabama ... 2007). It is an undesirable species in forest management, it causes difficulty for establishing fire adapted species like Table Mountain pine (*Pinus pungens* Lamb.), because of paulownia's ability to quickly establish itself after a disturbance such as fire (Evans et al. 2006).

The species is widespread in part because it produces an abundance of seeds (Drake et al. 2003), estimated to be up to 20 million per plant (Remaley 2005), which are small, lightweight, and easily spread by wind or water. The seeds germinate quickly when in contact with mineral soil (Remaley 2005) and seeds remain viable in the soil for many years (McCarthy 2005). Paulownia's continued use as an ornamental, for wood production (Miller 2003), and mined land reclamation (Zhao-hua et al. 1986) has increased its opportunity to spread and outcompete native species.

Control methods used for paulownia include mostly herbicidal control using Arsenal AC® or a formulation of glyphosate applied by stem injection into the main stem of mature trees (Miller 2003). Prescribed fire has not been successful in the removal of this species (Evans et al. 2006).

Study site

The study site was at the Winfred Thomas Agricultural Research Station in Hazel Green, Alabama (34°53'51''N, 86°34'25''W). The elevation is 236 m. The paulownia trees were planted approximately 20 years ago as part of an agroforestry research project. The trees were planted in rows along with Tulip poplar (*Liriodendron tulipifera* L.), Red oak (*Quercus rubra* L.), and Pecan (*Carya illinoinensis* (Wangenh.) K. Koch).

Table 1. Paulownia treatment design.

Season and year of burn, replications	Diameter class, cm	Burn time, s
Control n=10	DBH ≤ 20.1	None
Control n=13	DBH ≥ 20.2	None
Winter 2010		
n=21	DBH ≤ 20.1	15
n=22	DBH ≤ 20.1	30
n=23	DBH ≥ 20.2	40
n=25	DBH ≥ 20.2	60
Spring 2010		
n=21	DBH ≤ 20.1	15
n=17	DBH ≤ 20.1	30
n=23	DBH ≥ 20.2	40
n=23	DBH ≥ 20.2	60
Summer 2010		
n=19	DBH ≤ 20.1	15
n=17	DBH ≤ 20.1	30
n=23	DBH ≥ 20.2	40
n=24	DBH ≥ 20.2	60

Experimental design and sampling

Two hundred fifty-eight royal paulownia trees were treated, while 23 trees served as the control. The 258 trees and the control trees were divided prior to treatment into two diameter classes (diameter at breast height (dbh) of 1.30 m above ground): 1) dbh between 3.8 and 20.1 cm and 2) dbh between 20.2 and 68.6 cm. Ten trees from the dbh ≤ 20.1 cm size class and 13 trees from the dbh ≥ 20.2 cm size class were randomly selected as controls and were left unburned (Table 1). In both diameter classes the trees were randomly selected to be burned during winter, spring, or summer. In the dbh ≤ 20.1 cm size class, 61 trees were randomly selected to be burned for 15 seconds and 56 trees for 30 seconds. In the dbh ≥ 20.2 cm size class, 69 trees were randomly selected to be burned for 40 seconds and 72 trees for 60 seconds. All trees were flagged and tagged with numbers for future identification. The fire was powered using a torch (Red Dragon, model VT 3-30 C 527.5 $MJ \cdot h^{-1}$) and a 7 kg propane tank. The burn time was recorded using a stopwatch. Treatments were applied in the winter (February and March) of 2010, spring (April and May) 2010, and summer (August) 2010. Mortality was examined and documented in the summer of 2011. All stump sprouts from the winter, spring, and summer 2010 burn were recorded in August of 2010, and examined again one year later.

Hypothesis and statistical analysis

Chi-square test was used to determine if there was a difference in mortality and sprouting among the seasons of treatments for each length of burning. It was also used to test the differences in mortality and sprouting among each treatment, including the control, regardless of season. We employed Bonferroni correction for multiple comparisons. Fisher’s Exact Test was used instead of Chi-square in instances when cells had a count of less than five. We considered results to be significant if p<0.1. The experimental design was a split plot design.

Results and Discussion

The mortality data that we collected in August of 2011, which was at least one full year after completion of burning in winter, spring, and summer of 2010, indicated that not all treatments were able to cause mortality in the experimental trees over the period of time that we examined (Table 2). There was no tree mortality among the trees from the control treatment, or among the trees from the small diameter class that were burned for 15 s, regardless of the season of burn (Table 2). Mortality did occur, however, as a result of the longer burn of 30 s in the small diameter class, as well as 40 s and 60 s in the larger diameter class. Greater mortality occurred in the small diameter trees after 30 s burn and in the large diameter trees after 60 s burn than in the control (p=0.035, p=0.005, respectively, Table 3).

However, the percent mortality after burning trees in the large diameter class for 40 s was not different from the percent mortality in the control (p=0.333, Table 3). When we combined the mortality data from all seasons, we found as expected that for the small diameter trees there was higher mortality after burning for 30 s than for 15 s, and for the large diameter trees there was higher mortality after burning for 60 s than 40 s (p<0.001 in both size cases, Table 3, Figure 1 and 2). The mortality after 30 s treatment was an average of 25 % and after 60 s treatment was an average of 31.9% (Table 3).

There was no difference in mortality

Table 2. Percent tree mortality ± standard error in August of 2011 for treatments applied in winter, spring, and summer of 2010.

Burn length, s for two size classes	Season of burn			Average
	Winter	Spring	Summer	
	Mortality, % ± standard error			
Small Diameter Class				
0	0.0±0.0	0.0±0.0	0.0±0.0	0.0
15	0.0±0.0	0.0±0.0	0.0±0.0	0.0
30	13.6±7.5	17.7±9.5	47.1±12.5	25.0
Large Diameter Class				
0	0.0±0.0	0.0±0.0	0.0±0.0	0.0
40	0.0±0.0	0.0±0.0	17.4±8.1	5.8
60	4.0±4.0	26.1±9.4	66.7±9.8	31.9

Table 3. Differences in the percent mortality of paulownia trees following burning the main stem for different lengths of time.

Pairwise treatment comparisons	Difference in mortality, %	*P*-value
Small Diameter Class		
Control vs. 15 s	0.0	N/A
*Control vs. 30 s	–25.0	0.035
15 s vs. 30 s	–25.0	<0.001
Large Diameter Class		
*Control vs. 40 s	–5.8	0.333
*Control vs. 60 s	–31.9	0.005
40 s vs. 60 s	–26.1	<0.001

* Indicates Fisher's Exact Test analysis. In all other comparisons Chi-square tests were used. We used Bonferroni correction for multiple comparisons.

between trees burned in the winter for 15 s and those burned for 30 s (*p*=0.233, Table 4). However, when the burn was carried out in the spring or summer, the 30 s burn resulted in greater mortality than the 15 s burn (*p*=0.081, *p*<0.001, respectively, Table 4). We observed similar results for the large diameter class, where burning for 40 s or 60 s in the winter resulted in the same percent mortality (*p*=1.000), but burning in the spring and summer resulted in greater mortality of the trees burned for 60 s than those burned for 40 s (*p*=0.022 and *p*=0.001, respectively, Table 4).

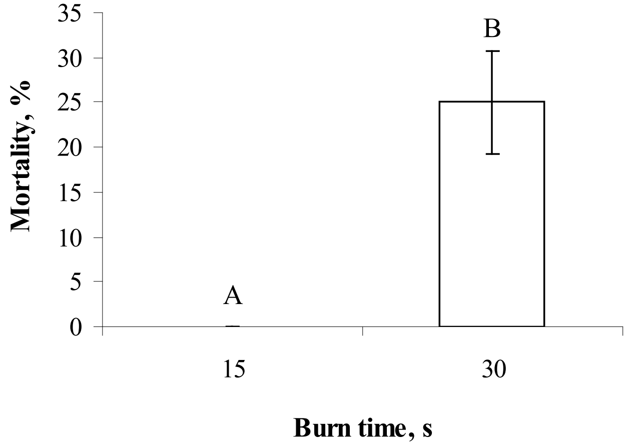

Fig. 1. Paulownia mean percent mortality and standard error in the small diameter class after a 15 s and 30 s burn. Different letters indicate significant difference at the *p*<0.1 level.

None of the trees died if they were burned for 15 s, regardless of the season of burn, so we did not look for a season effect (Table 5). Similarly, we did not compare the season effect on mortality of the trees burned for 40 s in the winter and spring, because no mortality was observed. There was no difference in percent mortality after burning for 30 s in the winter versus the spring (*p*=0.333, Table 5). However, there was a difference in percent tree mortality in each season for each of the other burn lengths. For the 60 s burn lengths, mortality after spring burn was greater than after winter burn. After the 40 s and 60 s burn lengths, mortality after summer burn was greater than after spring burn, and mortality after summer burn was greater than after winter burn.

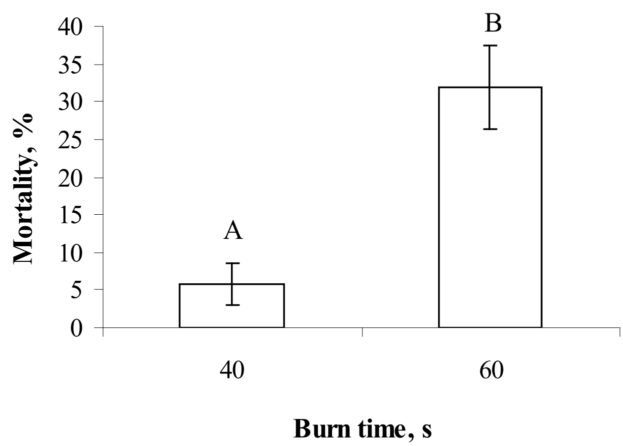

Fig. 2. Paulownia mean percent mortality and standard error in the large diameter class after a 40 s and 60 s burn. Different letters indicate significant difference at the *p*<0.1 level.

Table 4. Differences in the percent mortality of paulownia trees following burning the main stem for different lengths of time.

Size and season of treatment	Pairwise treatment comparisons	Difference in mortality, %	*P*-value
Small Diameter Class			
*Winter	15 s vs. 30 s	–13.6	0.233
*Spring	15 s vs. 30 s	–17.7	0.081
*Summer	15 s vs. 30 s	–47.1	<0.001
Large Diameter Class			
*Winter	40 s vs. 60 s	–4.0	1.000
*Spring	40 s vs. 60 s	–26.1	0.022
Summer	40 s vs. 60 s	–49.3	0.001

*Indicates Fisher's Exact Test analysis. In all other comparisons Chi-square tests was used.

Table 5. Differences in tree mortality following burning (comparison of the effect of season of burn).

Size and burn time, s	Pairwise season comparison	Difference in mortality, %	*P*-value
Small Diameter Class			
15	Winter vs. Spring	0.0	N/A
15	Winter vs .Summer	0.0	N/A
15	Spring vs. Summer	0.0	N/A
*30	Winter vs. Spring	–4.1	0.333
*30	Winter vs. Summer	–33.5	0.011
30	Spring vs. Summer	–29.4	0.022
Large Diameter Class			
40	Winter vs. Spring	0.0	N/A
*40	Winter vs. Summer	–17.4	0.036
*40	Spring vs. Summer	–17.4	0.036
*60	Winter vs. Spring	–22.1	0.015
60	Winter vs. Summer	–62.7	<0.001
60	Spring vs. Summer	–40.6	0.005

* Indicates Fisher's Exact Test analysis. In all other comparisons Chi-square tests was used. We used Bonferroni correction for multiple comparisons.

The results were similar with the 30 s burn, but with the exception that mortality after the winter burn was not different from mortality following the spring burn.

Stump sprouting observed in August, 2011, which was a minimum of one full year after burning that took place in winter, spring, and summer of 2010, showed that sprouting occurred after each of the burns, but no sprouting was observed in the control (Table 6). Sprouting after burning for 40 s and 60 s was more common than in the control trees (p=0.067, p=0.011, respectively), but no difference was found between the percent of trees with new sprouts in the control and the 15 s burn or the control and 30 s burn (p=0.333, p=0.114, respectively, Table 7). The greatest percent of trees with stump sprouts, 29.6 %, occurred after the 60 s burn.

There was no difference in percent of trees with sprouts after burning for 15 s and for 30 s during the winter or summer (p=0.664, p=0.324, respectively, Table 8). However, greater sprouting occurred after the spring 30 s burn than the spring 15 s burn (p=0.081, Table 8). There was no difference in percent of trees with stump sprouts after burning for 40 s or 60 s during the spring (p=0.153, Table 8). The same was observed after burning during summer as well (p=0.956, Table 8). Differences in percent trees with sprouts were found in the 40 s treatment and 60 s treatment during winter (p=0.047, Table 8).

No differences were found in sprouting occurrence when the main stem was burned for 30 s between the following: winter and spring, winter and summer, and spring and summer (p=0.212, p=0.212, p=0.333, respectively; Table 9, Figure 3). Similar lack of differences between seasons was found in the results for 60 s burns (Table 9, Figure 4). The same sprouting average of 30.4 % was observed after the winter and spring 60 s burn.

The 60 s summer burn caused, on average, 28 % of the trees to sprout (Table 6). Similarly, seasonal differences were not found in comparisons of sprouting after winter and summer burn for 15 s, spring and summer burn for 15 s, and winter and spring burn for 40 s (p=0.202, p=0.158, p=0.203, respectively; Table 9). Seasonal differences were observed in comparisons of sprouting after spring and winter burn for 15 s, winter and summer burn for 40 s, and spring and summer burn for 40 s (p=0.077, 0.032, and p=0.095 Table 9). No sprouting occurred after burning for 15 s in the spring, but 14.3 % average sprouting did occur after the 15 s winter burn (Table 6).

Table 6. Mean percent ± standard error of paulownia trees with stump sprouts after each treatment.

Burn length for two size classes, s	Season of burn			Average
	Winter	Spring	Summer	
	Mortality, % ± standard error			
Small Diameter Class				
0	0.0±0.0	0.0±0.0	0.0±0.0	0.0
15	14.3±7.8	0.0±0.0	5.3±5.3	6.6
30	9.1±6.3	17.7±9.5	17.7±9.5	14.3
Large Diameter Class				
0	0.0±0.0	0.0±0.0	0.0±0.0	0.0
40	4.6±4.5	13.0±7.2	27.3±9.7	14.9
60	30.4±9.8	30.4±9.8	28.0±9.2	29.6

Table 7. Differences in the percent of paulownia trees with new stump sprouts following burning the main stem for different lengths of time.

Pairwise treatment comparisons	Difference, %	*P*-value
Small Diameter Class		
*Control vs. 15 s	–6.6	0.333
*Control vs. 30 s	–14.3	0.114
15 s vs. 30 s	–7.7	0.056
Large Diameter Class		
*Control vs. 40 s	–14.9	0.067
*Control vs. 60 s	–29.6	0.011
40 s vs. 60 s	–14.7	0.013

* Indicates Fisher's Exact Test analysis. In all other comparisons Chi-square tests was used. We used Bonferroni correction for multiple comparisons.

Table 8. Differences in the percent trees with new sprouts as a result of burning for the particular lengths of time during each season.

Size and season of treatment	Pairwise treatment comparisons	Difference, %	*P*-value
Small Diameter Class			
*Winter	15 s vs. 30 s	5.2	0.664
*Spring	15 s vs. 30 s	-17.7	0.081
*Summer	15 s vs. 30 s	-12.4	0.324
Large Diameter Class			
*Winter	40 s vs. 60 s	-25.8	0.047
Spring	40 s vs. 60 s	-17.4	0.153
Summer	40 s vs. 60 s	-0.7	0.956

* Indicates Fisher's Exact Test analysis. In all other comparisons Chi-square tests was used.

Table 9. Differences in the percent trees with new sprouts as a result of burning (comparison of the effect of season of burn).

Size and burn time, s	Pairwise season comparison	Difference, %	*P*-value
Small Diameter Class			
*15	Winter vs. Spring	14.3	0.077
*15	Winter vs. Summer	9.0	0.202
*15	Spring vs. Summer	–5.3	0.158
*30	Winter vs. Spring	–8.6	0.212
*30	Winter vs. Summer	–8.6	0.212
*30	Spring vs. Summer	0.0	0.333
Large Diameter Class			
*40	Winter vs. Spring	–8.4	0.203
*40	Winter vs. Summer	–22.7	0.032
*40	Spring vs. Summer	–14.3	0.095
60	Winter vs. Spring	0.0	0.333
60	Winter vs. Summer	2.4	0.284
60	Spring vs. Summer	2.4	0.284

* Indicates Fisher's Exact Test analysis. In all other cases we used Chi-square tests and Bonferroni correction for multiple comparisons.

Sprouting occurred almost 6 times more often after the summer 40 s burn, an average of 27.3 %, than after the winter 40 s burn, and occurred at almost double the rate of sprouting after the spring 40 s burn (Table 6).

Results from our work demonstrate that applying high-intensity directed fire to the base of the stem is indeed able to cause mortality in royal paulownia, even in trees up to 68 cm in diameter. Burning paulownia trees with diameters from 3.8 cm to 20.1 cm for 30 seconds and burning trees with diameters from 20.2 cm to 68.6 cm for 60 seconds may be preferable as it results in greater mortality than the shorter fire exposure. Burning paulownia stems with diameters smaller than 20.1 cm for 15 seconds should not be used because this length of burning was not effective. In a similar study, stems of *Acacia* species burned with higher intensity fire had greater stem mortality (Wright and Clarke 2007). The most adequate season to burn in order to cause the greatest mortality in paulownia is summer, which could be because of active growth and less carbohydrate reserves in the roots during summer than spring (Bowen and Pate

1993). Successful mortality can be obtained by burning in spring as well, but burning in winter for the examined lengths of time results in low levels of mortality. Similarly to our results, greater morality occurred in ponderosa pine (*Pinus ponderosa* C. Lawson) when burning took place in the growing seasons rather than in the dormant seasons (Harrington 1993).

Paulownia trees burned in the summer for 40 s sprouted more frequently than trees burned in the winter or spring for the same length of time. However, this difference among seasons was not observed for the 30 second treatment of the smaller trees or 60 second treatment of the larger trees during any season. This could be a result of the extremely hot fire that we applied. Other studies have used prescribed burning which does not normally get as hot and burn as long as the high-intensity directed fire in our study. Due to the intense heat, the basal buds may have been damaged, as was desired, which resulted in similar sprouting for among the treatments and among the seasons. Since sprouting occurs at similar rates regardless of season, burning should be applied in frequent intervals during each of the seasons to determine how many repetitions should be applied to successfully eradicate these species. Others report that it may take five annual burnings to finally reduce the stem

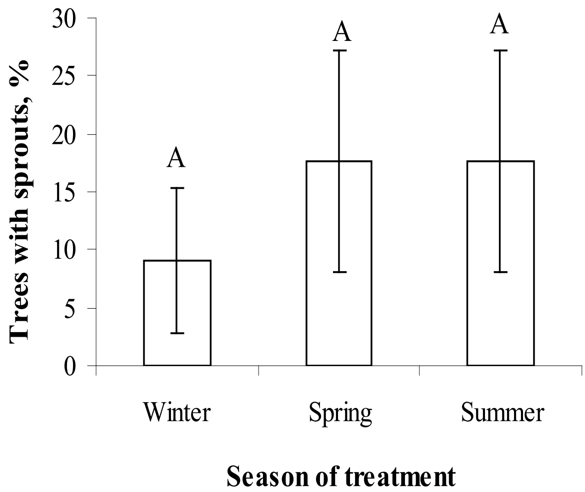

Fig. 3. Mean percent and standard error of small diameter paulownia trees with sprouts after burning for 30 s in winter, spring, and summer.
The same letters indicate no difference at the *p*<0.1 level.

