Bulgarian National Scientific Program „Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters“

Commissions for Local and Regional Development and Land Use and Land Cover Change at the International Geographical Union (IGU)

LOCAL AND REGIONAL ASPECTS OF NATURAL HAZARDS

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Local and regional aspects of natural hazards

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Program Objective: Secure a sustainable, favorable, and safer living environment for the population of the Republic of Bulgaria.

Expected results:

Developing systems for predicting adverse and catastrophic phenomena;

Formulation of strategic measures to reduce emissions of harmful substances in the atmosphere in order to reduce the health risk, biodiversity loss, and the adverse impact on the ecosystems;

Assessment and mapping of the spatial-temporal distribution of the risks of adverse events and natural disasters;

Drafting comments and recommendations to the National Action Plan for Adaptation to Climate Change;

Tracking of the main mechanisms and pathways for the formation of the characteristics of the atmosphere, the hydrosphere and the lithosphere, respectively their impact on quality of life, health risk, etc.

Expected Fundamental Results:

Generation of new knowledge about processes and interactions in the atmosphere, hydrosphere, lithosphere and biosphere from local to national scale, their impact on quality of life, health risk and ecosystem conditions;

Further elucidation of the interactions of natural and human phenomena and processes at different scales, their impact on the quality of life, health risk and the state of ecosystems.

Expected Applied Results:

Measures and recommendations aimed at forest adaptation in the face of negative environmental change;

Development of air quality forecasting systems to produce maps of the current and expected pollution in the country, as well as in pilot cities (Sofia, Plovdiv and Varna);

Construction of an early warning system that indicate risks to human health in selected pilot cities;

Mapping of the most typical, socially important diseases in the country that identify the areas of markedly high morbidity and/or mortality and their geospatial correlation with bioclimatic parameters and air pollution;

Investigation of the responses of organisms to catastrophic events: global warming and cooling, changes in global ocean levels, global anoxic events, supervolcanic eruptions and the response of marine and terrestrial ecosystems to catastrophic events. The impact of climate on phyto- and zooplankton indicator species will be investigated.

Assessments of the changes in seawater chlorophyll distribution, current speed, and direction and identification of problems for mariculture development in the coastal zone of the Black Sea.

Identification of the reasons for the extinction of the oyster along the Bulgarian Black Sea coast and development of measures for the sustainable use and conservation of turbot stocks in view of their rational exploitation.

REVIEW OF LOCAL AND REGIONAL ASPECTS OF NATURAL HAZARDS

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Abstract. This paper presents the local and regional aspects of natural hazards. In 2021, five times more people have been affected by such events, compared to 1990. The basis for more frequent and more destructive natural disasters is the combination of resource depletion, destruction of ecosystems, and certain economic activities. Adverse consequences of natural hazards are increasing social and economic inequality and deepening ethnic and political conflicts. Problems, such as climate change and infectious diseases, are becoming an increasing challenge to national security and world peace.

Keywords: COVID-19; natural disaster; ground conditions; universal thermal climate index; superficial soil

Introduction

The relevance of local and regional impacts of natural hazards is constantly increasing, especially in relation to geospatially targeted policy making. Natural hazards are divided into several groups: geological - earthquakes, volcanic eruptions, landslides; meteorological – cyclones, lightning, fires, drought, avalanches, hail, storms, extreme temperatures; oceanic - tsunamis and sea storms; hydrological – flooding and tides; biological - epidemics, insect infestation, etc. [1]. In 2021, five times more people are affected by such events compared to 1990. The basis for more frequent and more destructive natural disasters is a combination of resource depletion, ecosystem destruction, population growth and human activities [2]. Adverse consequences of natural hazards are increasing social and economic inequalities and deepening ethnic and political conflicts. Problems such as climate change and infectious diseases are an increasing challenge to national and global security [2].

Earthquakes occur most often in areas where there are faults in the earth's crust, in volcanic activity, etc. Adverse effects of earthquakes are destruction of buildings

and human casualties. Over 25 000 people have died in earthquakes in the last 10 years. In Nepal, earthquakes have occurred 34 km east-southeast of Lamjung on 25 April 2015 with a magnitude of 7.8 and 77 km east of Kathmandu on 26 April 2015 with a magnitude of 6.7, killing 5,343 people and injuring 11,520. The most recent stronger earthquake was on 14 August 2021 in Haiti with a magnitude of 7.2 in which 2,207 people were killed and more than 12,000 injured and over 130,000 buildings including medical and religious buildings were destroyed or severely damaged.

Climate change, for example, has in recent years exacerbated a wide range of environmental problems. More frequent and intense droughts, record temperatures, floods and storms are devastating crops, destroying forest areas, disrupting the habitability of some areas, increasing forced displacement of many people, and severely testing national and international institutions [2]. From 1970 to 2019, droughts have claimed 650,000 lives, storms 580,000, floods have caused 59,000 deaths, while 56,000 deaths occurred from extreme temperatures [3]. A series of fires in Australia in late 2019 and early 2020 have burned an estimated 16.8 million hectares of land, destroyed over 5900 buildings (including 2204 homes) and killed many animals and at least 28 people. In Turkey, over 200 fires burned in Antalya, Mugla, Adana, Ayden, Isparta and Denizli provinces in 2021, in which 1352 buildings were severely damaged or destroyed, at least 770 people were affected and 8 people were killed. In July of 2021 only, floods in Europe killed 242 people: 196 in Germany; 42 in Belgium; 2 in Romania, 1 in Italy and 1 in Austria. In July and August of 2021, floods have caused multimillion dollar damages also in Turkey, China, India, Afghanistan, Pakistan, the USA, and New Zealand.

Infectious diseases' outbreaks have often been serious enough to undermine the economy and threaten social stability. In the poorest developing countries, such diseases weaken and impoverish families and communities, deepen poverty, and widen inequalities, substantially reduce life expectancy, and negatively affect the overall economy. Over the centuries, the number of deaths and injuries from warfare pales in comparison to those from disease. It is estimated that 111 million military and civilian deaths occurred in all wars during the 20th century, an average of 1.1 million per year. Infectious diseases now cause 14 times as many deaths each year. During World War I, 20-40 million military and civilians died from the influenza virus - many more, in comparison to the deaths from direct involvement in the war itself [2, 4]. The AIDS pandemic has claimed more than 42 million lives since it began in 1981 [5]. Since the start of the Covid-19 pandemic in 2020, 246,594,191 cases and 4,998,784 deaths have been recorded worldwide as of 01 November 2021 [6].

For these reasons, the study of natural hazards (geological, meteorological, oceanic, and biological), and especially their regional and local impacts, is an increasingly important task that faces scientists from most scientific fields.

Materials and methods

The international seminar on *Local and Regional Aspects of Natural Hazards* in Varna, Bulgaria took place between August 12 and 14, 2021 as a face-to-face discussion among 42 scientists from Bulgaria, Romania, Poland, Ukraine, Slovenia, Germany, Israel, and Peru. Organizers of this event that precedes the International Geographical Union Congress in Istanbul, Turkey has been the Commission for Local and Regional Development, Land Use, and the Land Cover Change Commission at the International Union (IGU) and the National Scientific Programme "Environmental Protection and Risk Reduction from Adverse Events and Natural Disasters". Researchers discussed the 24 presentations and seven posters, dedicated to diverse local and regional aspects of natural hazards. These proceedings include more detailed results from the seminar, which targets the locations and scales presented in Table 1 below.

Table 1. Overview of the papers in the Proceedings of Local and regional aspects of Natural hazards

Paper	Location of the study	Scale
[7] Bournaski et al., 2021	Primorsko municipality, Bulgaria	Local
[8] Rudenko et al., 2021	Ukraine	National
[9] Rangelov et al., 2021	Bulgaria	National
[10] Spasova and Dimitrov, 2021	Sofia, Bulgaria	Local
[11] Vasileva et al., 2021	Bulgaria	National
[12] Zhiyanski and Sokolovska, 2021	Kardzhali, Bulgaria	Local
[13] Mirchev et al., 2021	Mountain areas in Bulgaria	Local
[14] Glushkova and Anev, 2021	Bulgaria	National

Results

The work of *Bournaski et al* (2021, in this issue) presents a study that demonstrates an application of the methodology of the Inter-American Development Bank for Assessment and Analysis of the Risk of Natural Disasters on the territory of the coastal Municipality of Primorsko in the Bourgas District of Southeastern Bulgaria, which is undertaken within a project of the Climate, Atmosphere and Water Research Institute of the Bulgarian Academy of Sciences. The following disaster processes and phenomena are considered: landslides, earthquakes, droughts, floods (channel and fast-flowing), storms, winter meteorological phenomena (snowfall, ice), with proven negative consequences in the Municipality under study. Its results demonstrate that the region is characterized by low and medium risk levels. Relevant recommendations for preventive actions have been provided to the municipal authorities.

Rudenko et al. (2021) present an assessment and visualization of hazards and risks of emergencies for Ukraine. The scientists from the Institute of Geography of

Ukrainean National Academy of Sciences have worked on this theme since 2010. They produced an Atlas of Natural, Technogenic, and Social Hazards and Risks of Emergencies in Ukraine – first for this country. The purpose of the Atlas is to provide a regional analysis of potential hazards and risks. It includes 143 maps, which are structured in five sections: Introduction; Prerequisites for Potential Emergency Sources; Hazards, related to possible deterioration in the living conditions of population and enterprises; Emergencies in Ukraine; and Emergencies Prevention. The Atlas maps are also presented in electronic form in quadtree format. The called Atlas Solutions Framework AtlasSF has been used in its preparation. The structure, goals, objectives, functions of the Atlas address the gaps in the Risk Management System of Ukraine, which are also outlined in the paper.

The investigation of *Rangelov et al.* (2021) aims to develop methodology for the study of data sources for ground soil conditions. The integral parameter reflecting the properties of the surface ground layers is so called Vs_30. This parameter is an integral characteristic of the ground conditions used in almost all procedures of the seismic hazard mapping software. The Vs_30 measures the velocity of the transverse seismic waves to the depths of 30 meters of the ground layers. The transverse seismic waves (S-waves) are the most destructive component of any seismic influence. This parameter depends on many factors, such as density and type of rocks, sediments of the surface earth's strata, surface water level, the strength of the medium, etc. The main task – archive information extracted from old data sources - is applied for different geophysical parameters of the ground – rock composition, depth distribution of the different layers, density, porosity, water saturation, and many others which characterize the first 30 meters of depth. The physical properties can be obtained by different geophysical methods, frequently used for completely diverse tasks, not related to the physical properties needed in this study. The data collection can also be done by in situ measurements, boreholes sampling, lab tests, etc. Due to the complicated conditions – buildings, stock, noisy environment, etc. – in densely populated areas in the large cities, such investigations very frequently are not possible. Thus, the main sources of information are the old archives.

Spasova and Dimitrov (2021) studied the link between human thermal comfort or discomfort and cases of stroke in the age group over 60, defined as "adults" (60-74 years) and "old" (75-89 years), according to the criteria of the World Health Organization, also considering their gender distribution. The prolonged heat load on the human body negatively affects all people, but especially vulnerable are elderly people suffering from cardiovascular disease. The data for the disease have been provided by Adjibadem City Clinic Tokuda Hospital, Sofia and refer to the period between the years 2007 and 2011. To determine the heat sensation, the

investigators have used the so-called Universal Thermal Climate Index (UTCI), which is a world-renowned and widely used climate index that characterizes the heat impact on the human body. UTCI is of thermos-physiological significance and is valid in a wide range of external weather conditions, including extreme weather events. It reflects the physiological reactions of the "statistically average person", based on the method of heat balance of the human body. The index is used to assess discomfort in both hyperthermia and hypothermia and is presented as temperature scaled. The average number of patients admitted during different UTCI values in the warm half of the year (covering the months of May-September inclusive) has been compared and evaluated.

Molecular methods for detection of Cyanotoxins, as an emerging risk in Bulgaria, have been studied by *Vasileva et al*. (2021). Occurrences of cyanobacterial mass in freshwater lakes are usually formed by Anabaena, Microcystis and Planktothrix, which can produce cyclic heptapeptide hepatotoxins - microcystins. Hepatotoxins are inhibitors of protein phosphatases that cause bleeding in the liver of humans and animals, but also show strong tumor-promoter activity. Toxic cyanobacterial species are a risk factor for the environment and human health that requires their early detection at low concentrations. Such an approach is the application of methods for detecting DNA from toxic microalgae in water samples by polymerase chain reaction. Microcystis contain the peptide synthetase gene cluster, which is a complex of 10 genes, mcy (A-J), which control the synthesis of polyketides and peptide synthetases, associated with microcystin synthesis. Only microcystin-producing cyanobacteria carry the mcy genes that can be used as a biomarker for early detection. Also, the genetic differences within this gene cluster determines the level of production of secreted microcystins. The aim of the study consists in early detection of toxic microalgae by real-time polymerase chain reaction (qPCR) in samples taken from Bulgarian dams. Two test approaches have been used - TaqMan and SYBR Green I dye. The obtained results prove the presence of cyanobacteria in all the samples, and these have also been compared with hydro-biological analysis which confirms the results. PCR methods provide qualitative results that can be used for early detection for potentially toxic cells at the beginning of the bloom when the toxin concentrations are too low to be detected.

The work of *Zhiyanski and Sokolovska* (2021) deals with the analysis of the general characteristics of soils in urban forest parks in a case-study region of Kardzhali and aims to define tendencies in the current soil processes. The superficial soil in three forest parks Arpezos-North, Central City Park and Prostor Park, located in urban and peri-urban zones, are studied along a transect with three plots in three repetitions. The general soil characteristics are analyzed following standard procedures. Based on the results, it concludes that the soils in the studied parks are in good ecological condition

in terms of stock of nutrients and organic matter. The lower C/N ratio (Prostor Park) indicates faster nitrogen release into the soil and its availability for plants. The higher ratio (Arpezos-North Park and Central City Park) leads to an equilibrium state between the processes of mineralization and immobilization. Alkalization processes are more pronounced in the surface layers of soils in urban parks (Arpezos-North Park and Central City Park) than in park in peri-urban area (Prostor Park). Regarding the heavy metals and metalloids content, the investigation determines a tendency in uppermost section of the soils of Prostor and Central City Park to contain more Cu, Zn, Pb and Ni. The analyses on the current condition of soils, as a fundamental component of urban forest parks in the Kardzhali case-study, provides a basis for further monitoring of the status of the green system in the city and support the outlined measures for their sustainable management.

Health condition of Pinus Peuce and Pinus Heldreichii Forest stands in the mountain areas in Bulgaria have been studied by *Mirchev* et al. (2021). In the period 2020-2021, the health status of eleven stands of Pinus Peuce and P. Heldreichii has been assessed in Pirin Mountain (4 stands), Rila Mountain (3 stands), Slavyanka Mountain (2 stands), Vitosha Mountain (1 stand) and Konyavska Mountain (1 stand). The survey is based on remote sensing and terrestrial verification. The remote sensing data is obtained by capturing by an unmanned aerial vehicle 'Autel Robotics EVO II' equipped with multispectral camera 'Parrot SEQUOIA'. During the field studies, an assessment of the defoliation of tree crowns and a registration of damages caused by abiotic and biotic factors has been conducted. The defoliation in Pinus Peuce stands varies between 21.3 percent and 44.8 percent, and in Pinus Heldreichii stands – between 24.5 percent and 49.5 percent. Abiotic damages by strong wind, wet snow and ice-break have been registered in the studied stands. Among the biotic factors, the main damages have been caused by fungal pathogens (Heterobasidion annosum, Diplodia sapinea, Cenangium ferruginosum) and bark beetles (Ips sexdentatus, I. amitinus, etc.).

The last article of *Glushkova and Anev* (2021) reveals the productivity and physiological response of different poplar clones. Two hundred cuttings of four hybrid poplar clones – "BL", "Agathe", "45/51" and "37/61" – have been placed in rooting containers in 2 variants of cultivation - soil substrate and compost. The necessary growing activities for the poplar saplings have been taken during the growing season, including watering and treatment against pathogens and insect pests. The growing parameters - height and diameter of the seedlings of 1-year-old plants have been measured and the differences between poplar clones reported. The rate of light-saturated photosynthesis and transpiration rate have been measured with a portable infrared gas analyzer Li-6400 and water use efficiency has been calculated. The effect of genotype (clone) and substrate on the health status, growth

in height and diameter and the physiological indicators - intensity of photosynthesis, intensity of transpiration and water use efficiency - are studied. The results of the study show the presence of significant clone differences of the studied functional parameters which pertain to the growth and productivity of the studied four hybrid poplar clones at a young age. Poplar clone "BL" was found to show the best growth characteristics, compared to the others at the age of seedlings one year. The growing substrate has also a significant effect on the variability of growth and physiological parameters among different poplar clones.

Conclusion

In conclusion, scientists from different scientific fields present here some of the newest aspects of the impacts of natural hazards in Bulgaria. The research results offer concrete solutions and innovative approaches for the management of the territory and communities in case of a natural disaster. The broad application of interdisciplinary approaches in the presented papers undeniably highlights the significant advantages of geographical investigations in this field of knowledge, as well as its important practical relevance for regional and local planning and land use.

On behalf of the Organizing Committee, we would like to thank all participants for their interest in the conference theme and for their contributions to this volume.

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AN INTEGRATED APPROACH TO DISASTER RISK ASSESSMENT ON THE EXAMPLE OF PRIMORSKO MUNICIPALITY

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Abstract. This paper demonstrates an application of the methodology of the **Inter**-American Development Bank for assessment and analysis of the risk of natural disasters for the territory of the municipality of Primorsko in Southeastern Bulgaria, implemented by a project of the Climate, Atmosphere and Water Research Institute. The following disaster processes and phenomena are considered: landslides, earthquakes, droughts, floods (channel and fast-flowing), storms, winter meteorological phenomena (snowfall, ice) with proven negative consequences in the municipality of Primorsko. The results show that the region is characterized by low and medium risk levels. Relevant recommendations for preventive actions have been provided to the municipal authorities.

Keywords: natural disaster; risk assessment; floods; intense rainfall; Primorsko

Introduction

More than sixty natural phenomena and processes are known to modern science, which develop without human intervention and can be described and classified as natural disasters. According to their origin can be - hydrometeorological, geological, biological, and environmental hazards. According to the territory they cover - local, regional, global. According to the way of origin and development - slow-emerging and fast-emerging. An example of a slow-emerging disaster is drought. According to the way they flow - sudden (earthquakes, avalanches), fast (running for hours or days) and lasting weeks or months (drought, landslides, etc.).

A characteristic feature of natural disaster risks is that they all develop and take place in the environment, and in recent decades they have increased with the tendency to acquire a cross-border and / or global character, which requires new approaches to their management.

Natural disasters are the result of the intersection of two completely different forces/factors - the natural danger itself and the vulnerability of the environment. The formed or increasing "pressure" on the society (the negative impact due to

a potentially destructive phenomenon) is formed on two sides - by increasing vulnerability and the strength of the natural danger. As there are no methods and means to prevent most of the natural disasters, to reduce the "pressure", the vulnerability must be reduced. Environmental vulnerability indicates the extent to which the environment can be affected by a natural disaster or the extent to which the current state of the environment can contribute to the intensification of a natural hazard.

The factors that create and maintain vulnerability are rooted mainly in political, economic, and social systems and governance structures. Conditions for insecurity and vulnerability of people and their property are, for example, location, unsustainable (vulnerable) buildings, facilities, and infrastructure, means of subsistence at risk, impossibility to recover lost assets, limited opportunities to increase income, lack of insurance, dangerous settlements areas, pre-disaster conditions of the environment, etc. The most vulnerable groups of the population are those in which recovery after a natural disaster is the most difficult and takes the longest. As a rule, "the poor are more vulnerable than the rich."

There are different approaches to the natural disaster risk assessment [1, 2]. Here is considered an integrated approach applied for risk assessment in the Municipality of Primorsko in southeastern Bulgaria. Greater attention is paid to the typical rain floods (pluvial) in the area. Unlike river floods (fluvial), which periodically occur on the same critical sections of rivers, pluvial floods are more difficult to predict due to the probabilistic nature of the process itself and their spatial and temporal distribution.

Materials and methods

A risk assessment methodology proposed by the **Inter**-American Development Bank has been used, which addresses four main factors quantified by relevant indicators:

a) dangerous natural phenomena – DANGER (behavior of natural disasters in the past and extrapolation assessment for probable future development, quantitative indices for the recurrence of natural hazards);

b) to what extent the elements of the environment (population, economy, buildings and facilities, infrastructure) are exposed to these phenomena – EXPOSURE (evaluation indicators determined mainly on the basis of statistics);

c) the vulnerability of the population, the economy and the environment – VULNERABILITY (unemployment, population density, social status, etc. according to statistics);

d) the possibilities for counteracting the dangerous phenomena - RESOURCES FOR COUNTERACTION (indicators are not only for the sustainability of buildings and infrastructure facilities, but also for economic, social and managerial parameters).

Additionally, a fifth factor RISK PERCEPTION is assessed (how people and the public react to risks according to their own beliefs and risk constructs).

Only factors a) and b) are analysed in the paper.

