Mitigating vulnerability of water resources under climate change CC-WARE

- SEE programme
- Priority axis: Protection and improvement of the environment
- Area of intervention: Improve integrated water management and flood risk protection
- Financed by European regional development fund /ERDF/
- Web site: www.ccware.eu

Austria

Bulgaria

Greece

Hungary

Italy

Romania

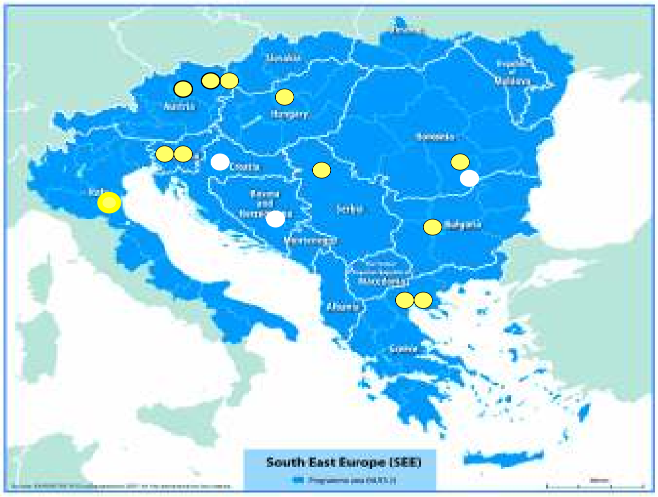
Slovenia

Croatia

Bosnia and Herzegovina

Serbia

Moldova



EFRD/IPA partners

Associated strategic partner

Project partners

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PP1	Municipality of the City of Vienna, MA31 Vienna Waterworks (AT)
PP2	Municipality of Waidhofen an der Ybbs (AT)
PP3	University of Ljubljana (SL)
PP4	Public Water Utility Ljubljana JP Vodovod-Kanalizacija d.o.o. (SL)
PP5	National Institute for Environment (HU)
PP6	National Forest Administration (RO)
PP7	National Meteorological Administration (RO)
PP8	Executive Forest Agency (BG)
PP9	Thessaloniki Water Supply & Sewerage Co sa (GR)
PP10	Decentralised Administration of Macedonia and Thrace, Water Directorate of Central Macedonia (GR)
PP11	Regional Agency for Environmental Protection in the Emilia-Romagna region (IT)
IPA1	Jaroslav Cerni Institute for the Development of Water Resources (RS)
ASP1	National Institute of Hydrology and Water Management (RO)
ASP2	Ministry of the Environment and Spatial Planning, Slovenian Environmental Agency (SI)
10% PP1	Hydro Engineering Institute Sarajevo (BA)
10% PP2	Croatian Geological Survey (HR)
10% PP3	South Regional Development Agency (MD)

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Project objective

The main objective of the project CC-WARE is the development of an integrated transnational strategy for water protection and mitigating water resources vulnerability which builds the basis for an implementation of national / regional action plans.
To achieve the project goal, the implementation of the following specialized Work packages /WP/ is envisaged:

WP 3 Vulnerability of Water Resources in SEE

- Common methodology for assessment of present and future vulnerability of water resources in climate change conditions
- Vulnerability indicators
- Mapping water quantity and water quality vulnerability
- Water protective forests
- Mapping water vulnerability in test-areas

WP 4 Management options for mitigating vulnerability of drinking water resources

- Assessment of forest ecosystems and best sylvicultural practices for protection and preservation of water resources in climate change conditions
- Forest ecosystem service – "supply of drinking water"
- Analysis of relevant legislation and policies to ensure drinking water, protection of water sources and assessment of land use on European, national and regional level
- Best forest practices and measures catalogue for mitigation on water resources vulnerability in southeast Europe

WP 5 Transnational Strategy for national and regional Action Plans

- The activities in WP 5 are based on WP3 and WP 4 and are combined in Common transnational strategy for mitigation of vulnerability of water resources in southeast Europe
- National examples of best practices – forest management options for protection of water resources in climate change conditions

Results

WP 3 Vulnerability of Water Resources in SEE

Climate Changes

The climate is the main natural driver of the variability in the water resources. Atmospheric precipitation, air temperature and evapotranspiration are commonly used for assessing and forecasting the water availability. Climate change data results from CC-WaterS project were used and were obtained from three regional climate models RCMs (RegCM3 – ITCP, Aladin – CNRM, Promes – UCLM), based on A1B scenario.

Data time intervals:
- 1961-1990 (baseline climate)
- 1991-2020 (present climate)
- 2021-2050 (future climate)

Main climate variables are:
- precipitation (RR)
- temperature (T)
- potential and actual evapotranspiration (PET and AET)

Additional climate indicators:
- UNEP Aridity Index
- De Martonne's Index of Aridity

Temperature
The data retrieved by the ensemble models show that the air temperature will increase in all the seasons, and in all the regions of the SEE area. Comparing the 2021-2050 and 1991-2020 mean temperatures, the highest differences occur during the summer, when the Balkan Peninsula may be with 2.0-2.5°C warmer, while the temperature could generally increase with 1-2°C. The increasing trend is present in the other seasons, but at lower rates (1.0-1.5°C in autumn, 0.5-1.5°C in spring and winter).(Figure 1)[1]

[1] Spatial resolution for all maps is 25 km (0,25°).

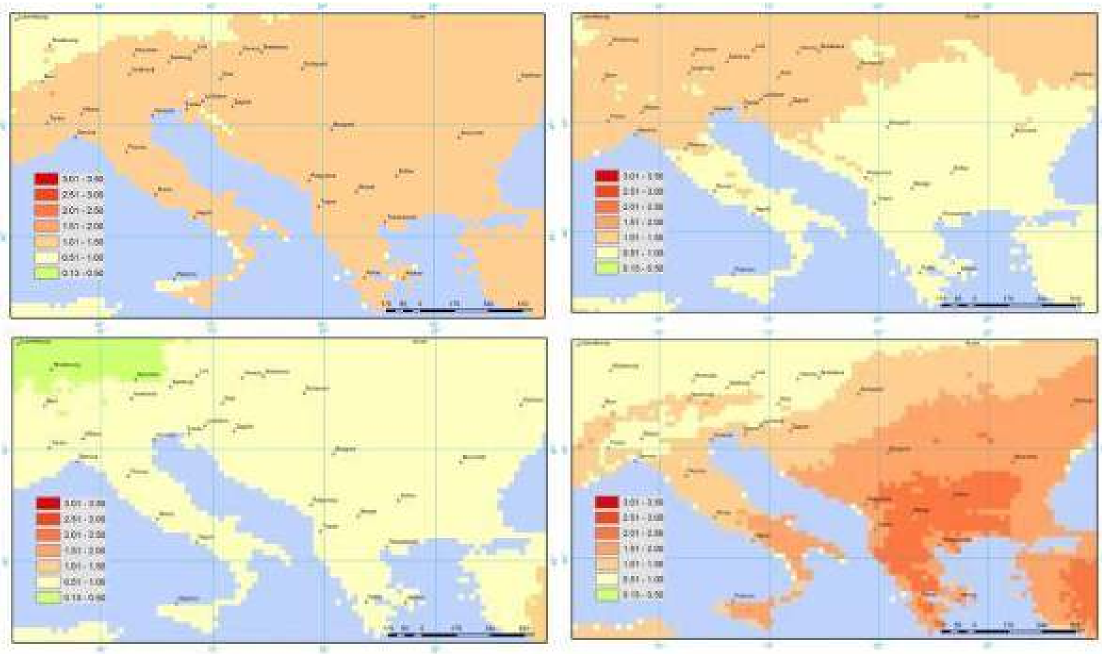

Figure 1 Differences in annual temperature values (^{o}C) between future and present period for fall, winter, spring and summer

Annual precipitation amount

The ensemble precipitation varies between annual amounts of 300 - 400 mm in the southern part of the Balkan Peninsula and Italy, and over 1.700 mm in the Alps. The differences (Figure 2) between the future period (2021-2050) and present (1991-2020) reveal that the analysed region is at the edge between the northern areas expecting increasing amounts, and the southern ones where decreasing is likely to occur in the next decades.(Figure 2)

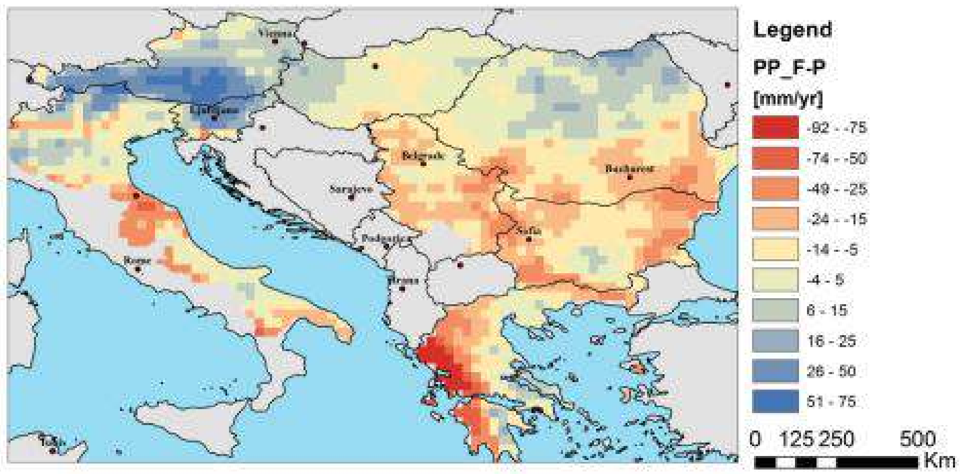

Figure 2 Differences in annual precipitation amount (mm) between future and present period according to ensemble of RegCM3, ALADIN and PROMES models.

Annual actual evapotranspiration

The annual AET decreases from the western to the eastern part of the SEE area. The highest values occur in the southern part of the Alps and in Greece. The present AET pattern will be preserved in the future, but some fluctuations in the absolute values can be predicted. Thus, the annual AET will increase with 10-25 mm in the northern part of the SEE area, mainly in the mountains, and will probably decrease slightly in lowlands. (Figure 3)

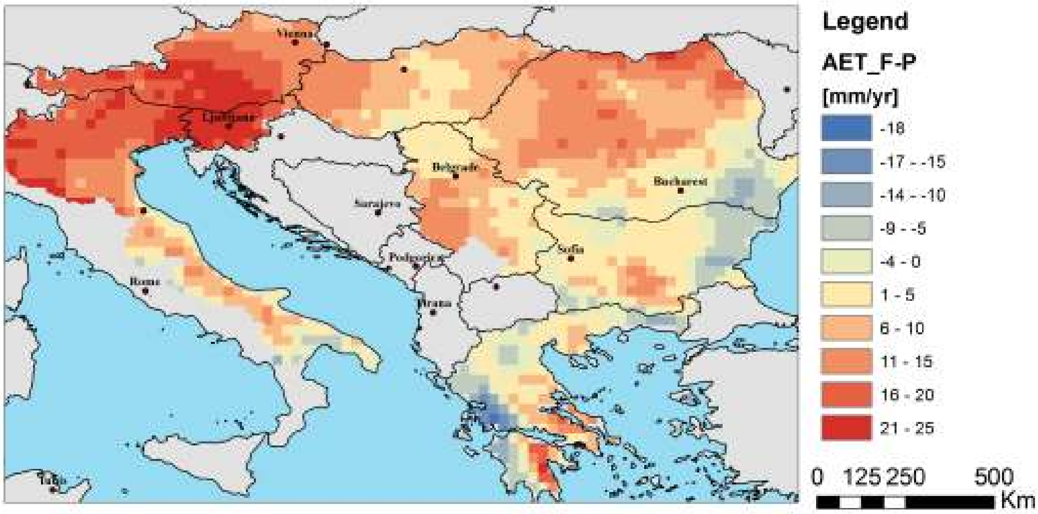

Figure 3 Differences between future and present annual actual evapotranspiration (mm) according to ensemble of RegCM3, ALADIN and PROMES models for present and future period.

UNEP Aridity Index

Some relevant changes in the aridity can be expected in the eastern part of the SEE area. According to the UNEP Aridity Index, significant territories from the eastern parts of Romania and Bulgaria could become dry sub-humid in the next decades, and the semi-aridity will be more extended in the eastern parts of Greece. The general pattern of the territorial distribution will remain unchanged. (Figure 4)

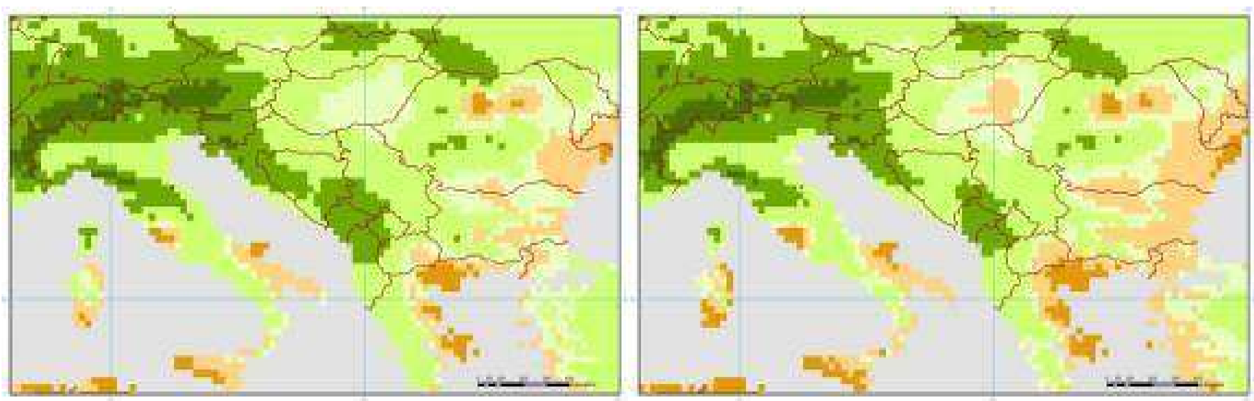

Figure 4 UNEP Aridity Index (mm) according to ensemble of RegCM3, ALADIN and PROMES models for present and future period.

