Ekológia (Bratislava) Vol. 31, No. 4, p. 370–378, 2012
doi:10.4149/ekol_2012_04_370

FOREST CONSERVATION AND IMPROVEMENT THEIR ADAPTATION TO CLIMATE CHANGE IN BULGARIA

NADEZHDA STOYANOVA, DIMITAR STOYANOV

Forest Research Institute, Bulgarian Academy of Sciences, 132, St. Kliment Ohridski Blvd., 1756, Sofia, Bulgaria; e-mail: n.g.stoyanova@abv.bg
University of Forestry, 10, St. Kliment Ohridski Blvd., 1756, Sofia, Bulgaria

Abstract

Stoyanova N.G., Stoyanov D.: Forest conservation and improvement their adaptation to climate change in Bulgaria. Ekológia (Bratislava), Vol. 31, No.4, p. 370–378, 2012.

All research on the influence of climate conditions on the growth and evolution of woods is becoming wider, including the knowledge of optimizing activities connected with sustainable control. To achieve significant reduction in the influence of dangerous consequences from climatic anomalies, it is necessary to apply certain measures in these woods to ensure their adaptability to climate changes in threatened areas. In this study, the weather conditions in the low wood-belts of the southwestern part of Bulgaria are described for two regions with different climatic influences. These are in the Transcontinental and the Continental-Mediterranean forest vegetation areas. Measures are discussed to reduce the negative effects on forest vegetation due to climate change. Forest protection and adaptation to climate change are specific activities related to the implementation of forestry activities, anticipating adverse climatic effects. In this way, environmental risks to forest areas threatened by negative climate effects can be reduced by implementing preventive action.

Key words: ecology, forests, climate change, Southwestern Bulgaria

Introduction

Environmental risk to forests in terms of climate change is becoming more topical. Modern climate change can lead to deterioration in forest ecosystems and loss of plant biodiversity. For Bulgaria, this primarily refers to forest areassituated at an altitude of less than 800 m. Many scenarios predict a reduction inisture, an increase in average and minimum air temperatures and increased frequency and intensity of adverse and hazardous weather conditions (Raev, 1997; Raev, Rossnev, 2003a; Koleva, Alexandrov, 2008). These may cause a future warmer and dryer climate in Bulgaria, and possible drastic deterioration of environmental conditions for the development of forests. These particularly include the common oak-wood belt zones. As a result of current studies, trends of worsening climatic conditions for growth and development of forests in different regions of Bulgaria have been established (Raev, Rossnev, 2003b, 2004; Raev et al., 2003; Stoyanova, 2009, 2010; Stoyanova et al., 2010).

In recent years, there has been steadily increasing interest in issues related to environmental conditions and protection of forests, and in their sustainable development and environmentally friendly use. The objective of this work is:

- to characterize changes in the low forest vegetative zones, in areas with differing climatic influence in Southwestern Bulgaria
- to discuss measures which will reduce the negative effects of climate change on forest vegetation

Study area

The studied forest areas are located in Southwestern Bulgaria. These are different areas of low forest vegetative areasin the Aegean catchment areas, located at an altitude of less than 800 m. In Table 1, these are designated R1K in Kyustendil and R2S in Sandanski. The weather stations' geographical coordinates and altitude used for meteorological data source to source NIMH BAS (Stat. Y., 2007) are also listed in Table 1, and this shows the Kyustendil and Sandanski stations are situated at 520 m and 206 m a.s.l.

Based on hypotheses developed by Pavlov (2006) for the distribution of vertical zones of potential vegetation in mountain ranges, the subject R1K Low Mountain middle belt of deciduous broadleaf forests was treated up to an altitude of 800 m at Rila, up to 500 m north of this area and up to 1000 m in the south.