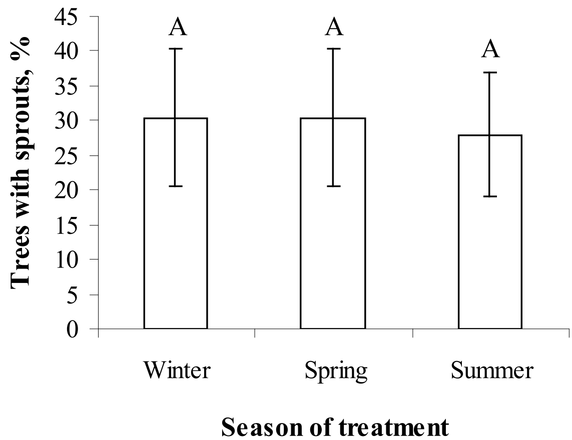

Fig. 4. Mean percent and standard error of large diameter paulownia trees with sprouts after burning for 60 s in winter, spring, and summer.
The same letters indicate no difference at the *p*<0.1 level.

numbers of shrub live oak to what they were before the first treatment, while desert ceanothus sprouts were almost all killed by a second burn (Pond and Cable 1961).

Conclusion

The method used in this study was successful at causing mortality even in large size trees of the studied species. To successfully kill paulownia, burning should take place in the summer. Additionally, trees between 3.8 cm and 20.1 cm in dbh should be burned for 30 seconds and trees between 20.2 cm and 68.6 cm for 60 seconds. In our study these treatments caused the most tree mortality, although stump sprouting was stimulated. Although we did not burn the sprouts, burning them after the following growing season may reduce the resprouting rate of this species. Repeated burning of the sprouts should be further studied for this species. Pond and Cable (1961) reported that sprouts from Wright's silktassel (*Garrya wrightii* Torr.) and Hollyleaf buckthorn (*Rhamnus crocea* Nutt. ssp. *pilosa*) were completely eliminated by four annual burns by a torch with flame temperature of 1,500 °C.

The cost for the equipment used was a total of $92.95. The torch cost was $63.00 and the propane tank $29.95. Assuming labor wages at $7.25·hr^{-1}, the approximate average cost for supplies and labor was $1.46 per paulownia tree. However, the cost can be lowered with scaling up of the treatment. This can be achieved with some of the already widely available flaming equipment currently used in agriculture (e.g., Red Dragon® vegetable bed flamer). Some adaptations in the design may be needed for forestry settings. Future studies of this method may try to develop a more accurate cost estimate. We also recommend testing how many repeated burns of the sprouts are needed for the plant to no longer be able to carry out vegetative reproduction.

Acknowledgements

This material is based upon work supported by the National Science Foundation, Center of Research Excellence in Science and Technology (CREST), Center for Forest Ecosystem Assessment, Award No 0420541 and by the United States Department of Agriculture Higher Education Challenge Grant No 2007-38411-18113. Any opinions, findings, conclusions, and recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the United States Department of Agriculture.

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FORESTRY IDEAS, 2013, vol. 19, No 1 (45): 41–48

THE EFFECTS OF DIFFERENT METHODS AND ROOTSTOCKS PHENOLOGYCAL STAGES ON SWEET CHESTNUT (*CASTANEA SATIVA* MILL.) SPRING GRAFTING

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Received: 08 October 2012 Accepted: 14 April 2013

Abstract

In this study Sweet chestnut spring grafting onto same rootstocks has been made. Two-year-old seedlings in the open field were used as rootstocks. Two phenological stages of the rootstocks have been tested – dormancy condition (end of February) and the beginning of growing season (end of March). The grafting methods were chip budding, cleft graft, side veneer graft and splice graft. Criteria for assessment of the results were the percentage of grafting components union, main shoot growth, lateral shoots number and growth. Significant differences in grafting success and plant development were found in different phenological stages and in grafting methods. It was mainly recommended to perform splice grafting during the spring using “dormant” and “active” rootstocks. By splice grafting both graft success and growth of the scion (86.7 to 93.3 % graft success and 23.7 to 26.2 cm graft shoot height) can be realized.

Key words: Sweet chesnut, spring grafting, chip budding, cleft graft, side veneer graft, splice graft.

Introduction

Sweet chestnut in Bulgaria is found in limited and fragmented isolated fields. It has entered the customs and traditions of people, in the places where it can be found; therefore it has high social and economic importance, especially for fruit production (Glushkova 2006).

Castanea sativa Mill. belongs to the so-called “multipurpose” species due to its various beneficial properties and wide range of valuable products obtained from it (Milev and Iliev 2007).

The problems in chestnut breeding are mainly due to ubiquitous disease known as cancer caused by the fungus *Cryphonectria parasitica* Murrill. (Avramov 2002). Recent studies showed that everywhere in the world where this species is cultivated, plantations were in disquieting phytosanitary state. In Bulgaria, almoust all plantations are affected. The disease raises the question about the biological existence of the species (Iliev and Mirchev 1992, Milev and Sotirovski 2007).

Currently a number of researchers and international research groups are exploring diverse ways for overcoming the problem (Robin and Heiniger 2001, Milev et al. 2005, Milgroom et al. 2008, Risteski et al. 2013). A possibility in this direction is to explore and to produce resistant clones with additional requirements of the harvest qualities, the wood and the growth rate (Iliev and Mirchev 1992, Craddock and Bassi 1999, Petrov 2005, Milev and Sotirovski 2007).

However, genotypes with high resistance to cancer can't be selected through seed propagation. These problems with Sweet chestnut breeding outline the importance of vegetative propagation for production of seedling. In addition, vegetative propagation allows the achievement of early, frequent, abundant and benign harvests in the garden type crops.

In vegetative propagation, cloning of mature genotypes is always preferred because they have the phenotype show of their genetic potential (Franclet 1980, Zobel 1981). It is known, however, that the rooting of Sweet chestnut cuttings is difficult, depends on many factors, including the stages of the donor plant and does not give practically significant results (Dirr and Heuser 1987).

When propagation by cuttings is very difficult or impossible, the method of grafting is applied for reproduction of valuable genotypes (Broshtilov 2000).

This study aimed to determine suitable phenological stages of chestnut rootstocks and successfull methods for spring grafting and budding.

Material and Methods

The vegetative propagation experiment was carried out in forest nursery "Ivanik", Forest Enterprise Petrich. A source of scion wood was the existing clonal colection in the nursery. The analysis of embedded cultivars on their resistance to cancer showed that the only variety with no visible damage from the disease is the French variety Marigoule (cv. '*Marigoule*'), wherefore it was used for the extraction of shoots. The scions were taken in the beginning of February and were stored at 4°C until they were used for grafting.

Two-year-old seedlings were used as rootstocks in the open field.

To study the influence of the phenological stage of the rootstock, the grafting was carried out in two periods:

End of February (26–27.02.2011) – dormant stage ("dormant" rootstocks);

End of March (20.03.2011) – beginning of growing period ("active" rootstocks).

To determine the optimal methods of grafting were tested:

1. Budding: chip budding;

2. Grafting of three bud scions: cleft graft, side veneer graft, splice graft.

For each method 3 repetitions with 25 graftings were used. The scion and the rootstock were fasten by special grafting rubber strips. The rootstock shoots were remorved on 03 May 2011.

The grafted saplings were not shaded during the growing period.

The percentage of graft success, length of main and lateral shoots and the number of scion shoots were the criteria for the evaluation of the results.

The results were analysed by One-Way ANOVA followed by a post hoc LSD test at $p<0.05$ (statistical package SPSS11).

Results and Discussion

T-budding trials showed that the rootstocks' bark could not be separated from the wood in both phenological periods of grafting work Therefore, this method has not been included in the experiment and the chip budding had been selected as a primary grafting method.

The results of the grafting success are presented in Table 1.

The highest percentage of grafting success occurs in splice graft (average 90.0 %), and the worst/lowest result – in chip budding (average 37.3 %). This result is different from the recommendations of Nedev et al. (1966), Petrov (1976), Milev et al. (2007), Celik et al. (2009), Bratels (2012), Dirr and Heuser (1987) to use chip budding when the bark separation is not possible.

Table 1. Grafting success of the components, depending on the phenological stage of the rootstocks and the method of grafting (%).

Grafting methods	Phenological stage of the rootstock		Average per method
	Dormant	Active	
Chip budding	21.33±8.74a	53.33±8.74bc	37.33±4.40a
Cleft graft	40.00±2.00b	81.33±8.11de	60.67±4.40b
Side veneer graft	69.33±5.81cd	77.33±3.53de	73.33±4.40b
Splice graft	86.67±5.33de	93.33±3.53e	90.00±4.40c
Average of phenological stage	54.33±3.11	76.33±3.11	

Note: Means with the same letter are not significantly different.

As a whole, the various types of grafting showed better possibilities for scion and rootstock union for both phenological periods. On average, for both periods of work, lower grafting results were obtained by using dormant rootstocks – 54.3 %. Grafting on “active” rootstocks leaded to an average percentage of components’ union – 76.3 %.

The phenologycal periodicity of grafting has been studied by many authors. The majority of them agree with the recommendation for a summer (July to August) T-budding (Nedev et al. 1966, Petrov 1976, Grbić 2004, Dirr and Heuser 1987). According to other authors, the suitable phenological periods for grafting are winter (Grbić 2004, Bartels 2012) and spring before the beginning of growing (Petrov 1976, Celik et al. 2009, Ozturka et al. 2009). The results of the present study however showed lower percentage of components’ union during the dormancy period regardless of used grafting metods.

The success of grafting is higher in spring, after the begining of the growing season. In support of these results are the studies made by Serdar and Soylu 2005. However, their results show that splice grafting can be equally successful in both phenological periods.

In addition, during spring, it is possible to obtain inverted radicle graft (Ozturk and Serdar 2011) and inverted T-budding (Serdar and Soylu 2005).

The statistical indicators of significance of various studied factors (rootstocks phenological state and method of grafting) are presented in Table 2.

As it can be seen from Table 2, grafting success depends on the phenological state of the rootstock (Significance level 0.000), used method of grafting (Significance level 0.000) and the combined effect of the two factors (Significance level 0.029).

From a production point of view, a matter of interest is not only the successful union of the grafted seedlings, but also the growth of the top shoot of the grafting (Table 3). The growth rate of the top shoot

Table 2. Significance of stock phenological stage and grafting method on the results.

Indicator	Grafting success		Top shoot length		Average nomber of shoots		Average length of the lateral shoots	
Factors	F	SL	F	SL	F	SL	F	SL
Phenological stage	24.99	0.000	0.42	0.519	0.06	0.941	1.94	0.165
Method	25.45	0.000	68.91	0.000	57.72	0.000	95.54	0.000
Phenological stage x Method	3.89	0.029	1.08	0.360	0.47	0.703	0.81	0.489

Note: *F* – Fisher's criterium; *SL* – Significance level.

is not only criterion for the duration of the production cycle, but also an indicator for the physiological status of the scion as a result of more or less successful graft union.

The longest top shoot growth was observed at splice grafting while the shortest one was observed at chip budding and side veneer grafting method in both phenological stages of the rootstock.

The most delayed growth of the top shoot was reported for chip budding and side veneer grafting (from 3.8 to 9.5 cm), while the most intensive growth was observed in splice grafting (from 23.7 to 26.2 cm). The results showed that the phenological stage of the rootstock does not affect the growth of the vegetative sapling. This was the reason why the obtained results from the different methods of work in both periods were synonymous from a statistical point of view.

In general, the reason for the small size of the scion shoots could be caused by the comparatively unsuitable conditions in the open field. Ozturk and Serdar

Table 3. Effect of the phenological stages of the rootstock and the method of grafting on the growth of the top shoot (cm), average number of scion shoots and average length of the lateral shoots (cm).

Grafting method	Growth of the top shoot		Average number of scion shoots		Average length of the lateral shoots	
	Phenological stage of the rootstock					
	dormant	active	dormant	active	dormant	active
Chip budding	3.77±0.87a	5.68±0.85a	1.00±0.00a	1.10±0.07a	0.00±0.00a	0.11±0.08a
Cleft graft	17.35±1.68b	15.03±1.35b	2.43±0.11c	2.27±0.10c	9.97±1.56b	10.31±1.21b
Side veneer graft	8.74±1.26a	9.48±1.23a	1.60±0.09b	1.69±0.07b	1.81±0.73a	3.21±0.67a
Splice graft	23.68±1.70c	26.21±1.36c	2.49±0.14c	2.46±0.08c	17.14±1.43c	20.77±1.39d

Note: Means with the same letter are not significantly different.

(2011) indicated that the most intensive growth of scion shoots could be obtained by using an overshadow of the saplings.

While the phenological stage of the rootstock have not proven its influence on the growth of vegetative saplings (Significance level 0.519), the grafting method has proven its significant effect (Significance level 0.000) from a statistical point of view. The combination of these two factors, however, also showed a statistically significant impact on the length of the top shoot (Significance level 0.360) (Table 2).

The average number of shoots formed from scion wood (Table 3) can also be used as an indicator for the physiological stages of the graft. From a production point of view, this criterion correlates with the capacity of the crown of the vegetative saplings, respectively their quality.

The lowest average number of lateral shoots is developed after chip budding (1 to 1.1 pc.). It is a logical result because only one bud is used in the budding methods. The highest number of shoots was observed in splice graft and cleft graft (2.3 to 2.5 pc.).

According to this indicator the results showed (Table 2) that the phenological stage of the rootstock itself is not significant (Significance level 0.941) as in combination with the method of grafting (Significance level 0.703). Statistically significant impact on the average number of shoots has only the method of grafting (Significance level 0.000).

As an additional indicator of the graft growth potential, the average length of lateral shoots can also be considered as a criterion of its successful union. From a production standpoint, it can be relied on the lateral shoots to form part of the stem when the top shoot is damaged by a biotic or abiotic factor. In the production of cultivated saplings, most often the cause of such damage is its breaking off as a consequence of the rapid growth and the influence of wind.

Statistically reliable differences between the two different phenological stages of the rootstocks were not observed in chip budding, cleft grafting and side veneer grafting (Table 3).

The average length of the lateral shoots of the scion is lowest (0 to 3.2 cm), after chip budding and side veneer grafting. The growth of the lateral shoot was most intensive after splice grafting (from 17.1 to 20.8 cm).

The results showed (Table 2) that the growth of the scions, with regard to the three selected criteria, is influenced only by the grafting method but not by the phenological stage of the rootstock.

The present study outlines the splice grafting as a method that ensures both the highest percentage of components union and the best scion’s growth, which is in line with the recommendations of (Bratels 2012, Grbić 2004).

Despite of the recommendations for cleft grafting (Serdar et al. 2005, Duman and Serdar 2006, Bratels 2012) and side veneer grafting (Huang et al. 1994, Milev et al. 2007), which methods can reach components’ union up to 100 %, the present study showed that these methods are more suitable for work with rootstocks in “active” condition and do not lead to sufficient results before the growing season. Other authors recommend whip grafting (Celik et al. 2009, Serdar and Soylu 2005) and whip and tongue grafting (Craddock and Bassi 1993).

In correspondence with the opinions of many authors (Nedev et al. 1966, Petrov 1976, Grbić 2004, Milev et al. 2007, Bartels 2012, Dirr and Heuser 1987), Sweet chestnut seedlings, including newly germinated seeds (Ozturk and Serdar 2011) are suitable rootstocks for grafting of the same species, though (Grbić 2004) shows the possibility of using *Quercus cerris* L. seedlings as well.

As it is known, in heterovegetative propagation, the scion transfers its ontogenetic stages of vegetative development to the vegetative sapling, thanks to which, early harvests could be expected. During the implemented studies, reproductive organs were formed even during the first growing season after grafting – in splice grafting during the first and second phenological period, respectively 2.67 % and 1.33 % of the saplings and in side veneer grafting during the dormant period – 2.67 %.

As a technological element of Sweet chestnut grafting, it can be noted that after the transplantation of the scions, the rootstock reacts actively by wakening of numerous dormant buds and by intensive development of shoots on the rootstock below the point of grafting. As it is known from practice, shoots hold up the growth of the scions, which requires their regular removal during the entire growing period.

Conclusion

Based on the obtained results, the following conclusions and recommendations can be made:

In the vegetative propagation of Sweet chestnut both rootstocks in active or dormant stage can be used. This finding allows for significant expansion of work periods and increase of the production volumes.

In spring grafting the T-budding is not applicable, and the side veneer grafting does not provide reliable union of the components.

In cleft grafting and in chip budding "active" rootstocks shoud be used and for splice and side veneer grafting both "active" and "dormant" rootstocks can be used.

The phenological stage of the rootstock affects the components union in chip budding and in cleft grafing. In splice grafting and side veneer grafting, results in both work periods are identical.

The highest rate of union and growth of grafts are reached in splice grafting, which determine it as the general and the most appropriate method of grafting.

The highest percentage of components union is obtained in splice, side veneer and cleft grafting on "active" rootstocks.

Based on the complex criteria it can be recommended in spring grafting of Sweet chestnut, with relatively equal width of the components the method of splice grafting to be used, and when the scions are collected from significantly thinner shoots in comparison to the rootstocks, the side veneer grafting is recommended.

The results, conclusions and recommendations offer the possibility to go beyond the established narrow frames in the practice for work with summer T-budding in the production of cultivated saplings of Sweet chestnut. They enable the utilization of the spring period of work, by using rootstocks in different phenological stages and methods of grafting.

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ECOSYSTEM SERVICES PAYMENT AND NON-MARKET VALUATION: IMPLICATIONS FOR BULGARIAN PRIVATE FOREST MANAGEMENT

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Received: 04 February 2013 Accepted: 25 April 2013

Abstract

Ecosystem services payment (ESP) is widely proposed as effective mechanism to internalize externalities. Non-market valuation techniques are often used to measure ESP. Elaborating the relationship between non-market valuation and ESP, this article emphasizes the importance of property rights and opportunity costs for ESP arrangement. The Bulgarian private forest is used as an example to highlight the potential impacts of changes in the institutional arrangement of property rights on ESP and sustainability of Bulgarian private forestry and ecosystem services.

Key words: consumer value, shadow value, willingness to pay, non-market valuation, appraisal value.

Introduction

Non-market valuation of ecosystem services has received significant attention for the past few decades. Non-market valuation is used to measure the value of products or services without market prices. An objective of non-market valuation is to inform the public of the importance of ecosystem services using monetary value, which is easier to understand, interpret and compare with other goods and services. People including ecologists who used to be reluctant to pricing ecosystems now favor the approach. While ecosystem services are critical for human beings to survive and have better quality of life, we should know that highlighting the importance of the ecosystems is not the main reason for non-market valuation. Rather it is the welfare impact of trade-offs of marginal changes in ecosystem services or between various ecosystem services that is the focus of attention in non-market valuation. The increasing demand for ecosystem services and alternative uses of natural resources make non-market valuation important. Since there is often no market to convey the marginal value and/or opportunity costs of supplying ecosystem services, non-market valuation is used to measure them toward a better decision making. Marginal value is the additional value gained from small increment of consumption or production of a product. Marginal value is not constant but usually is diminishing for either consumer or producer. And in this context it is important to keep in mind the distinction between use-value, exchange-value and marginal value. Decisions are made at the margin rather than at the total or at average (Zhang and Li 2005).

Recently ecosystem services payment (ESP) has become a popular mechanism to internalize the costs and benefits of ecosystem services. Since there is no market for ecosystem services, suppliers do not have incentive to provide the services, leading to under supply rather than the optimal level as many of the environmental services have (positive) externalities (Arrow et al. 2000). Therefore, creating institutions that can internalize the externalities offer solutions (Pigou 1932, Coase 1960). Externalities refer to costs or benefits to other people not included in own cost and benefit analysis. For example, when a pulp and paper mill pollutes water it is a cost to many people downstream, but not included in the cost of the mill. The cost is called negative externality. Tree plantation generates benefits to society such as carbon sequestration and other ecosystem services, but the benefits are not considered by forestland owners. These are called positive externalities. It is believed that if positive externalities can be paid and negative externalities penalized, suppliers would have incentive to adjust their activities in optimal manner as externalities are internalized. This article attempts to clarify a few important questions regarding non-market valuation and ESP. Using the Bulgarian private forest as an example it discusses the potential consequences of changes in forest property rights on forest management and ecosystem services supply and sustainability of Bulgarian private forestry.