De Martonne's Index

The values of de Martonne's Index of Aridity illustrate that substantial changes are likely to occur over the eastern part of the Balkan Peninsula in the next decades, leading to shifting from semi-humid to semi-aridity. In the rest of the SEE area, the shifting from one aridity category to another is less evident. (Figure 5)

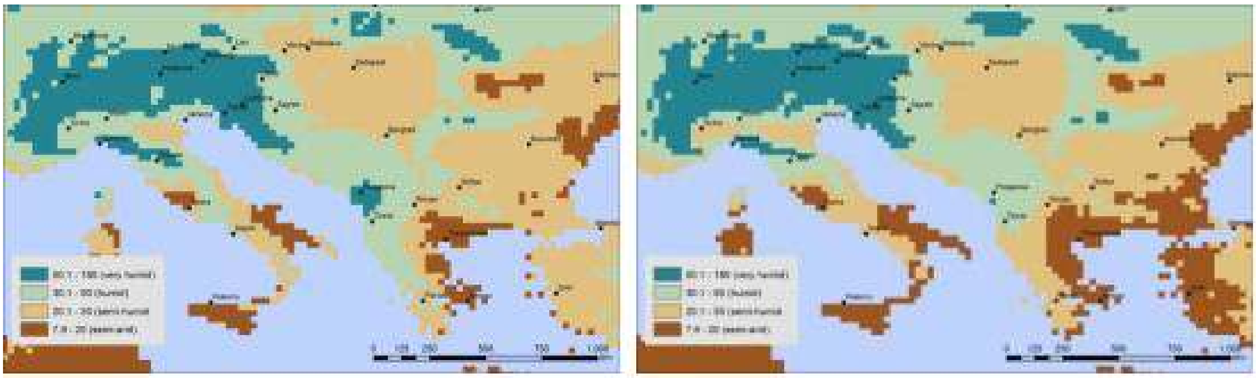

Figure 5 De Martonne's Index (mm) for present and future period

Southeast Europe is not homogeneous regarding climate changes

Increasing temperature trends (esp. summer season)

Decreasing precipitation trend (esp. in south regions)

Evapotranspration: strong increase in whole southeast Europe

Drought: comparatively stable; increase in some region (incl. Romania, Bulgaria and Greece)

Water resources sensitivity to climate changes

Water quantity

According to UNEP methodology (2009), vulnerability is a function of water availability, use and management parameters. The following indicators were estimated:

Table 1 Indicators for water quantity sensitivity

INDICATORS	SYMBOL	UNITS	DATA SOURCES & FORMULAS
Precipitation	P	mm/yr = (l/m2)/yr	CC-WaterS SEE Project
Actual evapotranspiration	AET	mm/yr = (l/m2)/yr	Budyko formula
Water demand - total	WD	mm/yr = (l/m2)/yr	WD = WDp + WDa + WDi
Water demand - population	WDp	(l/m2)/yr	EUROSTAT, Partner Countries
Water demand - agriculture	WDa	(l/m2)/yr	Partners countries, FAO, Eurostat
Water demand - industry	WDin	(l/m2)/yr	EUROSTAT, Partner Countries
Local Total Runoff	LTR	mm/yr = (l/m2)/yr	LTR=P-Eta
Local Total Runoff	LTRI	ND	LTR normalized 0-1

Index			
Local Water Exploitation Index	LWS	ND	LWS=WD/LTR

Local total runoff

Water availability was calculated as a simplified water balance:

Q = P – AET, where Q is total runoff (surface and groundwater).

In all periods it is obvious that in the Alps and Carpathian total runoff is high, whereas in all other parts it is relatively low, which means less water is available (Figure 6). Differences among periods are very small, therefore relative change of absolute values of local total runoff (ΔLTR) was calculated.

In mountainous areas of the Alps and Carpathians there is a slight positive change. There local total runoff might be higher in the future. On the other hand in western and eastern part of Greece, NE Bulgaria and SE Romania scenarios show that local total runoff would diminish.

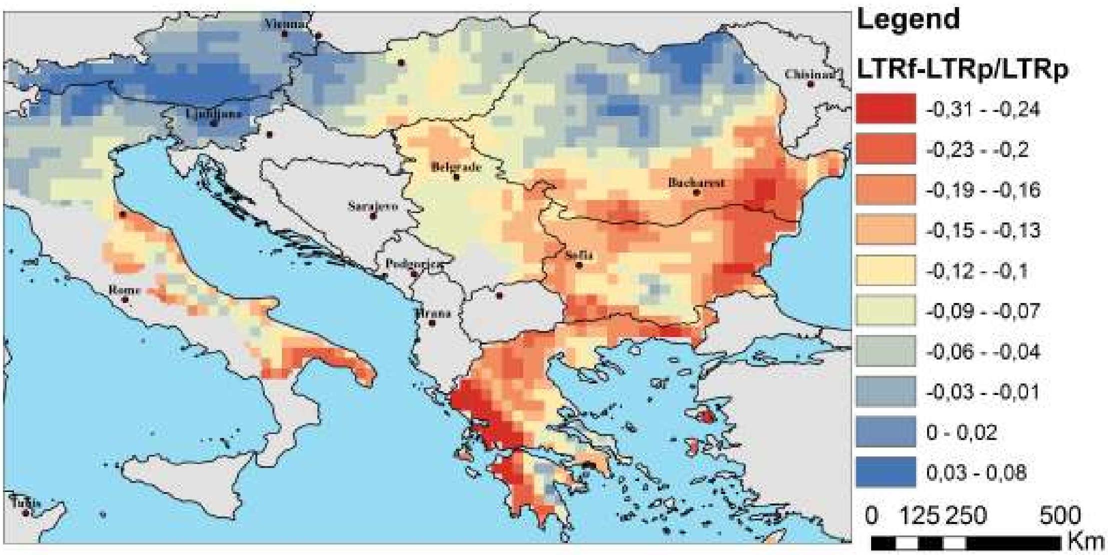

Figure 6 Relative change of Local total runoff (ΔLTR) (mm) according to ensemble of RegCM3, ALADIN and PROMES models for baseline, present and future period

Water demand

Water demand is estimated as water withdrawal by sectors. Future water demand can be estimated regarding population growth (domestic water use), GDP changes (industrial water use) and land use changes (agricultural water use). Nevertheless, all these are also subject to policy. Future water demand will be assessed applying different scenarios (Figure 7).

Future scenarios used:
10 % decrease of WD
0 % change (no change)
10 % increase of WD
25 % increase of WD

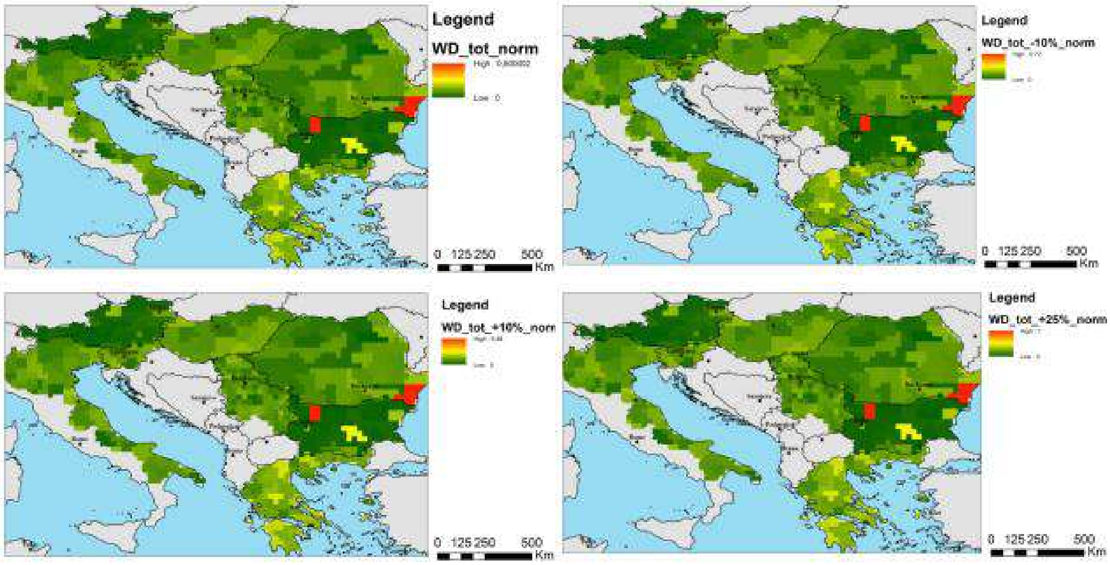

Figure 7 Water demand for present and future scenarios for CC-WARE countries within SEE area

There is a high industrial water demand in the area north of Sofia /Kozlodui area/ and along Marica river (Plovdiv) in Bulgaria.

Local water exploitation index (LWEI)

Water exploitation index (WEI) or water stress, which is the ratio of total water demand (domestic, industrial and agricultural) to the available amount of renewable water resources that consists of surface water and groundwater safe yield (river discharge or runoff and groundwater recharge). Values from 0,2 to 0,4 indicate medium to high stress, whereas values greater than 0,4 reflect conditions of severe water limitations (Vörösmarty et al. 2000).

From WD maps and LTR maps, LOCAL WATER EXPLOITATION INDEX (LWEI) was calculated as a ratio between WD and LTR for all periods and scenarios.

LWEI=WD/LTR, where LWEI is Local Water Exploitation Index, WD is Water Demand and LTR Local Total Runoff.

The name LOCAL Water Exploitation Index is because total runoff was calculated as direct runoff, not taking into consideration inflowing and outflowing runoff to and out of the 25x25 grid cell. There is a high water stress on annual level in the SEE region already in the present state (P), except in mountainous regions. (Figure 8)

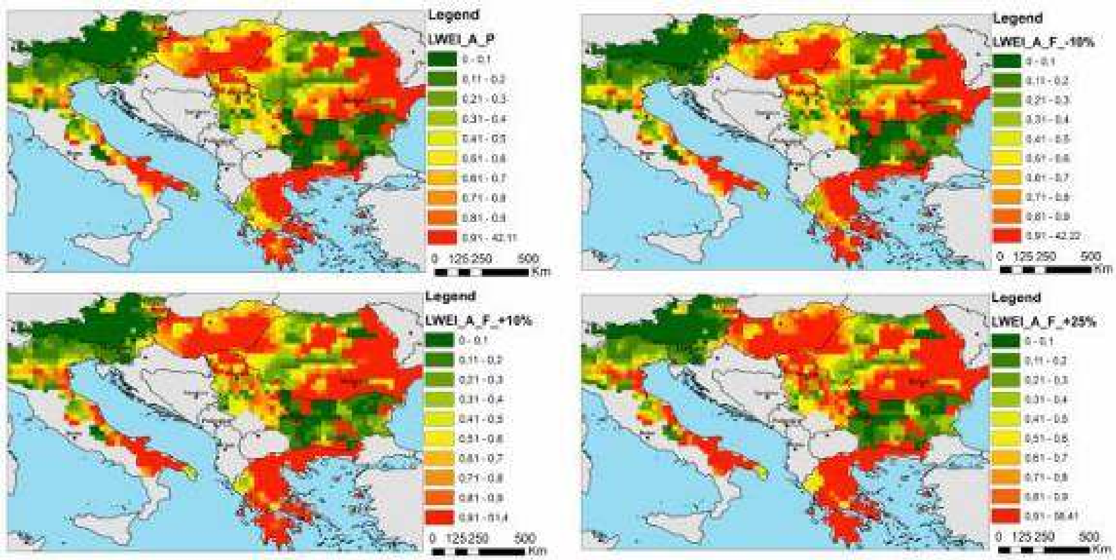

Figure 8 Local Water Exploitation Index (LWEI) for present and future scenarios of water demand for CC-WARE countries within SEE area.

Overall water quantity sensitivity

Table 2 Overall Water Quantity Sensitivity as a function of annual and seasonal vulnerability

			Annual sensitivity				
			very low [0-0.2] 1	low [0.2-0.4] 2	medium [0.4-0.6] 3	high [0.6-0.8] 4	very high [>0.8] 5
Seasonal sensitivity	very low	A	A1	A2	A3	A4	A5
	low	B	B1	B2	B3	B4	B5
	medium	C	C1	C2	C3	C4	C5
	high	D	D1	D2	D3	D4	D5
	very high	E	E1	E2	E3	E4	E5

Overall sensitivity				
very low	low	medium	high	very high

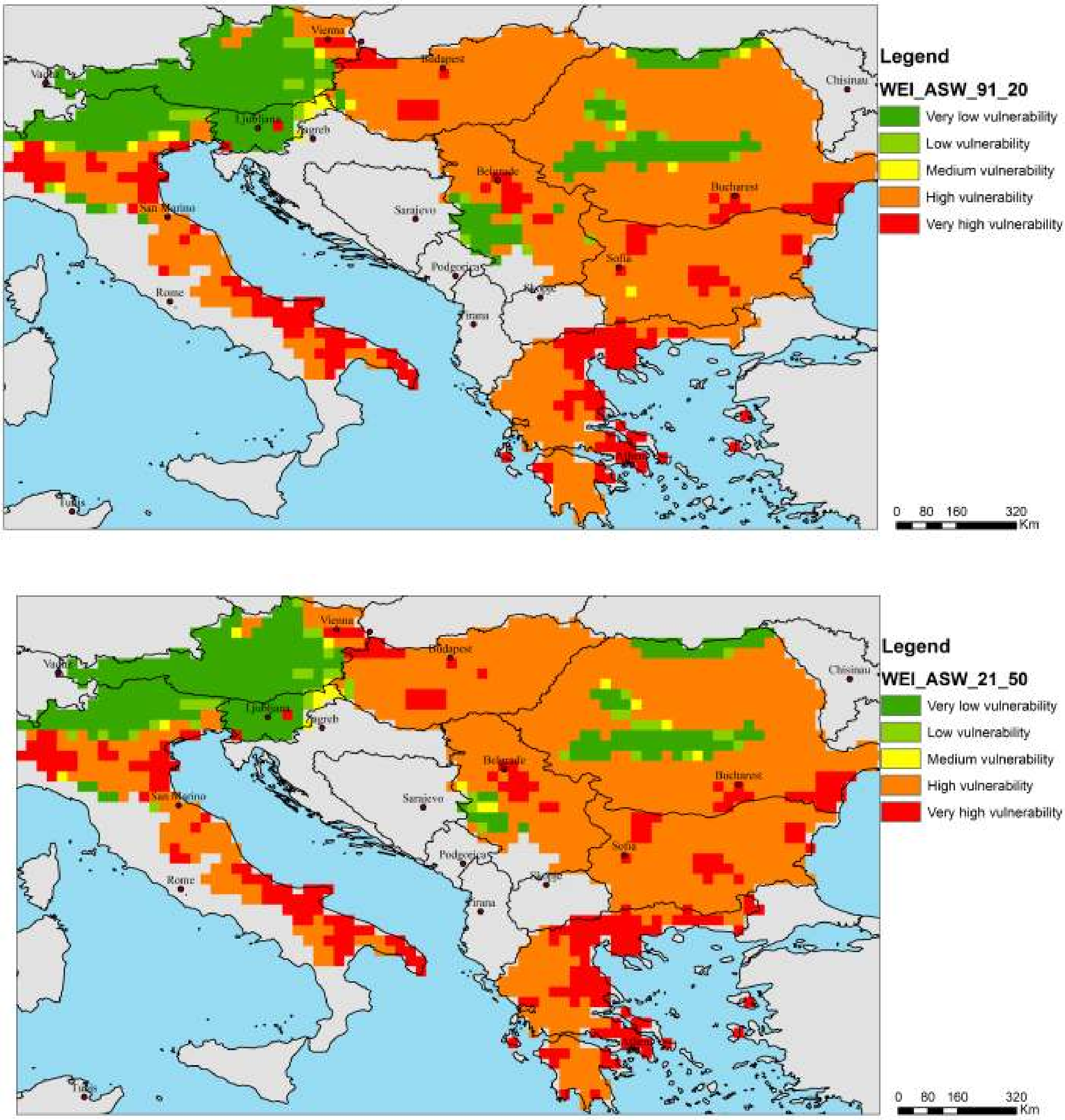

Figure 9 Overall Local Water Exploitation Index (LWEIo) for present and future scenarios of water demand for CC-WARE countries within SEE area.