In addition, the R2S site was treated as a two-plant belt according to the hypothesisof lumbar zonal distribution of potential vegetation of the Pirin. These consisted of : (1) the foothill belt of Sub-Mediterranean deciduous and evergreen broadleaf forests and bushes up to 300 m altitude, and up to 600 m on the southern slopes and 2) Midlow mountainous zone of broadleaf deciduous and coniferous forests from 300 to 900 m altitude, up to 500 m on the northern slopes and to 1100 m in the south.

T a b l e 1. Climate characteristics: (general data, source: NIMH BAS; Stat. Y., 2007) and the location of forest vegetation under regionalization in Bulgaria (Pavlov, 2006).

Indices	Regions	
	R1K	R2S
1. *Meteorological stations*:	Kyustendil	Sandanski
2. *Location of meteorological station*:		
• altitude (m)	520	206
• east geographic length Greenwich	22°41′	23°16′
• north latitude	42°17′	41°33′
3. *Average annual data (2006) for*:		
• atmospheric pressure (hPa)	955.7	992.8
• average air temperature (°C)	10.6	13.9
• annual amount of precipitation (mm)	616	453
• average relative humidity (%)	69	65
4. *Location of areas*:		
• forest vegetation area	Transitional Continental area	Continental-Mediterranean
• forest vegetation province	Transitional West Bulgarian Province	Continental-Mediterranean south-western Bulgarian
• forest vegetation region	Srednostrumski Kyustendil-Blagoevgrad region	South Srednostrumski valley and foothill area

In methodological terms, this adopted approach has been used in other studies to characterize the climatic conditions in different regions of the country (Raev, Rossnev, 2003a; Raev, 2006; Tonkov et al., 2009; Stoyanova et al., 2009, 2010; Dimitrov et al., 2010, 2011). Data on precipitation and air temperature are compared, and the complex methods used reflect the specifics of conditions for growth and development of woody vegetation. Determination of the index of dryness is by de Martonne (Bojinov, Nikolov, 1993).

Results and discussion

Climatic characteristics and forest vegetation

Forest ecosystems in Bulgaria were formed under the influence of temperate and Mediterranean influences. In climatic terms, the country is divided into three areas: a temperate climatic zone, a continental climatic zone and a continental Mediterranean climatic region (Tishkov, 1982; Pavlov, 2006). According to the phyto-geographical division of Bondev (1982, 1991), Bulgarian territory has three geographical-botanic areas: the European deciduous forest area, the Eurasian steppe and forest-steppe region and the Mediterranean area.

According to this forest vegetation partitioning, Bulgarian territory determined by Pavlov (1997) had a three-tier hierarchical system of regionalization, and this study concentrates on these different forest vegetation provinces and regions. This is reflected in Table 1, where R1K forest vegetation exists in the continental area and R2S is located in the strong Mediterranean influence of Continental-Mediterranean forest vegetation.

Data in Table 1 characterizes changes in the basic data (source: NIMH BAS; Stat. Y., 2007). This revealed that the air temperature in 2006 was almost four degrees higher in sites at 206 R2S m a.s. l., compared to R1K at 520 m altitude. VIS. Rainfall was recorded at 453 mm and 616 mm in these two sites, which indicates that precipitation was approximately one third less in R2S located at lower altitude. These results confirm the relationship of increasing rainfall and decreasing air temperature with increasing altitude.

Dynamics of precipitation and temperature

Figure 1 compares data on annual rainfall between 1997 and 2006 in the R1K and R2S sites, as reflected in the two regions of low forest areas of southwestern Bulgaria under different climatic influences.

This data shows that rainfall decreases with decreasing altitude. The average rainfall during this period was 561.1 mm for R1K (Kyustendil at 520 m a.s.l.) and 507.1 mm for R2S (Sandanski 206 m a.s.l.). Comparatively less rainfall occurred in 2000, with 306 mm for site R1K and 237 mm for site R2S, and here Sandanski experienced the highest temperature of 14.9 ^{o}C.