Floods (channel and fast-flowing, pluvial, and fluvial) with proven negative consequences in the municipality of Primorsko are considered in the present study [3, 4]. More important new data from recent years for floods and relevant maps on the territory of Eastern Bulgaria can be found in [5]. The following possible disaster processes and phenomena are not considered: landslides, earthquakes, droughts, storms, winter meteorological phenomena (snowfall, ice).

Vulnerability, exposure, perceptions are considered, and the integral characteristics of the risk profiles are built. Risk factors are indexed with specific quantitative values (indicator values or levels) and weighted by weighting factors. They are selected based on empirical observations, population statistics, economic opportunities of the region, social and governance parameters.

The selected methodology is applied for the territory of the Municipality of Primorsko on an area of 350 km² with a population of 7 526 inhabitants (in 2011) and settlements: town of Primorsko, town of Kiten and the villages of Pismenovo, Novo Panicharevo, Yasna Polyana and Veselie, fig.1.

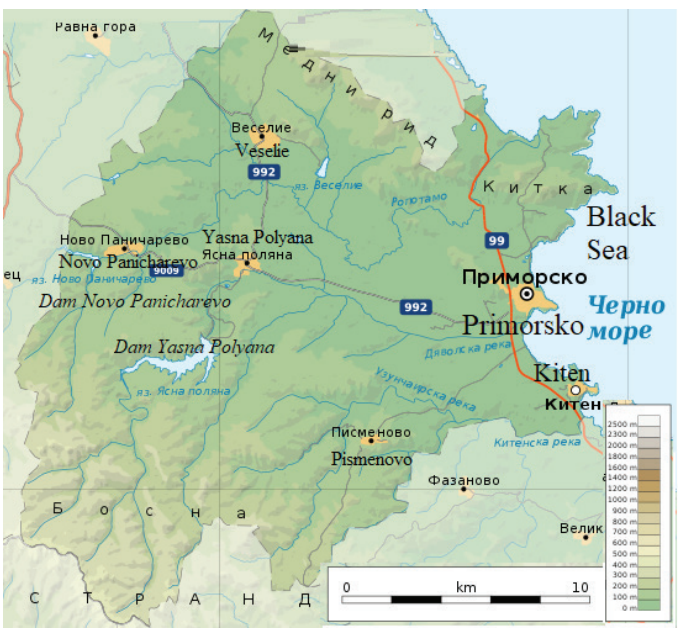

Figure 1. Geographic map of Primorsko Municipality (adapted from bg.wikipedia.org)

The analysis of geomorphological conditions and factors for the manifestation of unfavorable and dangerous natural processes is the basis of the approach to natural risk assessment [6]. The relief is predominantly flat to low mountain, with most of it falling in the northern branches of Strandzha Mountain to the west and the southern parts of Medni rid to the east [7]. In the middle of the studied area stretches the valley plain with the Dyavolska River with orientation west - east. The whole territory has a slight slope in the direction of the Black Sea to the mouths of the rivers Ropotamo, Dyavolska and Karaagach. There are two dams on the territory - "Yasna Polyana", built along the Dyavolska River, which supplies drinking water to all villages south of Bourgas and Sredets, and "Novo Panicharevo", built along the river Ropotamo, about 500 meters above the village of Novo Panicharevo. There is one Precipitation monitoring station near the village of Veselie.

The period after 2005 is characterized by intense rainfall, which led to floods in many regions of Bulgaria and even to human casualties. In the summer of 2014, heavy rainfall fell for hours, exceeding the monthly rainfall rate. They happened three times in the municipality of Primorsko - on July 16, September 6, and October 25, 2014. In the valley of the Ropotamo River, according to the operation of the dams "Yasna Polyana" and "Novo Panicharevo" on September 5-6, 2014, fell 266 l/m^2. The population of the village of Novo Panicharevo needs to be evacuated.

Figure 2. During the floods of September 2014, the bridge over the Ropotamo River near the village of Veselie collapsed during the torrent

A huge tidal wave floods over 50 houses and destroys several bridges along the Ropotamo River, fig.2. For the whole month of September, the total rain is 437.5 l/m^2. Part of the water outflow filled a free volume in the Yasna Polyana dam and then overflowed. Such a situation was observed in July of the same year when a flood was caused in town of Primorsko and the roads leading to it. The measured rain at the precipitation station near the village of Veselie was 248 l/m^2/day.

Results

The prepared risk maps of the territory are based on available historical flood data and simplified approximate methods with limited accuracy. The analysis of the topographic conditions is a method used to identify the extent of flooding, to establish the low runoff zones, to determine the path of runoff of rainwater and the inflow of water from neighboring areas. It is performed in a GIS environment in combination with expert assessment.

In outlining the risk zone in the village of Yasna Polyana, data from the technical expertise on the condition of the road infrastructure, historical data on the floods and assessment of the damage after them, as well as information from injured residents were used, fig.3. The area at risk of flooding includes almost the entire riverbed of the Dyavolska River in the village, despite the built protective dike - it must protect the houses located nearby if the water level rises.

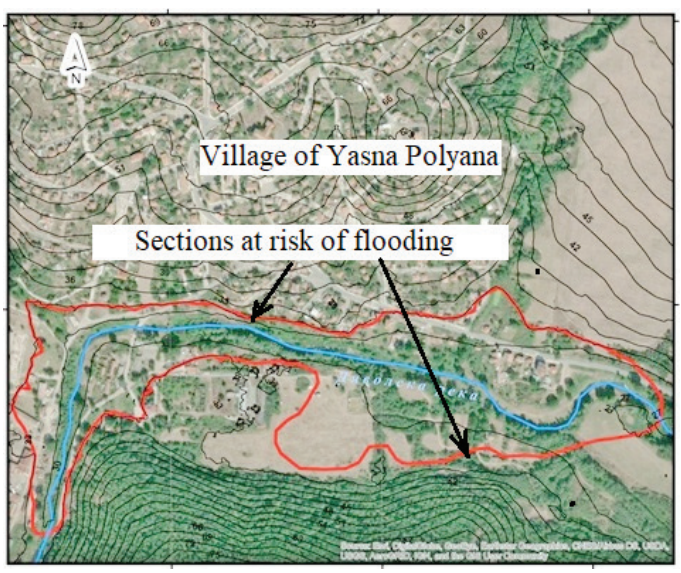

Figure 3. Area at risk of flooding in the village of Yasna Polyana from the overflow of the Dyavolska River (adapted from a project map)

The areas at risk of flooding in the town of Primorsko are determined with the adequate presentation of the terrain conditions in the studied areas, Fig.4.

A typical example of river flooding (fluvial) is the road between Bourgas - Primorsko in the area around the bridge over the river Ropotamo. When high waters come due to torrential rains, the Ropotamo river flows out of its bed and floods the adjacent sites, Fig.5.

The warmer climate on the territory of the municipality, as located in the southeastern part of Bulgaria with a predominantly flat to low mountainous relief, has a mitigating effect on the other natural risks analyzed in the present study. The main morphodynamic processes are the erosion along the river-valley network, the abrasion along the coastal strip and the wind activity important for the dune genesis along the sea coast. Slope processes such as intrinsic gravity (ground collapses) and aqua-gravitational (landslides) are also of lower intensity.

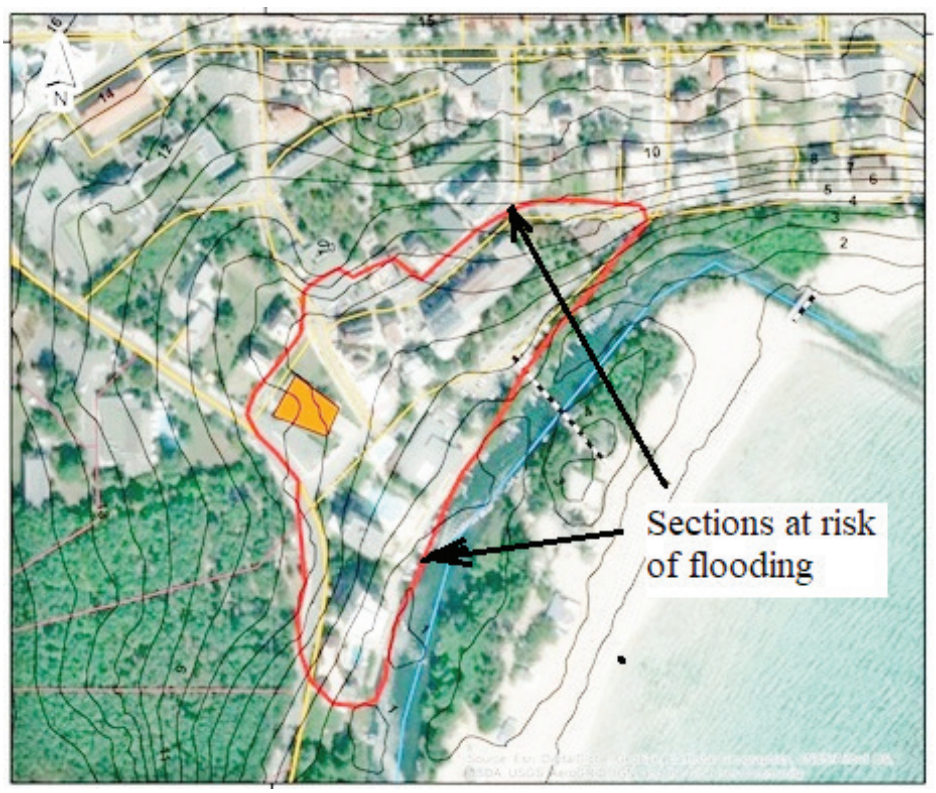

Figure 4. Town of Primorsko - South. Areas with the lowest altitude at risk of flooding (adapted from a project map)

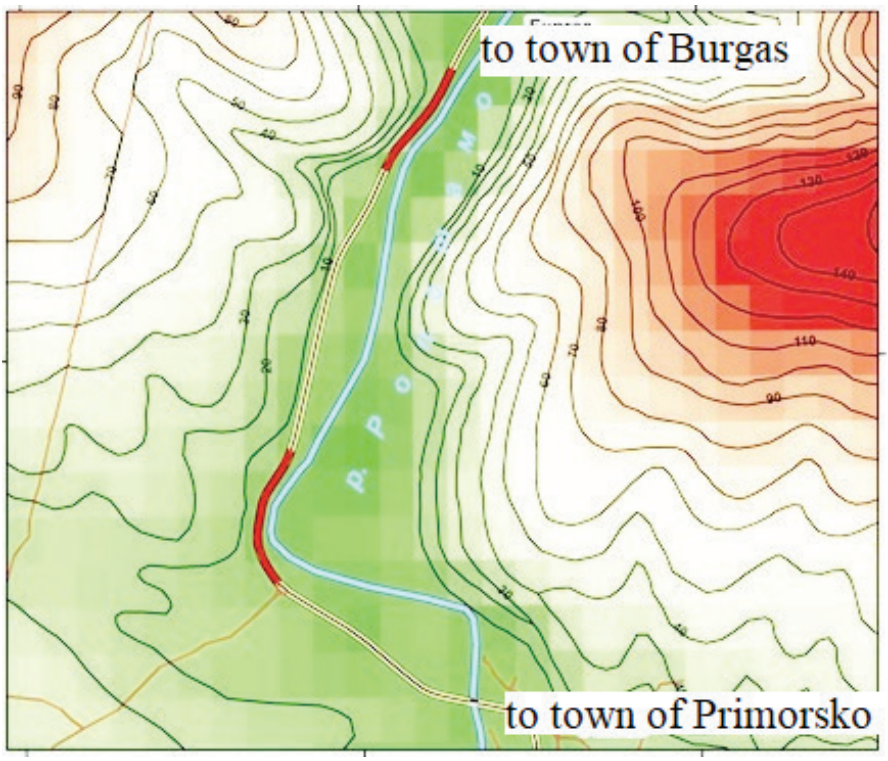

Figure 5. Topographic plan of the town of Primorsko – North, bridge on the river Ropotamo (adapted from a project map)

Discussion

The results show that the region of Primorsko municipality is characterized by relatively low and medium risk levels.

– The lowest risk levels are characterized by geophysical natural phenomena (landslides, earthquakes) and winter meteorological phenomena (winter storms, icing processes, heavy snowfall).

–The processes of drought are of medium risk levels, as negative consequences can be expected for agricultural production, lack of water resources, increased risk of forest fires and health care.

– The risk of floods caused by torrential rains due to flat terrain at low altitudes in combination with unfavorable hydrogeological conditions is relatively higher. The latter are associated with a decrease in the filtration properties of alluvial deposits in the direction of the Black Sea, which hinders the natural outflow of groundwater and leads to an increase in their level. An additional unfavorable factor

is the recharge of groundwater in the alluvial deposits of the Sarmatian aquifer and fissure waters. The presence of a nearby river network with small current slopes is also an unfavorable factor.

Conclusion

The application of the described integrated methodology using specific current and historical data on the natural, social, and economic conditions in the study area, helped to build basic risk profiles for individual natural hazards threatening the population and infrastructure of Primorsko municipality.

As the municipality has a low and medium disaster profile, the focus of risk management efforts is recommended to be focused both on higher risk processes as floods caused by torrential rains and on the expected complex impact of some unexpected but extreme phenomena. The recommendations made to the municipal authorities include: Preventive activity related to spatial planning, measures for prevention and training of people from the administration, as well as the general public, for proper response to natural hazards.

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ASSESSMENT AND VISUALIZATION OF EMERGENCIES RISKS IN UKRAINE

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Abstract. Assessment and visualization of hazards and risks of emergencies are important tasks for Ukraine. The scientists from the Institute of Geography of Ukraine NAS were working on this theme during 2010-2014. The Atlas of natural, technogenic and social hazards and risks of emergencies in Ukraine became the result of this work. It was created for the first time in the country. The purpose of the Atlas is to provide a regional analysis of potential hazards and risks on the territory of the country. There are 143 maps in the Atlas which are structured in 5 sections: Introduction; Prerequisites for potential emergency sources; Hazards of possible deterioration in the living conditions of population and enterprises; Emergencies in Ukraine; Emergencies prevention. Atlas maps presented in electronic form on the master disk in quadtree format. The Atlas is created with the usage of so called Atlas Solutions Framework AtlasSF. The structure, goals,objectives, functions of the mentioned Atlas of Emergencies and tasks that can be addressed using it as well as gaps in risk management system in Ukraine have been outlined in the paper.

Keywords: emergencies; risks; natural hazards; technogenic and social hazards; electronic atlas; Ukraine

Introduction

The existence of modern human civilization is impossible without its impact on the environment. Emergencies, first natural, technogenic and later social, are the exclamation mark by which nature warns people against self-destruction. Each emergency should make humanity think about the limits of possible interference in the balanced functioning of ecosystems on our planet. Unfortunately, in their efforts to "improve" their living conditions, humanity has gone so far that it is almost impossible to stop. It remains to overcome the consequences of its ill-considered actions. They include technogenic disasters, adverse natural processes and phenomena, social conflicts, etc. Humanity tries to change something in its worldview to prevent the inevitable global catastrophe.

The number of global and regional emergencies has increased significantly over the last decade. It happened due to natural and social factors. In total, thousands of emergencies of various levels have been registered in the world. There were powerful earthquakes, droughts, hurricanes, tornadoes, tsunamis, floods and technogenic disasters of different types, including accidents at nuclear power plants. Mass protests, terrorist attacks, street riots and clashes of youth groups have taken place too [10]. They caused enormous material damage and resulted in significant casualties.

The emergencies display's intensification and their negative consequences have forced managers to think about ways to prevent them [9, 11]. The scientists first started studying critical and catastrophic natural phenomena as a process of interaction with a territory [8]. The intensity of the natural phenomenon impact on the socio-economic development of the territory was the most focus. Later, the interaction process between natural phenomena and territory became deeper. Now it is considered more as a consequence of dangerous industrial, agricultural and other human activities [6].

According to the Ukrainian legislation, *emergencies of technogenic and natural character are a disturbance of normal conditions of life and activity of people on separate territory or objects or a water object. It can be caused by an accident, catastrophe, natural phenomena, or other dangerous events as an epidemic, epizootic, and fire. These accidents have led (or may lead) to the impossibility of living in the territory as well as providing economic activity there or can cause (caused) people death or significant material losses* [16].

Among many sciences, geography and cartography pay considerable attention to the assessment and mapping of emergencies [1]. The degree of geosystems' disruption assesses through the study of broken or suppressed interconnection between their components. It happens after certain dangers' display and can lead to loss of quality and natural environmental properties of natural components. Moreover, it can cause their destruction, human and alive organisms' losses, deterioration of human health and living conditions.

Scientists and managers are in constant agreement with the main approach to risk assessment. Today it is based on three main concepts: emergency prevention, readiness to eliminate possible negative consequences, emergency response mechanism.

Among lots of effective methods of assessing and managing emergencies risk, GIS technology is actively used for a long time [7]. It allows creating a database of potential hazards, their condition and the risks of emergencies. The result of GIS technology is electronic maps. In the world, such systems function due to the work of the relevant crisis centres, where the relevant thematic atlases of various types, separate maps, etc. are created.

In most cases, the main object of mapping is potential sources of the danger of natural, natural-anthropogenic or technogenic type.

Ukraine, with a certain delay, if to compare with other countries, finally carried out a regional analysis of the potential objects' location which are a threat to human life.

There are about 15,000 potentially dangerous facilities in the country. Almost 800 million tons of waste are generated annually (about 36 billion tons have already been accumulated, many of them are dangerous). The factor of depreciation of fixed assets of enterprises, which often reaches 90%, and outdated production technologies are also dangerous [3, 12, 13].

The need to create an Atlas of natural, technogenic and social hazards and risks of emergencies in Ukraine (further and more *the Atlas of Emergencies*) became acute due to the awareness of society and government officials of the huge dangers to human life, increasing their harm and complicating the consequences. According to various estimates, about 200-300 emergencies of different hierarchic levels occur in Ukraine every year. These are emergencies of state, regional, local and object levels (Fig. 1). They have different causes of formation (Fig. 2) and significant negative consequences.

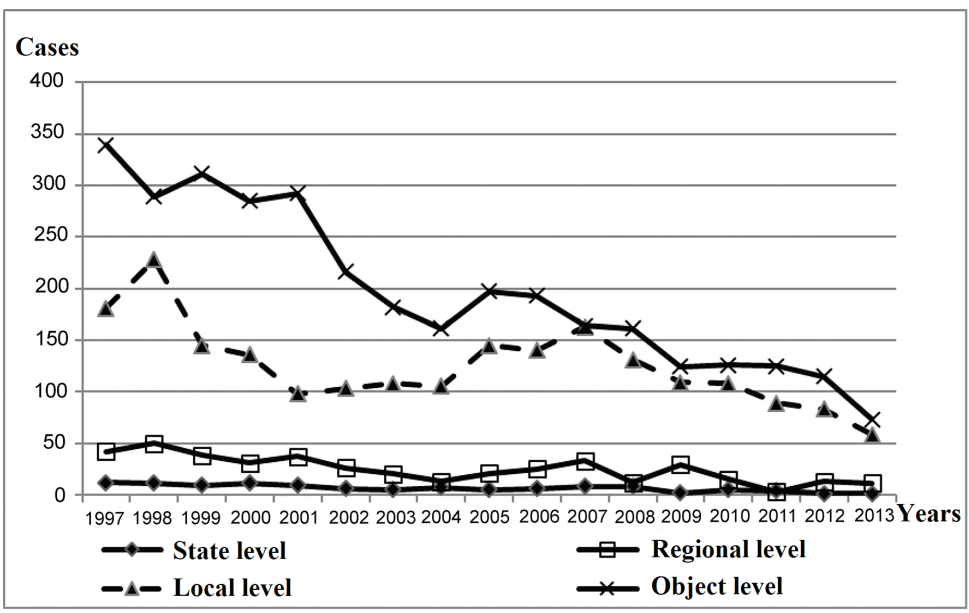

Figure 1. Ukraine Emergencies by the levels of manifestation (1997-2013)

Unfortunately, the localization and elimination of natural emergencies consequences but not the prevention of emergencies are the remarkable feature of the hazards and risks management system in Ukraine till now. A similar approach

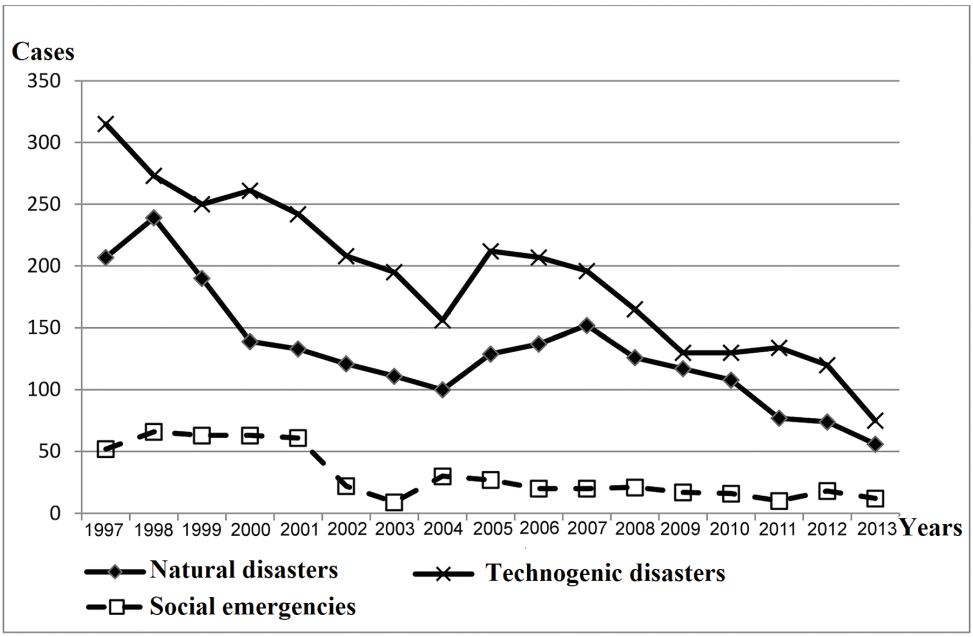

Figure 2. Ukraine Emergencies by nature of occurrence (1997-2013)

is observed in the case of accidents, which are based on potential objects of technogenic or environmental nature. It is often difficult to separate the objects of potential leakage of hazards and risks both by origin and by their activity. The above emphasizes the need for high quality, detailed and on-time assessment and visualization of the emergency's hazards and risks in Ukraine.