Local Water Surplus in the future (LWS)

Annual local surplus of water resources is calculated as the difference of local total runoff and water demand. (Figure 10)

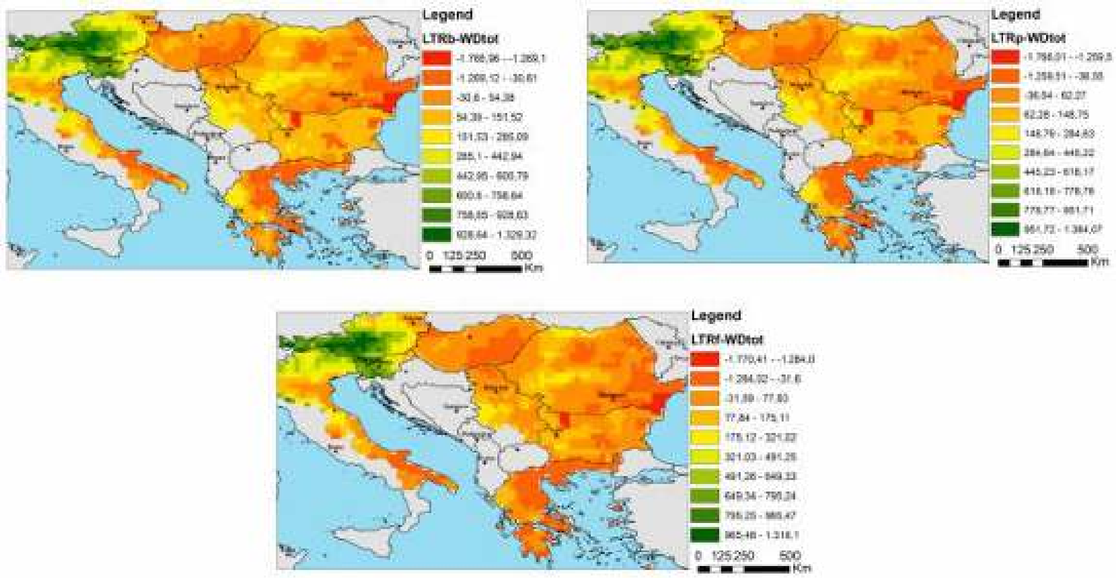

Figure 10 Annual local surplus of water resources (LWS) for baseline, present and future with present water demand data for CC-WARE countries within SEE area

Water quality

Water quality sensitivity indicators

Main indicator for water quality sensitivity is land use. Data set is Corine Land Cover (CLC2006). Present land use impact on water quality is reflecting in existing water quality. Water resources at risk are defined for water bodies by each Member State.

Future land use scenarios (% changes – storylines) were evaluated in accordance with EEA study "Land-use scenarios for Europe: qualitative and quantitative analysis on a European scale (EEA 2007).

Table 3 Indicators for water quality sensitivity

INDICATORS	SYMBOL	DATA SOURCES & FORMULAS
Land use load coefficients	LUSLI	land use load coefficients for particular land use - literature
Pollution load - PLI	PLISW	$SUM(LUSLI_i \cdot CLC\ AREA_i)$
Water quality index SW	WQISW	PLISW normalized from 0 to 1
HG factor	HG	HG factor according to IHME map categories
Pollution load - GW	PLIGW	$PLISW \cdot HG$
Water quality index GW	WQIGW	PLIGW normalized from 0 to 1

Future scenario shown on Figure 11 is a scenario where agricultural land is excluded, which reduces the water quality vulnerability in the future period.

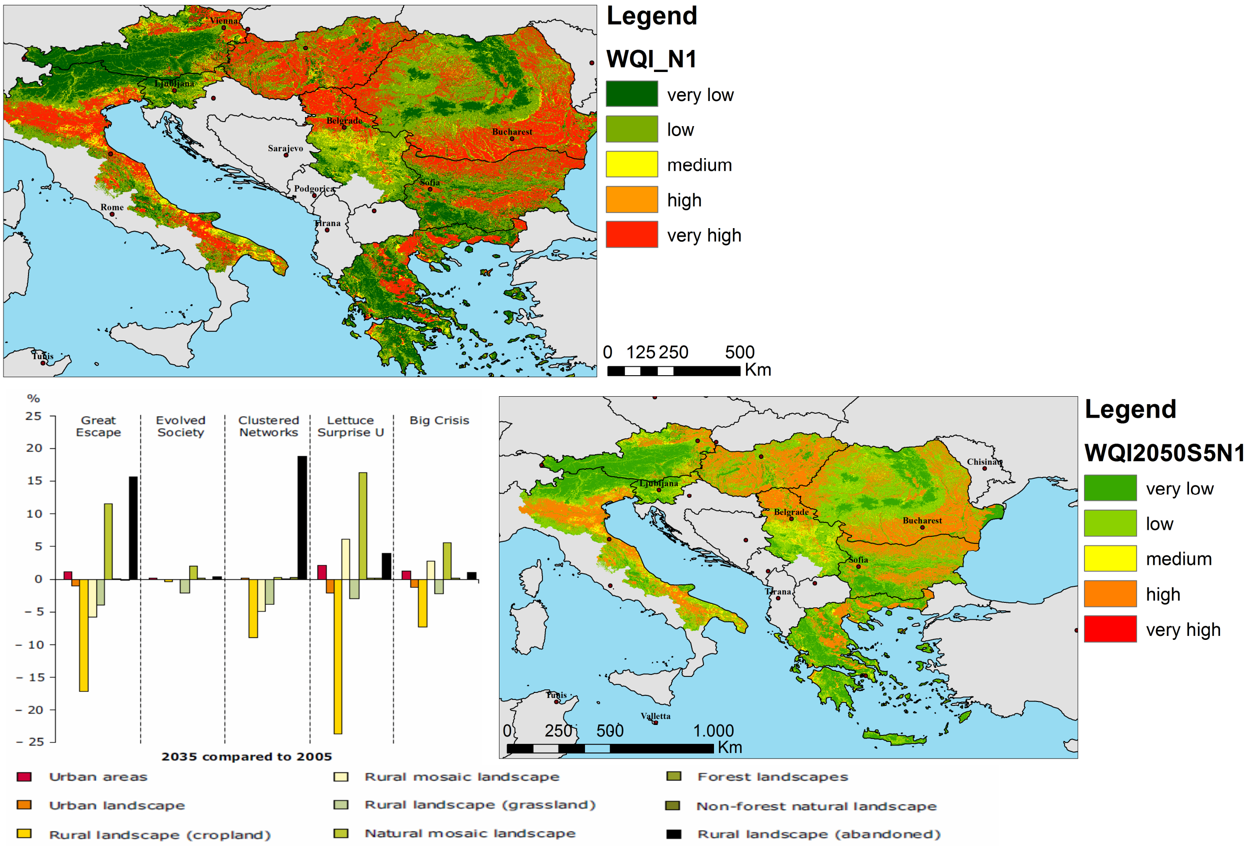

Figure 11 Differences in Water quality index for present and future period

WP 4 Management options for mitigating vulnerability of drinking water resources

In the framework of WP 4 analysis of relevant legislation and policies to ensure drinking water, protection of water sources and assessment of land use on European, national and regional level was done. As result the following gaps and recommendations were identified:

Gaps identified:

There is no integrated and common approach of forest-water management. The related legislation is more or less sectoral. According to the Strategy for the Development of the Water Sector: “The state is not sufficiently prepared for the impending climate change at the Balkans. The negative effect of global warming will be felt in the next 10-20 years much stronger than previously considered”. It is also pointed out that there are some discrepancies between the objectives, tasks, mechanisms and outcomes. According to the Strategy, the issues of provision and treatment of drinking water, “………… financial support for ensuring water quality, the activities for maintenance and control of reserve water sources, the status of water protection zones are not precisely settled in the legislation.

There are no standards concerning the interaction of climate change and trends in water management”.

Important guidelines and changes concerning the RBMP update and the vulnerability analysis of water supply in water shortage conditions, drought and climate change have not been yet transposed completely. They are still recommendatory and integrated management is not entirely implemented.

Certain problems related to the water-protective functions of forests are as follows:

- The conflict between the increased protected areas and/or the area of forests with special functions and the need to increase of wood consumption.
- Slowing down the process of turning coppice into seed plantations as well as the implementation of not always appropriate types of fellings for their transformation.
- The deterioration in health and quality of small-scale private forests, caused mostly by logging, which leads to the loss of their water-protecting functions.
- The construction of forest roads for extracting of harvested wood in protective forests has negative consequences, one of which is the loss of water-protecting function.

Some of them are pointed out also in the National strategy for the development of forest sector (2013-2020).

There are no clear financial mechanisms for the implementation of this Strategy as well as for the implementation of the EU Forest Strategy and Biodiversity Strategy.

Forest Act includes a special chapter on the management of ecosystem services and the benefits from them, but the secondary legislation, which should determine the methodology for their evaluation and payment, is still under preparation.

The solution of above mentioned problems is more or less political commitment at national level which should be taken by the decision-makers.

Recommendations

The process of harmonization of the national legislation, the Water Act in particular, with European legislation on the basis of the Water Framework Directive should continue. A unified state policy is required. It is necessary to transpose the standards related to the updating of management plans on climate change and vulnerability and risk analysis of water supply /water resource systems under conditions of water shortage, drought and climate change.

The Water Law needs changes to provide the development of long-term measures for ensuring water supply, optimization of dam and water system management and new schemes and decision support systems in reservoir management. All this should be included in the future plans for water supply management in drought periods and in RBMP.

Integration of measures is needed in RBMP and in the general plans in the WSS sector, which are result of advanced analysis of the water supply and water resource infrastructure, the priorities and indices of reliability of water supply, water resource management and maintenance of the sanitary-protection zones and water protection forests. It is imperative to make joint analysis of the water protection forests and the management of the water resource /water supply/ systems and to specify additional arrangements to be set in the updated plans for River Basin Management.

Improvement of legislation related to the preservation of water and forest resources and implementation of efficient systems for monitoring and control of actions, laid out in the legal framework.

Development of economic incentives to encourage private forest owners to conduct better management and preservation of their forests is needed.

Integration of the efforts of various institutions in charge of drinking water management to provide improved legislation related to water preservation, control and management of water protection areas.

Optimization of government / public institutions responsible for preservation and utilization of water resources and for the implementation of actions mitigating the vulnerability of water resources under climate change conditions is needed.

It is also necessary to unify the terms and definitions used in forest, water, health, etc. legislation.

Forest ecosystem service "supply of drinking water" in climate change conditions

Forest ecosystems and water resources are closely related - forests are crucial to the sustainable management of water ecosystems and resources, while water is essential for the sustainability of forest

ecosystems. Forests play a crucial role in the hydrological cycle. They influence the amount of water available and regulate surface and groundwater flows while maintaining high water quality. Forests contribute to the reduction of water-related risks such as landslides, floods and droughts and help prevent desertification and salinization.
Forests return less water to the soil than, well-managed grassland or cultivated areas, as a greater quantity of water is given back to the atmosphere through evapotranspiration. Forests are important water users. However, the dense and deep root system of forest soils and the high porosity of its essentially organic horizons make for excellent water infiltration and retention capacity. Surface runoff is minimal and groundwater recharge more efficient, resulting in regular stream flow during the year. Forest management usually results in low input of nutrients, pesticides and other chemicals compared to more intensive land uses such as agriculture. By minimizing erosion, forests reduce the impairment of water quality due to sedimentation. By trapping sediments and pollutants from up-slope land uses and activities, forests help protect water bodies and watercourses. Through the stabilization of river banks, tree and shrub roots reduce erosion in riparian zones, preventing siltation downstream.
The preservation of water quantity and quality is one of the main contributions of the forest ecosystems in Bulgaria. Forest ecosystems secure and preserve 85% of water runoff or they ensure about 3,6 bill. $м^3$ clean drinking water in the country. This is the main ecosystem service delivered by forests. The appropriate forest management practices secure this ecosystem service in sustainable way.
Water quantity and quality are influenced by forest composition, forest age structure, soil erosion, air temperature and precipitation amount. During the last decades climate change have an important effect on water availability and quality in many regions of the world.
According to climate scenarios for southeast Europe the increase of mean monthly temperatures and the decrease of the precipitation amount, especially in the south regions is envisaged /CC-WaterS project, FututeForest project/.
It is expected that climate changes will cause extreme weather events, such as increase of surface runoff, floods, droughts, forest fires, calamities, changes in snow cover, etc. All these events will influence the vegetation period and hydrological cycle of forests and will reflect on water quantity and quality.
Climate change scenario A1B of IPCC (2007) envisages increase of mean annual temperature with 2-3 ˚C and decrease of annual precipitation with 60-100 mm for the country.
The De Martonne’s index (J = P (T +10), where P and T are annual precipitation and air temperature shows that towards 2050, about 25% of the forest area in the lower altitudes /14% of the total area in Bulgaria/ is expected to have a value around or below 20. Such areas are identified as being with critical conditions for of forest vegetation. Montaineous forest will be slightly affected. Exceptions are possible only in the south border areas, where forest vegetation is xerophytic.

Impact of climate change on forests and forest watersheds

The most important expected climate change impacts on forests are:

1. Changing habitats, respectively tree species, most suitable for them;
2. Reduction of total and net primary productivity of forests for the country and the emergence of regional deficits of wood raw material;
3. Destruction of vegetation and degradation of forest areas (including erosion) in all altitudes due to:
    - Increase the number and scale of forest fires as result of prolonged dry periods;
    - Increase in forest damage due to storms (winds), torrential rains, wet snow, late spring frosts, which will support secondary pathogens and insect pests.
4. Reduction of wooded areas in the lower altitudes and increasing forest area over timber line in the alpine zone;
5. Loss of biodiversity at all levels and increase of the risk of spreading invasive species.