Problem Formulation

What is valued in non-market valuation?

The difference between willingness to pay (WTP) and shadow price and between total value and marginal value are very basic in economics but still often overlooked when we apply them to non-market goods. WTP is the value to the users, and is the maximum amount they are willing to forego in order to acquire a unit of some good or service. Often non-market valuation is used to value everything (total value) of some resources (e.g., species), having it or not having it at all. But in reality, we never choose these two extremes. There are plenty of choices (trade-offs) in between, such as small change of the resources. Another problem is to claim ESP using only willingness to pay.

Non-market valuation methods (e.g., contingent valuation (CVM) or travel cost method) estimate how much a consumer values a particular natural or environmental service. Consumer value is measured by the maximum WTP, and it is the utility gained from consuming an extra unit of a product. Economists also use shadow prices to measure how profit is affected by the lack of resources (capital, labor, land and other inputs), where shadow price is defined as the marginal cost of relaxing the resource constraint by one unit. In other words, shadow price is the value of an additional unit of the resource to the firm. For example, if a manufacturing firm suffers from energy supply, the shadow price is what additional profit can be made if additional unit of energy is provided. Since willingness to pay is not shadow value of the ecosystem service, using it for the purpose of shadow value (the welfare impact of relaxing constraint) is not appropriate. Rather we need both willingness to pay and an estimate of the opportunity cost of supplying the ecosystem service when making decisions about paying for an ecosystem service.

The use of willingness to pay becomes more problematic when it is not measured at the margin. No matter how valuable the functions of ecosystems and how much natural resources contribute to individual or society welfare, the marginal value might be very low when the resource is in relative abundance. As van Kooten (1998) points out, the argument is not that the value of all natural and environmental resources may be large, but for most specific resources, such as the benefits of biodiversity, the value is small at the margin. The paradox of diamond and water is partly not considering the difference between marginal value and total value. When we say “water is so important”, it only means water as a whole resource and not the marginal unit.

Who pays who?

Prior to Coase (1960), it was believed that polluters (e.g., creating noise, dirty water) create negative externalities and should be responsible to abate pollution. Coase showed that the socially optimal level of pollution would be same regardless of who has the right to pollute if transaction costs are zero. If the polluter has the right to pollute, the affected parties have no right to stop the polluter but would need to pay or bribe the polluter not to or lower the pollution level. Conversely, if the polluter does not have right to pollute, he can pay the affected parties for polluting.

Ecosystem services are exactly the opposite of negative externalities like pollution; they are positive externalities. For example, fruit tree garden owners create positive services for bee farmers; upstream forests provide ecosystem services for downstream reservoir or hydropower corporations. It is natural to expect the beneficiaries (bee farmers and reservoir owners) to pay for the ecosystem service. However, we also see a lot of opposite cases. For example, forestland owners are not allowed to practice clear-cutting of their forests, or change their land use from forestland or wetland to cropland, suggesting the owners do not have rights, or their rights of managing their land are taken away. If they don’t provide the services, they are asked to pay or buy credits to compensate for the loss of ecosystem services. The opportunity costs or economic loss induced by an environmental policy restriction is exactly the compensation owed by the society to the land owner that supplies ecosystem services. Therefore, property right arrangements are critical to the question of who should pay ecosystem service and landowners’ incentives to supply ecosystem services.

Method

What should be ESP?

Many studies argue that ecosystem services are underpaid and poorly financed as it is claimed that willingness to pay is much larger than the payment or subsides. We should know that estimated willingness to pay cannot be used as a basis for ESP. Rather the potential level of compensation is expected to be somewhere between the opportunity cost of providing the additional ecosystem services and marginal willingness to pay for them. Let us consider an example. Suppose there is a reservoir owner downstream (player 1) and a private land owner upstream (player 2). The land can be used for (1) farming, (2) pine tree intensive monoculture for timber production, and (3) hardwood trees for multiple uses. Suppose that from the private land owner perspective, pine tree can generate the highest profit whereas from reservoir owner point of view hardwoods are beneficial. Let us further suppose that the payoff matrix for the reservoir and land owner can be characterized as Table 1. The first cell (X+5, 6) indicates that the gain for downstream reservoir is (X+5) and the farm is 6 if land is used for farming and no compensation is made by reservoir owner to the land owner. The amount X can be any number depending on the reference point. As we only care about the marginal change, it is 3 if the land use is changed from farming to pine trees, and 7 from pine trees to hardwood trees; what is the value of X does not matter.

Now the question is: how much compensation the reservoir should provide to the private land owner? First, let us see the non-market value of pine trees and hardwood trees? Using farming as reference (or base), WTP of the reservoir or positive externality from farming to pine is 3 units and from pine to hardwood is 7 units. But if the land owner plants pine tree, no compensation can be requested as the farm owner does not bear opportunity costs and still likes to grow pines without compensation from the reservoir owner. The result of **(*X*+8, 7)*** is called a Nash Equilibrium under non-collaboration game.

If land use is changed from pine to hardwood, 7 additional units of positive externality are generated, and the 7 units are also the WTP from pine to

Table 1. The payoff matrix between downstream water reservoir owner and the private land owner.

		Player 2: Upstream private land owner' management options		
		(1) Agricultural farming	(2) Intensive pine tree monoculture	(3) Multiple use hardwood forest management
Player 1: Downstream reservoir owner' options	Pay 0	(X+5, 6)	**(*X*+8, 7)***	(X+15, 2)
	Pay 2	(X+3, 8)	(X+6, 9)	(X+13, 4)
	Pay 4	(X+1, 10)	(X+4, 11)	(X+11, 6)
	Pay 6	(X–1, 12)	(X+2, 13)	**(*X*+9, 8)****

Modified and adopted from Zhang (1997).

hardwood for the reservoir, but the opportunity cost to the private land owner is only 5 units. It is apparent that as long as the marginal benefit to reservoir is larger than opportunity costs of the private land owner, and the opportunity cost is less than the compensation, collaboration would make both sides better off. For example, the result of **(*X*+9, 8)**** is a Nash Equilibrium under collaboration game. Under this collaboration, the landowner gains 1 than if he were to plant pine and the reservoir would gain 1 unit with 6 units as compensation to the private land owner.

The above example is based on no or little transaction cost. Considering the nature of forest management, externalities of forest management are hard to measure and monitor. Therefore, the transaction costs are usually high. Any trading would involve transaction costs which are costs of researching for information, contracting and final enforcement. The costs are loss to society. If the gain from trading cannot exceed the potential loss from transaction, either the trading would not take place or no gain made to the society. Using the above example again, if the transaction cost is larger than 2, no gain will be generated from deal. In other word, society has not gained from the change from pine to hardwood management. Interestingly, if the regulation that the forestland owner has to plant hardwood is in place and costing little to implement, the society gains, but the welfare distribution is becoming questionable.

At the societal level, marginal benefit minus opportunity cost (plus transaction cost) is the gain from the land use change from pine to hardwood production. The non-market value of externalities is really dependent on which point is used as a reference. Looking at Table 1, if agricultural farming is the reference point, then the value for hardwood is 10 but only 7 if pine is the reference point. In addition, knowing the value of externalities alone would not lead to a meaningful policy design and WTP cannot be used as ESP. ESP is not the total non-market value but a value between the opportunity costs to the land owner associated with providing the non-market service and the opportunity value to the beneficiary (the reservoir). ESP is like any other trading leading both sides to gain. The difference from other trading is that the property right arrangement is not as apparent as in the case of other products and services, and ecosystem services are often public goods.

WTP and “what should be paid” (WSP)

Considering the limitations of WTP as measurement for ESP, Zhang and Zheng (2011) for the first time proposed and discussed the concept of “what should be paid” (WSP). What should be paid measures fair compensation based on public or expert opinion or appraisal value of compensation. Appraisal value is the value made by appraiser using some methods, mostly comparing with the price of similar and recent traded property, present value of all expected income from that property and costs to create and produce a similar property. When respondent is asked for WTP, several possibilities may arise: if a respondent assumes that other people will be free-riders, WTP might potentially be lower; if the respondent tells his true consumer value (WTP), then WTP might be larger than WSP. “What should be paid" seems subjective and not scientific, but reflects the consensus of many consumers and producers about the level of costs and values.

Zhang and Zheng (2011) argued that WSP might be an appropriate measure to determine ESP, and found that on average, willingness to donate to urban tree programs was on average $13.53 (about 24 %) less than the money respondents thought should be used to support such a program. "What should be paid" (WSP) can be derived from public opinion surveys or from professional appraisals. WTP only considers the consumer value but ignore the opportunity costs. WSP is based on the judgment of each individual of their evaluation of fair compensation for ecosystem services. Their judgment likely is based on value and costs as well as substitutes. WSP better reflects the trading price than WTP for ecosystem services and is likely easier in implementation.

WSP can also be derived from surveys consisting of various stakeholders and experts. WSP can also be derived from appraisals. Appraisers are routinely faced with situations in which no such evidence is available. In fact, appraisers are required because of the absence of a ready market. Appraisers have been doing good job in pricing of non-market goods. Appraisal value is usually defined as an amount expressed in terms of money that may reasonably be expected for a property in exchange between a willing buyer and a willing seller, neither under compulsion to buy nor to sell and when both are fully aware of all relevant facts, including the assumption that the earnings support a continuation of the product line. Appraisal value is the value measured in a hypothetical market. Appraisal method addresses the limitation of CVM and makes comparison between benefits and costs and between individual value and social value.

Empirical Application

Bulgarian private forestry and new regulation

A long restitution process has been underway in Bulgaria since 1995, involving the transfer of state forest to ownership of non-state entities. The situation at the end of 2006 indicated that about 78.6 % of the forest area was still in state ownership. The largest non-state owners included municipalities with 10 % of forest area. The individual families owned 10.6 % of the forestland. The woodlots in individual ownership are very small, most of them around 1 ha in size. Only about 5 % of the forest holdings in private ownership exceed 50 ha.

The private forest owners are considered to be unsustainable as they do not have the necessary capacity and skills of forest management. More importantly, they are either living far from the forest properties, have limited interest in managing forests or to collaborate with other forest owners under collective or cooperative management. As the public is getting more aware of the significance of the environment and ecological value of forests, it is important for private forestland owners to follow sustainable forest management criteria.

It is argued that unsustainable practices and non-suitable operations of the private forest owners can lead to the loss of important species and rare forest habitats, especially in the low mountains, lowlands and riparian forests around wetlands and rivers. Consequently, during the development of legislation and regulations on private forests, requirements for protection and maintaining biodiversity, reduction of pollution, are going to be stronger particularly if the forests are located in critical watershed protection and close to villages or river streams. Private forest owners are asked to follow new regulations of sustainable forest management. The regulations would impose more restrictions on private forest owners, or take away some property rights. The impacts would be reduction of property value compared with no restrictions, and the owners would have less interest in the property. A worst case scenario will arise when the property is abandoned if the owners cannot gain from the property.

Toward Sustainability: market mechanism or regulation?

In order to address this issue, Table 2 illustrates a hypothetical game between the public (player 1) and a private forestland owner (player 2) and potential outcomes. Suppose the government or the public offers three options to the private forest owners: (1) no restriction, (2) must follow sustainable forest management or face some penalties, and (3) provide incentive to the owners who practice sustainable management. The forest owners could respond with three management strategies: (1) non-active management or simply giving up the ownership as no economic return is generated, (2) profit maximizing management, and (3) sustainable forest management.

If no restriction is applied, the land owner will pursue his own profit or land value maximization: suppose the profit is $P1$ and the additional ecosystem service generated is $E1$ compared to no management.

If regulations are applied and private land owners have to use sustainable forest management: suppose the profit is $P2$, and the additional ecosystem service is $E2$ compared to profit-oriented management. If $P2$ is still positive, regulation will lead to the transfer of

Table 2. The payoff matrix between the public and private forestland owners under alternative property rights arrangements.

		Player 2: Private forest owner' management options		
		(1) Non-active management	(2) Profit oriented management	(3) Sustainable forest management
Player 1: Public/ government' options	No restriction	(X, 0)	**(X+$E$1, $P$1)**	(X+$E$1+$E$2, $P$2)
	Must practice sustainable management	**(X, 0)**	(X+$E$1–F, $P$1–F)	($P$2, X+$E$1+$E$2, $P$2)
	Subsidize A if sustainable management	(X, 0)	(X+$E$1, $P$1)	**(X+$E$1+$E$2–A, $P$2+A)**

Note: $P1>P2$

some benefit from private land owners to the general public: it is not that the public pay for the ecosystem services to the private land owner; rather the private land owner pays for the ecosystem service to the public. In case the profit *P*2 is negative (meaning it is no longer profitable), the private land owner might simply give up the ownership, and the land would become non-active management leading to reduced ecosystem service such as level *X*.

If incentive such as subsides are provided to private land owners who practice sustainable management, the question is how much incentive should be provided. Comparing the situations in (3) and (2) the additional ecosystem service from sustainable management is *E*2 which can be called welfare value or WTP of the public. It must be noted that the ecosystem from sustainable management is *E*1+*E*2 if comparing with non-active management (1). Since there is no opportunity cost for the ecosystem service *E*1, and the opportunity cost of *E*2 is reduced profit (*P*1–*P*2) for the private land owners. Therefore, the WTP is *E*2, the ESP should be between (*P*1–*P*2) and *E*2. If the land owners cannot make any income when they adopt sustainable forest management, it is likely the landowners will give up the ownerships. One possible result will be less ecosystem service and less economic return. The potential result, as shown in Table 2, will be (***X*, 0**). If ecosystem services are compensated to the land owners with ***A***, the result will be (***X*+*E*1+*E*2–*A*, *P*2+*A***) leading to gains for both the welfare of private land owners and the public from the arrangement of the ecosystem service rights.

The scenarios provided are illustrative of the private forest management and socio-economic consequences in response to public policies or property rights arrangement. They are intended to convey that the policy that force the private forest land owners to practice sustainable forest management might lead to reduced welfare for both public and private forest owner like **(*X*, 0),** which is even worse than no restriction. Alternatively, if incentive policy is provided, the result might be like **(*X*+*E*1+*E*2–*A*, *P*2+*A*).** The actual solution will be dependent on marginal benefits and opportunity costs. Thus, society should develop policies that lead to total welfare gains at least rather than simply transfer benefit from one stakeholder to another. Another important factor that should be included in the consideration is the transaction costs. No policy or regulation is costless. The costs involved include policy making, implementation and monitoring. Considering the numerous small and numerous private land owners, implementation costs could be very high. If the gain from the policy cannot exceed the potential costs of the policy, no regulation is better off.

Concluding Remarks

Ecosystems are important to humans but we often misinterpret willingness to pay (WTP), opportunity cost and ESP. WTP measures welfare or value from a consumer perspective whereas opportunity cost is the cost of supplying ecosystem services, and ESP must lie between WTP and opportunity cost (Zhang and Li 2005). Ideally, the most efficient allocation is at the point where marginal WTP is equal to marginal opportunity cost (i.e., balancing trade-offs at the margin). While it is helpful to use WTP to highlight the importance of ecosystem services, it is the analysis of trade-offs at the margin that should be the main focus of non-market valuation. As Solow (1992) pointed out, "there is a lot to be gained by transforming questions of yes-or-no into questions of more-or-less. Yes-or-no lends itself to stalemate and confrontation; more-or-less lends itself to trade-offs, the tricks is to understand more of what and less of what".

ESP mechanisms must be designed such that they lead to welfare gains rather than just welfare reallocation between stakeholders. The justification for ESP is to increase ecosystem services to the optimal level by internalizing externalities. While nothing is wrong when consumers are free riders when there is no opportunity cost, they will enjoy increased supply if externalities are internalized. We cannot simply use WTP as a measure to claim ESP; ESP is a result of the interplay between demand (willingness to pay) and supply (marginal opportunity cost). Often private forest owners are expected to comply with certain regulations. In the Bulgarian context, these regulations need to be evaluated as some unintended consequences might occur and forestland owners may give up management opportunity if ESP is not commensurate with the costs they incur. Very importantly the costs of policy and regulations need to be considered.

Acknowledgements

The authors would like to thank USDA-Borlaug Fellowship Program. All remaining errors and opinions are responsibility of the authors.

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FORESTRY IDEAS, 2013, vol. 19, No 1 (45): 59–68

ENVIRONMENTAL IMPACT ASSESSMENT OF THE A CATEGORY ASPHALTED FOREST ROAD "PHILLIPION – XILIA DENDRA – EXOCHI"

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Received: 05 October 2012 Accepted: 23 May 2013

Abstracts

As results of forest roads construction, a large number of impacts on the social and natural environment are identified, both at construction and operation phases. In this work an Environmental Impact Assessment for the asphalted forest road, of A category "Philippion – Xillia Dendra – Exochi" was conducted. Initially, we analyzed the concept of environmental impact assessments and recorded all the information about the location of the road. Then the information was collected necessary for the preparation work, such as related measurements, graded on the basis of the criteria forestry absorption and intensity. These criteria evaluate forestry, topographic and social factors that are indicators for the adaptability of the road environment and the capacity of the area to overcome the construction and to restore the balance of the forest ecosystem with minimum negative impact on the forest and the social surroundings. The intensity criteria by which the layout and the construction of a forest road is evaluated measures adaptation of the natural environment to the road construction. Finally, the investigation concludes that the specific forest road needs several interventions to improve and restore the environment after its construction.

Key words: environmental impacts, forests, pavements, roads.

Introduction

The first human beings used forests as a source of fuel, food, accommodation, water etc. Over the years, stone tools were replaced by metal ones and thus the industrial revolution began and with it the construction of forest roads and forestry activities, which resulted in a rise of productivity both in land cultivation and timber harvesting. Despite the beneficial use of modern digging machines, they also caused problems in the balance of the forest habitat.

The paper deals broadly with the issue of environmental impact assessments and specifically with the Environmental Impact Assessment of the A category asphalt road "Philippion – Xilia Dendra – Exochi".

Viewed from an economical perspective, the construction of a forest road must not be considered to be a negative undertaking. Although it can be a source of severe environmental impact it also has many positive aspects. In order to assess the degree of opening of a road forest analytical and empirical methods are mainly used. The analytical methods rely on theoretical models and take into account quantitative opening criteria (expressed in monetary units) in relation to road density (Kroth 1973, Abegg 1983). Empirical methods are based on knowledge of economic theory. Such are the dynamic methods (Stamou 1985, Karagiannis 1991) as well as the method of cost-benefit analysis (Stamou 1985, Doukas 1989, Karagiannis 1991) which takes into account only quantitative criteria irrespective of whether these are related to road density. Additionally, the assay value – benefit analysis is used to empirically assess quantitative as well as qualitative criteria (that can not be expressed in monetary units) and has been widely applied in the fields of engineering and forestry science.

The economic evaluation of environmental impacts is difficult because they cannot be assessed economically with accuracy since the individual factors are often qualitative and in many cases the situations that arise can be permanent or temporary, may have different influences on construction, restoration, maintenance and during operation (Tsochos 1997). In areas that have economic criteria, both quantitative and qualitative (environmental), we can apply the value-benefit analysis.