Materials and methods

To assess, map and quickly visualize the risks of life-threatening situations, the Institute of Geography of the National Academy of Sciences of Ukraine (NASU) has adhered to advanced key concepts, as in European countries. The concepts of a natural threat and technogenic (man-made) threat are the main among them. The threat is a dangerous phenomenon or substance or other dangerous objects of human activity. The natural threat is a dangerous natural process or phenomenon. The technogenic (man-made) threat is the impact of an object or phenomenon and vulnerability, which is determined by social indicators and the possible consequences of potential emergencies. There are different accidents, infrastructure failures, etc.

The process of the atlas' development was based on various sources of information following the themes of the maps. Graphic (primarily cartographic), digital, textual, photographic information was used. Different forms of presenting

information when developing maps were considered not in isolation but as a complement to each other.

The following types of resources were used in compiling atlas maps:

– object-oriented cartographic resources e.g., handwritten maps of expeditionary research, polygraphic, electronic and multimedia resources. For example, different maps and atlases published in print as well as maps and atlases recorded and published on CDs, geoinformation, Internet resources.

– data of GIS modules where statistical and other databases are organized.

– technological resources. They are classical tools for designing, compiling, and editing maps. Computer technologies of creating maps, preparing them for printing and publishing are very useful.

Thus, among the main sources of atlas data are the following: cartographic (general geographical and thematic maps, cadastral data, plans and maps), remote sensing data (remote sensing), data from direct field observations and measurements, hydrometeorological observations, environmental and other monitoring materials, economic and financial-statistical data, results of laboratory analyze, monographs sources.

During preparing the Atlas of natural, technogenic, social hazards and risks of emergencies, cartographic, analytical, and other materials were used. They were provided by the State Service of Ukraine for Emergencies, State Statistics Service of Ukraine, Institute of Geography of NASU, Ukrainian Hydrometeorological Institute of the NASU, National Research Center "Institute of Soil Science and Agrochemistry named after A.N. Sokolovsky", State Scientific and Technological Center for Soil Fertility Protection of the Ministry of Agrarian Policy and Food of Ukraine, State Institution "Central Sanitary and Epidemiological Station of the Ministry of Health of Ukraine", Lviv Research Institute of Epidemiology and Hygiene, Center for Medical Statistics of the Ministry of Health of Ukraine. National Atlas of Ukraine (2007), Ecological Atlas of Ukraine (2009) and the Atlas "Ukraine. Radioactive contamination" (2011) were used too.

The main research methods in solving the tasks were cartographic modelling and GIS analysis.

GIS analysis of emergency risks is based on computer modelling. It includes investigation of spatial distribution information models systems and interconnection of natural and man-made sources of emergency threats' interconnection's an automated creation and use. It involves the development of algorithms for assessing the risks for human life. This algorithmizing is a sequence of procedures according to the developed method of these risks' assessment.

The results of GIS analysis are presented in the form of a system of maps and indicators in tables or displayed in structural-dynamic diagrams and graphs.

The database of emergencies and the risk of their occurrence is the basis for geographic information mapping. At the same time, it can be an accumulator of

final information for new research. The created maps can become a source of information for the new maps.

Results

The master version of the classical type of atlas was created in the process of research (Fig. 3). It contains the maps in 4-level quadtree format. The technology used for the creation of the electronic version of the National Atlas of Ukraine was used in refactored form to create the Atlas of Emergencies. The technology is named Atlas Solutions Framework (AtlasSF, [19]). This technology allows using the vector and raster maps, non-cartographic documents, the content of the atlas and its design according to the needs of other atlases of the classical type.

The research of modern directions of the electronic atlases' development technologies is conducted. The Atlas of Emergencies prototype of the neoclassical type (AE 1+) is designed. The Conception of the Atlas of Emergencies of the geocollage type (AE 2) is introduced. The last one is also an atlas of the neoclassical type which is based on information technologies combined by the term Web 2.0. AE 2 is planned to be created in the future.

According to the results of research, such important constructions as the atlas of the classical type in a broader sense and the AtlasSF refactoring have been developed. Atlas of the classical type in a broader sense means atlas infrastructure. It is emphasized that such information systems have a defined and repetitive hierarchical structure from the atlas to atlas. It is determined by the so-called Conceptual framework of Atlas information systems. Important elements of atlas infrastructures are Operational, Application, Conceptual and General strata. Moreover, it may be appropriate to distinguish also the Datalogical, Infological and Organizational levels [20]. AtlasSF is a specification for the domain of atlas mapping of the GeoSolution Framework (GeoSF).

The results obtained during this research showed that an electronic Atlas of Emergencies was created in Ukraine for the first time. Presenting the information focused on the concentration of various types of phenomena, processes and objects that can be potential threats to human life is its special feature. The study highlighted those geographers and cartographer of Ukraine took into account world trends and domestic experts' backgrounds and created an absolutely new cartographic product within the country.

The results of the study confirmed its full compliance with the technical task and the Conception of the Atlas, which was created at the Institute of Geography of the National Academy of Sciences of Ukraine.

The atlas contains 143 various scale maps. Each section is accompanied by explanatory text, graphs, tables, and a range of photos.

The Atlas provides a general description of the *preconditions for potential sources of emergencies*, which is reflected in the maps of different sections. The "**Natural conditions**"

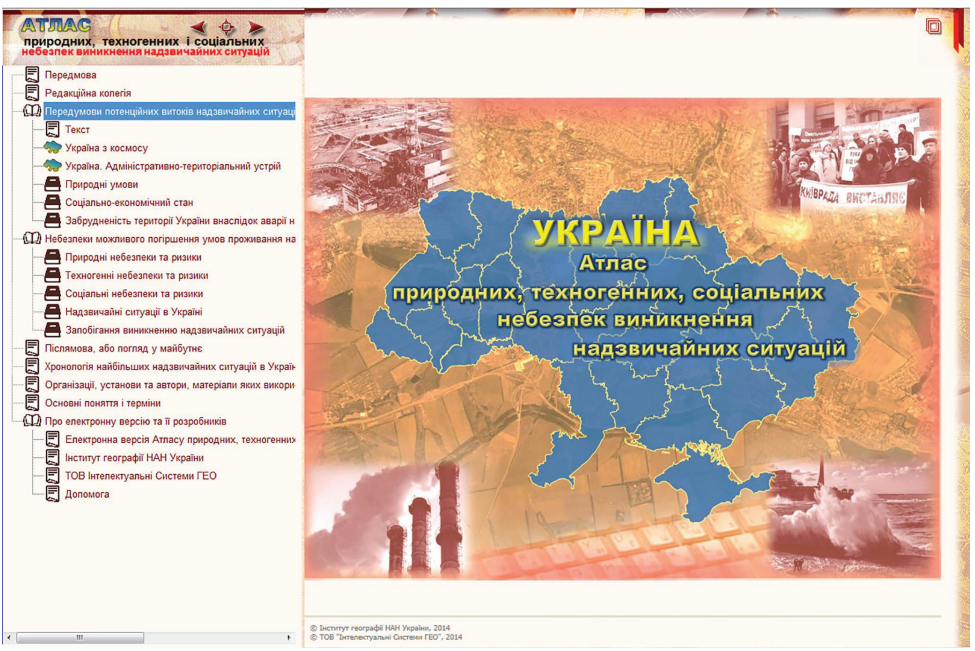

Figure 3. Title page of the Atlas of natural, technogenic, social hazards and risks of emergencies (electronic version)

section is presented by the maps of relief, hydrographic network, climate, vegetation, etc. "**Socio-economic status**" is lightened out with the maps of settlement, industrial, agricultural and transport development of the territory. The chapter "**Contamination of the territory as a result of the Chornobyl disaster**" is presented as well.

The five main sections of the Atlas contain maps that show the various hazards of *possible deterioration of the population living conditions and the work of enterprises*.

The section "**Natural hazards and risks**" pays attention to the analysis and mapping of factors of possible risks and dangers caused by processes on the land surface, different meteorological phenomena, natural-biotic and other factors. The firsts are gravitational processes, faults of the earth's crust, flooding, karst, etc. The seconds are blizzards, ice, hail, thunderstorms and squalls, very heavy rain, showers, snowfall, fog, etc. (Fig. 4). The thirds are soil pollution, forest and biodiversity condition, the spread of pests and parasites.

Ukraine surpasses developed European countries in terms of the saturation of its territory with industrial facilities. A significant part of them is potentially dangerous enterprises associated with production process and store highly toxic, explosive, and flammable substances. The section "**Technogenic hazards and risks**" highlights

the hazards and risks of emergencies due to the concentration of industrial facilities, depreciation of fixed assets, accumulation of waste, etc. (Fig. 5).

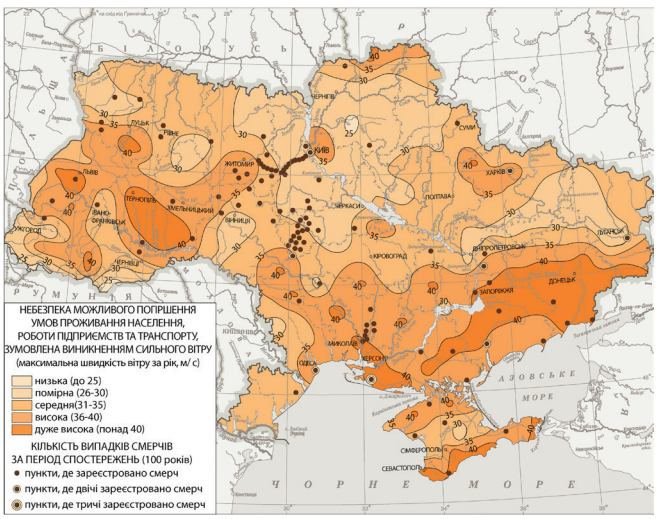

Figure 4 Ukraine. Tornado and strong wind
(arranged by S.A. Santalova [12, 14])

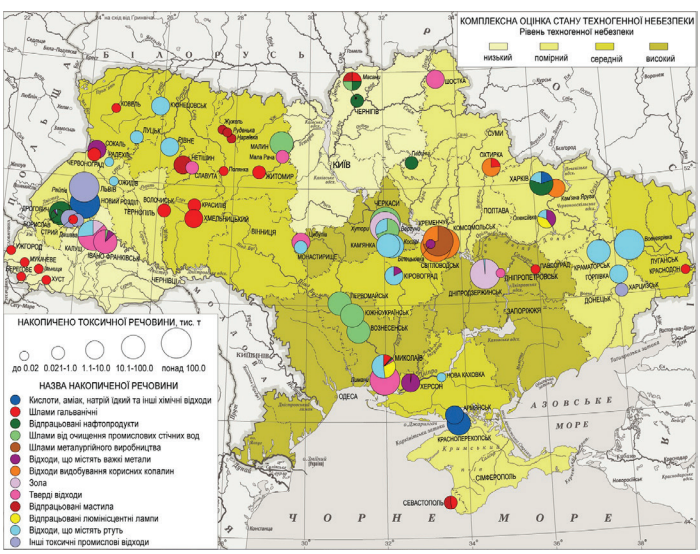

Figure 5 Ukraine. Toxic industrial waste
(by T.I. Kozachenko, T.M. Barabash)

A special place in lightening up the potential dangers of emergencies in Ukraine is allocated for social factors (section "**Social hazards and risks**"). Currently, the importance and relevance of detailed coverage of the social factors of emergencies are caused by the political and socio-economic transformation of Ukrainian society. A large part of emergencies is provoked by ill-considered human activities. Therefore, a detailed analysis of the spread, density, change of population and its other characteristics is an important and prerequisite for identifying the causes of emergencies.

In addition, social factors are easier to manage than natural, man-made and environmental, so their development can be more quickly prevented, predicted, and addressed through public administration tools. It can minimize their role in the emergencies appearing and help to reduce the scale and progress of emergencies in Ukraine.

The social factors of the emergencies are presented in maps devoted to the features of political and ethnic structure of society, population concentration and depopulation, socio-economic living conditions, level of social stability, morbidity, access to quality environmental resources (Fig. 6).

The Atlas developers showed the chronology of regional emergencies in Ukraine, losses and features of infrastructural support of their consequences' liquidation (section **"Emergencies in Ukraine"**).

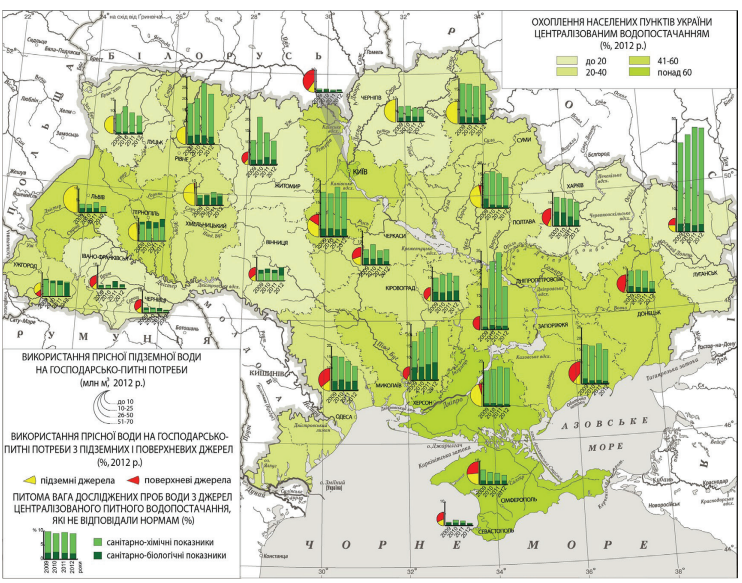

Figure 6. Ukraine. Quality of drinking water from sources of centralized drinking water supply (by K.A. Polyvach).

A retrospective analysis of emergencies in Ukraine in 1997-2013 shows that the most spread reason for their occurrence is the human factor. Considering the above, the safety of the population and the environment is becoming the most important criterion characterizing the quality of life and the state of the economy.

The final section of the Atlas **"Emergencies Prevention"** contains maps on environmental protection, showing the location of the governing bodies of the Civil Service of Ukraine for Emergencies, forces, means of prevention and elimination of emergencies, monitoring, evaluation, and forecasting.

Obtaining a spatial and systematic interpretation of knowledge about the conditions of emergencies, the attempts of society to prevent their appearance is an important task for our country. Such information contributes to the development of precautionary measures that help to avoid emergencies, eliminate their consequences, and purposefully inform citizens about the risks of emergencies. It makes it possible to assess the presence of deviations from the normal state of natural or technical objects, the threat of their destruction, possible population death or violation of its living conditions, the possibility of causing direct and indirect material damage, deterioration of environmental properties of nature as well.

Today the economic, social, and environmental processes are interdependent. It leads to the need for the authorities to find adequate tools for operational control over the condition of subordinate facilities and regions. The aim is to forecast risks and make alternative decisions for hazards prevention, justify measures to minimize potential losses and unproductive costs.

Such tools include modern geoinformation technologies which effectively support decision-making on prevention and response to emergencies of various origins. The principal advantage of these technologies is the ability to comprehensively reflect and operate spatially distributed, heterogeneous and dynamic factors of man-made, natural and social risk, taking into account their relationships and interactions at all levels of government. Many years of work on the Atlas of natural, man-made, social hazards of emergencies in Ukraine has made it possible to clearly understand the list of tasks that can be solved:

– to identify those regions of Ukraine that have potential hazards for the population life with respect to the activities of dangerous enterprises in various sectors of the economy, the functioning of the transport system, etc;
– to classify the regions of Ukraine due to the prevailing types of emergencies;
– to find out the condition of infrastructural provision of emergency response;
– to identify the features of the possible accident's prevention system;
– to identify problem areas in the collection, analysis and unification of information on the factors of emergencies, high-quality processing of which will help prevent their occurrence;
– to find out the gaps in the cooperation of scientists and managers regarding emergencies;

– to acquaint the public with the presence of emergency factors in the territory of their residence; that will allow the population to be armed with information and more quickly respond to emergencies;
– to make effective management decisions to prevent emergencies, not just to overcome their catastrophic consequences.

As the Atlas of natural, technogenic, social hazards and risks of emergencies in Ukraine in electronic format is a pioneer for our country, the next stage of cooperation between managers and scientists could be an Atlas of Emergencies with deep interactive features. It would help to prevent emergencies, rather than just localize, and eliminate their consequences. The creation of regional atlases is important too. Critical is a creation of the atlases and interactive maps of emergencies of the regions that suffer from their frequent occurrence, accompanied by human casualties and significant material damage. They are Transcarpathian, Ivano-Frankivsk, Chernivtsi, Luhansk, Donetsk regions.

As ensuring public safety is the current strategic priority of state policy, a significant contribution to this process could make the development of emergency atlases due to the reasons for their occurrence.

Discussion

Having completed any research and received a certain result, its authors already see any shortcomings and opportunities for improvement. Disadvantages related to some circumstances will be reported to the Atlas developers by those who use this product. They should be considered. After all, this Atlas is a pilot version, and the authors hope for the further development of this work, so they pay special attention to two issues.

The ***first problem*** relates to the improvement and practical application of the methodology for assessing the risks of emergencies. Many policy documents have been developed by the European Union (EU) [18, 4, 2]. Specific actions have been taken, in particular the establishment of the EU Citizens' Monitoring and Information Center, which involves 32 European countries [5]. The main risk assessment policy is based on three main tasks [15]:

- *prevention* that involves the development and consideration of design rules and criteria for the selection of sites of various types, coordination of stakeholders and compliance with the rules of disaster management, improving the effectiveness of legislative and financial documents;

- *readiness* that includes the teaching of experts, training and preparation of the early warning system, development of disaster management technologies;

- *disaster (emergency) response mechanism* that means the creation and operation of information and monitoring centre, special training programs and protection models.

In the future, taking into account these tasks, it is necessary for Ukraine to develop existing tools that would be based on appropriate approaches. This

problem is complex, even in the EU these methods are developed only for seismic and hydrometeorological phenomena, urban fires, and chemical accidents.

Risk assessment is subject to fundamental elaboration in the frame of methodology development. In this process, for Ukrainian authorities and scientists is important to take into consideration the probability and consequences of an adverse event, to determine the scale of danger, taking into account its implications and losses.

The ***second problem*** is associated with the needs of vocational training of GIS specialists and improvement of geoinformation technologies to produce and visualize the interactive atlases for assessing the risks of emergencies related to natural and man-made hazards.

Conclusion

The results obtained during this research demonstrate the goals, objectives, structure and functions of the Electronic atlas of emergencies which was created in Ukraine for the first time. Presenting the information focused on the concentration of various types of phenomena, processes and objects that can be potential threats to human life is its special feature. The study highlighted that geographers and cartographer of Ukraine took into account world trends and domestic experts' backgrounds and created an absolutely new cartographic product within our country.

The results of the study confirmed its full compliance with the Conception of the Atlas, which was created at the Institute of Geography of the National Academy of Sciences of Ukraine as theoretical background for such work [17].

The creation of this Atlas with spatial fixation of various technogenic (man-made) objects and natural phenomena, potentially dangerous for the society and nature, demonstrated their concentration and saturation in some regions. It found out the unsatisfactory technical condition of economic objects and noticed the trend in the intensification of natural phenomena.

Some problem issues for the further atlases development were highlighted during the research. They were associated with the needs of improvement of methodology for assessing the emergencies risks and provision of the vocational training of GIS specialists in Ukraine. In addition, the existing GIS programs and technologies must be updated.

As a final remark, the authors consider that the Atlas of Emergencies is an important tool for improving the risks and hazards management system in Ukraine. Also, it can be considered as important information on emergencies for the general public. Everyone has the right to know about the possible negative consequences and complications of their lives due to the existence of natural, technogenic (man-made) and social risks in the place where he or she lives. This thesis gives grounds to assert the expediency of further creating an interactive online Atlas of natural, technogenic and social hazards and risks of emergencies in Ukraine.