Of great importance for the behavior of forest stands is the degree of change in habitats due to climate change (Rafailov, Kostov 1994). The habitat with smaller buffer capacity (more dry and of lower fertility) are more vulnerable. Climate change will affect weaker habitats and mountain forests as the risk of multiyear water deficit is smaller.

Climate change will alter forests and the activities in them (Kostov, Stiptzov 2004):

1. The species composition of forests as in southeast Europe the share of drought-resistant species will increase at the expense of mesophytes and hygrophytes;
2. Changes in the age structure of forests with an expressed trend towards their rejuvenation. Younger forests are more flexible and adaptable;
3. Spatial structure of forest stands will also change as more frequent natural disturbances will increasingly lead to the formation of heterogeneous in age and composition of stands (as opposed to today's relatively even aged stands);
4. The productivity of forests in the country will decline. In areas where climate change will lead to acute or chronic shortage of available moisture (De Martonne's index <30) forests will be of low density, with a very low productivity. This will create prerequisites for a deficit of timber and all types of wood products in the context of the expected increased use of wood by over 20% towards 2020 (EU Forestry Strategy, 2013). Weak increasing of productivity due to the extension of the growing season in mountain forests would not compensate the reduced growth in the rest forest areas.
5. Increased risk of extreme events due to climate, changes the planning activities of logging in forests. The latter must be free in order to increase opportunities for the unpredictable increase of the so called "Compulsory use of wood" as a result of fires, calamities, etc.
6. Loss of forest cover due to difficult regeneration and/or degradation of stands. A number of stands will not be able to regenerate naturally and there is risk of further stand degradation;
7. Ecosystem functions of forests are gaining significant public importance. Restrictions on logging due to an increase in the proportion of protective and protected forests will increase the cost of the timber, respectively, will reduce the profitability of existing chains of exploitation, primary and secondary wood processing.

Water protection forests whose primary purpose is to guarantee and protect the supply of drinking water in Bulgaria occupy an area of 246 650 ha, which is 9.65% of forest areas in the country. Of these, 69.62% are state owned, 17.99% - municipal, 8.10% - private and 4.29% others. Water protective forests accumulate annually between 1-1.5 billion m3 of water.

Overall changes in forests and forestry as a result of climate change will affect diversely (but with predominance of negative effects) on the implementation of ecosystem function - the supply of clean drinking water from forests:

A. The change in species composition towards drought resistant and pioneer species will increase transpiration (Raev, 2003). On the other hand forest areas will be retained by soil and wind erosion and will preserve the forest litter, important for the water quality in forest watersheds (Kitin 1988);
B. Predominance of young forest plantations is associated with increased evapotranspiration, which reduces runoff in the watersheds;
C. The complex spatial structure and species composition of stands is expected to improve their mechanical stability and long-term preservation of ecosystem functions associated with watersheds;
D. Windfalls, fires, calamities and other extreme phenomena lead to serious local adverse changes in the watersheds, including disruption to the infrastructure providing drinking water. Preliminary preventive measures for their limitation are essential for the forests, especially in edge distribution areas for the different forest types. Additional investment funds in silvicultural activities will be needed to ensure suitable stand composition with better fire resistance and / or construction of fire facilities.

E. Impeded or delayed natural regeneration of forest stands in watersheds has a negative impact on both the quantity and seasonal distribution of water runoff, as well as on water quality characteristics (increased sediments, temperature, etc.);
F. Deficiency of timber is a potential risk for the increase of illegal practices in forests and disturbance of their ecosystem functions, so that control over markets of raw timber and forest guarding should be increased, especially in the areas mostly affected by the climate change.
G. Changing the sustainability of forest ecosystems increases the risk of non- sustainable flow from forest watersheds. Therefore it is necessary to introduce appropriate watersheds classification in order to achieve respective appropriate management.
H. Reducing the cost-effectiveness of traditional forestry operations, and the need to increase capacity for joint management of forest and water resources imposes to expand opportunities for funding of diversified activities through appropriate and attractive measures from EU funds.

In the framework of WP4 of CC-WARE project “Catalogue of best forest practices in water protected areas” for guaranteeing the forest ecosystem service “supply of clean drinking water” was elaborated.

Catalogue of best forest practices in water protected areas /for southeast Europe/

1. **Limitation of Clear-Cuts**
2. **Establishment of a Continuous Cover Forest System**
3. **Defined Crown Cover Percentage of Forest Stands -** within planar, collin and montane forest communities, crown cover percentage should range between 70 % and 90 % and within subalpine conifer forest communities, crown cover percentage should range between 60 % and 80 %. According to Bulgarian legislation crown cover percentage should me minimum 60%.
4. **Limitation of the Percentage of Timber Extraction**
5. **Continuous Regeneration Dynamics** - forest stands in water protected areas have to host a continuous regeneration phase on minimum 10-20 % of their spatial extension. Regeneration fellings of up to 20% are allowed. Sanitary felling is permitted only for separate trees
6. **Foster Stability, Vitality and Resilience of the Forest Ecosystems**
7. **Tree Species Diversity According to the Natural Forest Community**
8. **Improve the structural diversity of the forest stands –** ensuring tree species diversity as well as uneven-aged and multi-layered forest stands
9. **Forest Ecologically Sustainable Wild Ungulate Densities** – ensuring natural regeneration
10. **Protection of the Gene Pool of the Autochthonous Tree Species**
11. **Foster old, huge and vital tree individuals**
12. **Adequate Dead-Wood Content** – ensuring biodiversity in forest ecosystems
13. **Buffer Strips along Streams, Dolines and Sinkholes –** preservation of water bodies and karst landscape from direct infiltration of mineral deposits and sediments
14. **Adaptive Forest Management under Climate Change**
15. **Natural Forest Succession in Case of Stable Forest Ecosystems**
16. **Small-Scale Regeneration Techniques**
17. **Structural Thinning Operations**
18. **Artificial Recruitment Techniques -** if the natural regeneration dynamics do not provide adequate results in terms of tree species composition and/or of quantity of tree seedlings and saplings; the use of autochthonous plant material is mandatory; measure under climate change, if migrating tree species have to be supported
19. **Forest Fire Prevention**
20. **Limitation of Forest Roads**
21. **Adequate Timber Yield Techniques –** to prevent the disturbance of the soil- and humus layers
22. **Prohibition of the Use of Chemicals in Forestry Practices**
23. **Source Water Protection Policy and Institutional Implications -** establishment of an adequate legislative and administrative frame; integrated forest-water management
24. **Preservation of the Forests at the Tree Line and Timber Line (Subalpine Forest Belt in Mountainous Regions)**
25. **Integrative Planning Strategy for Watersheds (Forest Ecosystems with drinking water protection as focus)**

National examples as part of transnational strategy for protection of water resources in climate change condition

In the framework of WP5 the common methodology for vulnerability of water resources of CC-WARE project partners was applied in different test-areas in Bulgaria.

CASE STUDIES, BULGARIA

“TICHA” WATERSHED

Test area “Reservoir Ticha watershed”, Bulgaria

The reservoir Ticha watershed (Figure 12) is a sub-catchment of the Kamchiya river. The Ticha reservoir is created on the river Golyama Kamchiya near to the Ticha village and its water resources are used for multiple purposes such as irrigation, potable and industrial water supply, hydropower output and ecological discharge provision downstream of the dam.

The watershed area of the Ticha dam is 977 km^2. Its water storage corresponds to the requirements for a large dam. The waters of the Ticha dam are used for drinking water supply. The elevation of the watershed varies from 131 m to 1049 m, and its average slope is 16%.

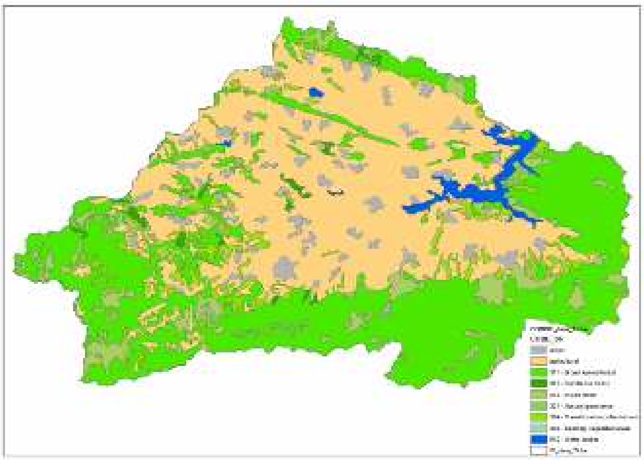

Figure 12 Reservoir Ticha watershed

A special feature of this reservoir is that it provides an important part of water demand outside of the watershed. These are both big domestic water supply systems /WS/ “Ticha-Soumen -Veliki Preslav” and WS “Ticha – Turgovoshte” and the largest irrigation system /IR/ “Vinitsa’. So, one part of the return waters remains in another watershed. The other three smaller irrigation systems are located along the river tributaries Dragaovska and Gyurlya inside the Ticha watershed.
The water resources vulnerability and the risk for water supply are determined according the proposed methodology. WEI and a system of indices estimating the water supply system performance such as Water shortage index WSHI, reliability in time (by years, months), reliability by volume are implemented. This makes possible, at local level, to obtain the vulnerability and the risk of water supply for each water user.
The methodology includes several stages as follows:

- Estimation of meteorological factors, scenario modeling and water resources (Figures13 – 15).

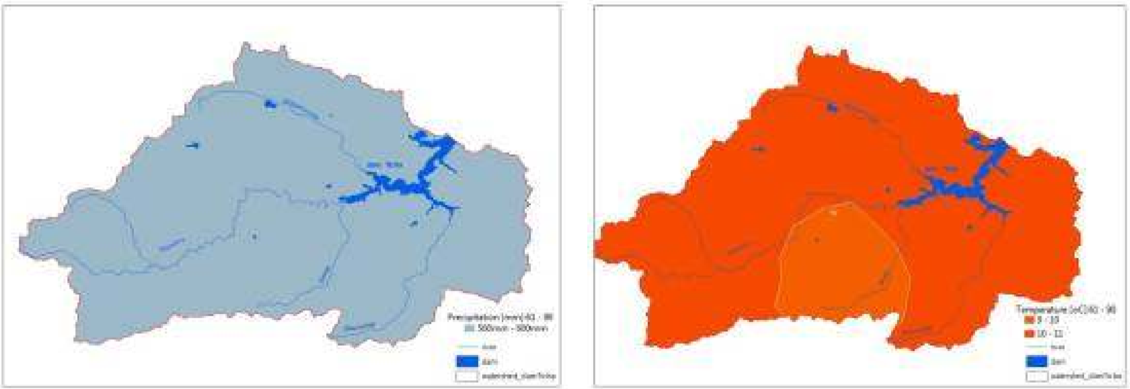

Figure 13 Spatial distribution of average annual sum of precipitation and temperature for the period 1961-1990

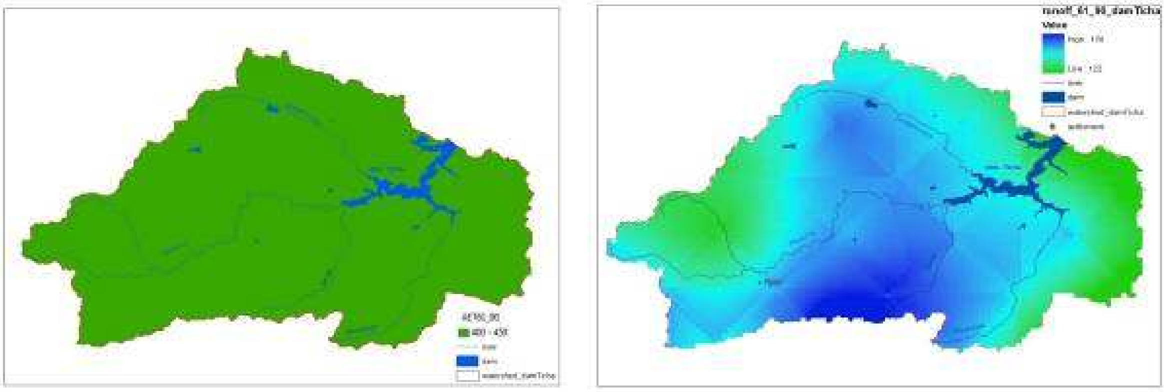

Figure 14 Spatial distributions of real evapotranspiration and runoff for the period 1961-1990

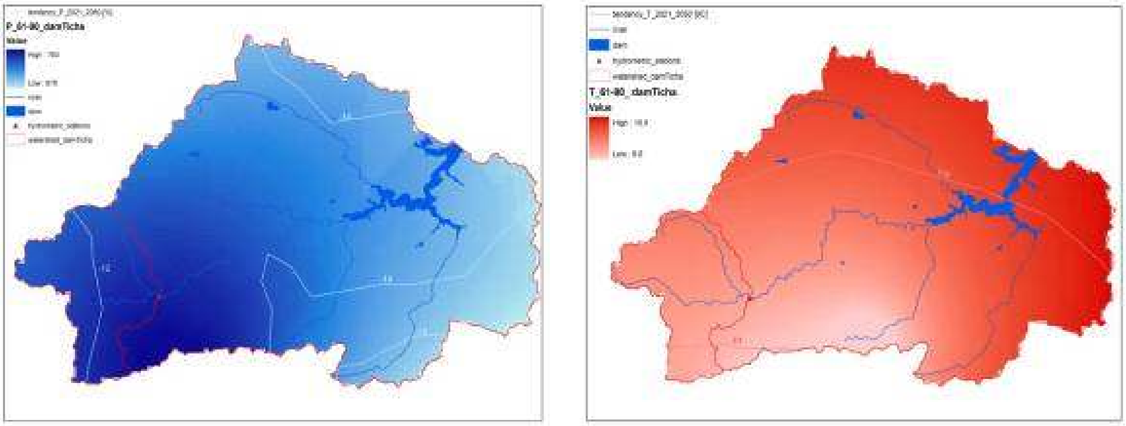

Figure 15 Trends of precipitation and temperature during the period 2021-2050

- A graphical scheme (calculation) of the reservoir Ticha watershed is developed containing the river network, all other water sources and irrigation systems, places of water intake, all water users and the way of water utilization
- An estimation of the recent and prognostic water demand is made. Ecological minimum for water ecosystems downstream the dam is determined.
- The parameters of the water resource system are given.
- A watershed network model, consisting of nodes and arcs, is developed and vulnerability assessment is performed. Through simulation program the water resources are allocated, in each one node. The balance is calculated and the described indices of water shortage (WSHI: water shortage index) by years, months and volumes, as well as the index of reliability are determined. The obtained results demonstrate the degree of meeting the requirements of water demand (Table 4) and the vulnerability in case of water shortages.