Materials and Methods

Research area

The forest that surrounds the city of Thessaloniki in Greece (Seix-Sou) is located to the northeast of the city at a relatively small distance from the city-centre. It occupies the southern and southwestern slopes of Mount Chortiatis, up to the Eptapyrgio – Asvestochori Road (Figure 1). The forest has a total area of 30.2 million m^2 (3,000 ha). The longitude of the forest is between 22°57´ and 23°04´ and its latitude – between 40°35´30´´ and 40°39´30´´. The maximum altitude is 400 m. The main tree species in this area are: *Quercus coccifera* Kit., *Pinus bruttia* Ten. and *Cupressus sempervirens* L. The forest road in question is 5.5 km long. It is

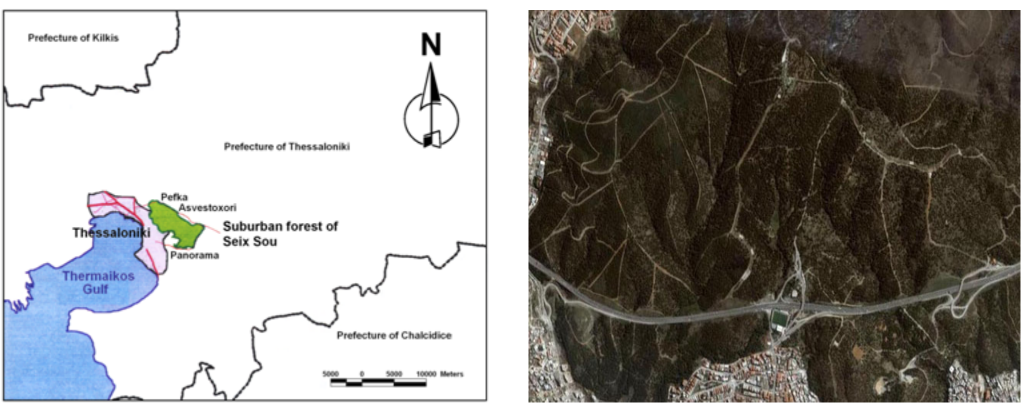

Fig. 1. Region of Seix – Sou.

to be a permanent road and its usage is for transportation but also for forest recreation. The direction is west – east and the exposure is western.

Methodology

The method, which would be applied, should be practical, effective and easy to use prior to road construction. If a forest road is a new construction, the intensity of the impacts and its ecosystem absorbency should be evaluated against certain criteria (Drosos 2009). These criteria are divided into 2 categories: the criteria of the absorbency capacity of the ecosystem and the criteria of the intensity effect of the forest road construction. Additionally for each criterion a weight coefficient is introduced. These coefficients resulted from a research based on specific questionnaires filled by specialized scientists on forestry and environmental issues.

The grading of these criteria depends on the following principle: We accept a situation as ideal (=100 %) with respect to forest protection against road construction. The percentage of deviation from this ideal situation will be subtracted from 100 %. The result will be the grading of the criteria.

A. As far as absorbency is concerned

These criteria are based on the opinions of experts (special scientists) and relevant literature (Warner 1973, Kotoulas 1987, Stergiadis et al. 1984, Ntafis 1990, Trzesniowski 1993, Drosos et al. 2006). The absorbency criteria are divided into 3 categories: 1st forestry criteria, 2nd topographic criteria and 3rd social criteria.

The weights of the criteria are: three (3) for the forestry criteria, two (2) for the topographic criteria and one (1) for the social criteria.

The forestry criteria are the following:

1. The kind of coverage, i.e. the percentage attributed to road coverage on the basis of the type of area that the road crosses: if it goes through a forest it is graded with excellent 100 %, if it goes through a wooded area it is graded with 25–50 % depending on its density, and if the road crosses a woodless area it is assessed with 15 %.

2. The forest species, i.e. the length percentage of the part of the road under study that crosses a mixed forest is graded with excellent 100 %; that of the part crossing a coniferous forest – with 70 %; and that of the part that crosses a broadleaf forest – with 50–80 % depending on the season when measurements are performed, that is if trees have leaves or not.

3. The management form, i.e. the length percentage of the part of the road under study that crosses a seedling (high) forest is graded with excellent 100 %; that of the part crossing a coppice forest is graded with 50 % and that of the part that crosses a composite or middle forest is graded with 75 % to 100 % depending on the seedling-coppice forest rate.

4. Age (forestry form), i.e. the length percentage of the part of the road under study that crosses a group-selective forest is graded with excellent 100 %; that of the part crossing a selection forest with 75 % and that of the part that crosses an even-aged forest – with 50 %.

5. The height of the trees, i.e. the length percentage attributed to the road under study on the basis of the height of the trees present in the area: if the road goes among large trees >20 m it is graded with excellent 100 %; among medium size trees 10–20 m – with 75 % and if the road

goes among small trees <10 m – with 25–50 % depending on their height.

6. The site quality. Good (first and second site quality), medium (third and forth site quality) and poor (fifth and sixth site quality). The percentage of the road crossing: good site quality is graded with excellent 100 %, medium – with 50 % and poor – with 25 %.

7. The productivity of the forest:

Category I (productivity over 3 $m^3 \cdot year^{-1} \cdot ha^{-1}$).

Category II (productivity 1–3 $m^3 \cdot year^{-1} \cdot ha^{-1}$).

Category III (productivity less than 1 $m^3 \cdot year^{-1} \cdot ha^{-1}$).

The percentage of the road crossing forest of category I productivity is graded with excellent 100 %, forest of category II productivity – with 50 % and forest of category III productivity – with 25 %.

The topographic criteria are the following:

1. The cross slope of the land. The percentage of the road passing along small slopes <8 % is graded with excellent 100 %, along medium slopes 8–20 % – with 50 and high slopes >20 % – with 25 to 5, depending on the slope.

2. The aspect. The percentage of the road passing at an altitude less than 1000 m with northern exposition is graded with excellent 100 %, southern – with 50 % and eastern-western – with 75 %.

The percentage of the road passing at an altitude over 1000 m, with eastern or western exposition is graded with excellent 100 %, and with northern or southern ones – with 70 %.

3. The terrain relief. The percentage of the road passing through a mild relief is graded with excellent 100 %, through a multifarious relief – with 15 % and through a varied relief with 50 %.

Social criteria depend on the number of humans affected by the road. Distance plays a major role in impact e.g.

1. Distance from a tourist resort (Since tourism is seasonal and is culminated during the peak season, each kilometer of the distance from the resort increases grading e.g. distance 0–1 km is graded with 0, 1–2 km with 10 %, 2–3 km with 30 % etc.).

2. Distance from the national and country road network (the same as with the resort).

3. Distance from a railway (it has no direct impact but if one sees the road from the train, he/she might want to visit the forest by car. However, it has impact due to noise).

4. Distance from an archaeological site (the same as with the resort).

5. Distance from an adjacent big city (the same as with the resort).

6. Distance from an adjacent village (the same as with the resort).

7. Distance from a European path every time the road crosses the path, its grading is reduced (e.g. if it crosses the path once it is graded with 80 %, if twice with 60 %, 3 times with 40 % etc.).

8. Distance from a natural or artificial lake or river (the same as with the resort).

B. As far as intensity is concerned

The criteria of intensity have been determined on the basis of the relevant literature and a specific questionnaire (Kotoulas 1985, Ntafis 1986, Mader 1990, Zundel 1990, Sedlak 1993, Becker 1995, Doukas 2004). The intensity criteria were divided in layout criteria and construction criteria. The layout criteria are the following:

1. The curve radius (the more it exceeds 25 meters the lower the grading).

2. The layout of the gradient (the higher than 0.5 m the height discrepancy be-

tween the ground and the gradient, the lower the grading).

3. The cross section (the larger than 0.5 m the distance of the centre line and the section point of the road with the ground, the lower the grading depending on the discrepancy in meters).

4. The road gradient (the percentage of the road where the road gradient is not 3–12 %, reduces the grading on a scale of 100).

5. The width of the road (the percentage of the road where the road width is different than 3.5 m with widening every 250 m, reduces the grading on a scale of 100).

6. The distance of serpentines (the less than 500 m the distance between serpentines, the lower the grading).

7. The distance of the forest road from a stream, from the forest boundaries and from dangerous sites.

● The percentage of the forest road that is located on a valley less than 10 m away from a stream bank reduces the grading on a scale of 100.

● The percentage of the forest road that is located less than 10 m outside the forest boundaries or less than 20 m inside the forest borders, for aesthetic reasons, reduces the grading on a scale of 100.

● The percentage of the road passing by a clay ground, large opening streams, unstable grounds, reduces the grading on a scale of 100.

8. The view of the forest road to morphological formations, vegetation, space projection, compatible constructions, and water areas.

● The percentage of the road where there are no morphological formations (no need to prevail), reduces the grading on a scale of 100.

● The percentage of the road, where the visual field is not consisted of vegetation forms providing even a limited variety; uniform cultivation in the form of geographical shapes reduces the grading on a scale of 100.

● The percentage of the road, where the visual view does not focus on the forest and the assiduous forestry interventions, is graded with a lower percentage on a scale of 100.

● The compatible constructions should be constructed of wood and stone and are graded with excellent 100 %; the construction of concrete – with 50 %; and the construction with the combination of the above materials – with 75 %.

● The percentage of the road, where the visual field include no water flows and streams, even with limited visual interest and clarity (provided that they exist), is graded with a lower percentage on a scale of 100.

9. The adaptation of the forest road in the environment.

The percentage of the road, which is not visually concealed when observed from the opposite slope from a spot of the same altitude, is graded with a lower percentage on a scale of 100.

The construction criteria are the following: construction machinery, construction materials, the seeding and mulching of side slopes, technical operations, drainage and supply.

1. Machinery for excavation works.

● The percentage of the road, where a hydraulic excavator has not been used on earthy grounds with ground slope over 60 %, is graded with a lower percentage on a scale of 100.

● The percentage of the road, where a hydraulic excavator has not been used on rocky grounds for fragment management, is graded with a lower percentage on a scale of 100.

2. Construction materials.

● The percentage of the road that has not been stabilized on a road gradient >10 %, is graded with a lower percentage on a scale of 100.

● The percentage of the road where the material of **road surfacing** is not taken from the site or does not consist of environmental-friendly recycled materials is graded with a lower percentage on a scale of 100.

● Depending on the construction materials, if the road is gravel-paved, it is graded with a lower percentage on a scale of 100. If it is asphalted or if it bears other construction materials, it is graded with 50 %.

3. Seeding and mulching of side slopes.

The percentage of the road's side slopes, where on the embankments with slope near the corner of the natural side slope and ground slope of about 60–70 %, natural or technical seeding and mulching has not been carried out, is graded with a lower percentage on a scale of 100.

4. Technical operations, drainage, supply.

● The percentage of road culverts that are not: a) Slab-roof culverts in openings 3–4 meters wide; b) Drain boxes on soil of poor bearing, 3–4 meter wide; c) Concrete pipes with embankment twice as large as the pipe's diameter, depending on the type and corner of bearing; d) Stabilized stream beds with concrete (passages), is graded with a lower percentage on a scale of 100.

● The percentage of the road retaining walls exceeding 3 m in height is graded with a lower percentage on a scale of 100.

● The percentage of exceeding the bridge's opening over 8 m is graded with a lower percentage on a scale of 100.

● The lack of drain dips (rills) across the surface at road gradient >10 % and length >100 m., is graded with a lower percentage on a scale of 100.

● The percentage of the main forest road where ditches on the road surface and the necessary sloping for its drainage lack is graded with a lower percentage on a scale of 100.

The evaluation of all these criteria of absorbency and intensity will be difficult and therefore the description of an E.I.A. in a profile form will be a necessary addition (Figures 2 and 3).

Final grading – Compatibility coefficient

The grading is carried out as follows:

1. To calculate the mean intensity value, we multiply the grade of each criterion by its weight and at the end; we divide the sum of the products by the total sum of the weights. This value is the mean intensity value (C_I) on a scale of 100 %. The same applies for mean absorbency (C_A). These figures, C_I and C_A, provided that weight coefficients are not subjective, indicate the approximate protection degree of the natural environment from the construction of the forest road.

2. To calculate the forest road's compatibility coefficient (C_C) we multiply the mean absorbency value by the mean impact intensity value.

When the compatibility coefficient is more than 60 % or 0.60 the construction is accepted under no special conditions. If the compatibility coefficient is 0.50–0.60 the construction is accepted under conditions. If the compatibility coefficient is less than 0.50, the impacts will be too big and there is a need to change the layout or to design activities for restoring the natural environment.

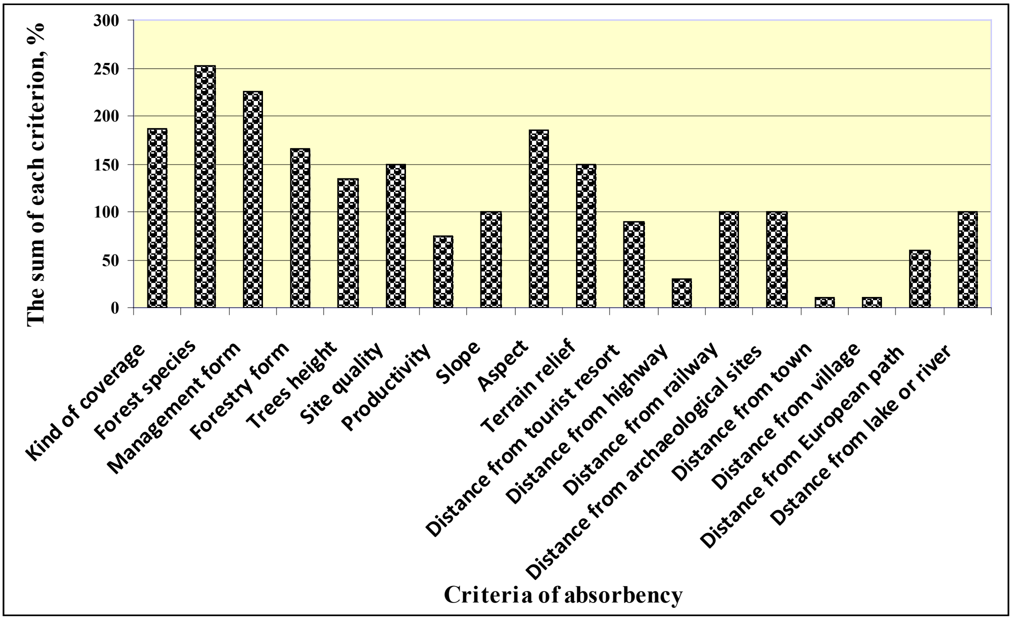

Fig. 2. The profile form of absorbency criteria.

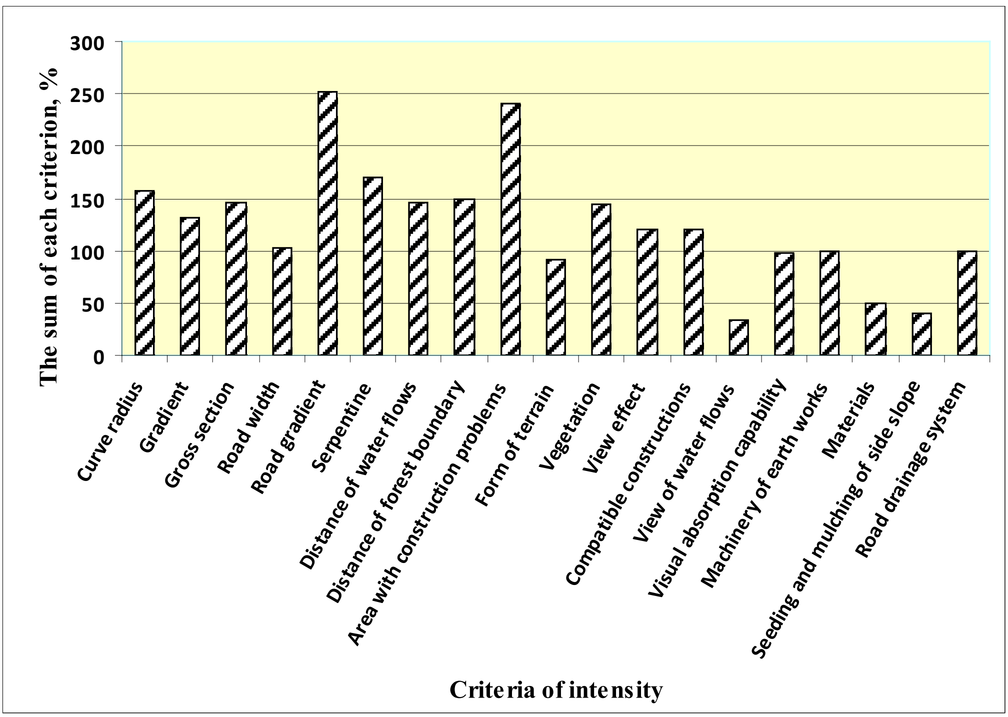

Fig. 3. The profile form of intensity criteria.

Results

The evaluation of the forest road intensity and ecosystem's absorbency resulted in Table 1.

To calculate the forest road's compatibility coefficient we multiply the mean absorbency value by the mean impact intensity value (Formula 1).

$C_C=C_I \cdot C_A=60.66\% \cdot 72.68\%=44.09\%$ (1)

It seems that the forest road in question has mean absorbency value of 60.66 % and mean intensity value of 72.68 %. The forest road's compatibility coefficient with natural environment is 44.09 % or 0.4409.

Conclusions and Suggestions

Because the compatibility coefficient is below 0.50 (*Cc*=44 %) the impacts are very large and there is a need either to change the layout or to design activities for restoring the natural environment. Generally, the low rate (<50 %) indicates that there have been (or will be) significant impacts on the forest because of the construction of forest road. In this case, the compatibility coefficient, although quite low (44 %) can be improved with additional new activities which will help the restoration of the natural environment, such as slope protection technical operations, seeding and mulching of side slopes etc.

In order to be acceptable the road needs to be improved substantially. Based on the results we see that problems emerge on absorbency because of: 1) the site quality is medium to poor so the density and the height of the trees are extremely low; and 2) it is inside a suburban forest and there is no wood production The main role that a suburban forest is called to fulfill is the protective one, secondly – the recreation role and then the healthy one.

Regarding the intensity, the forest road in question was not constructed as it should be according to the criteria of mixed section. Furthermore, the width of the road surface is well above the required width (3.5 m). There was no proper roadway and the road surface was stabilized through the process of embankment using healthy aggregates. Also the visual absorption capability is too low as well as the landscape especially in the form of terrain and in parts where water flows are extremely low.

On several locations the road is well above the grade line set out on the ground so that it can be constructed in a filling and in some cases even small trapezoidal cross sections were created.

The method used here for the characterization of the road network can also be used in the case of road construction assessments or of alternative road alignment projects so that we can choose the best methodology in terms of the smallest degree of environmental impact in order to improve certain aspects of road construction. The evaluation of the construction in a forest road depends on three parameters:

1. The cost of construction and rehabilitation of the natural environment;
2. The intensity of the effect that is not negative; and
3. The absorption of forest ecosystem.

Construction or maintenance of a road network that is compatible with the natural environment is also dependable on the availability of sufficient governmental funds.

In the assessment of environmental impacts, failings are identified, due to:

- the means or methods used for the assessment of all the direct consequences;

● the expected or unexpected future impacts;

● non-objective estimation of the magnitude of the direct consequences.

Interventions by scientists (such as forest engineers etc.) to restore the environment from the effects should be proportional to the absorbency of the natural environment, i.e. must not exceed the capacity of the environment to absorb the consequences of the construction of developmental infrastructures or works.

This method of calculating the compatibility coefficient for a proposed forest road should be applied to the primary route and all proposed alternative routes so that the optimal route for minimized environmental impact can be selected.

Table 1. Evaluation of forest road.