During the entire ten-year period of 1997–2006, annual precipitation for R1K most often fluctuated between 500 and 700 mm, with a maximum value of 705 mm in 2005.

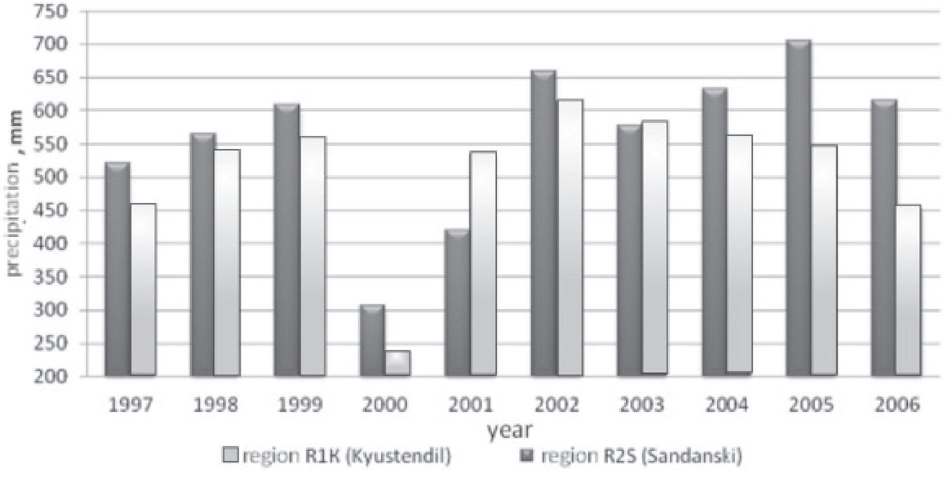

Fig. 1. Precipitation level in mm for R1K and R2S (source: NIMH BAS, Statistic Yearbook, 2007).

As apparent in Fig. 1 for the same period, the R2S annual precipitation mostly fluctuated between 400 and 600 mm, with a maximum of 614 mm in 2002.

Air temperature at these two weather stations over the same 1997–2006 period is compared in Fig. 2. These graphs highlight that the average air temperature for the entire ten year period increased with decreasing altitude, from 10.9 °C for the RK1 site to 14.28 °C for R2S.

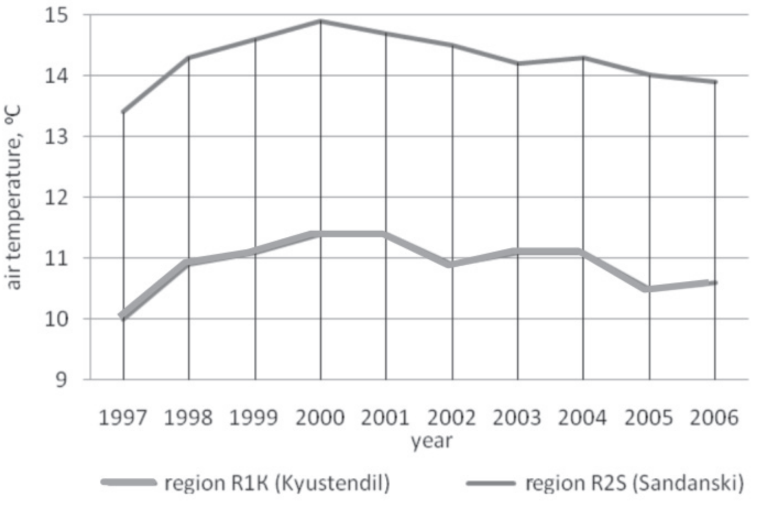

Fig. 2. Air temperatures (°C) in R1K and R2S (source: NIMH BAS, Statistic Yearbook, 2007).

For this entire 1997–2006 period, air temperature in R1K Kyustendil was lower and ranged between 10.0 and 11.4 °C, and the graph illustrates thatair temperature in R2S Sandanski was relatively high, ranging between 13.4 and 14.9 °C.