Table 4 Calculated values of WEI

River/point	WEI 1961-1990 %	WEI 2021-2050 %
River Ticha source up to the village of Ticha	8,45	19,3
Reservoir Ticha	42,0	77,2
River Draganovska	4,73	8,1
River Gyurlya	11,6	19,7

0-20	20-40	40-60	60-80	80 - 100
Very low	low	Moderate	High	Very high

Scale of vulnerability

As shown in the scale of WEI vulnerability, the rivers Draganovska, Gyurlya and the section of Ticha river from its source up to the village of Ticha have very low vulnerability for the basic period /0 -20%/. The value of WEI for the point res. Ticha shows middle vulnerability /40%-60%/ - the river watershed is loaded with demand and in dry periods will not be able to provide all the needs. (Table 5)

Table 5 Calculation of WSHI and index of reliability

Name	Annual demand	Short-age	Exceedance probability			
			by volume	by years	by months	index of reliability
	m3.102	m3.102	%	%	%	
WS SHUMEN-PRESLAV,settl.	200 000	0.0	100	100	100	0.000
WSTUGOVISHTE	62998	0.0	100	100	100	0.000
IR VINITSA	628470	78816	87,46	86,67	90,80	6,120
IRKRASNOSELTSI	22783	3055	86,59	80,00	90,16	5,417
IRCHERKOVNA	7401	100	98,65	96,67	98,45	0.123
IRGUERLOVO	4448	115	97,41	96,67	98,45	0,443
HPPTicha	800000	33122	95,86	83,33	93,06	1,248
Eco	195712	0.0	100	100	100	0.000

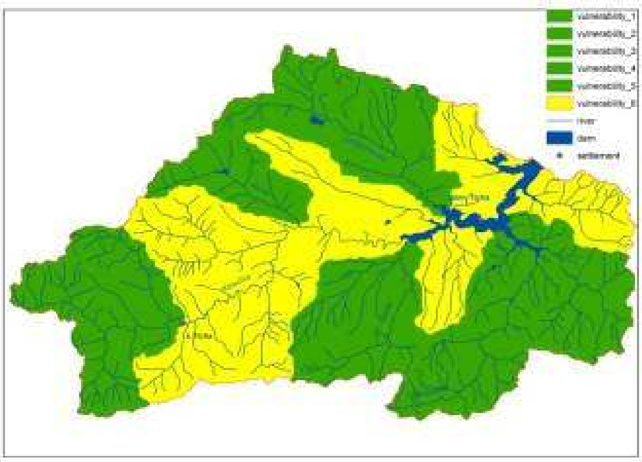

Figure 16 Vulnerability of Ticha watershed according WEI for the period 1961-1990

Drinking water supply is not at risk. It is provided up to 100%. There are some shortages in irrigation but they are acceptable because the standard of irrigation is 75%. WEI and shortages are in agreement.
During the period 2021-2050 WEI values are higher and some shortages in drinking water supply appear although they are not very high, but all the irrigation is at risk – very low probability of exceedance for IR "Vinitsa", where Pvolume = 50.3%, Pyear =43.3% and Pmonths =60,1%. Drinking water supply is provided up to 98,45 % of volume and ecological runoff - 100 %.

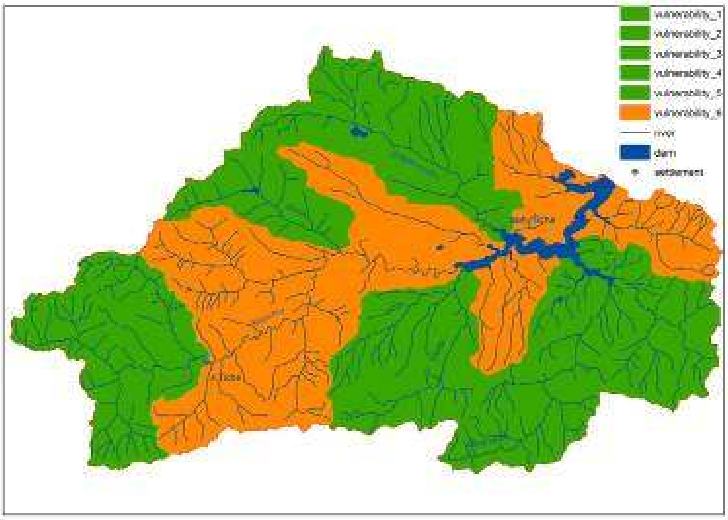

Figure 17 WEI for the period 2021-2050

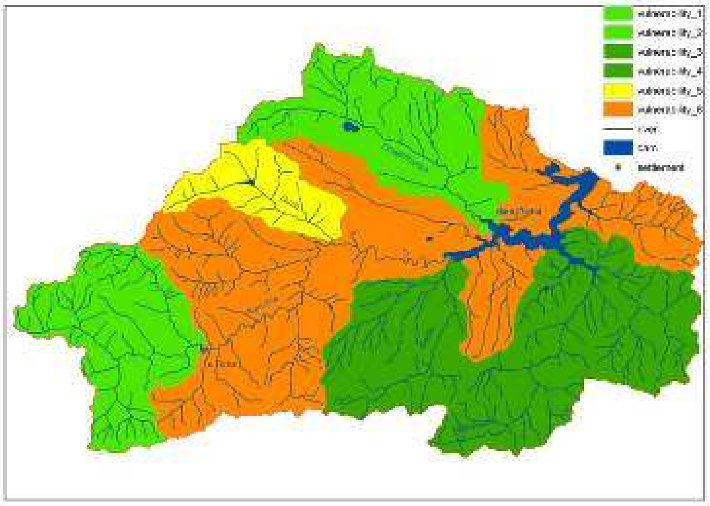

Figure 18 Vulnerability (WEI) and risk of water supply (WSHI) for the Ticha watershed in the period 2021-2050

Assessment of the drinking water quality vulnerability from the Ticha dam

Analyses of the loadings in regard to the quality of the surface water for drinking supply from watershed of the Ticha dam

Pressures that affect the quality of surface waters and those used for drinking water can be divided into 4 groups:

1. Diffuse sources of pollution:
    - Land use
    - Presence of small settlements without sewerage system
    - Waste disposal places not complying with EU requirements - without insulating pad surface and drainage system
2. Point sources of pollution:
    - Wastewater treatment plants
    - Sewerage system
    - Industrial waste water sources
    - Livestock farms
3. Significant areas of water use
4. Significant morphological changes:
    - Dams, roads

The high proportion - 41% of the arable land in the watershed supposes contamination of the surface waters of diffuse character. Using of fertilizers and pesticides and possible movement to the water bodies by runoff, water erosion or through the contact between groundwater and surface water, the existence of the grazing livestock are the main sources of the pressure on the water quality of the dam, which are used for drinking supply.

The large proportion of forest vegetation - 52.6% from the total area of the watershed - will have a preservation role for soil particles runoff and appearance of dissolved and suspended solids in the water of the Ticha dam.

Vulnerability of the quality of waters for drinking supply

According to the calculated indices for water quality vulnerability /WQI/ for the watershed of the Ticha dam 43.2% of the area characterizes with low vulnerability. Moderately vulnerable are 41.3%, and very low vulnerable are 2%.

The calculated values for the WQI for future scenarios WQI_2050 in relation to land use changes show negligible differences and WQI are in the same categories of vulnerability.

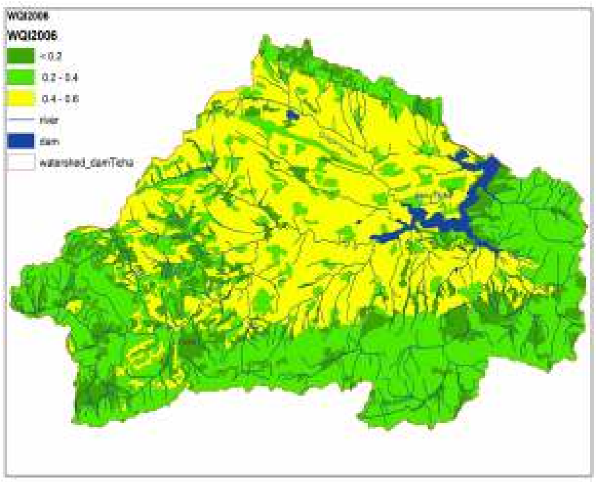

Figure 19 Map of water vulnerability of watershed of Ticha dam according to WQI 2006

The data in the figures 20 and 21 shows the spatial distribution of areas in Ticha watershed regarding vulnerability of water quantity and quality for drinking and household supply. Low and very low vulnerable regarding water resources quantity are the watersheds of the following rivers: r. Ticha up to village Ticha, river Draganovska, r. Gyurla, r. Gerila and r. Eleshnitsa. In terms of the vulnerability of the water quality to these categories only watershed of the r. Ticha at village Ticha and part of the watersheds of rivers Gerila and Eleshnitsa are referred. The area around the dam is moderately vulnerable concerning water quantity and quality. Over the forecast period - 2020 - 2050 this area falls in the category of highly vulnerable with respect to water quantity, while in terms of water quality it remains unchanged.

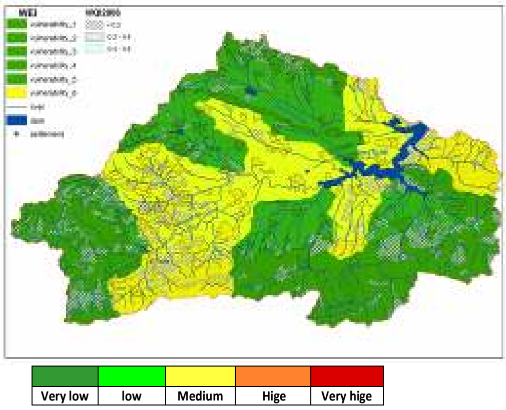

Figure 20 Map of vulnerability of the water quantity and quality (according WEI and WSHI) - period 1961 to 1990

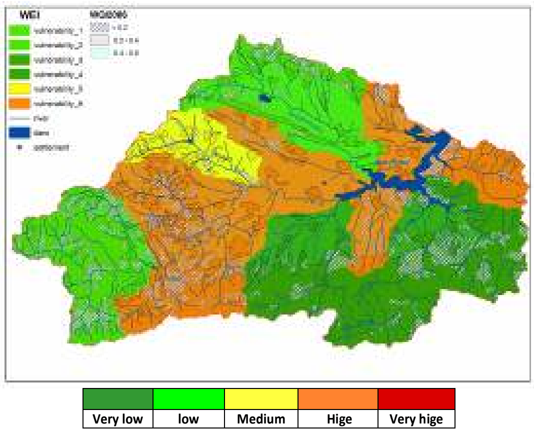

Figure 21 Map of vulnerability of the water quantity and quality (according WEI and WSHI) - period 2021 -2050

Management options for mitigating vulnerability of drinking water resources Impact of forests on vulnerability of water quantity and quality in climate change conditions

The expected negative climate changes, will result in shifts of plants, animals and habitats to the higher altitudes; shift of plants, animals and habitats in south-north direction; soil moisture decrease; increase of vegetation period duration; increase of the number of the invasive species; losses of wetlands, etc. Water quality and quantity are influenced by the tree species, forest type, forest cover within different parts of watersheds, forest management practices, etc.

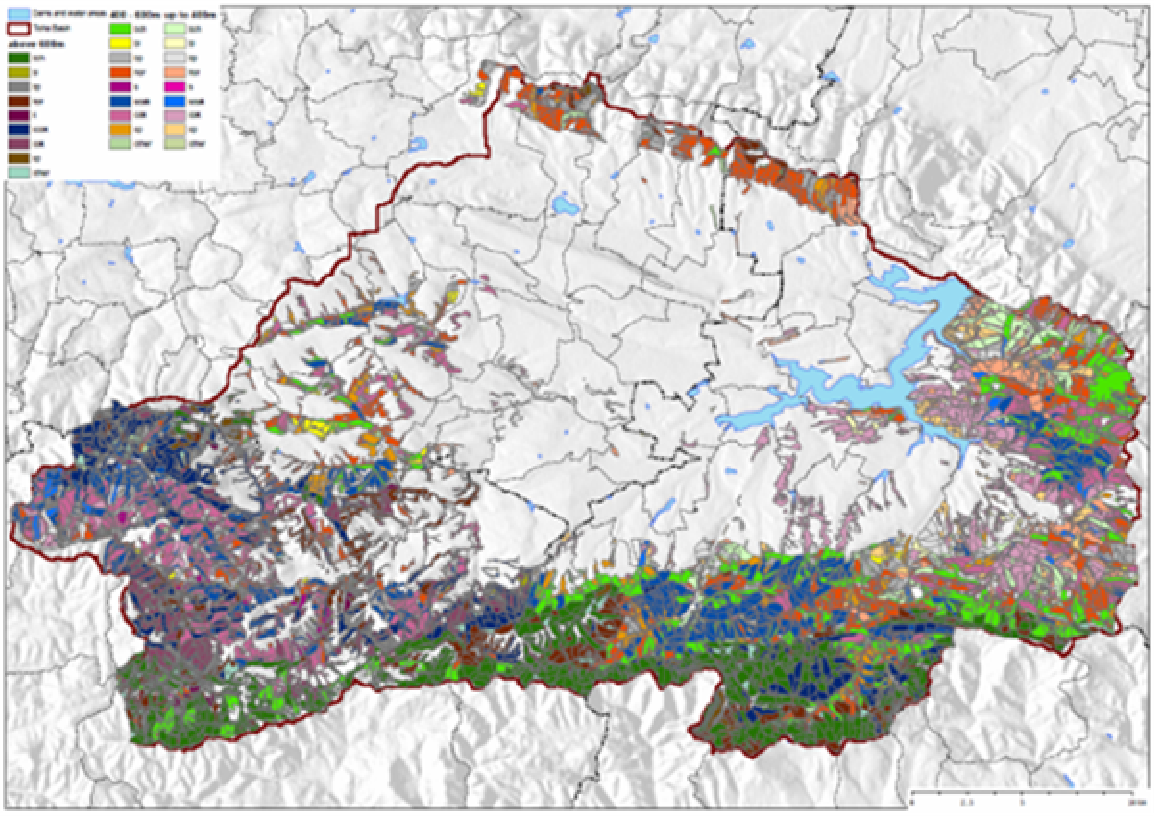

Figure 22 Distribution of the major tree species in the watershed of Ticha dam: sp – Scots pine, s - Spruce, bp - Austrian pine, bch - beech, hor - Hornbeam, soak - Sessile oak, oak - other oaks, bl – Acacia

Zone up to 500 m a.s.l.