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ARCHIVE INFORMATION EXTRACTION FOR GROUND CONDITIONS ASSESSMENT

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Abstract. This paper is targeted to the development of methodology, data sources and extraction from the archives of the parameters considering the soil ground conditions. The integral parameter reflecting the properties of the surface ground layers is so called V_{s_30}. This parameter is an integral characteristic of the ground conditions used in almost all procedures of the seismic hazard mapping software. The V_{s_30} means the velocity of the transverse seismic waves to the depths of 30 meters of the ground layers. The transverse seismic waves (S-waves) are the most destructive component of any seismic influence. This parameter depends on many factors such as density and type of rocks and sediments of the surface earth's strata, surface water level, the strength of the medium, etc. The main task – archive information extracted from old data sources - is solved for different geophysical parameters of the ground – rock composition, depth distribution of the different layers, density, porosity, water saturation and many others characterizing the first 30 meters of depth. The physical properties can be obtained by different geophysical methods, frequently used for completely diverse tasks, not related to the needed physical properties. The data collection can be done by in situ measurements, boreholes sampling, lab tests, etc. Due to the recent complicated densely populated areas in the large communities, very frequently such investigations are not possible due to the complicated conditions – buildings, stock, noisy environment, etc. Thus, the main sources of information are the old archives. Examples of the solutions are presented.

Keywords: ground conditions; archive information; methodology.

Introduction

The seismic hazard assessment is based on models for simulation of the expected ground acceleration. This study is focused to the V_{s_30} determination and digitalization as the very important parameter to the seismic hazard modeling. The V_{s_30} means the average velocity of the transverse seismic waves (S-waves) to the depths of 30 meters. This important characteristic is responsible for the S wave's velocity increase (rarely) and attenuation (most frequent case) in the most upper ground layer. That's why it is an essential element included in almost all software packages for seismic hazard determination. Increased difficulties appear with the V_{s_30} determination in densely populated areas in case of the seismic microzonation, seismic hazard and risk assessment, vulnerability of structures in the zones, urban areas, critical infrastructure, etc., and must be performed in near field distances of well determinate fault structures. All methods explored in such situations are very difficult to perform, due to the complicated measurement conditions in the urban environment. Due to this it is impossible to make regular grid of measurements points, to perform bore holes and/or to take samples for lab tests. Due to these difficulties a lot of archive useful materials must be extracted, collected, digitized and interpret. Usually, they are in analogue form and not usable in the recent processing technologies. In the recent times all analogue data and information must be transformed to the digital products to be used easily by all recent software.

Materials and methods

In the urban environment frequently the only way to obtain reliable primary geophysical data and information is to use the archives. To collect and exploit data and materials is important to find the respective archive units, to perform digitalization using different techniques, because of the different information sources (records, pictures, maps, photos, etc.), available in the libraries, stores, even newspapers and old books.

The following examples are presented just to illustrate the variety of sources and techniques used for digitalization. The focus of these archive materials is on the area of SW Bulgaria – the most seismic hazardous region of Bulgaria due to the M7.8 earthquake occurred on 4th April 1904 [1].

– Geological maps of different scales, layers of petrology composition, age, time of origin, thickness, roughness of the layers overlapping boundaries, lateral inhomogeneity, etc. Usually almost all found maps and schemes are presented on paper as colored pictures and legend describing the meanings of colors and symbols (fig.1.) [2].

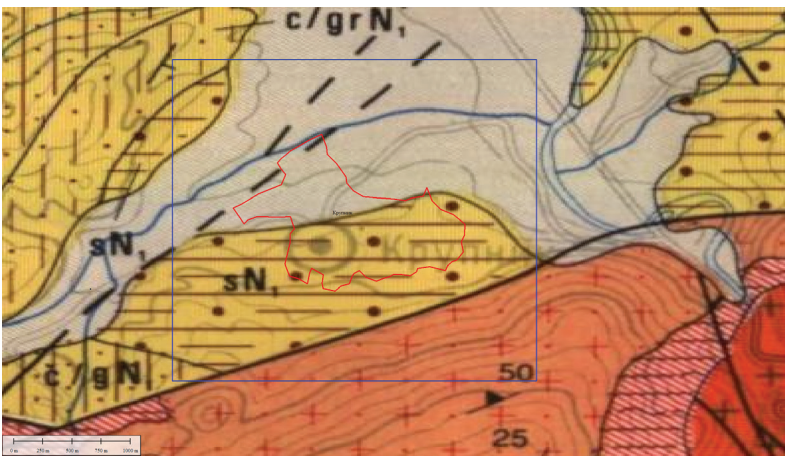

Figure 1. Analogue geology map (scale 1:100 000) of Krupnik (red line – town boundary), interested area (blue quadrat) [2]

– Morphology and surface faults (fig.2.) [3].
– Macroseismic maps (fig.3.) [1].
– Deep faults (fig.4.) [4, 5].
– Borehole diagrams.
– Pictures, sketches, schemes, photographs, etc.
– Seismic, electromagnetic, radioactivity profiles and measurement points, etc.
– Hydrogeology and water bodies maps, sedimentation analysis data, etc.

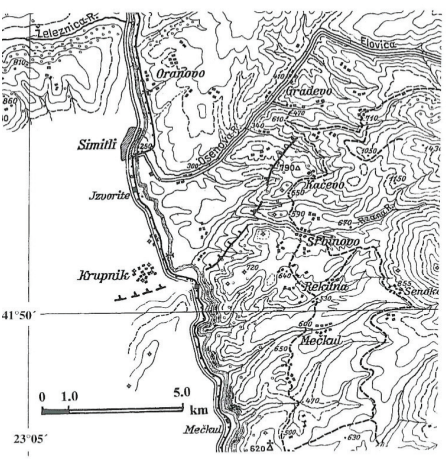

Figure 2 Morphology and faults map [3]

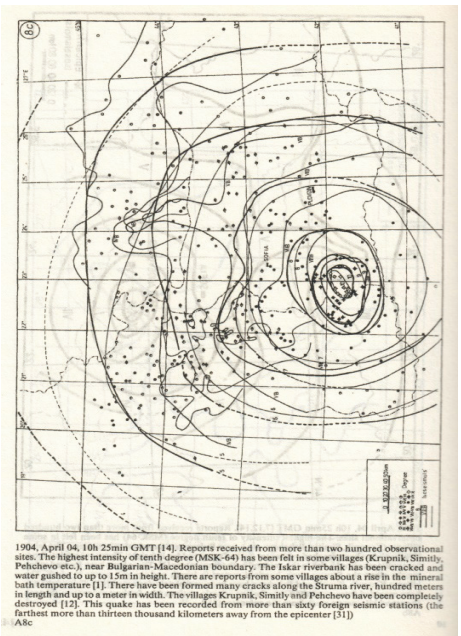

Figure 3. A facsimile of the macroseismic map of the 1904 (M7.8) earthquake [1]

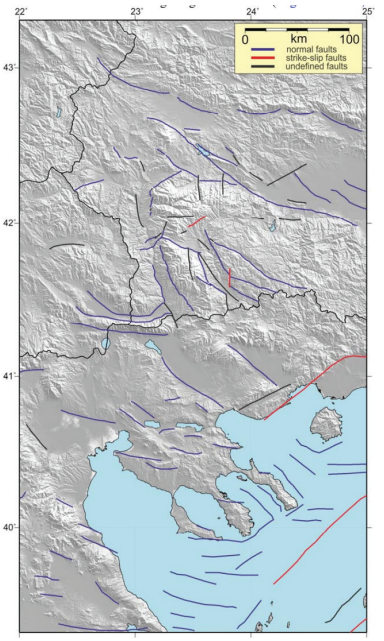

Figure 4. Faults in SW Bulgaria and N Greece [4]

To achieve the reliable digital products usable for the Vs_30 calculations several methods of digitalization are performed and earlier explored [6] (example descriptions follow):

– The used techniques for digitalization of the geology maps and schemes are photography, scanner, specialized software ("digit maps"-ArcGIS) and grid performance – for fig. 1, fig. 2 and fig. 4

– Digitized by photo and then processed by "Silver crest" special device – fig.3.

As the result of digitalization, integrated geology, geomorphology, and faults data processing and summarizing all archive information, a new digital map is prepared (for example – town of Krupnik – fig.5). On the digital map several important blocks with expected V_{s_30} is presented. The next step is using the high resolution prepared digital map to establish the values for each separated block. This needs grid establishment with the respective values of V_{s_30} – fig.6. The values are exported to the Excel table and can serve as an input to the specialized software for the seismic risk assessment [7]. Such a procedure has been performed earlier for the cities of Sofia, Plovdiv, Varna, Veliko Tarnovo and Rouse and gives reasonable results Ranguelov et al, 2020. These results have been performed for the seismic hazard calculations

Results

The results are presented step by step of digitalization, visualization, and presentation for the representative town Krupnik as part of South-West Bulgaria – the most hazardous earthquake place in the country. Maps illustrate the obtained results for the digital data-base usable for the calculations of the seismic hazard assessment (for example [8]). First step is to present the geology of the area in simplified form. Then the grid is necessary to cover the area, finally digital values of the blocks different in their V_{s_30} are presented as minimal and maximal value of the parameter.

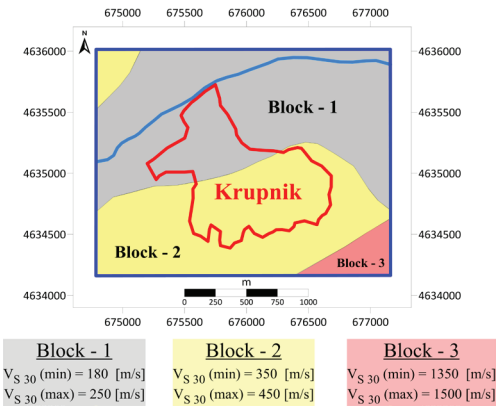

Figure 5 Digitized map "Krupnik" with simplified integrated geological structures (next step of digitalization of the necessary maps for V_{s_30} assessment)

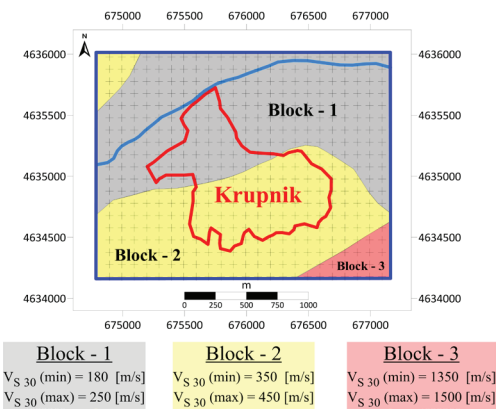

Figure 6 Digitized map "Krupnik" with simplified integrated geological structures, grid of the points and blocks with min and max of V_{s_30} values (final product for seismic hazard assessment calculations)

Discussion

The use of archive materials and sources of information about the old data mining is an important procedure to transform analogue measurement to the recent usable digital format. All available data sources – maps, tables, records, laboratory and field tests, direct and indirect measurements, etc., could be transformed by recent technology tools in useful digital database for modelling and calculations of the seismic hazard's assessment. The importance is presented by new and integrated digital maps which are ready for different scales usage. It is important to mention that frequently the archive data sources are targeted to the different studies and use. To transform them in recent, modern data base a great experience and expertise is performed by different specialists and experts. The main difficulties appear when the information sources are old, not clear pictured and containing names and indexes relative to the ancient presentations.

Conclusion

Summarizing the results of the research we can conclude that the transformation of data and information from old sources to the present digital form is not easy task and needs a lot of expertise and experts. The integrated methodology for digitalization of analogue archive sources is suggested, processed, performed, and presented. The focus point is the area of the strongest seismic event in Europe for the last 200 years – M7.8 seismic event of 4th of April 1904. For this area a lot of analogue sources exist, which gives the possibilities to use the extracted information for the V_{s_30} surface layers parameter – integral representing the ground conditions about several near field located populated towns and villages. The simplification of the geological conditions, considering the geology structures, rocks and their geophysical properties reflecting the influence to the Vs, needs a lot of complex knowledge and expertise. Same is valid for the geophysical data and its transformation, to match the purposes of the study. The obtained digital dataset is of major importance for the seismic hazard calculations by different software platforms. This will be the next step to use the digital database for practical purposes.

Acknowledgements. This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the Ministry of Education and Science (MES) of Bulgaria (Agreement № Д01-322/18.12.2019) - WP.I.10.and WP.I.4.3.

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UNIVERSAL THERMAL CLIMATE INDEX AND INCIDENCES OF STROKE IN THE AGE GROUP 60+ IN SOFIA, BULGARIA

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Abstract. The prolonged heat load on human body negatively affects all people, but especially vulnerable are elderly people suffering from cardiovascular disease. In the present paper we study the link between human thermal comfort or discomfort and cases of stroke in the age group over 60, defined as "adults" (60-74 years) and "old" (75-89 years) from the criteria of the World Health Organization, considering their gender distribution. The data for the disease were provided by Adjibadem City Clinic Tokuda Hospital - Sofia and refer to the period 2007-2011. To determine the heat sensation, we used the so-called Universal Thermal Climate Index (UTCI), which is a world-renowned and widely used climate index that characterizes the heat impact on the human body. UTCI is of thermophysiological significance and is valid in a wide range of external weather conditions, including extreme weather events. It reflects the physiological reactions of the "statistically average person", based on the method of heat balance of the human body. The index is used to assess discomfort in both hyperthermia and hypothermia and is presented as temperature scaled. The average number of patients admitted during different UTCI values during the warm half of the year (covering the months of May-September inclusive) was compared. Concerning the total number of cases, the largest number of patients with stroke is observed at UTCI values defined as "very strong heat impact", and the lowest - at comfortable thermal conditions (the so-called weather with "No impact"). Weather defined as "Moderate heat exposition" and "High heat exposure" occupy intermediate values for the number of patients in the clinic.

Men in the age group 60-74 were mostly negatively affected by weather defined as with "Very strong heat impact", and in the age group of old men this increase was not very pronounced. Older women may be most sensitive to weather with a "High heat impact", and with a "Very high heat impact" the number of hospitalizations was even decreasing. A similar trend is observed in older women.

An analysis of the statistical significance of the established differences was made and the applicability of the obtained results for the purposes of public health prevention was evaluated.

Keywords: Universal Thermal Climate Index; cardiovascular; stroke cases in Sofia

Introduction

The prolonged heat load on the human body has an extremely negative impact on people, regardless their personal health status but people suffering from cardiovascular diseases are amongst those under highest risk in hot environment. Though it has been found that the cardiovascular mortality shows its peak in winter, high temperatures during the summer season are also connected with higher rate of cardiovascular mortality. Most studies reveal that the victims of heat are older people – over 60 years old [1, 9, 10]. Older people are more vulnerable due to diminishing ability of their body to adapt to the abrupt weather changes and to the heat load. The share of the old people will increase from 18 to 28% in Europe at the year 2050. Several authors also state that women are more vulnerable to heat compared with men [4, 8]. In present research we aimed to reveal the relationship between the heat stress of the human (its feeling for thermal comfort or discomfort) and the cases of stroke in the age group over 60, defined as "adults" (60-74 years) and "old" (75-89 years) from the criteria of the World Health Organization, considering their gender distribution (table 1).

Materials and methods

To determine the heat stress, we used the so-called Universal Thermal Climate Index (UTCI), which is a world-renowned and widely used climate index that characterizes the heat impact on the human body. UTCI is of thermophysiological significance and is valid in a wide range of external weather conditions, including extreme weather events. It reflects the physiological reactions of the "statistically average person", based on the method of heat balance of the human body. The index is used to assess discomfort level in both hyperthermia and hypothermia and is presented as temperature scaled. UTCI values had been calculated with meteo data for Sofia from the synoptic observations in Central Meteorological Observatory of the National Institute of Meteorology and Hydrology. The weather conditions influence on the number of patients admissions with stroke in Adjibadem City Clinic Tokuda Hospital - Sofia, has been researched for the same time period of five years (i.e., 2007-2011) for that we have medical information of hospital admissions. Due to the specifics of the medical data provided by Tokuda Hospital (number of patients per 24 hours) we had to work with average values (i. e. average diurnal values) of meteorological parameters. Data from the Central Meteorological Observatory in Sofia has been used, because of the fact, that this is the nearest, representative for the region meteorological station. It is situated next to r.d. "Mladost" 1 of the Bulgarian's capital.

In this research the UTCI index has been calculated using the program BioKlima version 2.6, developed in Institute of Geography and Spatial Organization Polish Academy of Sciences (IGSO PAS) by Prof. Krzysztof Błażejczyk PhD.

Table 1. Age groups classification according to the World Health Organization

Years	Age group
0-14	children
15-44	young age
45-59	middle age
60-74	adults
75-89	old people
90+	longevous

Data for hospitalizations were provided by the Adjibadem City Clinic Tokuda Hospital – Sofia for the period 2007-2011. The average number of patients in the age groupe 60+ admitted with stroke (cerebrovascular insult) during different UTCI values during the warm half of the year (covering the months of May-September inclusive) was compared by T-test. Sex distribution of the patients in the age groupe 60+ was considered as well.

Table 2. The scale of UTCI and the degree of comfort

UTCI (°C)	Stress category
UTCI > 46	extreme heat stress
38 < UTCI < 46	very strong heat stress
32 < UTCI < 38	strong heat stress
26 < UTCI < 32	moderate heat stress
9 < UTCI < 26	no thermal stress
0 < UTCI < 9	slight cold stress
-13 < UTCI < 0	moderate cold stress
-27 < UTCI < -13	strong cold stress
-40 < UTCI < -27	very strong cold stress
UTCI < -40	extreme cold stress

Source: Blazejczyk et. al 2014

During the studied period 62 days were without thermal stress, 175 days – with moderate heat stress, 268 days with strong heat stress and 66 with very strong heat stress.

Results

The average number of patients admitted during different UTCI values during the warm half of the year (covering the months of May-September inclusive) was compared. Concerning the total number of cases, the largest number of patients with stroke is observed at UTCI values defined as "very strong heat stress", and the lowest - at comfortable thermal conditions (the so-called weather with "No stress"). Weather defined as "Moderate heat stress" and "High heat stress" occupy intermediate values for the number of patients in the clinic (Fig. 1).

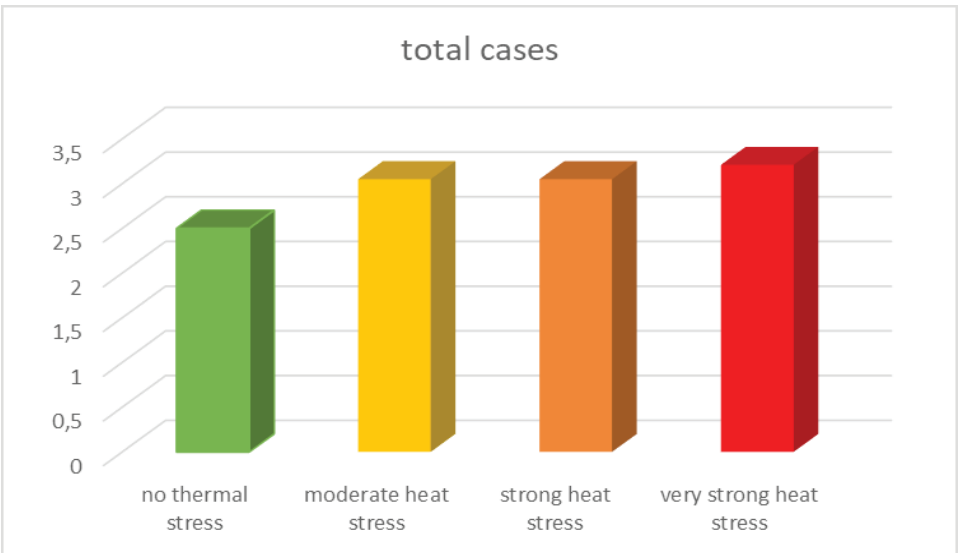

Figure 1. Total number of cases during different values of UTCI

Men in the age group 60-74 were mostly negatively affected by weather defined as with "Very strong heat stress", and in the age group of old men this increase was not very pronounced (Fig. 2). Older women may be most sensitive to weather with a "High heat stress", and with a "Very high heat stress" the number of hospitalizations was even decreasing. A similar trend is observed in older women (Fig. 3).

Table 3 presents the average number of admitted patients with stroke, as well as their statistical characteristics for all admitted patients with this diagnosis. In this table, x indicates the average number of admitted patients with stroke, σ - their standard deviation, and n - the total number of these cases for the period 2007-2011.