Criteria	Weights	Grade, %	Sum
a. Criteria of absorbency (*A*)			
1. Terrain conditions			
1.1. Forest	3	62	186
1.2. Broadleaved forest	3	84	252
1.3. High forest	3	75	225
1.4. Selection forest	3	55	165
1.5. Mean height	3	45	135
1.6. Site quality	3	50	150
1.7. Productivity	3	25	75
1.8. Slope	2	50	100
1.9. Aspect	2	92.5	185
1.10. Relief	2	75	150
2. Distance from			
2.1 Tourist resort	1	90	90
2.2. National and country road network	1	30	30
2.3. Railway	1	100	100
2.4. Archaeological site	1	100	100
2.5. Adjacent big city	1	10	10
2.6. Adjacent village	1	10	10
2.7. European path	1	60	60
2.8. Lake or river	1	100	100
b. Criteria of intensity (*I*)			
Layout			
1. Earthwork allocation			
1.1. Curve radius	2.10	75	157
1.2. Gradient	2.01	65	131
1.3. Cross section	2.25	65	146.25
2. Road width	2.04	50	102
3. Road gradient	2.52	100	252
4. Serpentine	2.13	80	170.40
5. Position of road			
5.1. Distance of water flows	1.83	80	146.4
5.2. Distance of forest boundary	1.65	90	148.5
5.3. Area with construction problems	2.40	100	240
6. Picture of landscape			
6.1. Form of terrain	1.83	50	91
6.2. Vegetation	1.80	80	144
6.3. View effect	1.70	70	119.7
6.4. Compatible constructions	1.60	75	120
6.5. View of water flows	1.65	20	33
7. Visual absorption capability	1.77	55	97.35
Construction			
8. Construction of forest road (only for existing road)			
8.1. Machinery for excavation works	2.16	2,16	100
8.2. Materials	2.08	2,08	50
8.3. Seeding and mulching of side slope	1.38	1,38	40
8.4. Road drainage system	2.31	2,31	100

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FORESTRY IDEAS, 2013, vol. 19, No 1 (45): 69–78

EVALUATION OF AHP APPLICATION FOR HYRCANIAN FORESTS THROUGH ROAD CONSTRUCTION POTENTIAL MAP

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Received: 03 November 2012 Accepted: 06 June 2013

Abstract

Forest road network planning in ameliorated forest is an important factor for constant forest development that not only leads to decrease in cost but also prevents forest destruction. Final decision in forest road planning is not possible just by optimization of one variable. Therefore, multi criteria decision methods have been developed. Analytic Hierarchical Process (AHP) is one of the most well-known multi criteria decision techniques that has been introduced for resolving planning needs. The purpose of this study was to evaluate AHP application in preparing road potential map for Hyrcanian forests in northern Iran. Study area is a part of No 7 watershed domain in northern Iran and corresponds to the general peculiarities of Hyrcanian forests. Regarding natural condition of Hyrcanian forests, in this study, 8 factors were taken in to account, such as slope, exposition, altitude, vegetation type, volume of growing stock, hydrographic peculiarities, geology and pedology. In order to validate indicators, a questionnaire was developed and distributed among road construction experts in Natural Resource Organization. Indicators' relative weights were calculated by Expert Choice software. After getting every layer validity ratio, these layers were synthesized in ArcGIS9.2 software to make potential map for road construction. Resultant potential map was compared with one proposed by university professors. Forty points were designated electively in both potential maps and were evaluated with regards to mentioned factors. Studies showed that results proposed by professors were more accurate than these proposed by experts. However, with regards to percentages and results obtained this method cannot be used safely in potential map preparation for road construction in Hyrcanian forests.

Key words: AHP method, forest road network, Hyrcanian forests, potential road construction map.

Introduction

Forests have always been considered as renewable and productive resources. Human need for wood and its productions is permanent and inevitable. Therefore humans have found out that for permanent and economic exploitation of forests, it is necessary to develop particular rules and orders. Forestry plans resulted from this attitude. Roads are the forest vital arteries in forestry plans and their main function is to open the forest and to make it accessible to apply methods of forestry, and finally forest management techniques (Najafi 2006). Road is an essential part in silviculture, afforestation and other required operations in forest (Hay 1996). On the other hand, road construction has harmful environmental consequences, like forest area diminution, natural canalization destruction and sedimentary soil and water destruction (Gardner 1997, Egan et al. 1985). The roadway grade should be carefully selected, not only to minimize the total road cost but also to reduce the environmental impact and to improve driver safety (Akay 2004).

Despite necessity of forest operation and importance of road in northern Iran forests, it's necessary to know that road construction is problematic too. Also, only some parts of northern forests in Iran have operation and road construction potential. Because of slope lands, unstable areas, ruined lands and environmental limitations in Iran's northern forests, activity opportunities are restricted. Therefore, it is necessary to select appropriate areas for road construction. In this way forest utilization will be constant (Najafi 2006). Type of forest road network designed, its optimal planning is a permanent forests development important factor that increases costs and destruction of nature and vegetation. It is necessary to identify the important points on eventual road and all probable points that road may cross, by topographic, vegetation, geology, pedology and other existing maps for a forestry plan and by using systems like GIS. Geographical Information Systems is a frequently used tool in the decision making process. It uses database queries to find the best solution requiring the least time and money (Erdas and Gumus 2000). The most important advantages of GIS application in road planning are: to fill a large number of layers in use, capacity of large volume data process, possibility of using digital maps in high correctness, easier editing capacity, high speed and low cost operating. These advantages caused growing use of GIS. The geomorphological mapping issues and the GIS role in doing it were consistently reviewed and applied on a small mountain area in Sweden by Gustavsson et al. (2006, 2008) and Gustavsson and Kolstrup (2009).

A comprehensive digital geomorphological mapping may be a useful tool for land reclamation planning, sustainable development of the area, risk and hazard assessment (Condorachi 2011).

In road planning for forest, different factors must be checked and their priority evaluated. In other word, final decision is not possible just by optimizing one factor. Obviously to resolve such problems is complicated and not easy task, especially when most of the mentioned factors are in contrast with each other and optimizing one may cause blight the other. Therefore some multi criteria decision methods divide the problems separately into smaller reasonable parts, and then synthesize the out coming results to make a global solution for main problem solving (Malczewski 1999). Hierarchical analyzing process is one of the most known multi criteria decision techniques, which was introduced by Saaty in 1980 to allocate rare resources and planning requirement for military purposes (Saaty 1997). Hierarchical analyzing process techniques make possible to formulate problem hierarchically and to consider quantity factors in problem too.

Moreover, applying this method show a composition to cooperation and incoherence rate of decision too, this is one of the significant advantages of this technique in multi criteria decision (Ghodsipoor 2009).

Malczewski (1999) in his research in Ohio state of US, advanced a step and manifested that as each effective factor has not the same effect on routing , in other word, their potency rate in routing are not similar, so these factors are to be validated. In his research he used mutual comparison method between validation methods, because of its strong theory base, high accuracy and easy application.

A comparison matrix is formed in this method. In this case to minimize personal ideas in validation, expert viewpoints about effective factors relative validity are used, and factors mutual comparison is done by expert choice software.

Heralt (2002) in a research in Romania, express that forest road network planning is a hard and engaging work and depend on numerous factors. Except costs, which have no essential role in forest road completion and development, factors such as road appropriate locational distribution in total rejoin, perspective pattern, forest hydrology role, and soil protection, have significant effects on forest road network planning.

Naghdi and Babapour (2009) during their study on Guilan's Shafarood forest, planned the road by GIS and AHP, used 6 maps of direction, height, volume per hectare, trees species, slope, and stability, and realized this method may be useful on Iran's mountainous forest and is preferred to road planning by traditional method. They used university professor view point to complete AHP questionnaires.

Mohammadi Sammani et al. (2010) performed a study on Guilan forest enterprise to road planning and evaluating technically and environmentally. They considered different factors which may affect the forest roads planning and used analytic hierarchical process (AHP) to compare them to each other. They used university road construction professor's ideas to complete AHP questionnaires too.

The objective of the present study was to evaluate potential map for road constructions resulted from road construction professor's ideas in universities and road construction experts in natural resources organization, and to compare them in nature, in order to evaluate the function of AHP method in Iran's northern forest.

Materials and Methods

The study area (3559 hectares) is located within the watershed number of 7 in north of Iran (Fig. 1). This forest is located on 48°44'36" to 48°49'58" latitude and 37°37'23" to 37°42'31" longitude and at altitude ranging from 280 to 2120 m above sea level.

Study area is mainly in rainy regions and in term of climate classification is ranged as humid climate. Most of the year is rainy and maximum rainfall is in September and October.

The study forest is classified as mountainous forests and belongs to hyrcanian forests, and it is easily accessible to outdoor operations and data and information are available, so this forest was chosen as study area.

In order to have constant access to countless forest gifts, expected activities during plan accomplishment must be

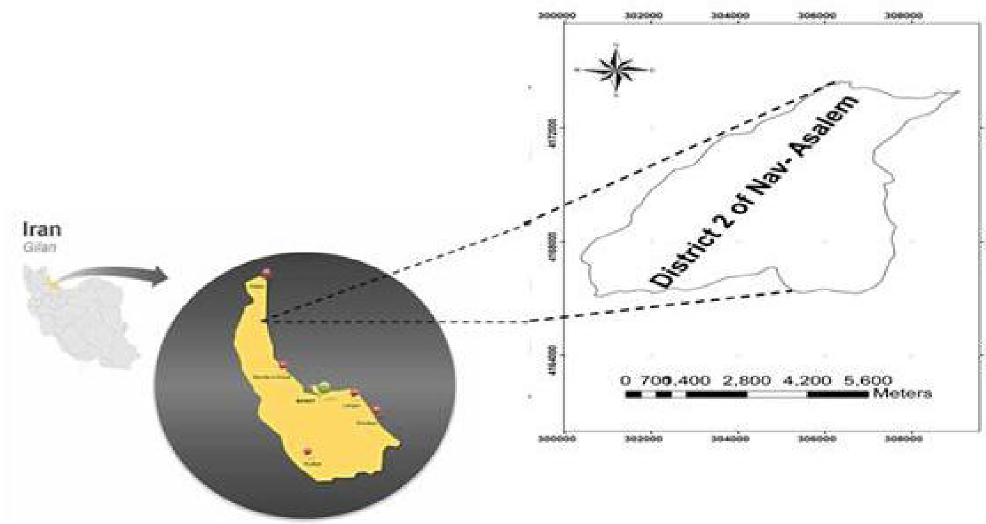

Fig. 1. The location of the study area.

in natural potential limits. Road network planning is the first activity in forestry plans preparation in which different ecological and economical factors must be considered, compared with each other and validated.

In this study, regarding hyrcanian natural condition, 8 factors were considered as effective ones and used for road construction potential map preparation. They were slope, aspect, altitude, vegetation type, volume of growing stock, hydrography, geology and pedology. Then to employ different experts' viewpoints in order to give value to each factor, a questionnaire was planned and the objectives, principles and general techniques were explained to road construction experts in natural resource organizations. Then the questionnaire was distributed among them and they were asked to present their view points about 8 mentioned factors by mutual comparison method (giving points are limited between 1 and 9). Next, questionnaires were collected, introduced factors relative values were calculated, and most effective factors on sylvan road path locating were determined by mutual comparison method in Expert Choice software, and each questionnaires variance was calculated. Saaty (1997) suggested if decisions variances were more than 0.1, it is preferred to modify decision. Also Mohammadi Sammani et al. (2010) in order to validate effective factors on road planning in Nav forest, district 1, which is located adjacent to district 2, and was very similar to district 1 topographically and climatically, applied analytic hierarchical process, except that they distributed questionnaire among university road construction professors and benefited their ideas. They gained different result from the result of this study, which is the base comparison.

After obtaining each layer validity ratio, in order to prepare potency map for road construction, in Arc GIS 9.2 software, each layer's validity ratio was multiplied by itself, and then these layers were add-

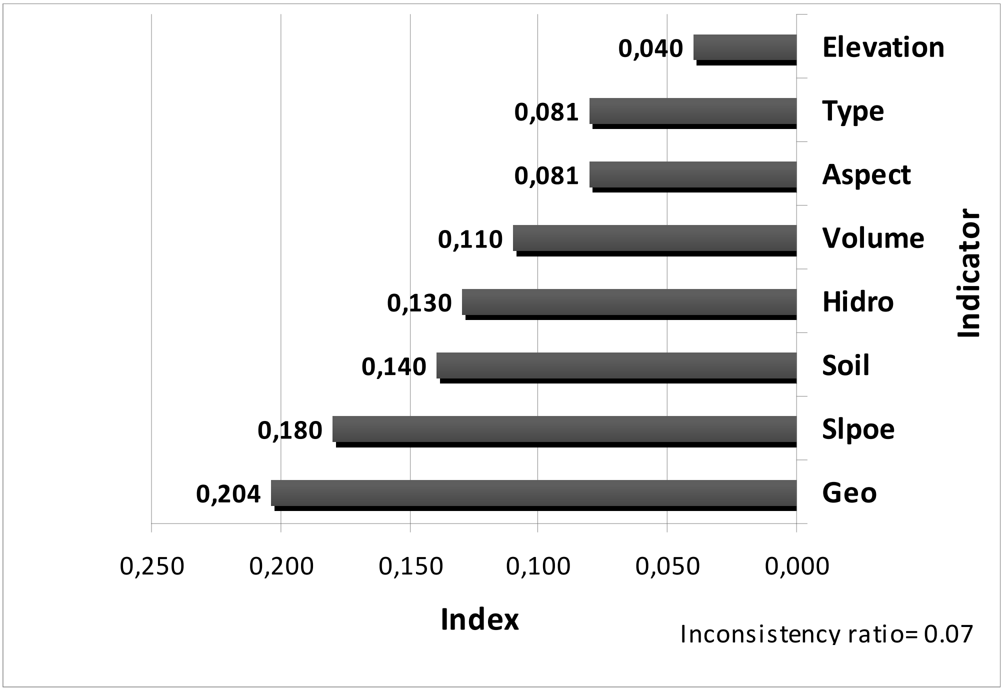

Fig. 2. Layers validation regarding to Natural Resource Organization expert's view points.

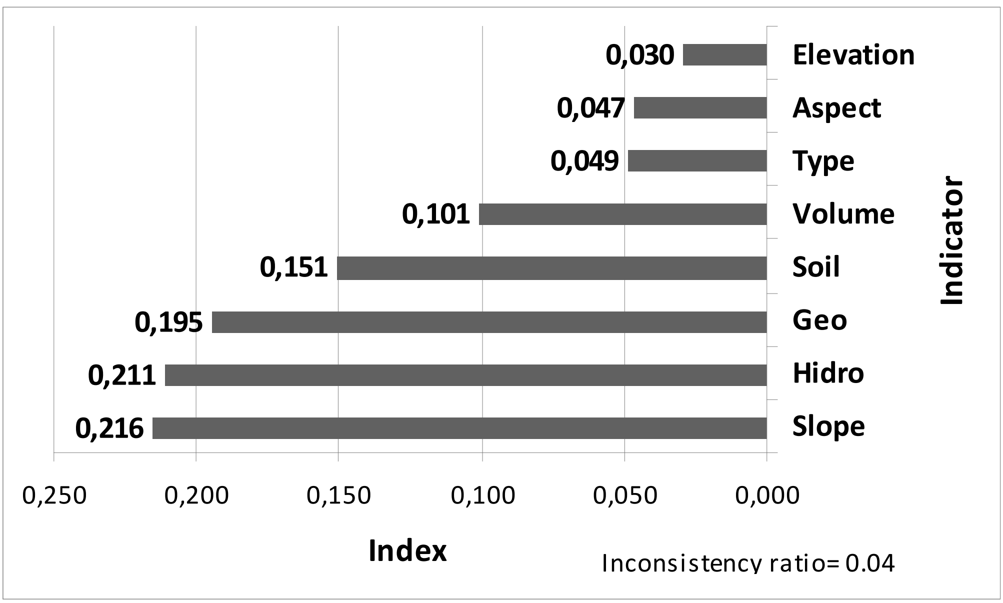

Fig. 3. Layers validation to university professors.

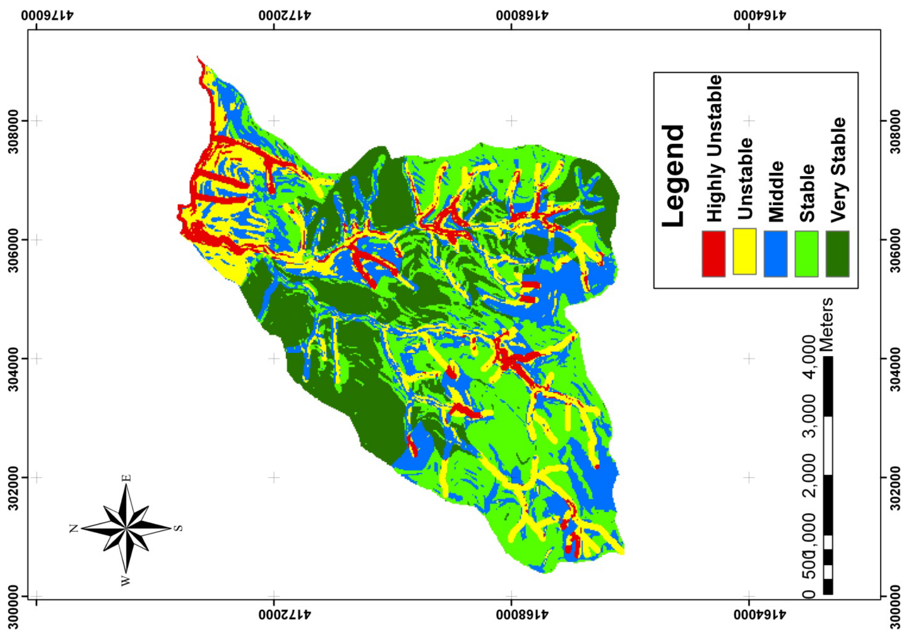

Fig. 5. Potency map to road construction by viewpoints of university professors.

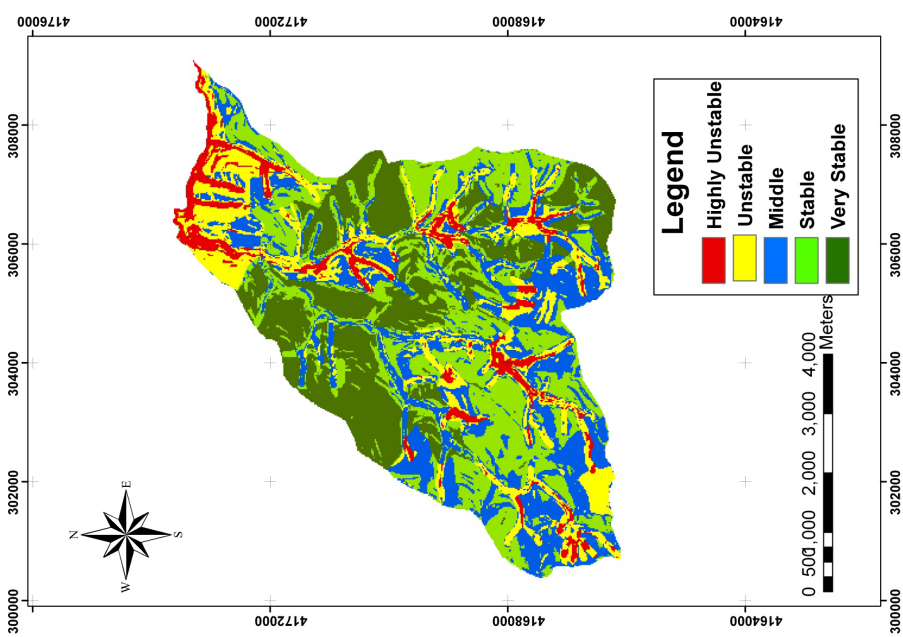

Fig. 4. Potency map to road construction by viewpoints of natural resources organization experts.

ed together. With compilation of these layers with regard to value of them potency map was prepared in 5 levels: very stable areas, stable areas, middle areas, unstable areas and very unstable areas. Very unstable areas are the areas which are unsuitable for road construction by all factors. Unstable areas are districts, which are suitable by 2 or 3 factors and other factors regarded are unsuitable. Middle areas in this division are districts which are suitable in 4 factors and unsuitable in 4 factors. Suitable areas which are suitable in most of factors are unsuitable in 2 or 3 factors. And finally, very stable areas are districts, which are suitable to road construction by all factors. In this classification the areas with more than 70 % slope were classified as very unstable areas without regarding other factors, because road construction in areas with such a slope is too hard and expensive. In next step, the resultant potency map regarding the ratios gained from expert's viewpoints were compared with potency map produced from resultant ratios by Mohammadi Sammani et al. (2010) regarding the 8 mentioned factors. Then 40 points were randomly selected and their coordinates were entered in to GPS. With regard to 10 areas were exist (5 area in potency map of experts view, and 5 areas resulted from defined ratios by Mohammadi Sammani et al., 2010), 4 control points were taken in each area. Next, prepared potency maps correctness was evaluated with outdoor observation.