The most vulnerable to climate change in the watershed of Ticha dam are coniferous forests, esp. coniferous plantations established outside of their natural habitat. The total area of these forests is 2800, 9 ha - Austrian pine – 1557. 4 ha, Scots pine - 1109, 7 ha and spruce - 127, 1 ha and Douglas fir - only 6, 8 ha. The Silver Lime covers 20,1 ha of the watershed. It could be expected that Silver lime will increase their area within the zone to 500 m a.s.l. and thus will ameliorate the water preservation and water retention functions processes of the forests. Observations show that the regeneration processes in prevailing part of

the coppice stands will recover with the common and oriental hornbeams - 113,6 ha, as well as shrubs species - hawthorn, blackthorn.
Forest management practices will be restricted within areas of Hornbeams forests as they are of high conservation value. As Hornbeam is well adaptive species with good regeneration ability, management activities to increase its area, need to be implemented. The total area of high-stem forests is 7217,2 ha, which is 43% of the total afforested area. They are presented mainly by oak and beech. Increase of Silver Lime participation in these forests is expected. This will improve the structure of the forest stands and thus – their water-preserving functions.

Zone above 500 m a.s.l.

The total area of the zone, higher than 500 m above sea level is 23477.22 ha. In this zone 59 % of the forests are high-stem deciduous forests including 10,1% mixed forests, which supposes more favourable water-protective functions. Oak forests which currently occupy 7558.2 ha, will play a key role in the future. The sessile oak forest have the highest share – 4627.0 ha, followed by the Hungarian Oak – 2777.4 ha, and Turkey Oak – with 152.6 ha.
Observation of the beech forests distributions, show that they occupy 5536.0 ha, of which 1921.8 are covered by Oriental Beech. The Oriental Beech is rather more thermophile than the European Beech and is expected to extend their area.
Both pessimistic and realistic scenarios for the watershed of the Ticha reservoir show that oak forests will increase their area, shifting upwards of the mountain and will occupy the areas currently occupied by beech forests. The European Beech (Fagus sylvatica L.) and the Oriental Beech (Fagus orientalis Lipsky) are late successional species in expansion and, being acetophilic species, will preserve their participation. It is more realistic to expect formation of mixed forest with lower growing indexes for the beech species. This trend will be however favorable for the water balance and the forest water protective functions.
The coniferous plantations cover 2833.1 ha. At the higher altitudes, their sanitary condition is expected to deteriorate at later stages. Their transformation might be postponed until the age of 40-50 years.

Water preserving functions of forests within the watershed of the Ticha reservoir

The main water preserving functions of the forests in Ticha watershed are to protect the water from pollutants, to improve the water quality of the water bodies, which are discharged in the reservoir and to ensure the planned water quantities.
The forests of the watershed with their structure and formed from them leaf mass, branches, acorns, seeds, dead debris, etc. develop a kind of a “filter” for the surface water preservation. They protect the reservoir from pollutants in the form of insoluble particles, detached from the soil and moved by wind. Forests reduce soil erosion. The forests to a great extent guarantee the annual amount of water in the dam and the required minimum water for maintaining the ecological balance of the river “Big Kamchia”. The forests limit the solid particles input to the water bodies and play an important role in the prevention of the water quality, ensuring the sustainable use of water supply for drinking purposes in future.
The hydrological efficiency of the forests is related to the re-distribution of the falling rains, which is mainly affected by their retention by the plant crowns and forest litter, by the exposition, age of the plants as well as by their management.
The tree crowns retain a significant part of the rains water, which leads to a decrease in the soil water content. The amounts of the retained rain water by the crowns (interception) of coniferous plants in Bulgaria aged from 20 to 30 years vary from 25 to about 38 %.
In a region closed to the watershed of the Ticha dam (Northeastern Bulgaria, Suvorovo) it is found out that for 20 to 24-old plantations of black pine at 505 mm annual precipitation, the interception is 32.6% while in Turkey oak forests the average annual interception is from 12.0 to 20.7 % and in the period November-May almost all amount of precipitations reaches the soil (Raev, 1989).
For the deciduous plants in the watershed, the predominant ones are older plants (above 80 years) – about 66%. It can be expected that the territories covered by this type of forest possess good water-protective

properties. These forests have also significant buffer capacities in relation to the preservation of water purity. Regarding the conifer plantations, 85% of them are at age of about 40 years. To increase their water retention ability thinning is necessary to be performed.
Some studies show that more significant vegetation cover changes are expected to occur at the zone located at about 500 m above the sea level. That is why we suppose that the water protection zone (zone II) for the protection of the water from reservoirs should be spread on the territories from the riverbank to the 500 m above sea level height. The riverbank of the Ticha reservoir is the longest one – up to 100 km. At this zone, the change of the land use, road and building constructions, rented areas for agricultural uses, etc. should not be allowed. In cases of insect attacks or other natural disasters a fast afforestation of the open areas is allowed in order to control the erosion processes.
The boundaries of water protection zone III should include the remaining territories of the watershed - 500 m above the sea level. Planned activities in this zone should be consistent with the forests' preservation functions, while the forestry management activities need to be directed to improving the water regulative and water preservative roles of the forests.

Recommendations for preserving the quantity and quality of the water resources through forest management practices in the watershed of the Ticha reservoir

The established tendencies and prospects in the watershed of the Ticha reservoir are as follows:

- a changes of the total forest area are not expected in the region of the watershed
- dryness of the coniferous and coppice forests is expected

Forest area is expected to change in future under the influence of:

- the ongoing reforestation processes that benefit the deciduous species – mainly of the genus Quercus
- secondary succession, accompanying the reforestation of the areas covered by coniferous plantations, reached the maturity and reforestation stage
- the wildfire risk increase
- changes related to the water runoff regime in relation to the temperature changes and expected torrential rainfalls
- a growing risk for the climatic extremes: heat waves, strong precipitation events (including heavy snow), drought and wildfires
- unfavourable consequences for quality of the surface and underground water resources
- pollution of the water sources and the accompanying diseases

The management of forests, threatened by climate change should be carried out by stands/ plantations, depending on the specific sylvicultural characteristics specific for the given habitat types. The guideline principles should be the development of such forests, which reduce the surface water runoff and increase groundwater. In this respect we recommend that all forests from the watershed of Ticha dam situated up to 500 m a.s.l. to be included into the category of forests with special water-protective function.

“Srechenska bara” watershed

The explored “Srechenska bara” watershed, is located in the alpine zone of the West Balkan Mountains. The altitude of the drainage basins of the separate tributaries varies between 950 and 1797 m. The total area of the drainage basin is 10 220 ha and 91% of it is forested. Broadleaved tree species are dominant- 86,72%. Water protectiже forests average site class is 2,6, average age- 102 years, growing stock /ha - 296 m3/ha and average increment- 27 323 m3 or 2,93 m3/ha.
The annual average rainfall amount is about 990 mm. The spring and summer rainfall maximum, respectively in May and June, and the winter minimum in February are most influential on the seasonal rainfall distribution.

The water catchment is conducted by a system of water captures organized in two main collective derivations.

- South derivation- located on the southern slopes of the mountain at about 1400 m, which collects its waters using two collective canals. “Srebarna- Ginski” canal and “Iskrecki” canal. The total area of this derivation’s drainage basin is 3895 ha with project catchable water amount about Q= 1400 l/sec, at built-up amount of hydroelectricity facility- Qbuilt-up = 1900 l/sec.
- North derivation- located on the northern slopes of the mountain at about 870 m. It collects water from the feeders of Ogosta river using two collective canals: “Strugarnica” canal and “Zanozhene” canal. The total area of that derivation’s water basins is 5246 ha with project catchable water amount Q 1300 l/sec, at built-up amount of hydroelectricity facility- Qbuilt-up = 2800 l/sec. This hydroelectric facility processes the water which has already went through “Petrohan” hydroelectric facility. “Vreshtitza” derivation also leads its waters towards the dam. It captures the water of the upper feeders of Vreshtitza and Rakovitza rivers using four water catchments in a zone with altitude between 760 and 560 m. The total area of its drainage basin is 875 ha and the catched water amount is Q 97 l/sec.

Apart from the water from these derivations, water from its own drainage basin flow into the dam. The area of its drainage basin is 225 ha and the average altitude is 460 m.

Water protective forests in “Srechenska Bara” watershed

The total afforested area of the drainage basins is 9312 ha, which is about 91% of the total water catchment area. Most common tree species are beech (Fagus sylvatica), spruce (Picea abies), Scotch pine (Pinus sylvestris) and fir (Abies alba). Beech occupies 7 817, 61 ha or 84% of the total afforested area, spruce- 675, 95 ha(7,26%), Scotch pine- 358, 57 ha (3,85%) and the fir- 190,55 ha or 2% of the area. These four tree species occupy 97% of the whole protective forest area. VIII age class stands are dominant (over 140 years old)- 33,5 %, followed by VII age class (age 121- 140)- 18,14% and II age class stands (age 21 to 40)- 11, 76% (Figure 23).

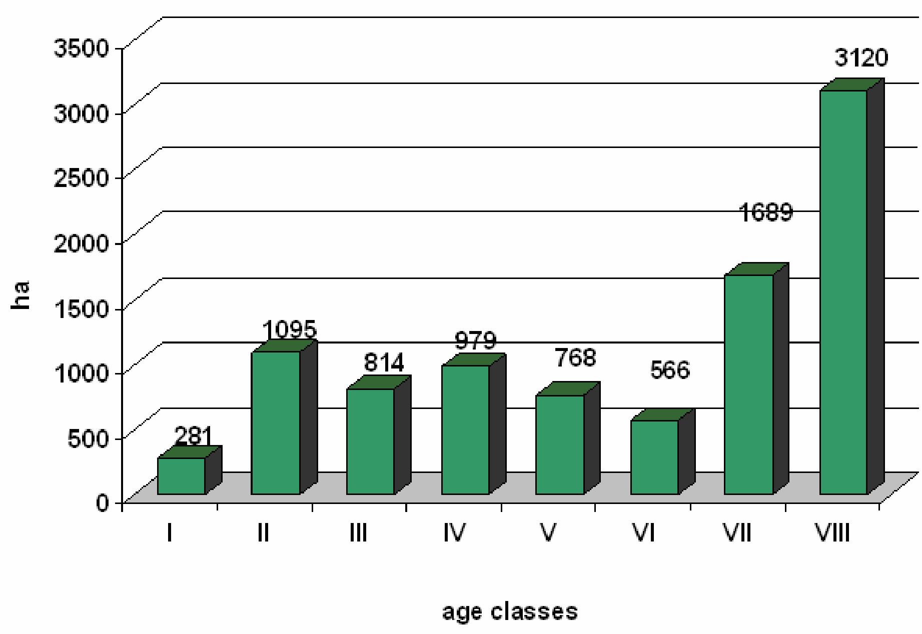

Figure 23 Distribution of forests according to age classes in “Srechenska bara” watershed

The total growing stock is 2 759 330 m3 and about 50% of it is in stands over 120 years old. (Figure 24)

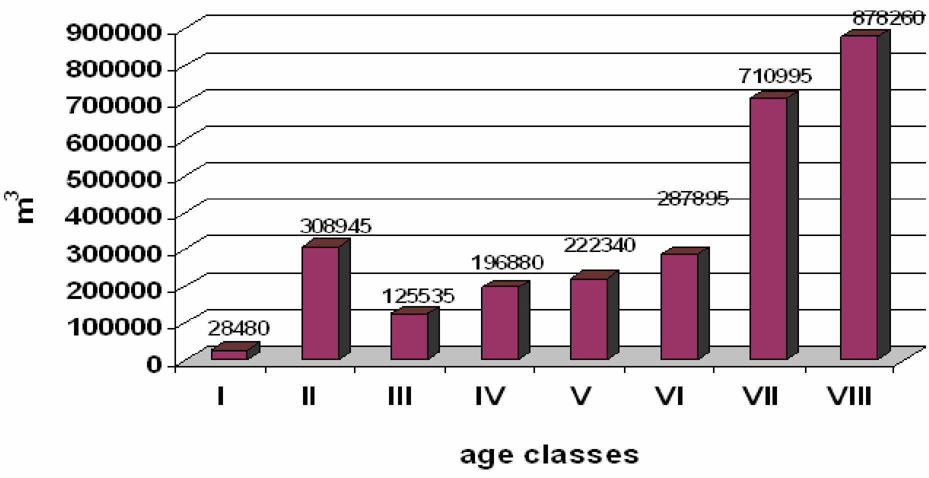

Figure 24 Distribution of growing stock according to age classes in "Srechenska bara" watershed

Impact of climate change on forests in the "Srechenska bara" watershed and recommended silvicultural activities

The forests in "Srechenka bara" watershed are located mainly on the northern slopes of the Balkan Mountain. The main water accumulation channels are located at about 700 m a.s.l. According to (Raev et al. 2011), this mountain region falls within the area of forest vegetation low to moderately (in the pessimistic scenario) vulnerable to climate change. Habitats are fresh and moist and they will not change significantly even at the expected changes in precipitations and temperatures. River flows will continue to be with a spring maximum.

The forests in water protective areas (WPA) under the altitude of 700 meters are moderately to highly vulnerable to climate change. Nevertheless these forests will not be significantly affected by the expected climate change as the main flow is formed in the upper part of the watershed.

Entire catchment area falls within Natura 2000 areas which defines restrictions to the management regimes.

The main tree species that dominates the forest vegetation is the beech (Fagus sylvatica L.), which occupies 87% of the area of the watershed. In the scenarios examined by (Raev et al. 2011), Kostov and Rafailova (2009) and others, the impact of climate change are noted following major risks and appropriate adaptive interventions for stands:

1. Increased damage in forest stands from heavy (wet) snow, strong winds and late frosts. Particularly vulnerable are the young, dense, even-aged beech stands, which occupy about 2500 ha. Water losses by evapotranspiration in these forests are great. Conducting of thinnings in them is a priority, with intensity at a single intervention up to 25%. Vulnerable are also the stands of very high age (over 140 years), which occupy about 4,500 ha. Most of them are hardly accessible, forming so called "closed basins". These "old forests", possess better water protective functions. On the other hand the century-old trees are highly vulnerable to extreme weather events. It is necessary to strengthen the monitoring and to invest in supporting heterogeneous structure of the stands by selective thinning or irregular shelterwood with intensity up to 20%.
2. Increased risk of erosion on the affected by natural disturbances or logging areas, especially on steep slopes, as prevailing in the watershed. The latter is supported by the existing brown forest soils with relatively deep but sandy (light) transitional (B) horizon that is easy to wash up;
3. Loss of increment and reduction of potential timber volume for harvesting due to possible adverse weather conditions. It should be added also possible deterioration in the quality of part of the

harvested wood due to shortage of the time for its utilization. Both events will lead to negative financial results for the owners and managers of the forest;

4. Loss of funds due to complicated management regime - the application of more sophisticated silvicultural systems requires higher qualification of staff, more complex management of the forest and more expensive felling;
5. Fire risk in forest stands will increase periodically due to expectations of prolonged droughts in summer and autumn and the presence of larger amount of dead wood. Risks of fires exist also in subalpine meadows. It is necessary to build up fire protection infrastructure, which does not currently exist in the majority of the area.