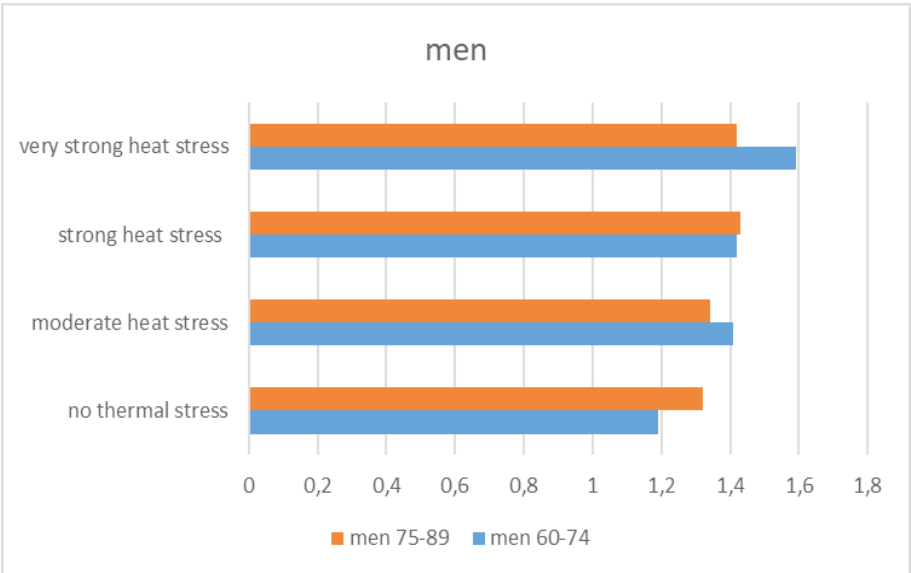

Figure 2. Number of men hospitalized with stroke during days with different categories of UTCI values

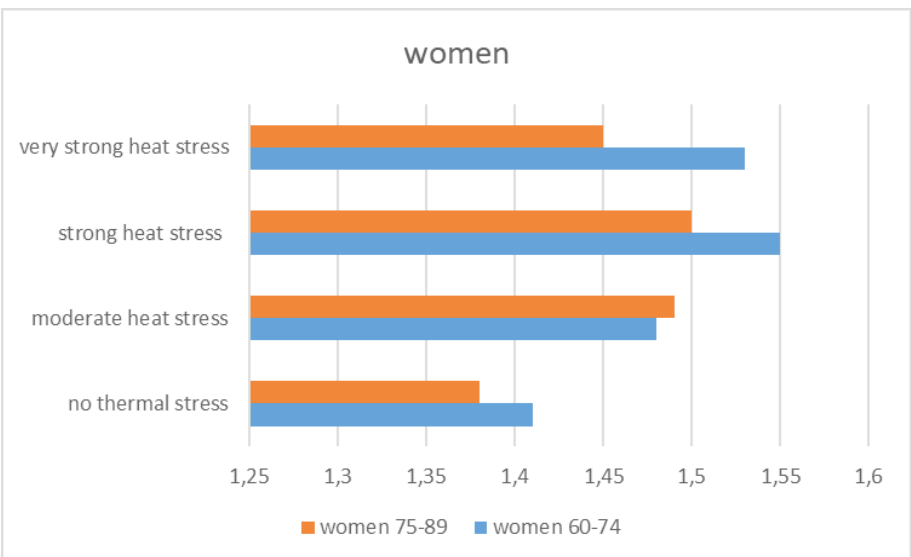

Figure 3. Number of women hospitalized with stroke during days with different categories of UTCI values

Table 3. Total number and statistical values of stroke of cases in days with different categories of UTCI values

Main data				Comparative analysis			
Intervals	x	σ	n	No thermal stress	Moderate heat stress	Strong heat stress	Very strong heat stress
No thermal stress	2.50	1.30	62	x	2.62*	2.75*	2.29*
Moderate heat stress	3.05	1.76	175	2.62*	x	0	0.55
Strong heat stress	3.05	1.84	268	2.75*	0	x	0.52
Very strong heat stress	3.21	2.14	66	2.29*	0.55	0.52	x

Statistically significant cases are shown with * at significance level $\alpha = 0.05$

The total number of stroke cases for the age groups 60-74 and 75-89 for men are presented in Table 4 and Table 5, and those for women in Table 6 and Table 7.

Table 4. Total number of cases of stroke in days with different categories of UTCI values – men in the age group 60-74

Main data				Comparative analysis			
Intervals	x	σ	n	No thermal stress	Moderate heat stress	Strong heat stress	Very strong heat stress
No thermal stress	1.19	0.40	62	x	2.93*	3.54*	3.64*
Moderate heat stress	1.41	0.78	175	2.93*	x	0.15	1.64
Strong heat stress	1.42	0.65	268	3.54*	0.15	x	1.6
Very strong heat stress	1.59	0.80	66	3.64*	1.64	1.6	x

Statistically significant cases are shown with * at significance level $\alpha = 0.05$

Table 5. Total number of cases of stroke in days with different categories of UTCI values – men in the age group 75-89

Main data				Comparative analysis			
Intervals	x	σ	n	No thermal stress	Moderate heat stress	Strong heat stress	Very strong heat stress
No thermal stress	1.32	0.67	62	x	0.21	1.16	0.83
Moderate heat stress	1.34	0.62	175	0.21	x	1.5	0.82
Strong heat stress	1.43	0.72	268	1.16	1.5	x	0.1
Very strong heat stress	1.42	0.71	66	0.83	0.82	0.1	x

Table 6. Total number of cases of stroke in days with different categories of UTCI values – women in the age group 60-74

Main data				Comparative analysis			
Intervals	x	σ	n	No thermal stress	Moderate heat stress	Strong heat stress	Very strong heat stress
No thermal stress	1.41	0.73	62	x	0.7	1.3	0.92
Moderate heat stress	1.48	0.70	175	0.7	x	0.99	0.5
Strong heat stress	1.55	0.77	268	1.3	0.99	x	0.2
Very strong heat stress	1.53	0.73	66	0.92	0.5	0.2	x

Table 7. Total number of cases of stroke in days with different categories of UTCI values – women in the age group 75-89

Main data				Comparative analysis			
Intervals	x	σ	n	No thermal stress	Moderate heat stress	Strong heat stress	Very strong heat stress
No thermal stress	1.38	0.62	62	x	1.12	1.33	0.56
Moderate heat stress	1.49	0.77	175	1.12	x	0.14	0.36
Strong heat stress	1.5	0.80	268	1.33	0.14	x	0.5
Very strong heat stress	1.45	0.79	66	0.56	0.36	0.5	x

Discussion

The heat load caused by extremely hot weather is an important factor that can worsen the health status of elderly people and patients with chronic diseases. This effect is even more unfavorable when these periods of thermal overload of the body are very long and continuous over time during the warm half of the year. Climate change and the expected more intense and more frequent periods with high temperatures and the increasing number of elderly people in the world will lead to an increased number of cases of hospitalization of elderly people in the coming decades. Numerous scientific studies show [1, 9, 10] that older people are more vulnerable to heat overload due to the body's decreasing ability to adapt to abrupt weather changes and heat stress. In addition, some elderly people are bedridden patients or live alone, which further increases their vulnerability to such extreme weather conditions. In general, studies of the dependence of mortality in such periods with extreme heat stress on the body predominate in the literature, and the number of studies on hospitalizations is insufficient [1]. Research on the effects of heat overload on the body and cases of stroke in general are few. Research on other types of diseases predominates. A study by other scientists [2, 11] showed an increase in the number of admitted patients with respiratory diseases (in the groups over 75 and 65-74 years) at extreme air temperatures (above 90% percentile). In Australia, there has been an increase in the number of

patients admitted with kidney disease and acute renal failure during periods of significant heat stress (in the groups over 75 years and between 65 and 74 years) [5, 6]. There was also an increase in the number of admitted patients with mental illnesses and behavioral disorders when the heat load is significant - for the age group 65 - 74 years compared to the rest of the year [5, 10]. Many researchers have found a stronger positive relationship between periods of significant heat load and the number of deaths from cardiovascular and respiratory diseases [1], and this effect is more pronounced in women. Lonely, poor and socially excluded people are particularly vulnerable.

Conclusion

Research has shown that men in the age group 60-74 are much more sensitive to heat (Table 4), with the largest number in weather with "Very strong heat stress" (1.6 cases per day). In men in the age group 75-89 years, the number of hospitalizations is approximately equal in weather with Moderate and strong heat stress (Table 5). Women in the age group 60-74 years have the highest number of hospitalizations in weather with strong heat stress (UTCI values), as the number of cases reaches 1.55 per day (Table 6). It is immediately followed by those in weather with very strong heat stress. The number of patients aged 75 to 89 years is highest in weather with strong heat stress (Table 7), followed immediately by those with moderate heat stress. The statistical significance test at ($\alpha = 0.05$) showed that in the total number of patients (men and women) the change in strong heat stress was the most statistically significant, followed by the cases with moderate heat stress. In men in the age group 60-74 years old, the number of cases with very strong heat stress is statistically significant, followed by those with strong heat stress while in the age group 75-89 years no statistically significant change in the number of cases was found. In women of both age groups 60-74 years and 75-89 years old, no statistically significant changes in the number of cases were found.

The obtained results could be useful in terms of taking preventive measures from the public health authorities and in developing policies in the field of climate change and public health, especially focused on the problems of the vulnerable groups of the Bulgarian population.

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CYANOTOXINS AS AN EMERGING RISK – MOLECULAR METHODS FOR DETECTION (STUDY IN BULGARIA)

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Abstract. Occurrences of cyanobacterial mass in freshwater lakes are usually formed by Anabaena, Microcystis and Planktothrix, which can produce cyclic heptapeptide hepatotoxins - microcystins. Hepatotoxins are inhibitors of protein phosphatases that cause bleeding in the liver of humans and animals, but also show strong tumor-promoter activity. Toxic cyanobacterial species are a risk factor for the environment and human health that requires their early detection at low concentrations. Such an approach is the application of methods for detecting DNA from toxic microalgae in water samples by polymerase chain reaction. Microcystis contain the peptide synthetase gene cluster, which is a complex of 10 genes, mcy (A-J), which control the synthesis of polyketides and peptide synthetases associated with microcystin synthesis. Only microcystin-producing cyanobacteria carry the mcy genes that can be used as a biomarker for early detection. Also the genetic differences within this gene cluster determines the level of production of secreted microcystins. The aim of the present study is early detection of toxic microalgae by real-time polymerase chain reaction (qPCR) in samples taken from Bulgarian dams. Two test approaches were used - TaqMan and SYBR Green I dye. The obtained results prove the presence of cyanobacteria in all the samples and they were also compared with hydrobiological analysis which proves them. PCR methods provide qualitative results that can be used for early detection for potentially toxic cells at the beginning of the bloom, when the toxin concentrations are too low to be detected.

Keywords: toxic microcystins; qPCR

Introduction

Cyanotoxins are produced by bacteria called cyanobacteria, also known as blue-green algae. They are natural inhabitants of a diverse environment, including freshwater, brackish and seawater. Occurrences of cyanobacterial mass in freshwater lakes are usually formed by *Anabaena*, *Microcystis* and *Planktothrix*, which can

produce cyclic heptapeptide hepatotoxins – microcystins [5]. Hepatotoxins are inhibitors of protein phosphatases that cause bleeding in the liver of humans and animals, but also show strong tumor-promoter activity [1, 5].

Toxic cyanobacterial species are a risk factor for the environment and human health that requires their early detection at low concentrations. Such an approach is the application of methods for detecting DNA from toxic microalgae in water samples by polymerase chain reaction [2].

The presence of cyanobacteria in the Bulgarian wetlands has been reported since the end of the 19th century, and in the second half of the 20th century the presence of toxic algae was reported for the first time. In 2004 the first study was published, which presents results from the analysis of samples taken from 15 dams in the country (drinking water dams: Iskar, Sofia; Yasna Polyana, Burgas; Studena, Pernik; Bistritsa, Sofia; Botunets, Sofia; Katina, Sofia, and lakes for fishing and water sports - from the Black Sea region - Shabla, Ezerets, Durankulak, Vaya and

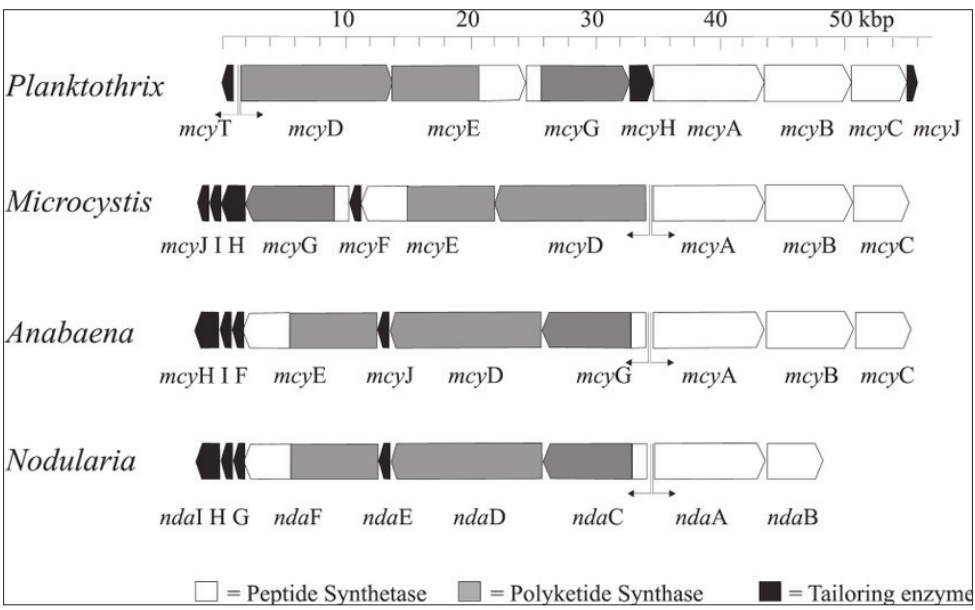

Figure 1. Scheme of the structural organization of the microcystin (*mcy*) gene clusters from Microcystis (Nishizawa et al., 1999, 2000 Tillett et al., 2000), *Planktothrix* (Christiansen et al., 2003) and *Anabaena* (Rouhiainen et al., 2004) and of the nodularin (*nda*) synthetase gene cluster from *Nodularia* (Moffitt & Neilan, 2004). Arrows indicate the direction of transcription, in which the (bi)-directional promoter sites have been indicated. The scale indicates the length of the gene clusters in kilo base pairs (kbp) [3]

Mandra, from Sofia - Dolni Bogrov and Druzhba, and from Pernik - Choklyovo swamp) [4]. The discovery of microcystins in these samples is performed by the method of High Performance Liquid Chromatography with a diode detector (HPLC-DAD). In a scientific paper M.P. Stoyneva-Gertner and V. Pavlova and team summarize the results of research in the 15-year period (2000-2015) in Bulgaria. The authors conclude that the results may signal the identification of cyanotoxins as an emerging risk factor for health in the country.

Microcystis contain the peptide synthetase gene cluster, which is a two-component of 10 genes, *mcy* (A-J), which control the synthesis of polyketides and peptide synthetases associated with microcystin synthesis (fig. 1). Only microcystin-producing cyanobacteria carry the *mcy* genes that can be used as a biomarker for early detection. Also the genetic differences within this gene cluster determines the level of production of secreted microcystins [2, 3]. The *mcy* gene cluster sequences have been characterized in *Anabaena, Microcystis,* and *Planktothrix*. Moreover, these sequences appeared closely related to the nodularin (*nda)* synthetase genes from *Nodularia* [7]. Several gene inactivation studies showed that the presence of the *mcyA*, B, D, E, F, H genes and the gene *mcyT* (in *Plankthothrix* spp.) is necessary for MCs production [8]. However, deletions in the N-methyl transferase domain of *mcyA* of *Anabaena* spp. strains resulted in the production of different MC variants [9].

According to *Directive (EU) 2020/2184 of 16 December 2020* concerning the quality of water intended for human consumption, in Annex I, Part B, there is a newly introduced pollutant: *microcystin-LR* (fig. 2), which must have a concentration of up to 1µl/l. The indicator is measured only in case of potential blooming in the water source (increase in the density of cyanobacterial cells or the potential for blooming formation) [6].

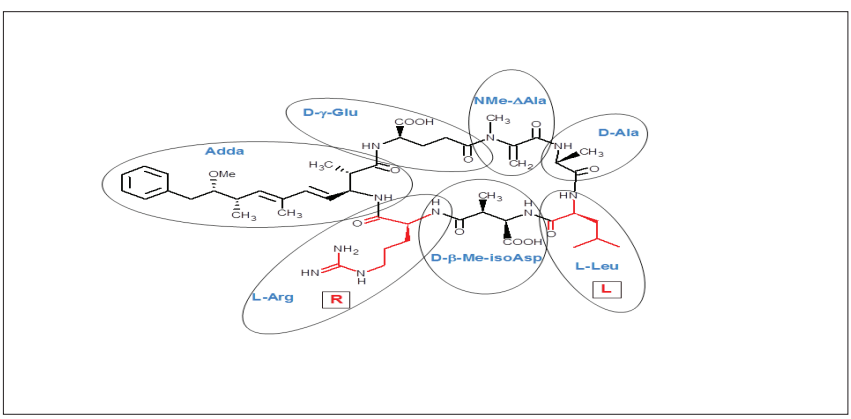

Figure 2. Microcystin-LR constituents *(www.en.wikipedia.org)*

The aim of the present study is early detection of toxic microalgae by real-time polymerase chain reaction (qPCR) in samples taken from Bulgarian dams.

Materials and methods

The subject of the study are samples taken from dams used for different purposes: *Iskar, Kokaliane, Bistritsa,* collected in the summer of 2017. During the bloom period in 2020 samples were taken from *Pchelin, Studena, Bistritsa* and they were compared to a positive control sample from Durankulak lake.

Molecular genetic methods

For the purposes of the present study, the samples from the dams were filtered through bacterial filters with a pore size of 45μm. The biomass thus obtained is subjected to further processing for DNA extraction, which was performed by ready-to-use kit - Mericon DNA Bacteria Kit (100) Cat No. 69525 QIAGEN (Fast Lizys buffer).

For real-time PCR, two test approaches were used - TaqMan and SYBR Green I.

Power of TaqMan method due to its unique design based on oligonucleotide double labeled probe and the exonuclease activity of Taq polymerase enzyme, whereas SYBR Green design based on binding of florescent dye to dsDNA. In SYBR Green method, any non-specific product like primer-dimer can make false positive results and this incorrect and shifted data can finally lead to decrease the performances [11].

The water samples were tested with RealTime PCR ABI 7300 (Applied Biosystems). For TaqMan were used primers for Cyanobacteria and a probe for Microcystis. The genetic marker used is specific for cyanobacteria - their 16S rRNA sequence. For SYBR Green I, the mcyB gene was selected, which is an indicator of microcystin synthesis.

For TaqMan:

• 16SCF 5 '- GGC AGC AGT GGG GAA TTT TC – 3'

•16SUR 5 '- GTM TTA CCG CGG CTG CTG G - 3'

• probe for Microcystis - 16SMT 5 '- CGC CGC GTG AGG GAG GAA GGT C - 3'. Fluorophores - CAL Fluor Gold 540 and BHQ-1 *(Metabion, Germany).*

For SYBR Green I:

Target Cyanobacteria 16S rRNA:

▪ Cya 359F 5'- GGGGAATYTTCCGCAATGGG – 3'

▪ Cya 781R 5'- GACTACWGGGGTATCTAATCCCWTT – 3'

Target mcyB (microcystin synthetase B):

▪ *mcyB* 2959F 5'- TGGGAAGATGTTCTTCAGGTATCCAA - 3'

▪ *mcyB* 3278R 5'- AGAGTGGAAACAATATGATAAGCTAC – 3'

The qPCR reactions were performed with 5 μL of DNA from the each samples:

For TaqMan: 0.4 μM of each primer, 0.2 μM of probe and Luna Universal Probe qPCR Master Mix (New England BioLabs Inc.) in a final reaction volume of 25 μL.

For SYBR Green I: 0.4 μM of each primer Cya359F/Cya781R and MCYB-2959F/3278R primer pairs, and SensiFAST™ SYBR Hi-ROX kit 2X, Cat. No BIO-92005 (www.bioline.com), in a final reaction volume of 20 μL.

Hydrobiological analysis

Microscopic analysis by the method of characterization of surface standing water bodies by hydrobiological analysis of phytoplankton [13].

Results

The obtained results from molecular analysis were compared with hydrobiological analysis.

Hydrobiological analysis

The conducted hydrobiological analyzes establish a diverse species composition in the surveyed reservoirs. Tables 1 and 2 present the results of the surveys conducted in 2017 and 2020.