Results

Derived results from analysis of distributed questionnaire among Natural Resource Organization experts by Expert Choice software, showed that geology layer by 0.204 validity ratio must be most important for forest road planning and respectively: slope, pedology, hydrography, volume of growing stock per ha, aspect, tree species and altitude were in next validity (Fig. 2).

However, result of the research derived from Mohammadi Sammani et al. (2010), which was achieved by university professors viewpoints showed that slope layer with 0.216 validity must have the highest effect on forest road planning. Hydrology, geology, pedology, volume of growing stock per ha, tree species aspect and height from sea level were in next validity levels, respectively (Fig. 3).

After analyzing the results of validations through analytic hierarchical process, studying layers by validity level of each one were combined and potential map to road construction was constructed on ArcGIS9.2 software (Fig. 4). Then using results of Mohammadi Sammani et al. (2010) a potential map for the same area was prepared, too.

Results from field visits showed that in 19 of 40 selected points (47.5 %) of university road construction professors' viewpoints case were compatible to nature. In 14 of 40 points (35 %) of natural resources organization experts viewpoints were compatible to field survey, and in 7 points (17.5 %) field survey observations contradicted to both professors and experts viewpoints.

Discussion

Today forest managers and foresters must be aware of forest road planning and construction, and care should be taken in road network planning, because road construction has the most share of forest management cost and environmental effects on forest ecosystem are likely irreparable, so road planning and forest road locating must be achieved as carefully as possible (Dutton et al. 2005). If forest road is planned and distributed well, it will make less damage to forest and vegetation and forest will be in the best state from optimum management perspective. Therefore, forest road planner must pay attention to these basic principles in the planning (Baskent and Keles 2005). Effective factors determination and validation in road construction and planning is essential.

In order to plan a forest road, effective factors for road construction must be considered from technical, cost, and environmental perspective. With this, in addition to time saving it may profit from various persons ideas (Qajar 2006).

Many works have been done using GIS about forest roads planning in hyrcanian forests, majority of them used universities road construction professor's ideas. Babapour (2008) applied in his work topography, slope, aspect, growing, volume of growing stock per ha, forest type, pedology and geology layers as effective factors. Badraghi (2009) used height aspect, slope, pedology, geology and volume of growing stock in road planning. Naghdi and Babapour (2009) in Guilan province forests evaluated forest road network using analytic hierarchical process and stability map. Also Mohammadi Sammani et al. (2010) attempted forest road planning in Nav Asalem forests. He applied new layers like hydrology that was not applied before. All these people benefited universities road construction professors ideas in their effective factors validation. But no one paid attention to expert's ideas that work on natural resource organizations, which are more in touch to these factors that might be useful in validation matter. In this research, this case was noticed for the first time, and organizations expert's ideas were used in factors validation. As mentioned, field researches showed that 47.5 percent of professor's ideas were similar to nature and 52.5 percent were in contrast to nature. Also in 35 percent of cases, expert's ideas were similar to nature and in 65 percent of cases their ideas were in contrast to what was seen in nature. There are plenty of reasons, which could explain this contrast, but it seems that the most significant reason for this discrepancy would be the factors like slope in hyrcanian forests. In this case, it is suggested that the ideas of people who perfectly know the study area should be used to validate the factors. These people might be professors or experts who know the area well. However, professor's ideas were slightly predominant according to nature than expert's ideas, regarding the high error rate (52.5 % in professor's idea and 65 % in expert's idea), cautious use of this method in practice for these forests is recommended and more researches in this matter seem necessary.

General Conclusion

In this research correctness of universities professor's ideas was relatively more dominant than results of experts' ideas; however, regarding the resultant percentages and consequences, this method cannot be used safely in potential map for road construction in practice.

Finally, further evaluation of this research results in other areas of hyrcanian forests is recommended. And in order to achieve road construction projects in forest, safety rate of other methods must be evaluated and appropriate method, having higher safety percent should be chosen and used in road construction projects, which take high costs in forestry plans.

Acknowledgements

We would like to thank and appreciate all of road construction experts in natural resources organizations who helped to achieve this research.

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FORESTRY IDEAS, 2013, vol. 19, No 1 (45): 79–90

PINUS NIGRA ARN. TREE RING CHRONOLOGY FROM SLAVYANKA MTS. IN BULGARIA IS STRONGLY RELATED TO REGIONAL DROUGHT EVENTS

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Received: 05 April 2013 Accepted: 20 June 2013

Abstract

Black pine (*Pinus nigra* Arn.), also known as Austrian pine, is one of the widely used species for dendroclimatic analysis in the European region. Yet, studies for Bulgaria are still scarce and lack for Slavyanka Mts. The position of the mountain on the border of climatic regions, its nature-protection status and the high value of the local *Pinus nigra* variety, outline the importance to study in more details the relationship between radial growth and climate variability and evaluate tree growth in conditions of ongoing change. We composed tree ring width and latewood width chronologies following classic methodology and calculated correlations with climate series from Sandanski meteorological station. We found positive significant correlations with precipitation in early summer (r>0.4) and significant negative correlations with temperatures from the current and previous summers (r>0.43). Spatial correlations with September PDSI reveal strong positive correlation for wide area over the Balkan Peninsula. We consider that the local origin of *Pinus nigra* may be valuable for composing chronologies of summer drought events for the period without meteorological data.

Key words: tree ring chronologies, climate, precipitation, temperatures.

Introduction

Tree rings provide very good proxy records of past environmental conditions. This was successfully used for developing high-resolution climate reconstructions for periods prior to the existence of instrumental measurements. Yet, trees belonging to different subspecies and growing at different locations vary from one another in their response to ecological conditions. Climatic sensitivity of trees also changes through time (Leal et al. 2008). Because of the observed climate changes in many parts of the globe in recent decades, updating existing and composing new tree-ring chronologies is particularly valuable in evaluating potential changes in climate–tree growth responses during this period (Leal et al. 2008, Hughes et al. 2011). The Balkan Peninsula is one of the regions with highest climate vulnerability in Europe, but proxies are scarce for the area and this limits better understanding of long-term climate variability (Trouet et al. 2012).

A number of dendrochronological studies evaluate the *Pinus nigra* species as sensitive to climate variability (Strumia et al. 1997, Akkemik and Aras 2005, Leal et al. 2008, Köse et al. 2012a, Levanic et al. 2012, Poljansek et al. 2012). The tree ring widths of *Pinus nigra* Arn. trees growing near the ecological limits for the species in the Vienna basin, Austria, showed strong and positive correlation with spring-summer precipitation (Leal et al. 2008). Studies from Turkey (Akkemik and Aras 2005, Köse et al. 2012a), Bosnia and Herzegovina (Poljansek et al. 2012) and Albania (Levanic and Toromani 2010) came to similar results. Amodei et al. (2013) studied the radial growth response to climate of three ecologically different populations of *Pinus nigra* ssp. *salzmannii* from the south of France. Proxy reconstructions of April–August (Akkemik and Aras 2005) and May-June precipitation (Köse et al. 2012b) were developed for Central and Western Turkey, respectively, by using *Pinus nigra* tree rings. For South-West Romania, a reconstruction of standardized precipitation index (SPI) indicating drought based of Black pine was made (Levanic et al. 2012). Wimmer et al. (2000) suggest that reconstruction of early growing season precipitation can be done with the use of false rings, formed by *Pinus nigra* trees from the Viennese basin. All these studies demonstrate well the suitability of Black pine for dendrochronological studies and especially for constructing proxy drought records.

Although there are many dendroclimatic studies on *Pinus nigra* for the western and central parts of the species' distribution area (Biondi 1992, Strumia et al. 1997, Richter et al. 1991, Fuster 2000, Leal et al. 2008, Andreu et al. 2008, Martin-Benito et al. 2008, Martin-Benito 2010) for the eastern parts of the range the studies are less. Yet, they have been progressing recently (e.g. Akkemik 2000, Hughes et al. 2001, Levanic and Toromani 2010, Poljansek et al. 2012, Köse et al., 2012a).

In Bulgaria dendrochronological studies of black pine were made for Western Rhodopes Mts. (Grozev and Nedelchev 1996) and Lozenska Mts. (Grozev and Yonov 1995). These early attempts demonstrated the suitability of local populations for tree ring analysis, but did not progress to long climate reconstructions. More substantial dendroclimatic analyses of this species' populations in the country still lack. For Slavyanka Mts., situated in the SW part of the country, there are no such studies yet.

The aim of this study is to determine the reaction of *Pinus nigra* trees in the region of Slavyanka Mts. to climatic conditions (temperatures and precipitation) and evaluate the suitability of the regional populations for climate reconstructions.

Material and Methods

Main characteristics and distribution of *Pinus nigra* in Bulgaria

Black pine (*Pinus nigra* Arn.) occurs in Central and South Europe and Southwest Asia. Trees of the species can be over 40 m high and up to 2 m in diameter and can reach ages of about 600 years (Richardson 2000). Tree ring boundaries in *Pinus nigra* wood are distinct with generally abrupt transition from earlywood to latewood. Occasionally false rings are observed in samples from lowland regions (Schoch et al. 2004). Missing or partially missing rings can occur in samples from sites with extreme conditions. The species is xerothermic and grows at altitudes between 400 and 1500 m a.s.l. mainly in steep areas on different soil types. It is not shade tolerant and prefers warm conditions. In Bulgaria is distributed *Pinus nigra* ssp. *pallasiana* (Roussakova and Valchev 2011). The species grows mostly on Rendzic Leptosols and Rendzinas on steep and often rocky slopes in the southern and western parts of the country. Local populations are well adapted to high summer temperatures and can resist low winter temperatures (Yurukov 2003). The local *Pinus nigra* ssp. *pallasiana* forests are classified as vulnerable habitat in the Red Data Book of Bulgaria.

Study Area

The studied trees are located near Goleshovo village in Slavyanka Mts., in Southwestern Bulgaria (Fig. 1). The diverse flora and fauna of the region define it as valuable from conservational point of view. Alibotush nature reserve, established in 1951 and declared a part of UNESCO's World Network of Biosphere Reserves in 1977, is situated in Slavyanka Mt.. The region of Slavyanka Mt. is also part of the ecological network of protected areas NATURA 2000.

The study area is at 1400 m a.s.l. Climate in the area is formed under strong Mediterranean influence. The precipitation maximum occurs in autumn and winter, while the summer is arid with high temperatures. Soils are mostly *Rendzic Leptosols* on limestone bedrock. They are thin and have low water holding capacity. Such combination of site conditions is expected to result in high sensitivity of the trees to available moisture and to minimize their sensitivity to non-climatic factors.

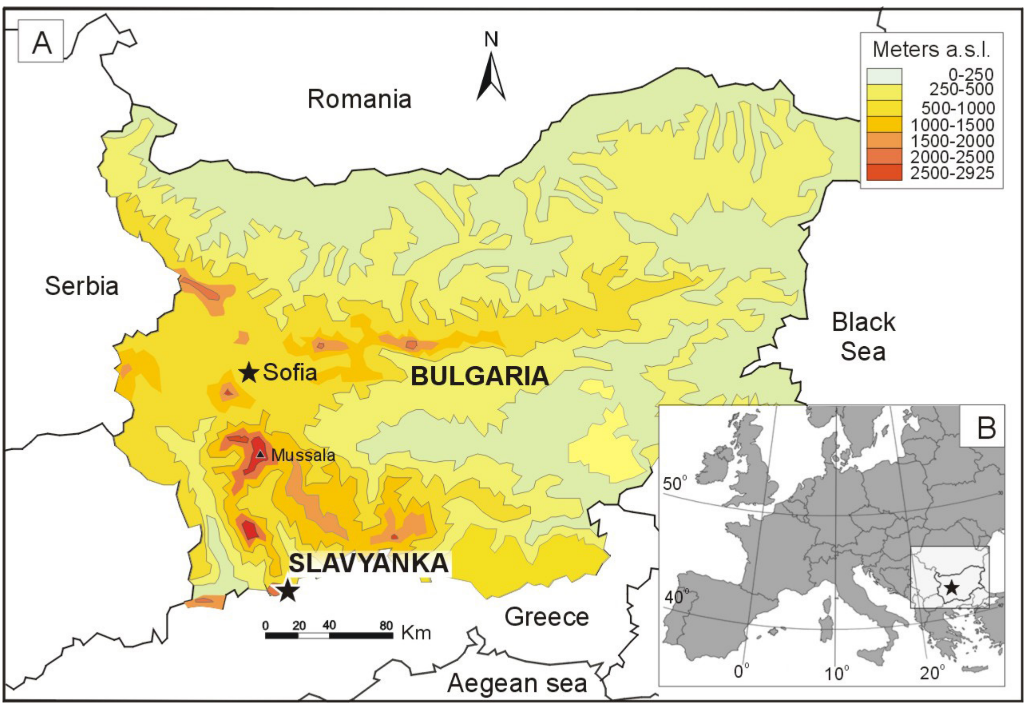

Fig. 1. Location of the study area.

Data collection and chronology development

We extracted 20 cores with increment borer at breast height from dominant trees. The cores were air-dried and mounted on wooden holders. After sanding with progressively finer sandpaper until the annual rings and tree ring morphology became clearly visible, all samples were scanned at 1200 dpi. Individual tree ring widths and latewood widths were measured with Cybis CooRecorder 7.3 software to the nearest 0.01 mm. The tree-ring width series were cross-dated both visually and with the software CDendro 7.3. The program COFECHA (Holmes 1983) was used for between-series correlation analysis and verification of measurement and cross-dating accuracy. The single tree-ring width series were standardized with ARSTAN (Cook 1985), using cubic smoothing splines with 50 % cutoff of 100 years for removal of age-related trend. This standardization method is data-adaptive and removes low-frequency signal from the series. Yet, the selected spline length preserves the decadal variability, which might be due to climate variations. Calculated series of index values were then used for building a standard chronology that does not contain age-dependent ring width variations. We also measured latewood widths and built a separate latewood chronology. Because the latewood chronology showed little low-frequency variance, we used the non-standardized (i.e. “raw”) latewood chronology for the correlation analysis. We computed several statistical parameters commonly used in dendrochronology from the tree-ring width series. The mean sensitivity (MS) measures year-to-year variation in tree-ring width and is thus considered an estimate of the extent to which the chronology reflects local climate variation. The first order autocorrelation reflects the influence of previous year’s growth on current growth. The expressed population signal (EPS) quantifies the degree to which the constructed chronology portrays the hypothetically perfect one (Wigley et al. 1984). We computed the EPS over 30-year windows lagged by 15 years and used an EPS value of 0.85 as a threshold for the reliability of our chronologies (Wigley et al. 1984).

We compared the standardized chronology from Slavyanka with other chronologies of the species from Bulgaria and the neighboring countries (Fig. 6). For the comparison we used a 266 years long (1741–2007) *Pinus nigra* chronology from Dobrostan region, Rhodopi Mts., Bulgaria, 1200 m a.s.l., (Shishkova and Panayotov 2013), 280 years (1730–2010) chronology from Baile Herculane, Romania, 1350 m a.s.l., (Levanic et al. 2012), 260 years (1750–2010) chronology from Bukonik, Albania, 900 m a.s.l., (Levanic and Toromani personal communication), 300 years (1719–2010) regional chronology from Bosnia and Herzegovina, 1500 m a.s.l. (Poljansek et al. 2012) and a 252 years (1751–2003) chronology from Scotida Forest, Greece, 1500 m a.s.l., (Kuniholm, International Tree-Ring Data Bank, ITRDB). We calculated *t* values and Glk values and Pearson’s correlations to estimate the similarity between the chronologies.

We also checked for matching years with narrow rings in the studied chronology and other Pine chronologies from Bulgaria.

Climate data and climate-growth correlation analysis

Climate data was obtained from the meteorological station in the town of Sandanski, which is situated 32 km to the north-west of the study area at 220 m a.s.l. The series are not homogenized, but verified and considered to be with high quality. Monthly precipitation sums and average monthly temperatures for the period 1931–2007 were used for comparison with the standard tree-ring width and the raw latewood width chronologies. We calculated Pearson's correlation coefficients between the chronologies and the climate series. In order to determine if the signal is temporally stable, we divided the data in two equally long sub-periods and calculated correlations for each of them. Correlation coefficients were considered significant if they exceeded absolute value of 0.235 for the whole period and 0.325 for the sub-periods.

Table 1. Statistical and descriptive parameters of the tree-ring width chronology and the latewood chronology.

Parameter	TRW chronology	LW chronology
Length	160	160
First year	1848	1848
Last year	2007	2007
Number of series	20	20
Mean width, mm	1.63	0.49
Mean sensitivity (MS)	0.241	0.357
Autocorrelation (1st order)	0.853	0.622
Correlation between series	0.592	0.575

Used abbreviations: TRW – tree ring width; LW – latewood width.

We examined spatial correlations, using 0.5º x 0.5º gridded data of self-calibrating PDSI for the period 1901–2002 (van der Schrier et al. 2006). The PDSI index provides standardized value showing prolonged droughts and is frequently used in climate analysis (Palmer 1965). Maps were generated using the KNMI Climate Explorer (van Oldenborgh and Burgers 2005).

Results

Tree-ring width chronology and a latewood width chronology were built out of 20 cores spanning the period 1848–2007 (Table 1). Latewood width was about 1/3 of the total tree ring width, which indicates that earlywood width has dominant effect over the whole tree ring width.

The raw tree ring width chronology has clear age effect with wider tree rings in earlier years and gradual decrease of the tree ring width (Fig. 2a). About 80–100 years after the establishment of most of the trees they started to have relatively stable growth with mostly year-to-year variations in tree ring width. The latewood width chronology does not show clear age effect. Both chronologies have relatively high 1-st order autocorrelation, which demonstrates serious influence also of the growth conditions from previous years. The mean sensitivity statistics is higher for the latewood width chronology, demonstrating higher year-to-year variation. The single series have very similar growth, which is demonstrated by the high between-series correlation (Table 1) and very high EPS values. They exceed the accepted threshold of 0.85 (Wigley et al. 1984) for the whole period (Fig. 2).