The available about 10% of Scots pine and spruce plantations are currently in the stage of intense transformation to mixed beech-coniferous stands, which is in accordance with the prescriptions for beech habitats in "Natura 2000".

The remaining 3% of other tree species are coppice oak and hornbeam forests located in zone I and II of water-protected area of “Srechenska bara” dam. They fall in areas potentially highly vulnerable to climate change (Raev et al., 2011). They require more stringent protection from fires that can be transferred from adjacent agricultural and other (urban) areas (ground monitoring). The management activities in these forests should lead to smooth conversion of small areas of coppice stands into high stem ones. Since in this area hornbeam (Carpinus betulus L.) participates in the composition of low stem beech and oak stands and it is highly adaptive to warmer conditions the expansion of its participation in the composition of future stands should be tolerated.

It can be stated that the forest vegetation in the watershed of “Srechenska bara” dam has the adaptive capacity to the expected climate changes in the region. The forest management will include long-term gradual and selective cutting and will ensure permanent coverage of the territory with uneven (heterogeneous) forest.

In the future the question about the provision of water quality and quantity from “Srechenska bara” dam will be relevant due to the fact that it is located in the lower zone where temperatures will increase significantly. This leads to increasing of water temperature in the dam. On the other hand the higher summer temperatures will increase consumption of water for domestic and other uses.

Velingrad municipality catchment

The investigated area is located in Western Rhodope Mountain. The altitude varies between 900m and 1000m. The annual average rainfall is between 750 mm and 960 mm. The maximum is in May and June and the minimum is in August and September. The population of Velingrad municipality receives drinking water from Batak and Belmeken dam and from several underground sources situated in the region.

Water protective forests in Velingrad municipality

There are 1314,5 ha water protective forests in Velingrad municipality situated in the territory of State Hunting Enterprise (SHE) “Alabak” (522,3 ha) and SHE “Chepino” (792,2 ha). Most common tree species are Beech (Fagus sylvatica), Spruce (Picea abies) and Scots pine (Pinus sylvestris). Spruce is most widely spread and occupies 567,7 ha or about 43,83 % of the water protective forests, followed by beech - 250,7 ha(19,36%) and Scots pine- 240,60 ha or 18,58 %. Those three tree species occupy 81,76% of the total afforested area (Figure 25). Coniferous tree species are dominant- 72 % of the total area. Water protective forests average age is 95 years, the growing stock is 217 m^3/ha and the average increment is 3136 m^3 or 2,42 m^3/ha.

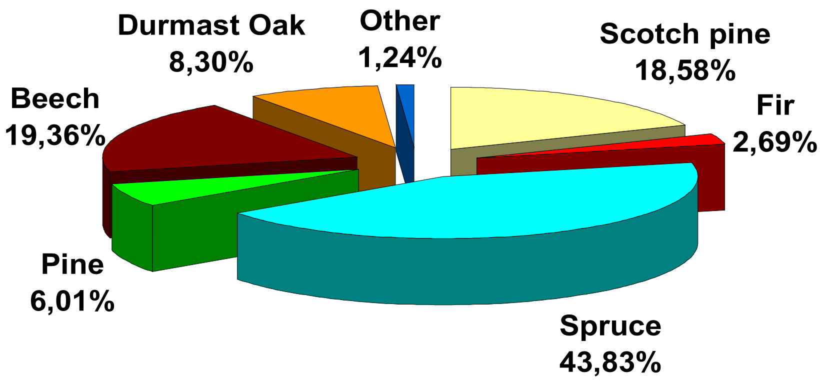

Figure 25 Distribution of tree species in the water protective forests of Velingrad municipality

Dominate stands of VIth age class (age 101- 120)- 26,8% , followed by Vth age class (age 81- 100)- 16,9 % and VIIth(age 121-140)- 15,4%.(Figure 26) Over 70% of the stands are mature.

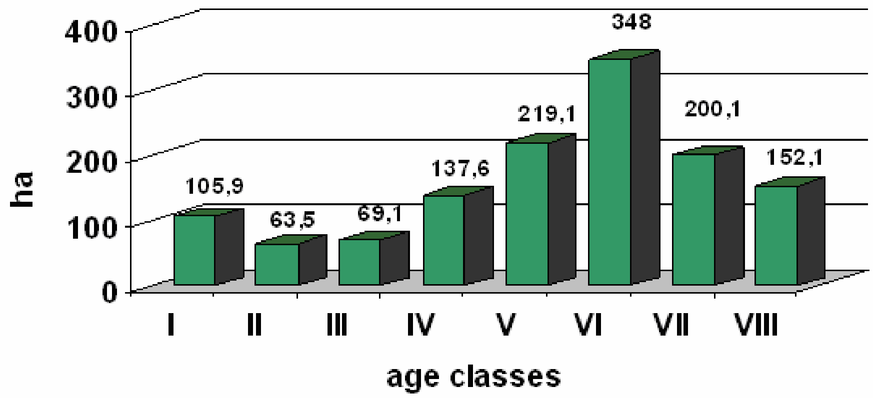

Figure 26 Distribution according to age classes of water protective forests in Velingrad municipality

The total growing stock is 281 410 m3. About 50% of it is in stands between 80 and 120 years old (Figure 27).

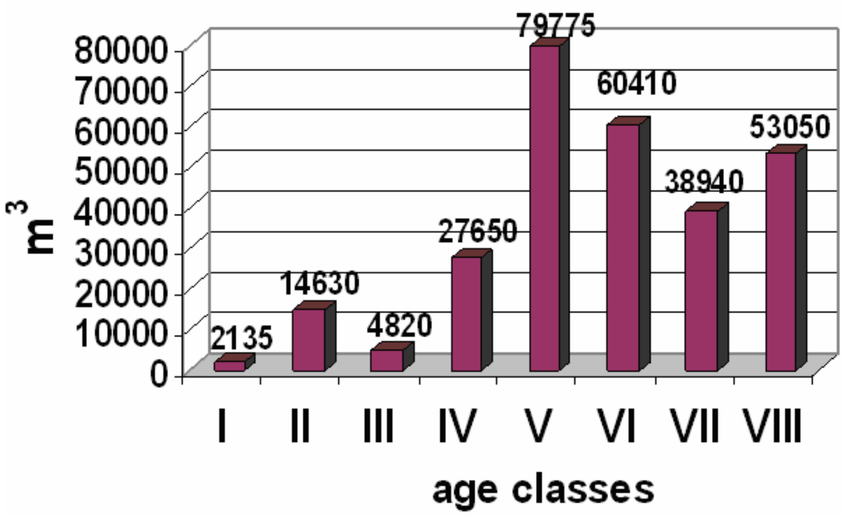

Figure 27 Distribution of growing stock according to age classes of water protective forests in Velingrad municipality

Impact of climate change on forests in the watershed of Velingrad and recommendations for their management

In Velingrad watershed forests in “Alabak” mountain are located on various slopes with different inclination, mainly with east and north aspects. Catchment’s areas are located over 900 meters above sea level. According to (Raev et al. 2011), the forests at this elevation are slightly to moderately vulnerable to climate change. The main tree species are: Scots pine, spruce, fir and beech, which are indigenous species in this area with a good adaptive potential and that build mostly mixed stands. Expected climate changes in the region are related to reducing the amount of rainfall within 10%, i.e. from about 900 mm to 750-800 mm per year, and temperature increase averagely with about 3 degrees. This will not change significantly the de-Marton index, which in this zone will remain at a value of around and above 40, i.e. conditions will continue to favor the existing forest tree vegetation. The river flow will continue to be with a spring maximum.

Territories of the water protective zone under of 900 meters a.s.l., are in the belt of the low oak forests which are moderately vulnerable to climate change. The main flow is formed in the upper part of the watershed where the vulnerability of forest vegetation is relatively low.

The area of the whole watershed falls within Natura 2000, which imposes some restrictions on the forest management regimes.

According to the examined scenarios (Raev et al., 2011), the impact of climate change could be expresses by the following main risks that will need appropriate adaptive interventions, concerning the main tree species in the region:

- Increase damage in forest plantations of heavy (wet) snow, strong winds and late frosts. Particularly vulnerable are the young, dense, even-aged stands and coniferous plantations, which occupy approximately 200 ha. Water losses by evapotranspiration in these forests are big. Conducting of thinnings in them is a priority with intensity at a single intervention up to 25%.

Vulnerable are also the old stands (over 140 years), which occupy approximately 300 ha. These “old forests", possess better water protective functions. On the other hand the century-old trees are highly vulnerable to extreme weather events. It is necessary to strengthen the monitoring on their condition and to invest in supporting heterogeneous structure by selective felling and irregular shelterwood felling with intensity up to 20%.

- Increased risk of erosion on areas affected by natural disturbances or on felling areas, especially on steep slopes as prevalent in the watershed. This risk increases also due to the existing brown forest soils with relatively powerful but sandy (light) transition (B) horizon, which washes up easily.

- The expected climate changes will create better conditions for the growth of Scots pine above 1200 m a.s.l. In the middle mountain belt beech will replace coniferous species (spruce, fir) as it is more adaptive to prolonged droughts. This process should be properly controlled through forest management practices in order to keep the mixed composition of the stands and their heterogeneous structure.

- Loss in increment and reduced timber volume due to possible adverse weather conditions. It should be added also possible deterioration of the harvested wood. Both events will lead to negative financial results for the owners and managers of the forest.

- Loss of funds due to the complicated management regime. The data from experimental station Bazenika show that the most appropriate way of managing coniferous forests in the watershed is implementation of selective fellings. (Rafailova 2003). Silvicultural systems for establishment of heterogeneous stands ensuring continuous forest coverage of the territory require highly skilled personnel and more expensive organization of fellings. Forest owners will require additional investments for the implementation of the above described practices;

- Fire risk in forest stands will increase periodically due to the expected prolonged droughts in summer and autumn and due to the increased quantity of dry wood and litter. The same danger exists for subalpine meadows in the area. Improvement of existing fire protection facilities is necessary.

The remaining 15% territories are occupied by oak and hornbeam coppice stands (9%) and black pine stands (about 6%), which are situated in the Ist and IInd belt of water protected area and are highly vulnerable to climate change (Raev 2011). They require more stringent fire protection regarding fires that can be transferred from adjacent agricultural or other urban areas. Forest management activities in these forests should lead to their transformation to high stem ones. Since hornbeam (Carpinus betulus L.) in this area is highly adaptive to warmer climate its expansion in the composition of future stands should the tolerated.

In general, forests in Velingrad watershed can be successfully adapted to expected climate changes in the region. No serious problems for the natural regeneration of forest stands are expected. In the future more relevant will be the problem for the water supply from Velingrad watershed because of the expected increase in the consumption due to higher summer temperatures.

In order to avoid problems for the natural regeneration of forest stands a Standard for the management of Water protective forests is proposed. This action is part of the implementation of WP5 on national/regional level/. The implementation of the recommendations and suggested standards will guarantee the supply of clean drinking water in the country.

Proposal of a Standard for management of water protective forests

In Bulgarian legislation there are no clear and unified measures and regimes for forest management in water protected areas or watersheds. In many cases, these practices are arranged in separate catalogs (case studies, lists), but higher level is the development of standards for their application. In such cases, appropriate criteria and indicators are those the performance of which guarantees in full scale the ecosystem functions of forests for sustainable drinking water supply.

Table 6. Standard for management of water protective forests

Principle 1. The management of Water Protective Forests (WPF) is implemented in accordance with the legislation and ensures full performance of their specific functions	
CRITERIA	**INDICATORS**
1.1. The management of WPF meets all national laws and local administrative requirements and is open for improvement	1.1.1. All responsible administrative persons are familiar with the relevant regulatory requirements and their obligations.
	1.1.2. In the responsible administrations there are copies of the applicable laws available for staff usage.
	1.1.3. The responsible administrations reflect and report the established incompatibilities with the law.
	1.1.4. The responsible persons are familiar with all relevant international conventions
	1.1.5. The responsible administrations have established a monitoring system (documented periodic inspections.)
***1.2. The* long-term land use rights and the restrictions on them (e.g. deed, customary rights or lease agreements*)* are unequivocally proven and they are managed according to management plan**	1.2.1. There are legal documents proving the ownership or the right to manage the forest area.
	1.2.2 Legislative act declaring the territory as Water Protective Forest (WPF) is valid.
	1.2.3. Valid plan for management of the water protective forest territories, prepared in accordance with the national legislation, is available and contain written description of the management

	purposes.
	1.2.4. The exact boundaries of all properties are labeled or clearly marked on the terrain and on maps (eg, along the natural boundaries).
	1.2.5. The responsible administrations keep registers for conflicts on property rights and use.