Index of dryness by de Martonne

Some recent trend changes have occurred in low forest vegitation zones in Southwestern Bulgaria (Stoyanova et al., 2010). Figs 3 and 4 compare the climate dryness index by de Martonne (De Martonne, 1926).

This data indicates that both R1K and R2S localities experienced a less favorable period for vegetation development after 1983, when this indicator more often exhibited values close to 20, or below 20, compared to the previous period of 1953–1983.

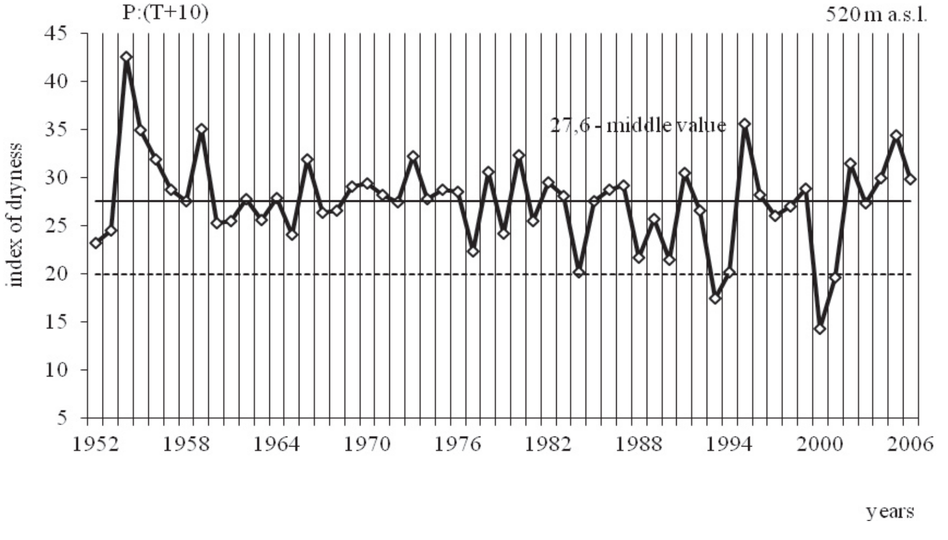

Fig. 3. Index of dryness by de Martonne for R1K at 520 m altitude, (Kyustendil), Stoyanova et al. (2010).

A trend has been established toward worsening water collateralization of forest ecosystems located below 800 m altitude. The data examined for Southwestern Bulgaria has confirmed an unfavourable period for forest development since 1983 compared to other areas of the country (Raev, Rossnev, 2003a, b; Stoyanova, 2010). Analyzed climate data indicatesenvironmental risk to the low forest vegetation zone. Underestimation of this problem, and the lack of assistance for adaptation to climate change will certainly have negative consequences for sustainable development of the forests in this region.

Forest ecosystems have a certain resilience to climate change, but significant changes in nature can contribute to their death. Plant organisms need specific environmental conditions for their growth and development and extreme or prolonged negative effects cause distortion in many of their functions. Drought and high temperatures are among the most adverse climatic factors.

In the event of climate warming, environmental conditions for growth and development of forest phytocenoses below 800 m altitude will be endangered. Possible changes in girdle wood-vegetation may result in deforestation at the lowest altitudes and an increase in the treeline. Phytocoenoses conifers have created a process of collapse in the lower regions of this country. This is considered to be due to non-compliance with environmental requirements for newly-wooded coniferous species, in the light of prevailing climatic conditions (Raev, 1989, 1997, 2005). Creation of a forest with mixed tree composition to achieve greater sustainability of dendrosenoses is therefore recommended.