Correlations of tree ring width and latewood width series with temperatures and precipitation show strong and temporally

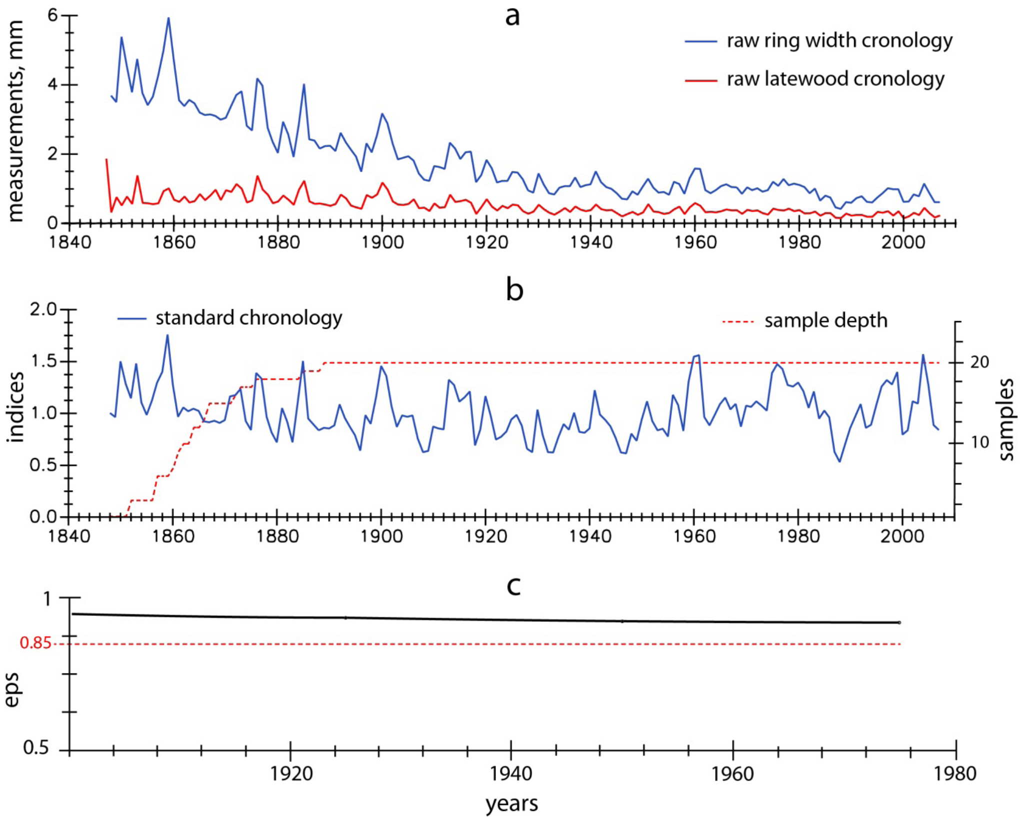

Fig. 2. Tree ring width and latewood width chronologies from *Pinus nigra* from Slavyanka Mts., Bulgaria: a – chronologies from averaged widths (raw chronologies); b – standardized chronology (blue solid curve) and number of used series (red dashed curve); c – EPS (black solid curve) of the standardized chronology.

stable effect of dry conditions in the summer period. The correlation between the TRW chronology and summer (July–August) and early autumn (September) temperatures of the previous year is negative and statistically significant (Fig. 3). Correlations with summer temperatures of the year of growth are also negative. Temporally most stable are the correlations with September temperatures from previous year (r=–0.43 for the whole period and r<–0.4 for the two sub-periods), July temperatures from growth year (r<–0.45 for the 1932–2007 period) and the averaged May–July temperatures (r=–0.44) of the growth year. Correlations with precipitation are positive for summer months of the year of growth and strongest for the May–July precipitation sums (r>0.45).

The relationship between latewood and climate conditions is similar (Fig. 4), but latewood width has slightly higher correlations with both July mean temperatures (r=–0.48) and May–July precipitation sums (r=0.54). The correlation coefficient between the latewood width chronology and September PDSI (r=0.57) is also very high. Spatial correlation shows that this signal is strong (r>0.5) for the region of West Bulgaria, as well as for the middle and eastern parts of Macedonia and the northern parts of Greece (Fig. 5).

It is worth noting that for many of the months the correlation coefficients for the period 1971–2007 are stronger than for the period 1932–1970.

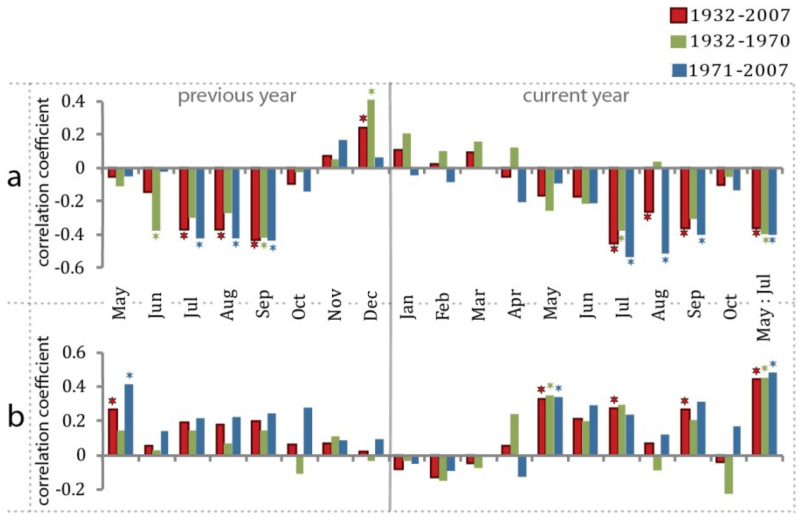

Fig. 3. Correlations between the standard tree-ring width chronology and: a – average monthly temperatures; b – monthly precipitation sums.

Note: Statistically significant values are marked with asterisk.

Years, in which narrow rings were produced, were 1880, 1883, 1896, 1908–09, 1918, 1928–29, 1946–47, 1984, 1987–88, 2000. Some of them match with negative pointer years from other studies of Black pine in the Western Rhodope Mts., Macedonian pine (*Pinus peuce* Griseb.) and Bosnian pine (*Pinus heldreichii* Christ.) in Pirin Mts. (1909, 1929, 1947, 2000) and Scots pine (*Pinus sylvestris* L.) in Vitosha Mountain (1918, 1988, 2000).

The comparison with other chronologies showed highest correlation with the one from Dobrostan, Bulgaria (r=0.63, t=6.8, Glk=0.62). It is the one with closest location (approx. 120 km to the north-east) and was influenced by similar

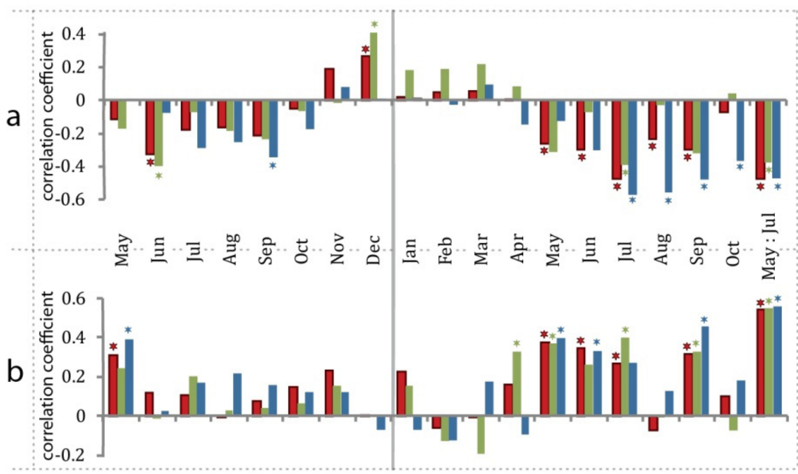

Fig. 4. Correlations between the latewood width chronology and: a – average monthly temperatures; b – monthly precipitation sums.

Note: Statistically significant values are marked with asterisk.

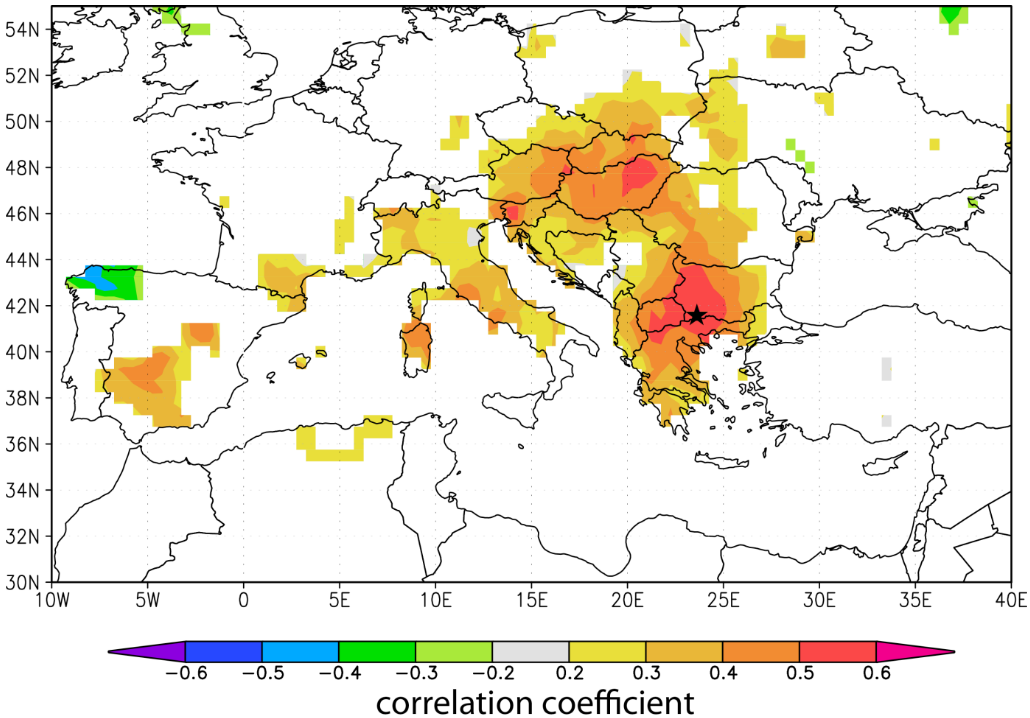

Fig. 5. Correlations between the latewood width chronology and September PDSI.

Note: The study site is marked with asterisk.

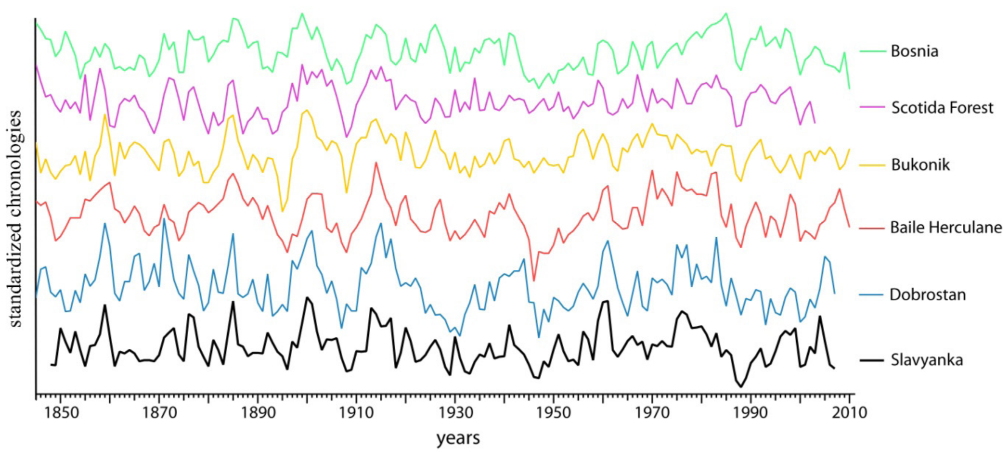

Fig. 6. The standardized *Pinus nigra* chronology from Slavyanka Mts., Bulgaria (black solid curve) compared to Black pine chronologies from Dobrostan (Bulgaria), Baile Herculane (Romania), Bukonik (Albania), Scotida Forest (Greece) and Bosnia and Herzegovina.

Note: Only the common period is shown on the graph.

climatic conditions to those of Slavyanka Mts. Also significant are the relations with the chronologies from Greece (*r*=0.54, *t*=7.07, *Glk*=0.63), Albania (*r*=0.58, *t*=7.1, *Glk*=0.7) and Romania (*r*=0.59, *t*=6.4, *Glk*=0.66). Correlation is lowest with the chronology from Bosnia and Herzegovina (*r*=0.49, *t*=6, *Glk*=0.66).

Discussion

High EPS and inter-series correlation suggest that the sampled trees reacted similarly to the factors influencing annual growth and the chronologies are suitable for climate-growth relationship analysis (Wigley et al. 1984).

Our results indicate that the studied trees are sensitive to the combination of high temperatures and low precipitation amounts in the growing season. This climate-growth relationship is typical for species, growing in conditions of moisture insufficiency (i.e. drought) and suggests it is useful to perform correlation analysis with drought indices (Fritts 1976). The high correlation with September PDSI demonstrates that indeed the dry conditions during the summer affect mostly the tree ring production. The effect of water shortage during summer months on tracheid formation may result from stressed due to moisture deficiency, general slowing down of physiological processes and finally production of fewer cells (Panayotov et al. 2013). Dry conditions can be a reason for reduction of cambial division and cell-wall thickening and earlier cessation of cambial activity. Because of drought, stressed trees may also allocate more carbon into reserves and favor root development, rather than use carbon to produce tracheid cells in the stem, resulting in fewer cells in tree rings and therefore formation of narrower tree rings (Martin-Benito et al. 2013).

Negative correlation between tree-ring widths and late summer and early autumn temperatures of the previous year may be explained by the fact that above average warmth in autumn (or late summer) of the previous year can prevent nutrient storage for the next year growing season and negatively influence the following year xylem functionality and therefore the produced tree ring (Levanic and Toromani 2010).

Latewood width is mainly influenced by conditions in late summer and early autumn because at that period take place the processes of production of new cells, that compose the latewood section of the tree ring and their transformation. For the region this is the period with lowest precipitation amounts. That is why the signal for regional drought events is stronger in latewood, than in tree-ring and earlywood widths. This is supported by the high correlation coefficient between latewood and September PDSI and is also confirmed by the significant spatial correlation. Because of this we assume there is a reason to consider latewood as more sensitive to drought and appropriate for climate reconstruction purpouses.

Our results correspond to those from other studies of *Pinus nigra* in Europe that characterize latewood as more sensitive to climate than earlywood (Lebourgeois 2000, Martin-Benito et al. 2013). A study from Southeastern Spain defines latewood as the most sensitive ring section, primarily influenced by current year precipitation, in trees from different crown classes (Martin-Benito et al. 2007).

Narrow rings, found in the chronology, are relevant to years associated with known years with dry summer conditions or preceded by dry periods, such as 1908, 1918, 1928, 1945–47, 1984–88, 2000

(Panayotov et al. 2013), which confirms the sensitivity to drought of the studied Black pine population.

The chronology can be complemented with other series from similar sites in the region, in order to increase its length and sample depth, which will make it more valuable for climate reconstructions.

The similarity of the studied chronology with others from the Balkan Peninsula is proof that it is representative of the conditions in the area and can be used in building a regional Black pine chronology.

Conclusions

This work characterizes the studied *Pinus nigra* chronology from Slavyanka Mts. in Southwest Bulgaria as sensitive to regional climate conditions. Earlywood and thus the entire tree ring width contain climate signal from previous year late-summer and autumn temperatures, whereas latewood width contain strong summer and early autumn drought signal, which is representative for the region. We consider that the chronology can be included in Black pine dendrochronological network for the region and used to study the past climate variability and especially drought events in Southeastern Europe.

Acknowledgments

We would like to thank Georgi Gogushev and Angel Dzhambazov for their help in the fieldwork. We are thankful for the comments of two anonymous reviewers, who improved the manuscript. This work was supported by project DTK 02/02/2010 of the National Science Fund of Bulgaria.

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FORESTRY IDEAS, 2013, vol. 19, No 1 (45): 91–99

CHANGES IN TOTAL NITROGEN CONTENT IN SOILS INFLUENCED BY FOREST FIRES IN BULGARIA

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Received: 24 May 2013 Accepted: 28 June 2013

Abstract

The paper presents results from investigation on total N changes in soils influenced by forest fires. Cinnamonic forest soils (*Chromic Luvisols*, FAO) and Gray forest soils (*Gray Luvisols*, FAO) have been investigated. The sample plots were set up in burned and unburned control areas. They were correspondingly situated in the Lower forestry zone (0–700 m a.s.l.) of the Tracian forestry area and the Lower forestry zone (0–600 m a.s.l.) of the Moesian forest area. Soil samples had been taken seven times for ten years in order to investigate the nitrogen content dynamics. The content of total N has been determined using the modified Kjeldal method. A relationship was detected between content of total N and soil type, type and intensity of fires.

Key words: forest fire, forest soils, total N, *Pinus nigra* Arn.

Introduction

Forest fires were very common during the recent decades. They should not be considered separately of the context of global climatic change. According to Kontev (2001), the fire is an environmental factor whose importance has been increased by human activity.

The forest fires cause material damages, environmental changes, air pollution and lead to soil degradation. This problem concerns not only Bulgaria, but also the other Mediterranean countries in EU (Greece, France, Italy, Portugal) and as well as USA and Australia (Tashev and Malinova 1998).

The fire suppression is followed by extensive restoration activities in the affected areas. Young stands that are located in the lower forestry zone have been influenced more frequently. Due to the fact that they are usually situated in remote locations, a lot of financial resources should be spent in order to achieve a recovery of timber production properties of the burned forest soils (Alexandrov et al. 2002).

The content of nitrogen is an important prerequisite for successful development of forest restoration processes and is often a limiting factor for the growth and development of the forest (Velizarova et al. 2002, Bogdanov 2008, Petrova 2009). For this reason, it is necessary to clarify the forest fire influence on the nitrogen content in soils as well as the depth and degree of the changes depending on the type and intensity of fire. This issue is of great scientific and practical interest.

Seilopoulos (2004) established different changes in content of total N and ammonium N (NH_4-N) depending on the value and duration of the maximum temperatures developed at various soil depths during the fire. According to Barnes et al. (1998), much of the nitrogen lost through burning is not in a form available to the plant. The ability of succeeding vegetation and soil bacteria to replace the available nitrogen lost in burning is an important factor determining the effect of fire on site quality. Covington and Sacket (1984, 1992) found a short-term increase in amount of available nitrogen after fire. The studies of Kivekäs (1939), Kutiel and Naveh (1987), Little and Ohmann (1988), Gillon and Rapp (1989) established an increased concentration of ammonium N (NH_4-N) and nitrate N (NO_3-N), and a decreased content of total N after fire. This fact was explained by burning the soil organic matter, in which the nitrogen is a basic component.

The data obtained by other researches on dynamics of nitrogen alterations show a sharp increase of total N immediately after the fire impact and decreasing to the level in unburned control areas two years later (Choromanska and DeLuca 2001, Parker et al. 2001). Kaye and Hart (1998) and Neary et al. (1999) indicated that the increase of total N is due to increase of its nitrate forms and reduction in speed of their immobilization. Some authors (Youngberg and Wollum 1976, Wells et al. 1979, DeLuca 2000, Newland and DeLuca 2000) consider that fire can enhance long-term nitrogen availability in forest ecosystems by favoring populations of nitrogen-fixing plant. Murphy et al. (2006) concluded that the major short-term effects of fire were on leaching whereas the major long-term effect was loss of nitrogen from the forest floor and soil during the fire.

The paper is aimed at establishing the dynamics and degree of total nitrogen changes caused by forest fires and the influence of fire intensity and type on different soils.

Material and Method

The object of the study were soils influenced by fires in the regions of Stara Zagora and Belogradchik in July 2002. The sample and control plots of 0.1 ha each have been set up in burned and unburned areas in order to investigate the soil properties changes. The plots in Stara Zagora region are located in the Lower forestry zone (0–700 m a.s.l.) of the Tracian forestry area (42° 38’ N, 25° 43’ E). The soils are Cinnamonic forest soils (*Chromic Luvisols*, FAO) influenced by strong crown and strong surface fire affecting thirty years old plantation of Black pine (*Pinus nigra* Arn.). The sample and control plots are situated at 400 m a.s.l., exposition is southwest with slope 10 °.