Table 1. Hydrobiological analysis- 2017 survey

Date - 15.08.2017 **Water reservoir**	**Species composition**
"Bistritsa" Treatment Plant	***Cyanophyta*** *Aphanocapsa spp* ***Euglenophyta*** *Trachelomonas volvocinopsis*
Dam "Kokalyane"	***Cyanophyta*** *Aphanocapsa spp.* ***Euglenophyta*** *Trachelomonas volvocinopsis* ***Chlorophyta*** *Cosmarium formulosum* *Pandorina morum* ***Chrysophyta*** *Dinobrion spp* ***Cryptophyta*** *Cryptomonas spp.* *Rhodomonas lacustris* ***Bacillariophyta*** *Cyclotella spp.* *Navicula spp.* *Synedra acus* *Fragilaria crotonensis*
Iskar" Dam - elevation 0	***Cyanophyta*** *Aphanocapsa spp.* *Oscillatoria amphibia* *Gomphoshaeria lacustris*

Iskar" Dam - elevation 0	***Bacillariophyta*** *Cyclotella comta* *Cymbella spp.* *Asterionella formosa* *Fragilaria crotonensis* ***Cryptophyta*** *Cryptomonas erosa* ***Chlorophyta*** *Cosmarium spp.* *Pandorina morum* *Chlorella spp.* *Coenococcus spp.* ***Dinophyta*** *Ceratiom hirundinella*
"Iskar" Dam - elevation 25 m	***Cyanophyta*** *Aphanocapsa spp* ***Chlorophyta*** *Pandorina morum* ***Bacillariophyta*** *Cyclotella comta* *Melosira italica* *Asterionella formosa* *Fragilaria crotonensis*

Table 2. Hydrobiological analysis- 2020 survey

Date - 02.10.2020 **Water reservoir**	**Species composition**
"Pchelin" Dam	***Cyanophyta*** *Coelosphaerium kuetzingianum* ***Chlorophyta*** *Ulothrix tenerrima* ***Bacillariophyta*** *Fragilaria capucina* ***Cryptophyta*** *Rhodomonas lens* *Cryptomonas erosa* ***Dinophyta*** *Ceratiom hirundinella*
"Bistritsa" Dam	***Cyanophyta*** *Anabaena solitaria* *Aphanotehece clathrate* ***Euglenophyta*** *Trachelomonas rugulosa* ***Chlorophyta*** *Scenedesmus spp.* *Coenococcus spp.* *Chlorella spp.*

"Studena" Dam	***Cyanophyta*** *Coelosphaerium kuetzingianum* *Anabaena solitaria* ***Bacillariophyta*** *Cyclotella spp.* *Epithemia spp.* *Fragilaria crotonensis* ***Euglenophyta*** *Trachelomonas spp.* ***Chlorophyta*** *Coenococcus spp.* *Oedogonium capillare*

Molecular analysis

The following figures represent the results from molecular genetic methods of the surveys conducted in 2017 and 2020. The results in fig. 3 present the TaqMan test approach. The genetic marker used is specific for cyanobacteria – their 16S rRNA sequence. The results from another test approach SYBR Green I are presented in figures 4 and 5.

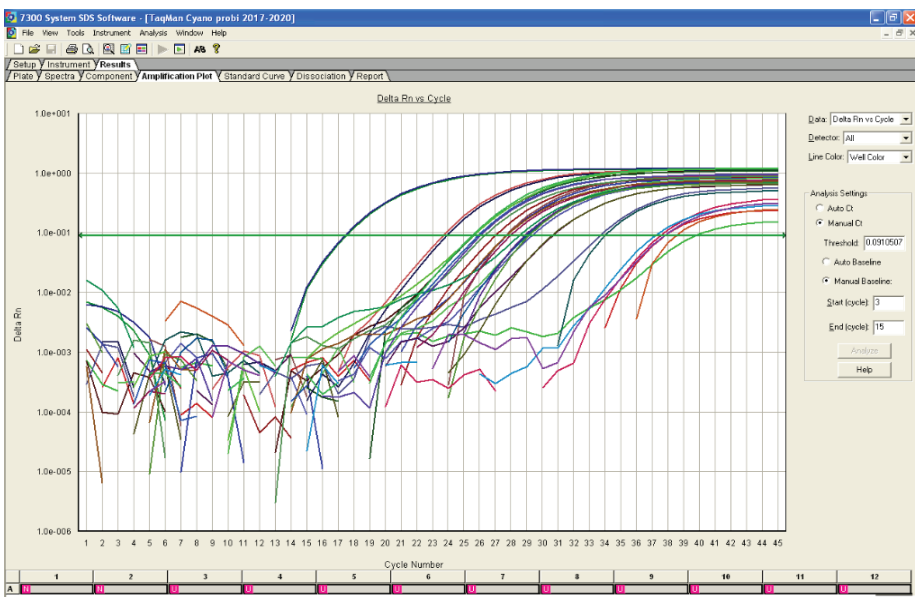

Figure 3. TaqMan – 16S Cyano

The obtained results prove the presence of cyanobacteria in all the samples relative to the peak of the positive control sample – Durankulak lake, observed at the far left of Fig.3.

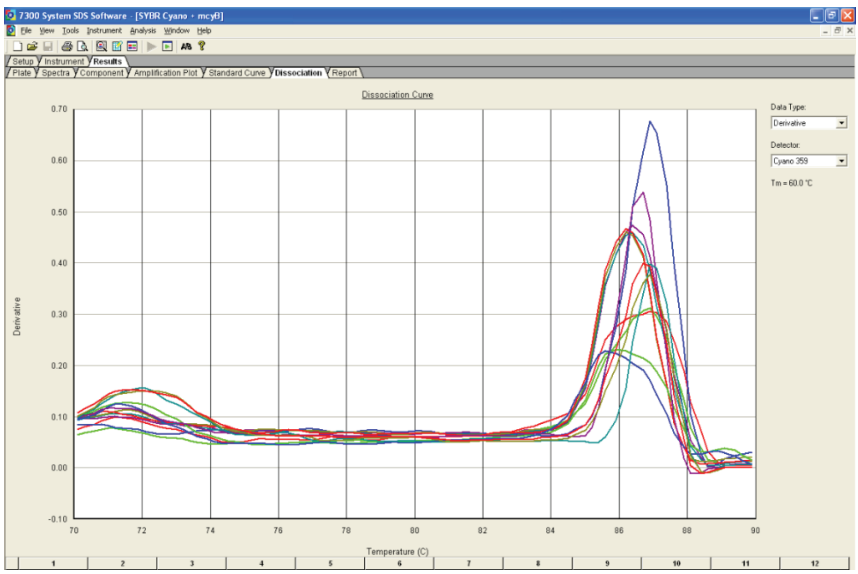

Figure 4. SYBR Green I – 16S Cyano

Positive samples for the presence of cyanobacteria in the melting temperature peaks between 86.5°C and 87.0°C [5] are shown in fig.4.

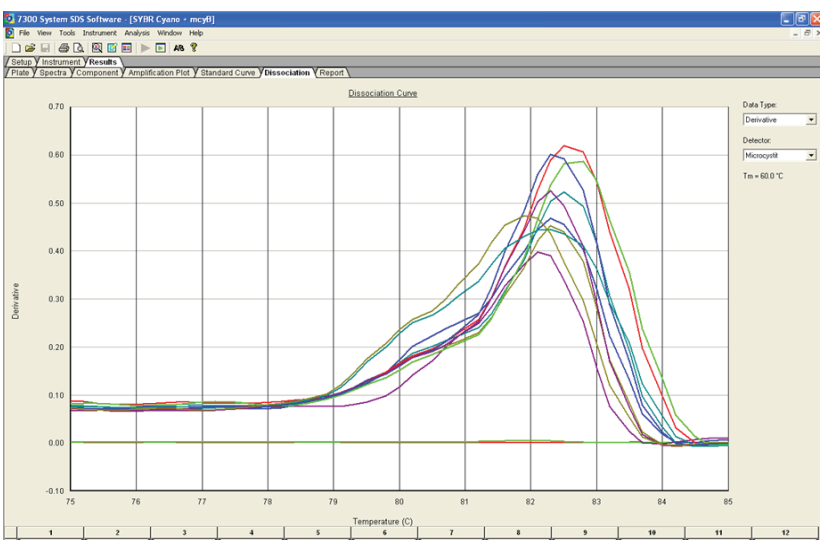

Figure 5. SYBR Green I – mcyB

Positive samples for the presence of the target gene *mcyB* in the melting temperature peaks between 81.5°C and 82.0°C [5] are shown in fig.5.

Discussion

The obtained results prove the presence of cyanobacteria in all the samples and they were also compared with hydrobiological analysis which proves them (tables 1 and 2, fig. 3 and 4). The conducted hydrobiological analyzes establish a diverse species composition in the surveyed reservoirs – tables 1 and 2. In the samples from the studied reservoirs in 2017, from the blue-green microalgae (cyanobacteria), although in small quantities, *Aphanocapsa spp*. was observed, as well as *Oscillatoria amphibia* and *Gomphoshaeria lacustris*. Of the listed species, only members of the genus *Oscillatoria* could be a source of cyanotoxins (neurotoxins) during flowering [1]. In the surveyed reservoirs in 2020, the hydrobiological analyses established the blue-green algae *Coelosphaerium kuetzingianum* and *Anabaena solitaria* - independently or jointly developed. In the Bistritsa dam and in the Studena dam they are in a period of flowering. It is known that species of the genus *Anabaena* can produce hepatotoxins.

In the three samples from 2020 - *Pchelin, Studena and Bistritsa,* the presence of the target gene *(mcyB)* that belongs to the gene cluster involved in the biosynthesis of microcystin was detected (fig. 5). Microcystins are synthesized on large multienzyme complexes consisting of polyketide synthases and non-ribosomal peptide synthetases in *Anabaena*. Nearly all of the 48 catalytic reactions necessary for the biosynthesis of microcystin can be assigned to the 10 proteins encoded in this 55 kb gene cluster [10]. Our results from the two dams - *Bistritsa* and *Studena* from 2020, were confirmed by the both types of analysis: hydrobiological (see in table 2) and molecular, that a toxic species is detected, such as *Anabaena solitaria*. Another potentially toxic cyanobacteria, who carry the *mcyB* gene is presumed to be in the third studied dam - *Pchelin*.

Conclusion

DNA-based detection methods of the genes involved in cyanotoxin biosynthesis have become popular because of their potential specificity, sensitivity, speed, and ability to identify potentially toxin-producing strains of cyanobacteria prior to the mass production and potential release of toxins into the waterbody [12].

In 2017 toxin-producing micro algae species are classified as an emerging risk as a result of climate changes. Toxic cyanobacteria are a particularly suitable target for detection by qPCR.

Due to the sensitivity and high specificity of the method a significant concentration of samples is often not required and it is possible to detect toxic genotypes long before a toxic cyanobacterial bloom may occur. Consequently, watercells that are at risk of toxic bloom formation can be identified early on in the growing season.

PCR methods provide qualitative results (presence/absence of the genes in a sample) that can be useful for the early detection of potentially toxic cells just at the beginning of the bloom when the toxin concentrations are too low to be detected [12].

Acknowledgements. This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the Ministry of Education and Science (MES) of Bulgaria (Agreement № D01-363/17.12.2020).

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ANALYSES ON THE GENERAL CHARACTERISTICS OF SOILS IN URBAN FOREST PARKS IN KARDZHALI

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Forest Research Institute – Bulgarian Academy of Sciences (Bulgaria)

Abstract. The aim of present study is to analyze the general characteristics of soils in urban forest parks in a case-study region of Kardzhali and to define tendencies of the current soil processes. The superficial soil in three forest parks Arpezos-North, Central City Park and Prostor Park located in urban and peri-urban zones are studied along a transect with three plots in three repetitions. The general soil characteristics are analyzed following standard procedures. Based on the results it could be summarized that the soils in the studied parks are in good ecological condition in terms of stock of nutrients and organic matter. The lower C:N ratio (Prostor Park) indicates faster nitrogen release into the soil and availability for plants. The higher ratio (Arpezos-North Park and Central City Park) leads to an equilibrium state between the processes of mineralization and immobilization. Alkalization processes are more pronounced in the surface layers of soils in urban parks (Arpezos-North Park and Central City Park) than in park in peri-urban area (Prostor Park). Regarding the heavy metals and metalloids content it was determined a tendency in superficial soils of Prostor and Central City Park, to contain more Cu, Zn, Pb and Ni. The analyses on the current condition of soils, as a fundamental component of urban forest parks in Kardzhali case-study provides a basis for further monitoring on the status of green system in the city and to support the outlining measures for their sustainable management.

Keywords: Kardzhali case-study; Urban forest parks; Superficial soil; General characteristics; Experimental data

Introduction

Climate change has been positioned as one of the most severe environmental threats facing us today [1]. Climate change is one of the defining disasters of the 21st century, and a crucial aspect of future sociological work [2]. Its primary impacts include changing temperatures, ocean acidification, or detrimental effects on biodiversity [3]. Climate change affects natural resources in different ways. Subsequently, the productive potential of soils, which depends on their properties

and climatic conditions, is influenced by these changes at different degree. At the same time the anthropogenic drivers can cause or intensify the process of soil erosion and degradation [4]. Due to the interdependence between human actions and natural disasters, solving problems is only possible through multilateral cooperation between all stakeholders and at all levels.

In recent decades, the environmental problems of the urban environment are exacerbated by climate change and local climate disasters combined with the growing concentration of urban population, increasing public and private transport, global environmental pollution [5, 6, 7]. At the same time urban green spaces are considered to be a cost-effective way for climate adaptation [8]. Therefor special attention on the condition of urban green spaces and their components is urgently needed.

The erosion processes and phenomena caused by geological-tectonic, climatic, hydrological, engineering-geological, and other factors have a significant development on the territory of the Kardzhali municipality in Bulgaria. Erosion is a process that mechanically damages soils by destroying the surface humus layer, and this leads to an annual reduction in soil fertility. About 15% of the territory of the municipality has a "moderate to high actual risk" of surface water erosion of soils (at 8 347 t / ha of soil losses per year), and 4% with a "high real risk" of erosion (at 20 535 t / ha soil losses per year), which is contributed by the vertical division of the relief, the intensity of precipitation and the way of using the territories [9]. To a large extent, the active water erosion in the Kardzhali region was reduced and controlled by the large-scale afforestation carried out in previous years - more than 1 million decares of new forests were afforested and anti-erosion technical measures were carried out. To develop measures that address the problems of erosion and land degradation and their sustainable management and governance in the region, it is necessary to identify and study the causes and main factors for soil degradation [10]. At local level the beginning of public landscaping in the city was set with the construction of the city garden, and over the years two more large parks were created - Gorubso Park and a park with a forest park "Space". And from the last decade - Arpezos - North Park, Business Park and Arpezos - South Park (ongoing), as well as the water mirror of the Arda River. Much smaller gardens and recreation areas located in the inter-block spaces, playgrounds, green areas on the streets and dividing green areas on the larger boulevards of the city, city exits, many squares and squares to cultural monuments. The green areas in the urban area cover 115 ha, which makes almost 10% presence of green areas for wide public use within the city. With the overall implementation of the first three stages of Arpezos - North Park, of the entire Arpezos Park in 2017, the green areas in the city have increased and now exceed 27 m^2 per capita.

The aim of present study is to analyze the general characteristics of soils in urban forest parks in a case-study region of Kardzhali and to define tendencies of the current soil processes. These key issues are discussed within the context of

identifying the milestone for further monitoring the condition of urban green spaces in regions, located in zones highly vulnerable to climate change and with ongoing degradation processes (erosion).

Materials and methods

The interaction between the natural physical and geographical conditions determined by the location of the town of Kardzhali in the Eastern Rhodopes and the anthropogenic factors, a result of human activity, affect differently the environmental elements in the urban area of the town, which is chosen as a case-study area in present analyses. Three urban forest parks are selected Arpezos – North, Central City Park and Park Prostor.

Arpezos North Park is the newest park in the town of Kardzhali, opened in September 2012 and is part of a comprehensive project for urban development. It is realized as a functional connection between the existing and newly designed nearby green areas (City Garden and Arpezos-South Park), along the bed of the main city-forming factor - Arda River, reconstructed in the so-called "Water Mirror", ensuring flood safety in the city. The project is implemented with a grant under the Operational Program "Regional Development" (2007-2013) and its idea is to fit the new park, complement and enrich the green system of the city. The green areas of the park are made up of a large variety of plant species, carefully selected and arranged in dynamic combinations. The implementation of landscaping activities relies on open grassy areas with resistant to trampling grass, mixed groups of deciduous and coniferous trees, evergreen and deciduous shrubs, ornamental grasses and perennials (perennial) flowers with appropriate aesthetic qualities and in accordance with the climatic conditions of the region. The periphery of some alleys and sites is shaped and highlighted by hedges of evergreen shrubs.

The Central City Park was established in 1920 with the planting of ornamental species. The construction of the modern city garden has undergone several reconstructions: in the period 1925-1930; in 1953 and 1970 and in the period 1995-2003 [11]. These reconstructions include expansion of its area, repaired and laid sewerage, water supply, alley pavements and architectural elements: sculptures, fountains, pergolas, gazebos, recreation areas. A variety of vegetation was imported, with a high interception rate (90%). During the last reconstruction a new combined children's facility was built, the alley network was reconstructed by replacing the asphalt pavement with paving stones and Ivaylovgrad pavement and the alleys for skateboards, rollerblades and bicycles were re-asphalted. New groups of conifers have been imported.

Park Prostor is located in the peri-urban part of the city. It was built more than fifty years ago. The park has a variety of vegetation and unique tree species. There are great conditions for relaxation and long walks and relaxation. In this park is the only children's railway in the area, which runs during the summer season on a railway track with a length of 1210 m. The train is a reduced copy of a real

train composition. Its path passes by the city stadium "Arena Arda", through a picturesque tunnel and goes around the whole park. The park has a special fenced area for walking dogs.

For study soils a same sampling design was applied in the three selected forest parks. In order to cover the variety of micro relief characteristics in the period May-September 2020 three (3) plots along transect passed from the center to the periphery of each forest park were selected. In each plot the superficial soil (0-10 cm) was sampled in three repetitions — with a total number of 9 samples per park. For determination of the general condition of the soils in studied parks, the soil properties are analysed for a mean sample. The following soil properties were determined: organic carbon (C_{org}) according to the Tyurin method; N_{total} according to Kjeldal; soil texture after Katchinsky [12]. The macro- and microelements concentrations in soils were determined following the standard procedures (ISO 11466:1995) and analyzed by optic emission spectrometer model ICP-Varian 715-ES.

Results and Discussion

The soils in studied urban forest parks are referred to Anthrosols sols according WRB [15] while the naturally distributed soils in the regions are Luvisols Haplic and as presented in Table 1.

Table 1. Soil types in urban forest parks in Kardzhali case-study

Anthrosols (IUSS WG WRB, 2015) in urban forest park	Soil type
	Natural soil type IUSS WG WRB (2015)
Arpezos-North	Calcic Luvisols
Central city park	Haplic Luvisols
Prostor – recreation and culture	Haplic Luvisols

The relative density, porosity, moisture, bulk density and coarse fractions are presented in Table 2.

Table 2. General physical characteristics of soils in urban forest parks in Kardzhali case-study

Urban forest park	No. plot	Relative density	Porosity %	Moisture %	Bulk density g/cm^3	Coarse fractions > 1mm	Coarse fractions > 3 mm
Arpezos North	1 2 3	2,6 2,5 2,1	66 66 66	9,38 26,90 13,24	1,46 1,43 1,42	23,60 18,48 13,81	15,41 9,74 35,35
Central Park	1 2 3	2,4 2,1 2,3	76 75 76	10,07 23,60 15,33	0,92 0,97 0,92	9,41 8,54 6,38	4,00 0,97 12,69

Prostor – recreation and culture	1 2 3	2,7 2,5 2,6	50 46 46	6,87 6,98 12,31	1,34 1,34 1,40	3,97 4,58 9,09	1,11 0,67 0,18

Table 3. Textural composition of the soils from the urban forest parks of Kardzhali case-study

Urban forest park	No.plot	1-0,25 %	0,25-0,05 %	0,05-0,01 %	0,01-0,005 %	0,005-0,001 %	<0,001 %	Sand %	Silt, %	Clay %	FAO 1990
Arpezos-North	1	21,10	41,78	12,27	4,09	4,09	8,18	62,88	28,94	8,18	SL
	2	24,33	39,99	4,12	4,13	12,37	8,25	64,32	27,43	8,25	SL
	3	37,31	18,85	12,44	n.d.	12,43	12,44	56,16	31,40	12,44	L
Central city park	1	54,60	4,00	16,52	8,25	4,13	8,26	58,60	33,14	8,26	L
	2	50,40	5,16	12,10	7,52	13,22	8,56	55,56	35,88	8,56	L
	3	40,85	6,48	14,90	4,15	18,30	6,60	47,33	46,07	6,60	SL
Prostor	1	35,48	59,12	0,11	-	0,42	0,85	98,62	0,53	0,85	S
	2	25,32	69,75	0,22	0,10	0,72	0,57	98,39	1,04	0,57	S
	3	26,00	67,53	0,58	0,12	0,35	0,95	98,00	1,05	0,95	S

*S-sandy; SL- sandy-loam; L-loam

Table 4. Macro-elements in superficial soil in urban forest parks in Kardzhali

Urban forest park	No. plot	Org. C, %	Total N, %	pH in H_2O	C:N
Arpezos- North	1	2,3998	0,1195	7,30	20,08
	2	3,3388	0,2206	7,43	15,14
	3	3,3756	0,2375	7,25	14,21
Central city park	1	2,3998	0,1777	7,45	13,50
	2	5,7387	0,2972	7,13	19,31
	3	3,4432	0,1378	7,41	24,99
Prostor	1	4,5082	1,8537	6,29	2,43
	2	6,5974	2,4052	6,63	2,74
	3	1,9992	1,5014	6,93	1,33

The soils of the studied three forest parks, which are part of the urban green infrastructure of the Municipality of Kardzhali, were formed under the influence of direct human activity, as a result of which changes in their genetic traits and properties have occurred. Therefore, they are referred to anthropogenic soils (Anthrosols) according WRB (2015). The distribution of this soil type has an intrazonal character depending on the specific local impact of the anthropogenic factor, which manifests itself in two directions: change of natural soils or formation of "new" soils. In the present case-study, the type of anthropogenic soils, based on the main directions of

anthropogenic impact, morphological features of the profiles and qualitative and quantitative characteristics of some diagnostic properties, is represented by the type of soils Urbic. Specific features that distinguish urban soils from natural soils, which for the parks in Kardzhali case-study area are cinnamon forests soil, leached, formed on alluvial parent material, sandy and sandy-clay [13] are further discussed. The factors that determine these specific features are the size of the settlement, the technology of creating, using and maintaining green areas, such as the application of heavy machinery, trampling, frequent digging, improper watering and fertilizing, intensive mowing, grass removal, collection and removal of leaf litter, accumulation of snow mixed with salt. Under these conditions, in older parks or suburban parks and sports areas, anthropogenization in green areas occurs only in the upper part of the profile of natural soils, which are in focus of the present analyses.