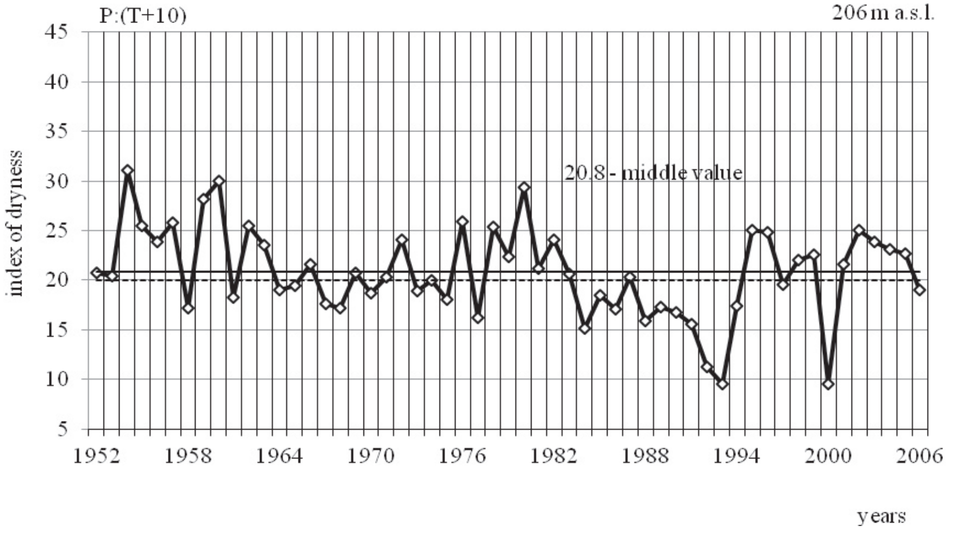

Fig. 4. Index of dryness by de Martonne (R2S, 206 m attitude, Sandanski), Stoyanova et al. (2010).

Research has been carried out on species capable of forming a drought-resistant and thermophyllic autochtonous forest. Taxons of the following nine studied species can provide greater adaptability toexpected xerophytization; *Pinus nigra* A r n., *Quercus robur* L., *Q. petraea* L i e b l., *Q. frainetto* T e n., *Q. pubescens* W i l l d., *Q. cerris* L., *Tilia tomentosa* M o e n h., *Fraxinus ornus* L. and *Corylus colurna* L. Permission has been given for the use of reproductive material from Bulgarian forest-tree genetic resources to European countries which are subject to climatic stress (Raev et al., 2005; Alexandrov, 2007). Analysis of the state of forests at global and regional levels is carried out herein. Questions regarding afforestation, tree stock dynamics, upper-wood lines, forest fires and floods in relationship to climate change are also discussed. In addition, the impact of expected climate change on forest populations under different models and alternatives is examined.

Increasing problems associated with climate change and biodiversity loss form the main global challenges for nature conservation. Climatic conditions are a determinant of geographical distribution of forest trees, and their distribution and status depend on a number of environmental indicators. Forest phytocoenoses in Bulgaria can be affected by dangerous phenomena including extreme maximum or minimum temperatures and drought due to the country's climatic characteristics. Raev and Knight (2003) reported that forests must be adaptable to drought changes to control forest resources inparts of the country situated below 800 m altitude. Based on our results and those of other authors concerning the climatic conditions in different regions of this country, the following measures are recommended to preserve afforestation in drought conditions: (1) the use of native tree and shrub species with known resistance to drought, (2) conservation and enrichment of the forests'plant biodiversity and (3) the creation of multi-age structured forests.

Activities to support forest adaptation to climate change

Natural conditions are influenced by continental and Mediterranean climatic influences due to the geographical location of Bulgaria, and relevant differences exist in the growth environment of forests in different areas. Forest vegetation is the main structure of natural potential in the catchment areas in this country (Stoyanova, 2003), and these natural complexes are recommended to support the adaptation of forests to climate change in areas at risk. The relief and hydrological characteristics of the territory of our country divides it into the Aegean catchment area, where this study area is located, and the Black Sea catchment area. These catchment areas have sub-direct runoffs to the river Danube and to the Black Sea. Protecting forests in the watersheds and supporting their adaptation to climate change are specific activities that must be undertaken.Therefore criteria must be developed to ensure preliminary ecological assessment of the protection requirements for the forests. This is especially essential to decrease the risk of climate anomalies in areas a less than 800 m altitude.