Principle 2: Forest stands structure in WPF. The structure of forest stands supports the protection of soil, water flow regulation, protection of biodiversity and ensures sustainable protection of the adaptative capabilities of forest tree species and stands

CRITERIA	INDICATOR
2.1 The species composition of stands in WPF ensures the implementation of their specific functions	2.1.1. The dominant forest tree vegetation is in its natural habitat, corresponding to the site conditions.
	2.1.1 Forests are mixed in composition or are in process of formation of mixed stands.
2.2 The origin of the stands in WPF ensures the implementation **of** ***their*** **specific functions**	2.2.1 In WPF stands with seed origin are dominant or are in the process formation
	2.2.2. In WPF stands with natural origin are dominant or are in the process of formation.
2.3 The stand age in WPF ensures the implementation of their specific functions	2.3.1 Mature stands predominate.
	2.3.2 Rotation period of even aged forests in WPF is increased by at least one age class
	2.3.3 In WPF uneven-aged forests dominate or are in the process of formation
	2.3.4 In WPF at least 10% of the total stock is dead wood
	2.3.5 Old, hollowed and withered trees are left in the forest, taking into account national requirements for work safety.
2.4. The structure of the WPF is in accordance with their main purpose	2.4.1 Stands with heterogeneous vertical and horizontal structure or with multilayer structure dominate.
	2.4.2 Stands with average canopy closure of 0.6-0.8 dominate or are in the process of formation in WPF
	2.4.3 In the stands of WPF could be found vital trees of all DBH classes
2.5. Fragmentation of WPF is not permitted and is limited. Guidelines to ensure the functions of WPF for: erosion control, minimizing the damage from logging, road construction and other mechanical disturbances, as well as water	2.5.1 The total area of infrastructural facilities in the water protected areas does not exceed 3% of the area suitable for afforestation.
	2.5.2 No afforestation is applied on natural open spaces-meadows, bogs, rocks, etc..
	2.5.3 There is 15 m buffer strip around the hydrographic network where no activities are performed. The strip is designed from the edge of the side slope towards the inner part of the stand.

conservation are developed and implemented	2.5.4. The location of existing and planned forest roads, bridges, warehouses and routes for transportation of harvested timber corresponds to the scale and intensity of management activities.
	2.5.5. During construction of forest roads for passing through elements of the hydrographic network, actions against drainage, flow deviation or water pollution should be taken.
	2.5.6. Before performing of big scale forestry activities such as forest road constructions, maintenance of drainage systems, etc. the contracting authorities have conducted environmental impact assessment and the contractors are informed and posses copies of the assessments.
	2.5.7. In construction of new roads the following should be considered:1) New roads are preliminary planned and mapped taking into consideration the existing water bodies. 2) The terrain features are not changed or not are slightly modified by the project, 3) Roads are designed and constructed on natural terraces, ridges and low-grade slopes. 4) Roads should not pass through ecologically sensitive areas. 5) The construction activities observe erosion control requirements. 6) The number of river crossings is minimized. 7). Roads and walkways should not be located close to rivers or streams.
	2.5.8. In the river beds no wastes from site preparation and any other activities shall not be placed.
Principle 3: Silvicultural activities in water protective forests. The silvicultural activities in WPF aim to improve and maintain the structure of forest stands to ensure their sustainable and optimal water protection functions	
CRITERIA	INDICATOR
3.1. Activities in young stands in WPF ensure the formation of viable heterogeneous forests which will perform their specific functions in long term period.	3.1.1 Thinnings ensure domination of indigenous tree species corresponding to the site conditions.
	3.1.2 Thinnings ensure formation of sustainable stands with high structural diversity. Thinnings are implemented unevenly in the area.
	3.1.3 Thinnings in belt III of water protected areas are with intensity up to 25%, in belt II - up to 20% and in belt I are not allowed.
	3.1.4 Thinnings ensure restoration of the indigenous forest tree vegetation and conservation of the overall genetic diversity.
	3.1.5. Combined method of thinnings, predominantly from above, are planed and conducted. This helps the regeneration on small areas in belt II of water protected zone.
3.2 Sylvicultural activities in mature stands ensure successful seed regeneration of indigenous tree species,	3.2.1 Regeneration fellings are conducted in belt III of water protected areas and outside their borders.
	3.2.2. Regeneration fellings ensure and tolerate natural regeneration of native tree species.

formation and sustainable maintenance of heterogeneous forest structure	3.2.3 Long-term shelterwood system is used with regeneration period over 30 years for coppice forests and over 40 years for high-stem forests.
	3.2.4. Selective thinnings are used.
	3.2.5 In stands where the shelterwood system already has started, the final phase of the system is not implemented even for coppice forests.
	3.2.6 Small group of century-old trees (at least 5) are left without any treatment (Old growth trees).
	3.2.7 The activities in coppice forests are directed to their transformation into seed stands.
	3.2.8. The spread of introduced in the past exotic species is monitored and, if necessary, measures are taken to control or eliminate them.
3.3. The protective functions of marginal mountain forest ecosystems have to be ensured	3.3.1. Stands and forest areas in the subalpine belt, and the 200 meter timberline are mapped and any commercial activities are not conducted there.
Principle 4: Afforestation activities in WPF. Afforestation and other silvicultural activities support rapid restoration and long-term implementation of water protective functions of forests	
CRITERIA	**INDICATOR**
4.1 Afforestation activities ensure establishment of vital heterogeneous forests corresponding to the site environmental conditions	4.1.1 In case of natural disturbances part of the area should be left to natural succession, unless there is a risk of rapid degradation of the habitat, as well as in belt I of water protective area.
	4.1.2 Afforestation is performed in group schemes, incl. pioneer tree species corresponding to the natural regeneration.
	4.1.3 No afforestation is conducted along the slopes of the hydrographic network, unless the same is not part of an integrated project for establishment of supportive facilities.
	4.1.4 If supplementation of natural regeneration or replenishment of previously established plantations is required, native tree species and origins collected at lower altitudes are used.
Principle 5: Protection of WPF. Activities to protect forests with water protective functions ensure their vitality and long-term provision of the ecosystem services	
CRITERIA	**INDICATOR**
5.1 Qualifications of the staff admitted for activities in WPF	5.1.1 Workers/employees are instructed in emergency procedures such as accidents, fires or spills of fuel and lubricants.
	5.1.2 Everyone in WPF should be aware on the prohibited activities in these forests.
	5.1.3. Practitioners who work in WPF are trained to implement adaptive management

5.2 Protection of WPA from fires and pollution	5.2.1 In areas with a high danger of fire firebreaks on the ridge parts are traced, shaped and maintained with breadth 1.5 times the height of adjacent stands.
	5.2.2 In WPF the use of chemicals for cultivation, protection against diseases, pests etc., and fertilization is not allowed.
	5.2.3 In using petrol chain saws and other mechanized tools biodegradable oils are applied.
	5.2.4 The forestry machinery and the operators of mechanized tools are equipped with absorbents.
	5.2.5 Efforts are being made by the manager to control and prevent the disposal of all types of waste in forests, including waste from visitors.
	5.2.6 Any leakage of oil / fuel from the forestry machinery is not allowed.
5.3 Protection of the forest territories	5.3.1 In WPA livestock grazing is prohibited.
	5.3.2. At high density of game populations the forest regeneration areas are fenced.
	5.3.4. In WPF no intensive game breeding stations and hunting traps are established.
Principle 6: Harvesting activities in WPF aim improvement of their specific functions	
CRITERIA	**INDICATOR**
6.1 The access in WPF is regulated and controlled	6.1.1 The access of vehicles and carts in WPF shall be governed and shall be subject to the relevant permissions. Access to belt I WPA is according to the requirements of Ordinance 3 of Water Act.
	6.1.2 Movement of any vehicles in wet soils is not allowed.
6.2 Logging in WPF is done according to the regulations and with the aim to improve and maintain the specific forest functions	6.2.1 During harvesting activities, the undergrowth and the standing trees left should be protected.
	6.2.2 Close-to-nature technologies must be applied for the transportation of harvested timber and temporary storages must be outside the belt I of WPA, buffer strips, hydrographic network and other vulnerable areas (springs, marshes, slopes, etc.)..
	6.2.3 Forestry equipment for removal and transportation of timber uses only roads incl. technology breaks
	6.2.4 Percentage of the logging wastes and of the brushwood is not removed out of the stands, in accordance with the existing regulation.
	6.2.5 The wastes from logging and the brushwood should not contaminate water courses and regeneration areas.

Methodology for valuation of forest ecosystem service "supply of drinking water"

In the suggested methodology the value of the ecosystem service is evaluated as equal to the loss of incomes from the wood production of the forest owner, i.e. the forest ecosystem implement only water protective function. The legislation, regarding protection of forest owner rights /Forest and Water acts/ gives the following alternatives:

- Forest with 100% wood production function – the forest ownership should be 100% economically managed, concerning the wood utilization
- Forest territories in zone I of water protected area - the forest ownership should be 100% economically managed, concerning the water supply
    - the forest territories falling in Belt I of water protected zone, economic realization of the ownership should be insured 100% by water consumption chain;
    - in Belt II of water protected zone, economic realization of ownership to be done with priority to water protection than timber production expressed in relation 75:25 %;
    - in Belt III of water protected zone economic realization of ownership to be done equally in ratio 75:25 % through two production functions;
    - in all forest territories of the country which are managed by imposed priority of timber production to water-protection function the economic realization of property is to consider this priority with ratio 75:25 %

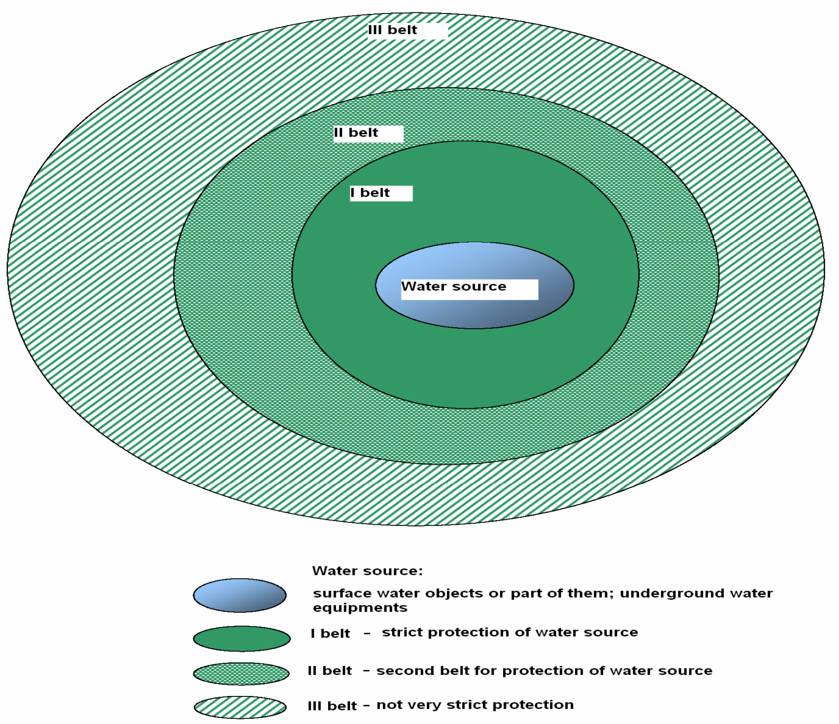

Figure 28 Forests with water protective function – vertical projection

Methodology – steps:

1. **Evaluation of investments in forest stands grown for timber production**
2. **Assessment of annual forest rent (R) for owners**
3. **Expert suggestion for forest rent apportionment between forest owner and forest user**

- **at different age managed forest (selective system of management)**

$$NFC_{year} = \frac{Wz_v^{cur} - FVv}{u}$$

where NFC is the net financial contribution from the stand managed at different ages, BGN/ha;
Wzvcur– the monetary value of 1 m3 timber from the current increment in BGN;
FVv – the updated value of the permanent expenses,BGN;
u- the period in which the current increment is accumulated, u=10 years

- **in an even-aged managed forests**

$$NFC\text{г} = \frac{\mathrm{Wu + Wa.(1+r)^{u-a} + Wb.(1+r)^{u-b} + \ ... \ + Wq.(1+r)^{u-q} - c.(1+r)^{u} - FVv}}{\mathrm{u}}$$

Where NFC is the net financial contribution from the even-age managed stand – BGN/ha;
Wu– the monetary value of the timber from regenerative felling in u year, BGN;
Wa, Wb,... и Wq – the monetary value of timber from thinning;
r – the norm of profitability of alternative investments for the period, a percentage, represented as a part of 1,0
u – the age of the stand, years

The annual forest rent from the forests (R)

$$R = \frac{NFC_{year}}{(1+r)} - (e+d).Q_{year}$$

(e+d) – the expenses of 1 m3 timber for cutting and primary woodworking and transport (logistic) expenditures of timber to the nearest warehouse, BGN/m^3
Qyear – the quantity of timber harvested for 1 year from the current increment in the selection system, or from the regeneration felling and thinning in even-age management system, BGN/m^3
The annual forest rent from the water protective forests in "Srechenska bara" watershed is:

- **in an uneven aged forest**

R = 64.00 BGN/ha/year

- **in an even-aged managed forests**

R = 184.00 BGN/ha/year

Example: application of the methodology in "Srechenska bara" watershed in uneven-aged and even-aged water protective forest stands

Table 7. Distribution of income from uneven-aged water protective forests in "Srechenska bara" watershed

	Income I BGN/ha		Area F ha	Income from the whole area BGN/year	
	Forest owner	Forest user		owner	user
I belt (100:0)	63,89	0,00	723,44	46220,17	0,00
II belt (50:50)	31,94	31,94	7867,41	251322,19	251322,19
III belt (25:75)	15,97	47,92	452,15	7221,90	21665,71
TOTAL	33,70	30,19	9043,00	304764,27	272987,90

Table8. Distribution of income from uneven aged water protective forests in "Srechenska bara" watershed

	Income I BGN/ha		Area F ha	Income from the whole area BGN/year	
	Forest owner	Forest user		Forest owner	Forest user
I belt (100:0)	184,22	0	723	133269	0
II belt (50:50)	92	92	7867	724648	724648
III belt (25:75)	46	138	452	20823	62470
TOTAL	97,17	87,04	9 043	878 740	787 117

Having in mind these quantities and the made accounts we can draw the conclusion that the forest owners should receive rent income from the price of water between 0.01 and 0.03 BGN/m3.

Transnational strategy for mitigation of vulnerability of water resources in southeast Europe

The elaborated transnational strategy incorporates the achieved project results, good practices and management options for mitigation of vulnerability of water resources in southeast Europe. It identifies important strategic issues regarding vulnerability of water quantity and quality and protection and preservation of water resources on transnational level to be used for national or regional planning. As a principle, management in the whole region should be based on:

- **EU directives** (Drinking Water, Water Framework, Groundwater, Urban Waste Water, Nitrate, IPPC ...) ensuring sustainable water use, clean drinking water and protection of sources;
- **EU strategies** (Blueprint, White Paper on Climate Change, Danube Strategy...) providing integration and cooperation.

The guiding principle is: **"Drinking water** in sufficient quantity and quality will be available for the whole population even under changing climatic conditions" (Blueprint "Safeguard European Water", EU 2020 strategy).

Strategic issues to be solved:

- **Current and/or future water scarcity** endangering safe drinking water supply of substantial population (permanent, seasonal, large scale, scattered, large cities).
- **Current and/or future water quality problem** endangering safe drinking water supply of substantial population (polluted drinking water resources, pollution evolving risk for drinking water resources, significant load of pollutants).
- **Availability of substantial resources in good quality** providing future drinking water source.
- **Protection of existing and future drinking water sources** (policies, strategies, legislation, plans and practices)
- **Exploitation of ecosystem services** as natural basis of the protection of drinking water resources (distribution of land cover in different safeguard zones, stability of functionality)
- **Reliability of drinking water supply system** (treatment, water loss, secondary pollution, financing, policies , strategies, legislation, safety plans, practices)
- **Socio-economic conditions** (GDP, employment, crisis, willingness to pay, affordability, awareness, pricing and cost recovery principle)
- **Governance** (authorisation, data bases and monitoring, incentives, decision making, cross cutting issues, role of NGOs)
- **Level of knowledge** (professional experiences and education, availability of good practices, research on impact of CC, future land use and socio-economic condition, decisions under uncertainty).