The general physico-chemical characteristics of the soils from the studied forest parks are given Tables 2, 3 and 4 and provide information about the susceptibility of the soil to degradation.

A widely used method of Katchinsky for determining the bulk density (g/cm^3) and one in which the most accurate results are obtained was applied. The bulk density depends on the peculiarities of the textural composition, the amount of organic matter, the structural condition of the soils and averages about 1.3-1.5 g/cm^3, and in the studied urban soils (Central Park) the bulk density does not exceed 1 g/cm^3. There is a tendency of a significant increase in the skeletal fraction (either over 1 mm or that over 3 mm) in the surface layers of the soils of Arpezos - North Park compared to Central City Park and park Prostor (Table 2). A similar trend is found with respect to the sand fraction (determined by ISO 11277: 2020), defined as on the triangular diagram [16]. This fraction dominates over the clay content especially in soils from park Prostor (Table 3). The mechanical composition of the soil, estimated using the triangular diagram, is determined based on the ratio between the three fractions: sand (particle size 2000-63 μm), silt (particle size 63-2 μm) and clay (particle size < 2 μm). Each point of the triangular diagram reflects the percentage of these three fractions, with the soils in Arpezos - North Park being defined as sandy to loamy and the soils in Central City Park as loamy to finely loamy, while for park Prostor the soils are referred as sandy according to their textural composition. In both parks, Arpezos – North and Central City Park, there is an increase in soil porosity (66-76%), which due to the predominance of coarse pores, is inactive. As a result of these features, the soils are characterized by a deteriorated structural condition (Table 2). Water capacity, i.e., soil moisture in the field varies widely (from 9 to 27%).

Soil acidity is determined in aqueous extract (ISO 10390:2005), and pH values express the activity of hydrogen cations in solution. The reaction defined in H_2O is proportional to the active acidity of the soil solution. The detection of an acid reaction indicates the presence of free acids or hydrolytically acid salts and is an indication of the presence of acidity. According to this indicator, the soils of the urban forest parks in Kardzhali case-

study are defined as slightly alkaline (according to Pelishek), with exception of soils in park Prostor, which characterize with low acid to neutral pH (Table 4).

The stock of soils with nutrients is determined by the quantitative content of organic carbon, total nitrogen, and total phosphorus, as well as the ratio between organic carbon and total nitrogen (C: N). The content and ratio of nutrients in the soil are directly related to soil fertility and plant nutrition. The full absorption of nutrients is enhanced in the presence of water, i.e., the level of soil moisture plays a decisive role in this process. In the present studies, the soil moisture from the terrain is higher in the surface substrates of the soils from park Arpezos-North and Central City Park and lower in soils from park Prostor (table 2).

Soil humus, (soil organic matter) is evaluated by the content of organic carbon in the soil (Table 4). According to the quantitative content of humus (according to the scale of Z. Naumov) and according to the mechanical composition, the soils fall into the category of medium humus (3-5%) and high humus (6-9%) content in soils [12]. There is some increase in soil carbon (between 6 and 8%), respectively humus (between 11 and 14%), in the surface arable layer of the urban garden (Central City Park), due to the improvement /additional fertilization of these areas. The variation of carbon content in the superficial layers of urbanized soil suppose different carbon stocks for determined also by the variations in bulk density.

Total nitrogen is part of the soil humus (makes up 1/20 - 1/12 of it) and only a small part, about 1%, is represented by its mineral forms. The amount of nitrogen in the soil, determined by a modified Kjeldal method (ISO 11261:1995), is closely related to the carbon content. This method does not consider the mineral compounds of nitrogen (nitrites and nitrates), but their content in the soil is very small and for describing general soil properties in present study can be neglected. Like carbon, the content of total nitrogen in the studied soils defines them as moderately stocked (from 0.10-0.20%) and well-stocked (from 0.20-0.35%) in Arpezos-North Park and Central city park, and very well-stocked (over 0.35%) in Prostor Park [14].

The ratio C:N, i.e., the amount of organic carbon to the amount of total nitrogen in the soil, reflects the degree of decomposition of organic matter and is an important indicator for clarifying the processes in the soil (Table 4). This ration is an indication of the favorable conditions for the existence and development of soil biodiversity and the stability of soil structure. The slower the decomposition of organic matter, the greater is the amount of carbon and the less the amount of total nitrogen released during decomposition. The calculation of the C:N ratio is used to determine the type of soil humus (Mull, Moder or Mor / Rohhumus). In our study, according to the values obtained for the C:N ratio (between 14 and 24), the type of decomposition in Arpezos-North and Central City Park is Mor and Moder, while at C:N less than 14 in Prostor park the type is referred to Mull [12].

Indicators are informative tools that present information in quantitative or qualitative terms. By containing information, indicators simplify the detection and

quantification of environmental processes, which are often complex. One of the indicators for assessment of the condition of the soils, developed according to art. 11, para 2 of Ordinance № 4 of 12 January 2009 for monitoring of the soils and used by the Executive Environmental Agency and Regional Inspectorates, is the content of total phosphorus in the soils. According to the five-point Scale for assessment of the content of nutrients in the soil, part of the "Indicators for assessment of soil condition", regulated in Ordinance № 4, the surface layers of soils from the park Arpezos - North and Prostor park have a low (286-547 mg/kg) content of total phosphorus (Table 5). In the soil layers of the Central City Park these quantities are higher and the soils are categorized in the group with average content (565-821 mg/kg).

The content of the total forms of potassium in the areas of park Prostor is also higher, varying between 6291 and 7439 mg/kg (Table 5). Phosphorus is also part of biologically important compounds, whose role for plants is especially important. In the soil it is found in limited quantities, mainly in the form of organic and mineral compounds, most of which are slightly mobile, slightly soluble, and inaccessible to plants. The concentrations and distribution of soil phosphorus depend on the phosphorus content of the parent materials and on the conditions of soil formation. Neutral and alkaline soils are dominated by phosphorus-containing minerals and phosphorus compounds such as calcium phosphates. In the studied sites from the municipality of Kardzhali there is a tendency to increase the content of total phosphorus in the soil layers of the Central City Park, probably related to the more intensive mineral fertilization of these areas (Table 5).

Table 5. Macro- and micro-elements (incl. some heavy metals and metalloids) in the soils of the forest parks in Kardzhali

Urban forest park	No. plot	P	Ca	K	Na	Mg	Al	Fe	Mn	Cu	Zn	Pb	Cd	Ni	B	S
		mg/1000 g														
Arpezos North	1	286,0	19910,5	3068,8	423,4	4381,5	19757,1	9952,2	478,5	8,3	104,0	48,5	<0,2	22,3	n.d.	337,4
	2	465,1	19394,3	3932,1	419,6	4663,9	20584,9	9966,5	615,6	6,8	83,8	37,8	n.d.	17,9	<0,2	569,6
	3	433,6	20100,8	3926,8	363,9	5078,2	20748,3	9901,5	569,8	5,8	83,8	37,2	0,4	15,2	n.d.	467,9
Central City Park	1	564,8	9956,8	4899,8	362,4	6484,0	21048,3	9994,3	748,6	13,0	133,0	68,7	<0,2	40,3	0,9	424,7
	2	810,4	18734,2	5400,2	364,6	7313,4	19347,7	9922,8	861,4	25,2	257,0	128,5	n.d.	55,1	1,4	718,2
	3	820,7	17914,6	5855,6	406,3	8150,6	20468,7	9958,9	753,7	23,4	368,5	171,2	1,2	62,9	5,1	1012,8
Prostor	1	543,9	14078,4	7438,7	980,1	10401,2	25612,2	14739,5	790,9	19,8	209,4	147,6	4,9	10,6	2,2	331,3
	2	509,6	15072,7	6291,2	707,8	8751,4	25848,2	14684,0	743,6	18,2	162,5	118,7	2,6	8,8	4,3	342,9
	3	546,8	10418,7	6981,9	265,0	7392,7	26382,6	14683,9	964,8	24,2	169,9	93,0	1,7	21,0	8,6	356,7

With regard to heavy metals and metalloids content, the results of the analyzes of the studied soils show that no excessive content was registered, i.e. above the maximum permissible concentrations (MAC) for heavy metals and metalloids in the soils of the green system of the city, defined as total content in mg/kg dry soil during extraction with aqua regia (ISO 11466:1995), according to Ordinance № 3 from 1 August 2008 on the norms for permissible content of harmful substances in soils (Table 5). Most likely this fact is a result of the discontinuation in recent years of mining and processing of lead-zinc ores. On the other hand, the urbanized soil layers in the populated part of the city, Arpezos-North Park and Central City Park, have a predominantly weakly alkaline reaction of the soils with pH 7.2-8.0 and light to medium sandy-loam textural composition, which is a prerequisite for reducing the degree of soil contamination.

Conclusion

Based on the analyzed general characteristics of the superficial soils from urban forest parks in Kardzhali the following conclusions can be summarized:

– The study shows that the soils in the urban forest parks of the city are in good ecological condition in terms of stock of nutrients/organic matter, estimated by the measured concentrations of total nitrogen, organic carbon and total phosphorus;

– Higher soil organic carbon content is determined for park Prostor, located in peri-urban area;

– The C:N ratio shows relatively good conditions for decomposition / mineralization of organic matter. The lower C:N ratio (Prostor Park) indicates faster nitrogen release into the soil and availability for plants. The higher ratio (Arpezos-North Park and Central City Park) leads to an equilibrium state between the processes of mineralization and immobilization;

– Alkalization processes are more pronounced in the surface layers of soils in urban parks (Arpezos North Park and Central City Park) than in park in peri-urban area (Prostor Park);

– There is a tendency for the soil layers of the Prostor and Central City Park to contain more heavy metals, especially Cu, Zn, Pb and Ni, as well as an increased content of S.

– The preliminary results indicate that the studied soils from forest parks in Kardzhaly case-study area, in general, are in good ecological condition in terms of heavy metals and metalloids content.

The analyses on the current condition of soils, as a fundamental component of urban forest parks in Kardzhali case-study provides basis for further monitoring on the status of green system in the city and to outline measures for their sustainable management.

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HEALTH CONDITION OF *PINUS PEUCE* AND *PINUS HELDREICHII* FOREST STANDS IN MOUNTAIN AREAS IN BULGARIA

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Abstract. In the period 2020-2021, the health status of 11 stands of Pinus peuce and P. heldreichii was assessed in Pirin Mt. (4 stands), Rila Mt. (3 stands), Slavyanka Mt. (2 stands), Vitosha Mt. (1 stand) and Konyavska planina Mt. (1 stand). The survey was based on remote sensing and terrestrial verification. The remote sensing data was obtained by capturing with unmanned aerial vehicle 'Autel Robotics EVO II' equipped with multispectral camera 'Parrot SEQUOIA'. In field studies, an assessment of the defoliation of tree crowns and a registration of damages caused by abiotic and biotic factors was conducted. The defoliation in P. peuce stands varied between 21.3% and 44.8%, and in P. heldreichii stands – between 24.5% and 49.5%. Abiotic damages by strong wind, wet snow and ice-break were registered in studied stands. Among the biotic factors, the main damages were caused by fungal pathogens (Heterobasidion annosum, Diplodia sapinea, Cenangium ferruginosum) and bark beetles (Ips sexdentatus, I. amitinus, etc.).

Keywords: Macedonian and Bosnian pines; health condition; remote sensing; defoliation; biotic factors

Introduction

The Balkan endemic Macedonian pine (*Pinus peuce* Griseb.) is distributed in Bulgaria in the mountains areas of Rila, Pirin, the Western Rhodopes, Central Balkan Range, Slavyanka and Vitosha, at an altitude of 1400 to 2100 m a.s.l.

The subendemic for the Balkans Peninsula, the Bosnian pine (*Pinus heldreichii* Christ) grows only in the Pirin and Slavyanka Mts. on karst terrains in the upper border of the forest areas.

In the harsh environmental conditions at the forest treeline, *P. peuce* and *P. heldreichii* are influenced by severe abiotic factors (wet snow, strong wind, ice breaks, extreme snowpack etc.), which are a prerequisite for the appearance of calamities of insect pests and epiphytotic diseases of fungal pathogens. It should be noted, that

till now, no special studies have been conducted on the health status of Macedonian and Bosnian pines in Bulgaria.

The aim of this study is to assess the health status of natural stands and plantations of *P. peuce* and *P. heldreichii* on the basis of remote sensing data and field verification.

Material and methods

The assessment of health status of Macedonian and Bosnian pine stands was performed through an integrated approach, including remote sensing data and terrestrial verification. In Bulgaria, a similar approach has already been applied in assessing the health of vegetation in green systems of Karlovo [1] and two forest reserves in Western Balkan Range [2].

Studied areas

The studies were conducted during the period 2020-2021 in six stands of *Pinus peuce* and five stands of *P. heldreichii* located in Pirin Mt. (4 stands), Rila Mt. (3), Slavyanka Mt. (2), Vitosha Mt. (1) and Konyvska planina Mt. (1) (Table 1).

Table 1. Main characteristics of studied areas

Sample plot	Region	Origin	Geographical coordinates	Altitude, m a.s.l.	Stand age (years)
Pinus peuce					
Panichishte	Rila Mt.	Natural stand	42°13′41.4″N 23°19′30.7″E	1948	150
Malyovitsa	Rila Mt.	Natural stand	42°12′32.3″N 23°23′24.1″E	1760	110
Treshtenik	Rila Mt.	Natural stand	42°04′55.8″N 23°37′04.9″E	1915	100
Vihren	Pirin Mt.	Natural stand	41°45′42.9″N 23°25′01.0″E	1969	150
Todorka	Pirin Mt.	Natural stand	41°46′02.3″N 23°26′57.0″E	1993	150
Goli vrah	Vitosha Mt.	Plantation	42°35′31.1″N 23°17′33.4″E	1814	90
Pinus heldreichii					
Banderitsa	Pirin Mt.	Natural stand	41°46′05.0″N 23°25′26.1″E	1876	150
Peyo Yavorov hut	Pirin Mt.	Natural stand	41°49′22.8″N 23°22′38.2″E	1716	130
Gotsev vrah	Slavyanka Mt.	Natural stand	41°23′30.4″N 23°36′34.9″E	1840	150
Marina Polyana	Slavyanka Mt.	Natural stand	41°23′57.7″N 23°36′42.1″E	1636	130
Viden peak	Konyavska planina Mt.	Plantation	42°20′52.6″N 22°50′16.3″E	1479	40

Remote sensing

Remote Sensing data was obtained by capturing with Unmanned Aircraft Vehicle (UAV) 'Autel Robotics EVO II' equipped with multispectral camera 'Parrot SEQUOIA'. The camera was equipped with a solar radiation sensor for calibration of the obtained reflex images.

The multispectral camera provides high-resolution images in a standard RGB channel and four channels of the electromagnetic spectrum: Green - reflected energy in the 530-570 nm spectral band; Red - 640-680 nm spectral band; Red Edge - 730-740 nm; Near-infrared - wavelengths in the 770-810 nm range.

Normalised Difference Vegetation Index (NDVI) was used to assess the vitality of trees, obtained by digital mixing of imagery, captured in the Red and near-infrared (NIR) range. It was calculated in accordance with the formula:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

NDVI is a spectral index used to measure the relationship between the NIR and red range of the spectrum indicates the vegetation condition and state of plant health due to chlorophyll absorption of specific wavelengths of light within red spectral range and high reflectance within the NIR range.

NDVI varies between -1.0 and +1.0, representing greens, where negative values are formed from clouds, water and snow, and values close to zero are primarily formed from rocks and bare soil. The forest canopy typically has values between 0.6 and 1.0. In forests, the very small values (0.1 or less) of NDVI correspond to empty or affected by human activity areas (roads, buildings, technical equipment, etc.), while moderate values (from 0.2 to 0.3) represent meadows and shrubs.

Terrestrial verification

In each sample plot, the assessment of tree condition was conducted on 40 trees according to ICP Forests Manual [3]. The rate of defoliation (loss of leaves in the assessable crown compared to a local reference tree in the field) was estimated in 5% steps, ranging from 0% (no defoliation) to 100% (dead tree).

Defoliation values were grouped in five classes: 0 – no defoliation (leaf loss up to 10%); 1 – slight defoliation (leaf loss >10-25%); 2 – moderate (leaf loss >25-60%); 3 – severe (leaf loss >60<100%); 4 – dead tree (leaf loss l00%).

Defoliation surveys were conducted in combination with detail assessment of damages caused by abiotic and biotic factors: wind throws, ice breaks, insect pest attacks, fungal pathogen infestations, etc.

Results

The analysis of the NDVI models showed that the studied stands of *P. peuce* were in relatively good condition. The presence of red stripes and spots on the maps is associated with roads, trails for lifts and ski slopes (Figure 1, A, C, F),

open spaces and buildings (Fig. 1, B), meadows (Figure 1, E) and rock screes (Figure 1, D).

The NDVI of *P. peuce* stands was quite high – it predominately ranged from 0.66-0.79 (Todorka Peak) to 0.89-0.92 (Goli Vrah Peak), with an average value between 0.69 (Vihren Hut) and 0.81 (Goli Vrah Peak) (Table 2), which is an indication of the good viability of Macedonian pine in studied stands.

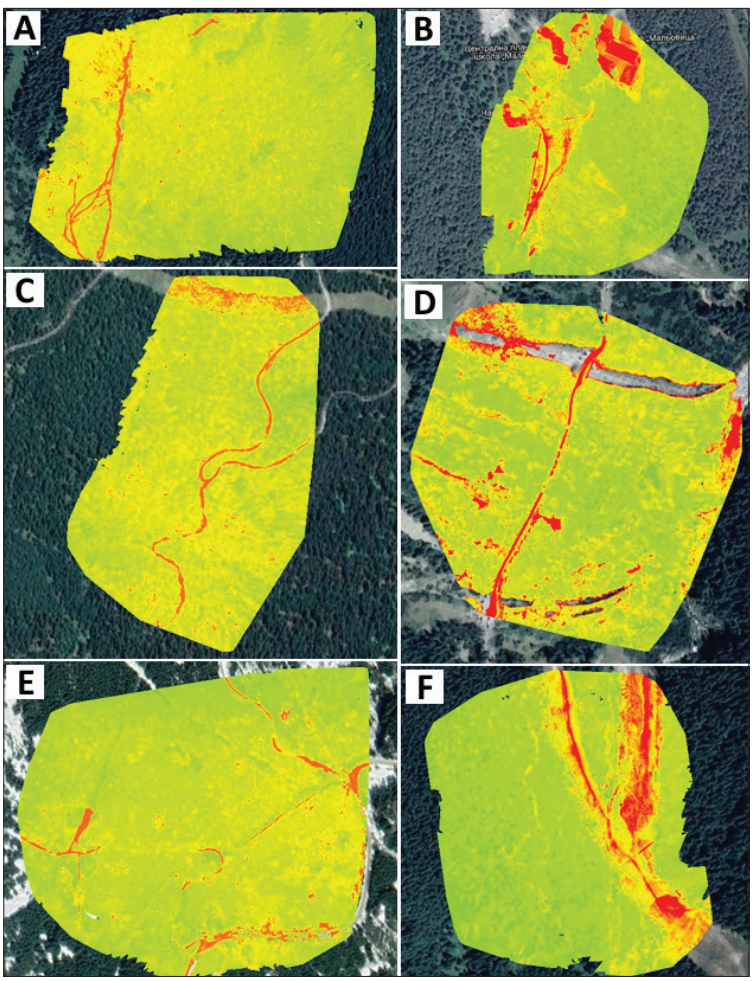

Figure 1. NDVI maps of studied sample plots of *Pinus peuce*: A – Panichishte; B – Malyovitsa; C – Treshtenik; D – Vihren Hut; E – Goli Vrah Peak; E – Todorka Peak

Table 2. NDVI of captured areas

Sample plot	Predominant range (Relative share)	Average value
Pinus peuce		
Panichishte	0.81-0.886 (38.8%)	0.78
Malyovitsa	0.66-0.79 (50.5%)	0.72
Treshtenik	0.81-0.86 (36.6%)	0.76
Vihren Hut	0.76-0.84 (31.6%)	0.69
Todorka Peak	0.80-0.88 (49.3%)	0.77
Goli Vrah Peak	0.89-0.92 (46.4%)	0.81
Pinus heldreichii		
Banderitsa	0.65-0.74 (37.1%)	0.61
Peyo Yavorov Hut	0.75-0.81(43.8%)	0.67
Gotsev Vrah Peak	0.79-0.84 (31.2%)	0.75
Marina Polyana	0.73-0.78 (43.0%)	0.69
Viden Peak	0.90-1.00 (29.5%)	0.77

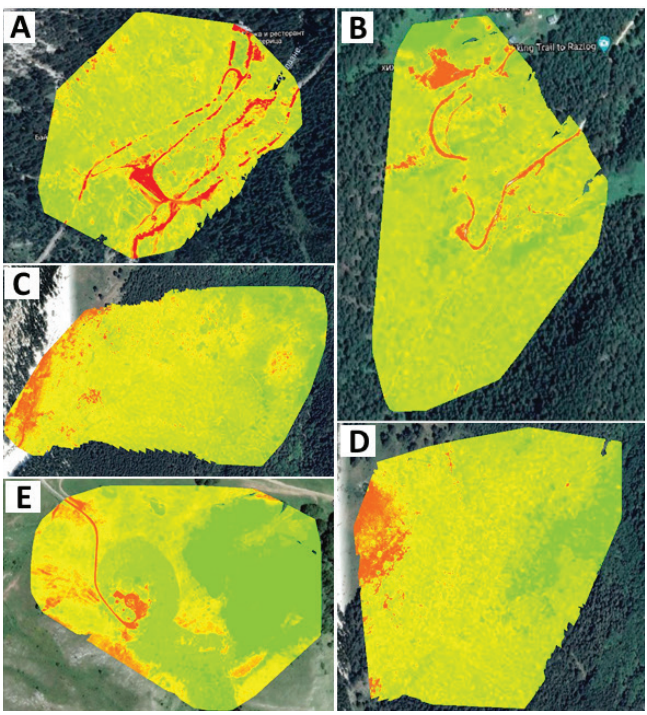

Figure 2. NDVI maps of studied sample plots of *Pinus heldreichii*:
A – Banderitsa; B – Peyo Yavorov hut; C – Gotsev Vrah Peak;
D – Marina Polyana; E – Viden Peak

The red stripes and spots on NDVI models of *P. heldreichii* reflect roads, parking sites, buildings, technical equipment (Figure 2, A, B, E) and meadows (Figure 2, C, D). The NDVI of Bosnian pine was also high, ranging predominately from 0.66-0.74 (Banderitsa) to 0.90-1.00 (Viden Peak), with an average value between 0.61 and 0.77 (Table 2).