Our methodological approach recommends that activities for adaptation of forests to climate change in Bulgaria should be implemented especially in the following areas:

- clarifying the dynamics of climatic indices and determining risk areas for forests and wood biodiversity,
- determination of unfavourable periods for tree species, revealed by depression of rainfall or high temperatures,
- zoning within the catchment areas by degree of endangerment and the risk of climate change,

- analyzing the health, performance and the extent of problems suffered by forests affected by drought. This should then be compared with relatively preserved forests so that differences between them can be accurately defined,
- compiling estimates for the resumption and development of woods,
- optimizing the composition of forest phytocoenoses to reduce the stress level of future climate change.

To achieve greater sustainability of forest ecosystems to climate change, the establishment of mixed forest composition phytocoenoses is recommended. Raev et al. (1995) proposed that future research must encompass several directions. These should include; (1) studying changes in natural complexes; (2) studying the processes of water balance in the forest species; (3) monitoring the status of forests, and (4) creating projects for afforestation with species resistant to climate change.

Conclusion

On the basis of the described climatic characteristics of these two regions in the low forest vegetation belt in southwestern Bulgaria, and a summary of our own and other authors' views on supporting the adaptation of forests to climate change, the following conclusions have been drawn:

The analyzed climate data show that conditions in certain years may be unfavourable for the state of forests in the lower forest vegetation belt of southwestern Bulgaria. Forest areas in Bulgaria located at an altitude of less than 800 m have become a very topical issue when environmental risks for forests influenced by climate change are examined.

A methodical approach to support the adaptation of forests in areas at risk from climate change is considered necessary. This approach can achieve a significant reduction in dangerous impacts of climate anomalies. It is further emphasized that the creation and management of forest phytocoenoses are important climatic indicators, and the key issue here is to establish a range of different forests which can maintain stable existence when confronted with peculiarities of climate and other environmental factors.

Forest protection and adaptation to climate change are specific activities related to the implementation of forestry activities in anticipation of adverse climatic effects. In these circumstances, preventive measures must be instituted to reduce the environmental risk to all forest areas threatened in this manner.

Translated by the authors
English corrected by R. Marshall

References

Alexandrov, A., 2007: Forests and climate change. Forest Science, 3: 3–8.

Bojinov, H., Nikolov, N., 1993: Climatic forest information system for Bulgaria (in Bulgarian). Forest Science, 2: 23–34.