The plots in Belogradchik region are located in the Lower forestry zone (0–600 m a.s.l.) of the Moesian forestry area (43° 70’ N, 22° 68’ E). The soils are Gray forest soils (*Gray Luvisols*, FAO) influenced by weak surface and strong surface fire under twenty-five years old plantation of Black pine. The altitude is 450 m a.s.l., exposition is north-northwest, slope 5 °.

The forest fires were classified in present paper on basis of visible impact signs. According to fire intensity they were determined as follow:

– strong crown fire – whole stems were burned and the stand was completely destroyed;

– strong surface fire – the stems were burned to a height of more than 0.5–1 m and the fire impact caused a destruction of the stand;

– weak surface fire – the stems were burned to a height of 0.5–1 m and the fire did not cause a destruction of the stand.

Soil samples have been taken immediately after the fire, 45 days, one, two, three, four and nine years later in order to investigate the dynamics of changes in total N content. Having in mind that the most significant changes of soil properties happen in the 10–15 cm depth (Raison et al. 1985, Barnes et al. 1998, Neary et al. 2008), the samples have been taken from the layers 0–5 cm and 5–15 cm.

The content of total N was determined using the modified Kjeldal method. The average content of total N has been calculated in order to establish the degree of the changes. The results were processed by statistical program Statistica 6. The arithmetical means (M) and standard deviations (SD) have been calculated. The alterations between burned and unburned control areas were analyzed in percentage terms.

Results and Discussion

The nitrogen forms most commonly assimilated by plants were the ammonium and nitrate ions. Their content was highly variable during the vegetation season. It depended on conditions of ammonification and nitrification, as well as their assimilation by the plants. Therefore, the determination of changes in available nitrogen content was difficult to achieve (Donov 1993). Therefore, the present work deals with changes in content of total N.

The dynamics of changes in total N content in Cinnamonic forest soils is presented in Table 1 and Figure 1 and 2. The data obtained showed a lack of lasting trend in the alterations during the first two years of the researched period. In the upper (0–5 cm) layer of the soil influenced by strong crown fire (P-1), an increase of total N by 29 % immediately after the fire impact was established and by 46 % 45 days later. One year after the fire there was a decrease by 24 % as compared to control plot (P-3).

The content of total N in lower (5–15 cm) layer decreased by 20 % immediately after the strong crown fire (P-1) and by 11 % 45 days later. An increase by 31 % compared to control plot (P-3) was observed one year after the fire.

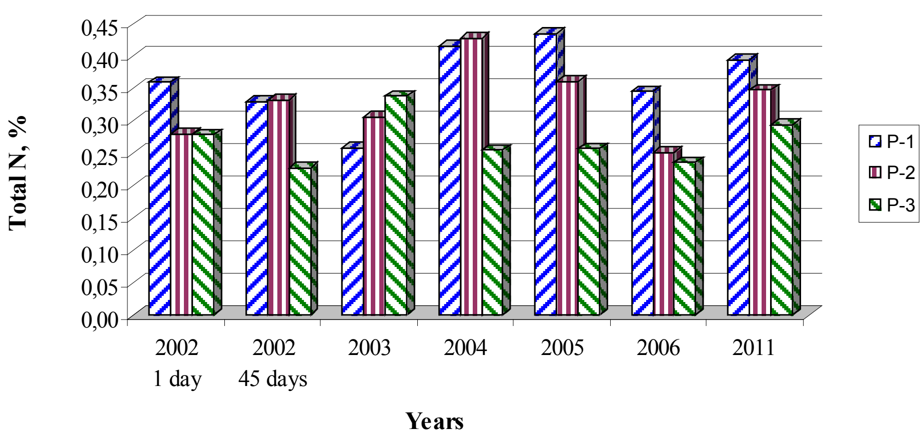

Fig. 1. Dynamics of total N content for depth 0–5 cm in Cinnamonic forest soils (*Chromic Luvisols*, FAO).

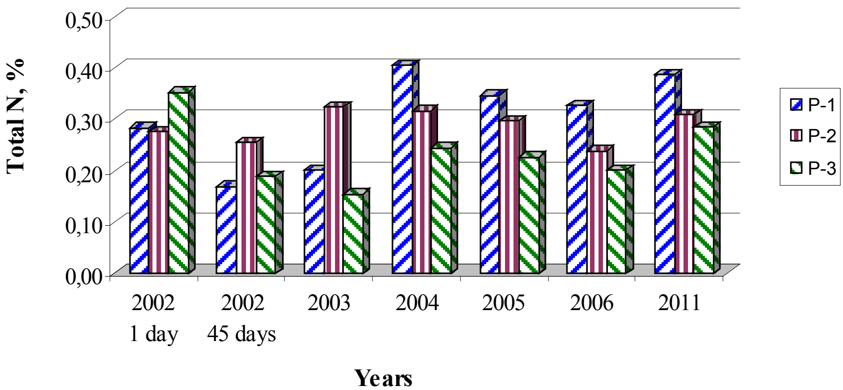

Fig. 2. Dynamics in total N content for depth 5–15 cm in Cinnamonic forest soils (*Chromic Luvisols*, FAO).

The results of investigated Cinnamonic forest soils influenced by strong surface fire (P-2) were also contradictory during the initial period of the study. Essential alterations have not been established in the 0–5 cm depth immediately after the fire. An increase by 47 % was found 45 days after the fire and a decrease by 10 % one year later compared to control plot (P-3). In the lower (5–15 cm) layer following initial reduction of 22 % it was recorded an increase by 35 % 45 days after the fire impact and by 110 % one year later.

After the second year of the period of study, the content of total N in burned area was higher than the unburned control area in both cases of fire impact. In the layer 0–5 cm the differences between area influenced by strong crown fire (P-1) and unburned control area (P-3) were 62 % in 2004, 69 % in 2005 and 47 % in 2006. For the depth 5–15 cm the increase was 66 %, 53 % and 63 %, respectively.

In the case of strong surface fire (P-2) the increase in both layers was 68 % and 30 % in 2004 and 41 % and 31 % in 2005, respectively. Four years after the fire the differences between burned and unburned areas were reduced to 6 % in layer 0–5 cm and to 19 % in layer 5–15 cm. The initial increase of total N can be due to the conversion of organic N released from burned plants to NH_4-N (DeBano et al. 1998, Raison 1979, Seilopoulos 2004).

Table 1. Dynamics in total N content in Cinnamonic forest soils (*Chromic Luvisols*, FAO) compared to control plot (±%)

Object	Depth, cm	1 day 2002	45 days 2002	1 year 2003	2 years 2004	3 years 2005	4 years 2006	9 years 2011
P-1	0–5	+29	+46	–24	+62	+69	+47	+34
	5–15	–20	–11	+31	+66	+53	+63	+35
P-2	0–5	0	+47	–10	+68	+41	+6	+18
	5–15	–22	+35	+110	+30	+31	+19	+8

The higher total nitrogen content of burned Cinnamonic forest soils was kept to the end of the period of study. In the case of strong crown fire (P-1) the increase in both layers was 34–35 % as compared to the control plot (P-3). In the case of strong surface fire (P-2) the differences between burned and unburned areas were lower – 18 % in layer 0–5 cm and 8 % in layer 5–15 cm.

The results of the study on Cinnamonic forest soils show that the strong crown fire (P-1) causes more significant and long lasting alterations in total N content as compared to the changes caused by strong surface fire (P-2). It might be explained by higher severity of the fire corresponding to a higher volume of burned biomass.

The dynamics of total N content in Gray forest soils is presented in Table 2 and Figure 3 and 4. In contrast to data obtained from analyzed Cinnamonic forest soils, different results were established in investigated Gray forest soils located in Belograd-

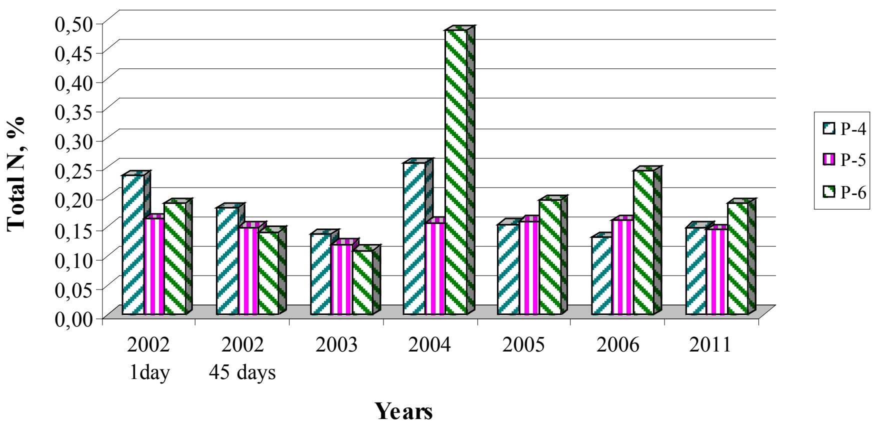

Fig. 3. Dynamics in total N content for depth 0–5 cm in Gray forest soils (*Gray Luvisols*, FAO).

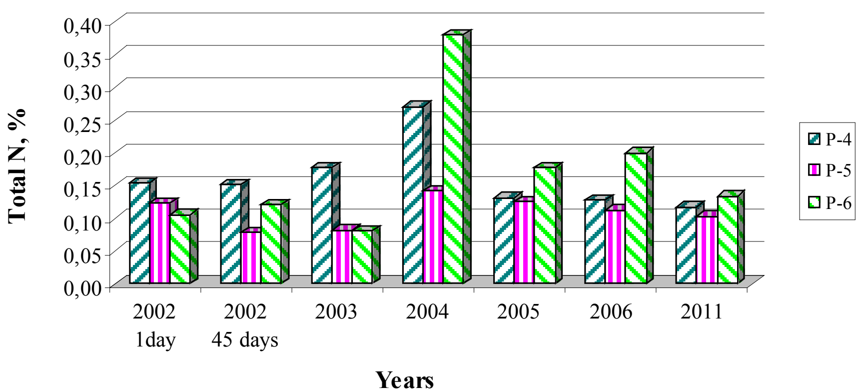

Fig. 4. Dynamics in total N content for depth 5–15 cm in Gray forest soils (*Gray Luvisols*, FAO).

Table 2. Dynamics in total N content in Gray forest soils (*Gray Luvisols*, FAO) compared to control plot (±%).

Object	Depth, cm	1 day 2002	45 days 2002	1 year 2003	2 years 2004	3 years 2005	4 years 2006	9 years 2011
P-4	0–5	+26	+29	+25	–47	–21	–46	–22
	5–15	+45	+25	+120	–29	–25	–36	–13
P-5	0–5	–14	+6	+9	–68	–19	–34	–24
	5–15	+16	–35	+1	–63	–28	–47	–23

chik region. Two years after the fire, in both cases of fire impact was found a decrease in content of total N compared to unburned control area. This lasted to the end of the period of study.

The amount of total N in the Gray forest soils influenced by weak surface fire (P-4) was higher as compared to control plot (P-6) during the first two years after the fire impact. The increase was 25–29 % for depth 0–5 cm and 25–120 % for depth 5–15 cm. After the second year the content of total N in burned area was lower than that in the unburned control area. The differences in upper (0–5 cm) layer were 47 % in 2004, 21 % in 2005 and 46 % in 2006. In layer 5–15 cm the decrease was 29 %, 25 % and 36 %, respectively.

The results obtained on Gray forest soils influenced by strong surface fire (P-5) were contradictory during the first two years of the investigation. After the second year the content of total N in burned area was lower than that in the unburned control area (P-6). For depth 0–5 cm the decrease was 68 % in 2004, 19 % in 2005 and 34 % in 2006. The differences for depth 5–15 cm were 63 %, 28 % and 47 %, respectively.

It was found that the differences between burned and unburned Gray forest soils located in Belogradchik region lasted nine years after the fire. In the case of weak surface fire (P-4) was established a decrease by 22 % in layer 0–5 cm and by 13 % in layer 5–15 cm. In the case of strong surface fire (P-5) the decrease in both layers was 23–24 %.

The average content of total N is indicative about the degree of the alterations and is presented in Table 3 and Table 4. The data obtained from studied Cinnamonic forest soils and Gray forest soils are contradictory, which is determined by the different dynamics of the changes.

The average content of total N in burned Cinnamonic forest soils was higher compared to unburned control plot in both cases of fire impact. The biggest change was recorded in the soil influenced by strong crown fire (P-1), which is characterized by a higher intensity corresponding to a higher volume of burned biomass. An increase by 41 % for depth 0–5 cm and by 34 % for depth 5–15 cm was established. In Cinnamonic forest soils influenced by strong surface fire (P-2) the increase was reduced to 25 % in layer 0–5 cm and 33 % in layer 5–15 cm. The standard deviations were between 0.02 and 0.07 (Table 3).

Essential alterations have not been established in Gray forest soils influenced by weak surface fire (P-4). The differences between burned and unburned areas amounted 2–7 % (Table 4).

A significant change in comparison with control plot (P-6) in Gray forest soils influenced by strong surface fire (P-5). The average total N content decreased by 18 %

for depth 0–5 cm and by 26 % for depth 5–15 cm. That is in conformity with a higher intensity of the fire corresponding to a higher volume of burned biomass and more significant changes of vegetation. In the case of strong surface fire (P-5) the stand was completely destroyed. The standard deviations were between 0.01 and 0.05 (Table 4).

The decrease in total N in Gray forest soils might be explained by lower intensity of the fires. According to Wells (1971) and Viro (1974), total N is highly correlated with organic matter and, when the forest floor burned, nitrogen decreased in relation to the severity of the fire. On the other hand, the forest fires increase the soil temperature that activates the development of soil microorganisms. This in turn could lead to a reduction in total N and an immobilization in both ammonium N (NH_4-N) and nitrate N (NO_3-N).

Table 3. Average content of total N in Cinnamonic forest soils (*Chromic Luvisols*, FAO)

Object	Depth, cm	M, %	SD	VS control, ±%
P-1	0–5 5–15	0.363 0.289	±0.04 ±0.07	+41 +34
P-2	0–5 5–15	0.320 0.286	±0.04 ±0.03	+25 +33
P-3 control	0–5 5–15	0.257 0.215	±0.02 ±0.02	- -

Table 4. Average content of total N in Gray forest soils (*Gray Luvisols*, FAO)

Object	Depth, cm	M, %	SD	VS control, ±%
P-4	0–5 5–15	0.177 0.154	± 0.05 ± 0.02	–7 +2
P-5	0–5 5–15	0.156 0.111	± 0.01 ± 0.02	–18 –26
P-6 control	0–5 5–15	0.191 0.151	± 0.04 ± 0.04	- -

Conclusion

The forest fire causes different changes in investigated soils. The alterations depend on the soil type and the type of fire, which is defined by fire intensity and distribution of forest combustible materials.

The total N increased in affected Cinnamonic forest soils (*Chromic Luvisols*, FAO) that contain larger amount of nitrogen. The increase is correlated with a higher volume of burned organic matter. It is due to a higher intensity of the fires and leads to the release of larger amount of nitrogen.

The total N is decreased in burned Gray forest soils (*Gray Luvisols*, FAO) that are characterized by less amount of nitrogen and nutrients. The decrease is in conformity with a lower volume of burned biomass. Similarly, the increase of soil temperature after the fire activates the development of soil microorganisms and nitrification. This might be a prerequisite for reduction in content of total N.

The larger volume of burned biomass and the deep changes of vegetation determine more significant and long lasting alterations in content of total N. Therefore, it is an important indicator that has ability to characterize the forest fire impact on the forest soils.

The changes lasted until the end of the researched period in the cases of strong fires. The results obtained nine years after the fire impact confirm the generally accepted opinion that the fire might cause long lasting alterations in soil properties and forest development depending on its severity.

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FIRST BREEDING OF THE SEMI-COLLARED FLYCATCHER (*FICEDULA SEMITORQUATA*) IN LOZEN MOUNTAIN (CW BULGARIA)

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Received: 22 May 2013 Accepted: 18 June 2013

Abstract

The vulnerable Semi-collared Flycatcher was found with two breeding pairs in 2012 and four pairs in 2013 in Lozen Mountain, CW Bulgaria, UTM square GN10. Three pairs inhabited a natural deciduous oak (*Quercus* sp.), and European hornbeam (*Carpinus betulus* L.) forest in a moist dingle, 915 m a.s.l. The other territory was a plantation of Scots pine (*Pinus sylvestris* L.) and Silver birch (*Betula pendula* Roth) crossed by a brook with Honey locust (*Gleditsia triacanthos*) along it, 885 m a.s.l. Two pairs occupied old woodpecker hollows in a dead poplar tree (*Populus* sp), and in a single Cherry plum (*Prunus cerasifera* Ehrh.), respectively.

Key words: Semi-collared Flycatcher, *Ficedula semitorquata*, breeding habitat, Lozen Mountain.

The Semi-collared Flycatcher *Ficedula semitorquata* (Homeyer, 1885) is a hollow breeding migrant inhabiting mainly mature, moist deciduous and rarely mixed forest in Bulgaria. Its breeding population is concentrated in Stara planina and Strandzha Mountains and moist forests along the lower reaches of rivers in the Black Sea catchment area (Iankov 2007, Nankinov 2009). The distribution and population size of the species have decreased as a result of habitat losses mainly in its breeding area (IUCN 2012). Consequently, it is classified as “vulnerable” in Bulgarian Red Data Book (Golemanski 2011) and “near threatened” in IUCN Red List (IUCN 2012).

The regular breeding of Semi-collared Flycatcher was known in Central West Bulgaria in the past: Lyulin Mountain, Vitosha Mountain, the city of Sofia and Samokov kettle (Nankinov 2009). Its current breeding in the area was reported in only one 10-km UTM square in Vitosha Mountain with up to 9 pairs (Iankov 2007). The species has not been found in Lozen Mountain for the last 50 years (Belichev and Milchev 2010).

Two pairs with singing males were observed in the central part of Iskar Hunting Ranch (IHR), Lozen Mountain, UTM square GN10, on 13.05.2012. A traditional transect used for the practical training of students since 2009 crossed the two pairs’ territories, situated themselves at a distance of 940 m from each other. The first territory included a moist dingle with natural oak (*Quercus* sp.) and European hornbeam (*Carpinus betulus* L.) forest at 915 m a.s.l. Dead and declining poplars

(*Populus* sp.) were in line only along the brook. The female visited several times an old woodpecker hollow situated at around 6 m height in a dead poplar. The other territory was in an artificial mixed plantation consisting of Scots pine (*Pinus sylvestris* L.) and Silver birch (*Betula pendula* Roth), crossed by a brook with Honey locust (*Gleditsia triacanthos* L.) along it, at 885 m a.s.l. The pair here occupied an old woodpecker hollow situated at around 3.5 m height in a broken, dry top of a single Cherry plum (*Prunus cerasifera* Ehrh.). The same hollows were occupied on 18.05.2013, but we found other two territories adjacent to the first pair in its dingle.

The forests in IHR are not among the preferred habitat types of the Semi-collared Flycatcher. They are mainly artificial, coniferous and 40–60 years old. Dead or dying trees with hollows are very rare. The new locality is about 25–40 km apart from the nearest and similarly detached, not numerous localities in Vitosha, Western Rhodopes and Sredna gora Mountains according to the maps in Iankov (2007). However, the similarity of breeding avifauna in IHR between the data of Iankov (2007) and Belichev and Milchev (2010) was only 49.4 %. Therefore, we suppose the existence of other unknown breeding localities in CW Bulgaria as a source of the new occupation, rather than to explain it with better condition of the Semi-collared Flycatcher population.

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