Bondev, I., 1982: Geo-botanical zoning (in Bulgarian). Geography of Bulgaria, Tome I. BAS, Sofia, p. 443–454.
De Martonne, E., 1926: Areisme et indice d‘aridite. Comptes Rendus de l‘Academie des Sciences de Paris, 182, 23: 1393–1398.
Dimitrov, D., Stoyanova, N., Miteva, S., 2010: Investigation of temperature and precipitation in ecological atation „Vasil Serafimov“sowtvest part Rila (in Bulgarian). Forest Science, 1: 89–99.
Dimitrov, D., Zlatanov, Tz., Raev, I., Stoyanova, N., Miteva, S., 2011: Scots pine (*Pinus sylvestris* L.) response to climate changes and thinning activities: a tree-ring study from south-east Rila mountain, Bulgaria. Silva Balcanica, 12, 1: 63–70.
Koleva, E., Alexandrov, V., 2008: Drought in the Bulgarian low regions during the 20th century. Theoretical and Applied Climatology, 92: 113–120. http://dx.doi.org/10.1007/s00704-007-0297-1
Pavlov, D., 2006: Phytocoenology. University of Forestry Press, Sofia, 251 pp.
Pavlov, E., 1997: Climatic-zonal gradients clarify the potential forest vegetation in Bulgaria (in Bulgarian). Forestry Ideas, 3-4: 8–28.
Raev, I., 1989: Research on the hydrological role of coniferous forest ecosystems in Bulgaria (in Bulgarian). Abstract of doctoral dissertation. BAS, Sofia, 61 pp.
Raev, I., Grozev, O., Alexandrov, V., 1995: The issue of future climate change and erosion afforestation in Bulgaria (in Bulgarian). In National Conference with International Participation 90 years Combating Soil Erosion in Bulgaria. October 16 to 20, Sofia, p. 84–93.
Raev, I., 1997: Climatic conditions in some representative scots pine ecosystems in Bulgaria (in Bulgarian). Forest Science, 3-4: 9–19.
Raev, I., Knight, C.G., 2003: Recommendations to decision makers (in Bulgarian). In Aridisation in Bulgaria. BAS, Sofia, p. 274–284.
Raev, I., Rossnev, B., 2003a: Impact of drought on natural forest ecosystems (in Bulgarian). In Aridisation in Bulgaria. BAS, Sofia, p. 95–112.
Raev, I., Rossnev, B., 2003b: Influence of aridisation on artifical ecosystems (in Bulgarian). In Aridisation in Bulgaria. BAS, Sofia, p. 121–130.
Raev, I., Staneva, M., Knight, C.G., 2003: Chronology of drought (in Bulgarian). In Aridisation in Bulgaria. BAS, Sofia, p. 19–22.
Raev, I., Rossnev, B., 2004: The impact of drought on national forest ecosystems. In Knight, G., Raev, I., Staneva, M. (eds), Drought in Bulgaria: a contemporary analog for climate change. ASHGATE. 336 pp.
Raev, I., 2005: Bulgaria. Part I, Forests research and monitoring. European long-term research for sustainable forestry: Experimental and monitoring assets at the ecosystem and landscape level. Part I: Country reports. Technical Report 3, COST Action E25. ECOFOR, Paris, p. 40–53.
Raev, I., 2006: Climatic conditions in representative forests of *Picea abies* (L.) K a r s t e n in the Rila Mountains. In Raev, I. (ed.), Environment and structure of the Norway spruce forests in the Rila Mountains. Sofia, p. 1–20.
Statistical yearbook, 2007: NSI, Republic of Bulgaria. II. Territory, surface area and climate (Source: NIMH BAS), Sofia, p. 15–24.
Stoyanova, N., 2003: Eco-forestry complex method for analysis of mountain ecosystems: specificity (in Bulgarian). In Proceedings of Science reports. International scientific conference 50 Years University of Forestry. Department of Ecology and Environmental Protection. Sofia, p. 165–167.
Stoyanova, N., 2009: Climate change and environmental risks (in Bulgarian). Forest, 5: 10–11.
Stoyanova, N., Dimitrov, D., Miteva, S., 2009: Climatic characteristics of the belt of coniferous forests of *Picea abies* (L.) K a r s t. in Northern Rila (in Bulgarian). Forest Science, 2: 89–99.
Stoyanova, N., 2010: Impact of climate change on forests in northeastern Bulgaria (in Bulgarian). Forest, 8: 21–22.
Stoyanova, N., Popov, E., Delkov, A., Stoyanov, D., 2010: Climate change and environmental risk status of the forests of low forest vegetating zone (in Bulgarian). Environmental Engineering and Environmental Protection, 2: 59-67.
Tishkov, V., 1982: Climatic division of Bulgaria (in Bulgarian). In Geography of Bulgaria T. 1. BAS, Sofia, p. 240–252.
Tonkov, S., Stoyanova, N., Bozilova, E., 2009: Pollen monitoring experiment in the coniferous forests of NW Rila Mts (Bulgaria). Phytologia Balcanica, 15, 3: 331–336.