The field verification confirmed the relatively good condition of *P. peuce* and *P. heldreichii* stands and plantations. They had a high degree of canopy cover (0.7-0.8) and low levels of defoliation, predominately in 0-2 classes.

In Macedonian pine, the average defoliation varied between 11.3% (Vihren Hut) and 20.3% (Malyovitsa) (Figure 3).

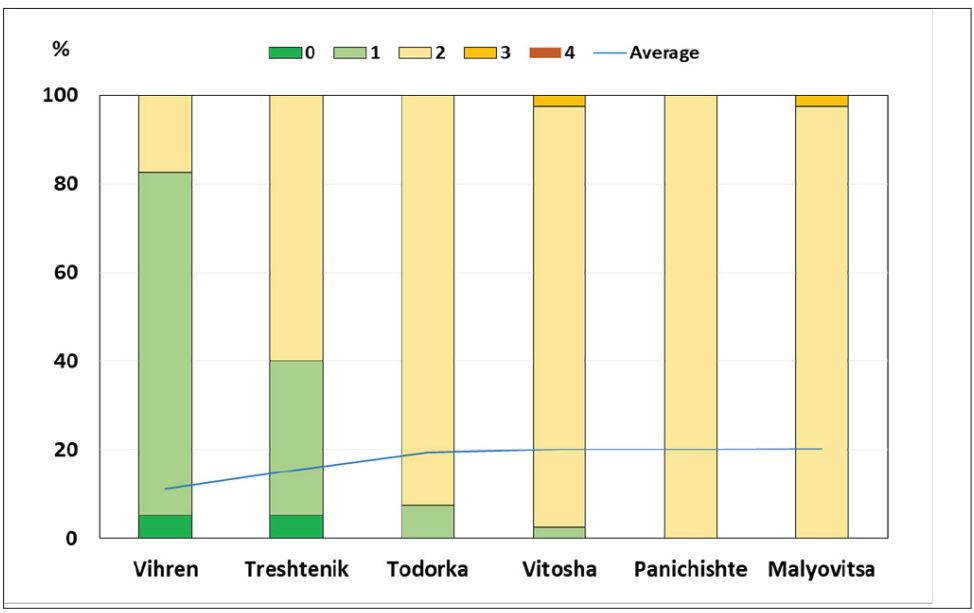

Figure 3. Defoliation of trees in *Pinus peuce* stands

Approximately the same average levels of defoliation were established in *P. heldreichii* stands and plantations, between 13.5% (Peyo Yavorov Hut) and 20.3% (Gotsev vrah) (Figure 4).

Damages by abiotic factors (windfalls, snowbreaks and icebreakers) have been found only in separate trees.

Damages caused by five xylophagous insects and seven fungal pathogens were established in *P. peuce* and *P. heldreichii* stands (Table 3). Among the bark beetles (Coleoptera: Curculionidae, Scolitinae), the most important was *Ips sexdentatus* (Börner, 1776) damaging the stems of Macedonian and Bosnian pine. The remain-

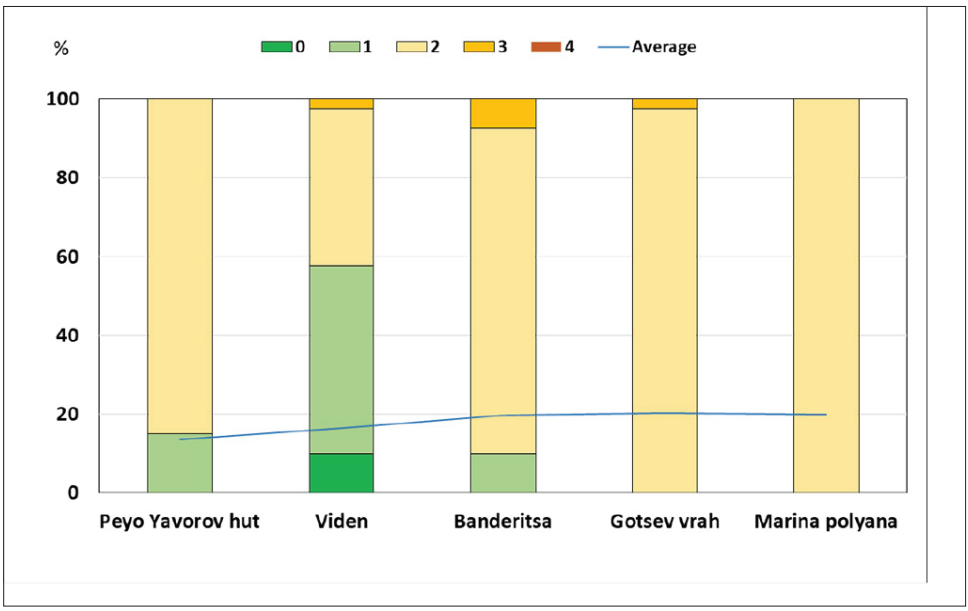

Figure 4. Defoliation of trees in *Pinus heldreichii* stands

ing three bark beetles, *Crypturgus pusillus* (Gyllenhal, 1813), *Ips amitinus* (Eichhoff, 1871) and *Pityogenes chalcographus* (Linnaeus, 1761) were found only in branches of *P. peuce* (Table 3). As concerns the longhorn beetle *Rhagium inquisitor* Linnaeus, 1758 (Coleoptera: Cerambycidae), it was recorded to develop under bark of fallen trees.

Table 3. Damages caused by biotic factors

Species	Host tree	Damaged organs	Importance*
Insect pests			
Ips sexdentatus	*Pinus peuce, P. heldreichii*	Stems	+++
Ips amitinus	*Pinus peuce*	Branches	++
Crypturgus pusillus	*Pinus peuce*	Branches	+
Pityogenes chalcographus	*Pinus peuce*	Branches	+
Rhagium inquisitor	*Pinus peuce, P. heldreichii*	Stems	+
Fungal pathogens			
Heterobasidion annosum	*Pinus peuce, P. heldreichii*	Roots and stems	+++
Armillaria mellea	*Pinus peuce, P. heldreichii*	Roots and stems	++

Fomitopsis pinicola	*Pinus peuce, P. heldreichii*	Stems	+
Cenangium ferruginosum	*Pinus peuce, P. heldreichii*	Branches	++
Cytospora pinastri	*Pinus peuce, P. heldreichii*	Needles	++
Lophodermium pinastri	*Pinus peuce, P. heldreichii*	Needles	+
Diplodia sapinea	*Pinus peuce, P. heldreichii*	Needles, branches and cones	++

*Importance: + Slight; ++ Moderate; +++ Severe

The fungal pathogens *Heterobasidion annosum* (Fr.) Bref., *Armillaria mellea* (Vahl) P.Kumm. and *Fomitopsis pinicola* (Sw.) P.Karst. caused damages on roots and stems of *P. peuce* and *P. heldreichii* (Table 3). *Cenangium ferruginosum* Fr. was established on branches, *Cytospora pinastri* Fr. and *Lophodermium pinastri* (Shrad.:Fr.) Chev. - on needles, and *Diplodia sapinea* (Fr.) Fuckel - on needles, branches and cones of both species. The most important was *H. annosum*, followed by *A. mellea*, *C. ferruginosum*, *C. pinastri* and *D. sapinea*.

Discussion

At present, no detailed studies on health status of *P. peuce* and *P. heldreichii* have been conducted in Bulgaria. Comprehensive studies on the complexes of insect pests and fungal pathogens on both species have also not been performed. There is only one exception related to bark beetles. [4] and [5] reported previously above mentioned four species (*Ips sexdentatus*, *I. amitinus*, *Crypturgus pusillus* and *Pityogenes chalcographus*) in trophycal connection with Macedonian and Bosnian pine in Rila, Pirin and Vitosha Mts. In addition, other representatives of bark beetles were reported on *P. peuce* or *P. heldreichii* in different regions of Bulgaria: *Hylastes ater* (Paykull, 1800), *Hylurgops palliatus* (Gyllenhal, 1813), *Pityogenes bistridentatus* (Eichhoff, 1878), *Pityogenes quadridens* (Hartig, 1834), *Pityophthorus lichtensteinii* (Ratzeburg, 1837), *Tomicus piniperda* (Linnaeus, 1758) [6, 7], *Pityophthorus buyssoni* Reitter, 1901 [8], *Orthotomicus laricis* (Fabricius, 1792) (Йоакимов, 1899), *Pityogenes conjunctus* (Reitter, 1887) (Pfeffer, 1984), *Pityophthorus knoteki* Reitter, 1898 (Pfeffer, 1936),

With exception of bark beetles, the weevil *Pissodes pini* (Linnaeus, 1758) (Coleoptera: Curculionidae) was recorded on *P. peuce* in Pirin Mt. [9]. In other regions of Bulgaria, two longhorn beetles, *Rhagium inquisitor* (Linnaeus, 1758) and *Acanthocinus griseus* (Fabricius, 1793) (Coleoptera: Cerambycidae) were reared from fallen stems and broken branches of *P. peuce* [10].

In conclusion, it should be noted that the results of present study showed very good health status of Macedonian and Bosnian pines in Bulgaria. In addition, it should be underlined that the combined approach from remote data and

terrestrial verification not only facilitates studies but also improves the quality of the results.

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PRODUCTIVITY AND PHYSIOLOGICAL RESPONSE OF FOUR HYBRID POPLAR CLONES GROWN ON DIFFERENT TYPE OF SUBSTRATE

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Abstract. In order to reveal the productivity and physiological response of different poplar clones 200 cuttings of 4 hybrid poplar clones – "BL", "Agathe", "45/51" and "37/61" were set in rooting containers in 2 variants of cultivation - soil substrate and compost. The necessary growing activities for the poplar saplings were taken during the growing season, including watering and treatment against pathogens and insect pests. The growing parameters - height and diameter of the seedlings of 1-year-old seedlings were measured and the differences between poplar clones were reported. The rate of light-saturated photosynthesis and transpiration rate were measured with a portable infrared gas analyser Li-6400 and water use efficiency was calculated. The effect of genotype (clone) and substrate on the health status, growth in height and diameter and the physiological indicators - intensity of photosynthesis, intensity of transpiration and water use efficiency were studied. The results of the study showed the presence of significant clone differences of the studied functional parameters pertained to the growth and productivity of the studied four hybrid poplar clones at a young age. Poplar clone "BL" was found to show the best growth characteristics compared to the others at the age of seedlings one year. The growing substrate has also a significant effect on the variability of growth and physiological parameters among different poplar clones.

Keywords: hybrid poplars; growth; productivity; photosynthesis; water use efficiency

Introduction

The continual increase in the consumption of wood raises the problem of rapid reproduction, whereat each year the area of fast-growing tree species plantations expands worldwide. Biomass production in short-rotation forestry is a result of various factors and their interactions, including spacing, site quality, weed management, fertilization, and genetic background [1].

Special attention must be paid on the selection of appropriate genotypes, which will ensure the yield of a sufficient amount of raw material and will increase the efficiency of energy plantations [2, 3].

Hybrid poplars (*Populus* spp.) are particularly well suited to short-rotation forestry, since they can reach very high productivity within relatively short periods of time for efficient fiber or energy production, CO_2 sequestration, or phytoremediation of polluted lands [4]. Hybrid poplar clones are traditionally used for enhancing biomass production, which are preferred tree species due to the relatively fast return of the investment and the possibility for establishment of sustainable and resistant to dustiness and smokyness agroforestry systems, even in the early years after afforestation.

Poplars are fast-growing tree species with high productivity and are suitable for growing in temperate climates. Their wood is characterized by specific qualities that determine its high demand in international markets. Poplars are also characterized by high levels of photosynthesis and water exchange [5, 6, 7]. Last but not least, the easy vegetative propagation of poplars should be emphasized, because of which significant areas of forest plantations have been established in recent decades and significant genetic fund of local and introduced species and hybrid forms and clones have been collected.

In addition to woody biomass production, poplars are also used for landscaping, for decreasing soil and wind erosion as well as in the construction of field protection belts, where they begin to perform their functions as early as the first 2-3 years after afforestation [8]. Poplars are also characterized with recreational and socio-aesthetic functions, since most often poplar plantations are created in areas with low forest cover.

The efficiency of the use of biomass for energy purposes depends mainly on the productivity and sustainability of the created plantations that's why an important point in management activities is the selection of appropriate genotypes, which will ensure the yield of a sufficient amount of raw material [2].

In the present study some functional characteristics related to the growth and productivity of hybrid poplar clones at a young age were presented, to assess their potential for biomass production. The effect of the clone and the type of substrate on growing parameters and physiological indicators - intensity of photosynthesis, intensity of transpiration and water use efficiency was also studied.

Materials and methods

Plant material

To reveal the studied parameters 200 cuttings of 4 hybrid poplar clones – "BL", "Agathe", "45/51" and "37/61" were set in rooting containers in 2 variants of cultivation - soil substrate and compost (Figure 1). The cuttings were standard sizes: length 20-25 cm and thickness 8-18 mm. Until planting, they are stored in

Figure 1. Poplar saplings - 2 months after planting the cuttings

plastic bags in a refrigerator at temperatures from +2 to + 5 ° C to avoid mold and to prevent drying. The planting of the winter stem cuttings took place when the period of permanent retention of high air and soil temperatures occurred.

The necessary growing activities for the poplar saplings were taken during the growing season, including watering and treatment against pathogens and insect pests. The growing parameters - height and diameter of 1-year-old seedlings were measured and the differences between poplar clones were reported. The effect of genotype (clone) and substrate on growth in height and diameter and the physiological indicators - intensity of photosynthesis, intensity of transpiration and water use efficiency was studied.

Physiological parameters

The rate of light-saturated photosynthesis (An, μmol CO_2 m^{-2} s^{-1}) and transpiration rate (E, mmol H_2O m^{-2} s^{-1}) of each leaf (three per sapling) were measured with a portable infrared gas analyzer Li-6400 (Li-Cor Biosciences, Lincoln, NE, USA) (Figure 2) at 1000 μmol m^{-2} s^{-1} air photosynthetic photon flux density (PPFD), ambient CO_2 concentration (413.4 ± 1.5 μmol CO_2 mol-1), air temperature (TA = 31.8 ± 0.3 °C) and relative humidity (HD = 40.8 ± 0.3 %). The values of gas exchange variables were recorded after lowering the total coefficient of variation less than 0.5%. The air pumped into the Li-6400 was passed through a buffering tank (10 L) with a constant flow rate (500 μmol air s-1). Water use efficiency (WUE, μmol CO_2 $mmol^{-1}$ H_2O) was calculated in each case of measurements as a proportion of An and E [9], separately for each leaf.

Statistical processing

The statistical processing of the obtained results for the studied physiological parameters was performed in Microsoft Excel for Office 365 (Microsoft, Redmond, WA, USA) and includes an outlayer test (Grubbs's test0 [10], a distribution normality test (Shapiro-Wilk test) [11], ANOVA [12] test for reliability of differences for the studied indicators, followed by test for reliability of differences between individual clones (Tukey Test) [13]. All tests were performed with a threshold probability of rejecting the null hypothesis of 5% (P-value <0.05). Biometric measurement data are also statistically processed. ANOVA test was used to prove the differences between the individual parameters and Tukey test to prove statistically significant differences between the studied hybrid poplar clones.

Figure 2. Portable infrared gas analyzer Li-6400 (Li-Cor Bioscience, Lincoln, NE, USA)

Results and discussion

A high percentage (over 90%) of rooting of poplar cuttings has been achieved. The highest percentage was obtained for poplar clone "45/51" - 97.5%, and the lowest - for "Agathe" - 92.0%.

The root collar diameter of 1-year-old poplar seedlings grown in soil substrate varies from 2.43±0.51 to 3.89±1.12 mm, and the differences between the individual clones are statistically significant (F = 4.250, Sign. = 0.007). The differences among poplar clones obtained for the height of the seedlings are also statistically significant (F = 5.153, Sign. = 0.002), as the values vary in the range from 111.43±22.09 to 157.45±35.12 cm (Figure 3). The highest values for both indicators were found for clone "BL", and the lowest - for clones "Agathe" and "45/51" for root collar diameter and stem height of the seedlings, respectively.

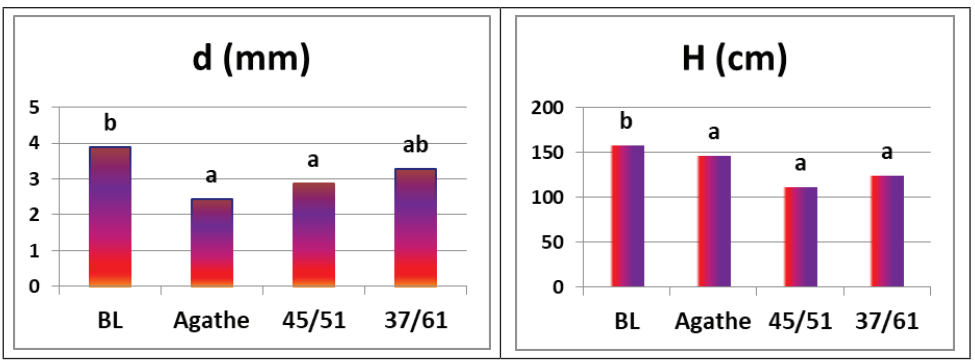


Figure 3. Growing characteristics of 1- year poplar seedlings – soil substrate
Note: Different letters indicate significant differences among means after Tukey's test ($P \leq 0.05$)

The root collar diameter of the seedlings grown in compost mixture varies in the range 2.65±0.82 mm detected for clone "Agathe" to 3.95±1.13 mm for "BL". The differences between the studied poplar clones were statistically significant (F = 3.213, Sign. = 0.03). The values for seedlings' height vary from 122.42±25.14 cm, for clone "45/51" to 152.11±43.10 cm for "Agathe". The differences between clones were not statistically significant (Figure 4).

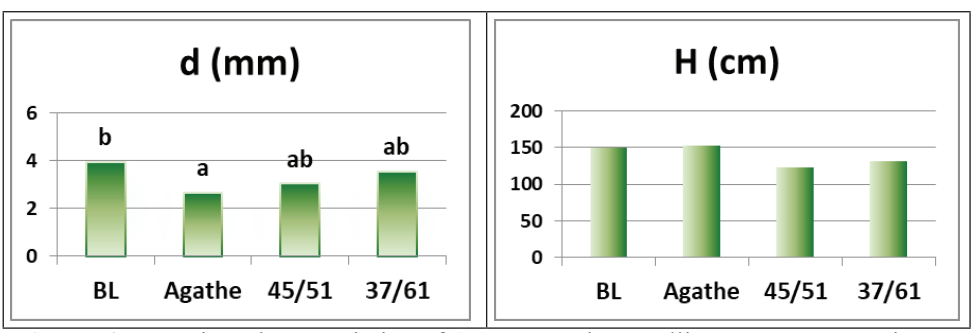
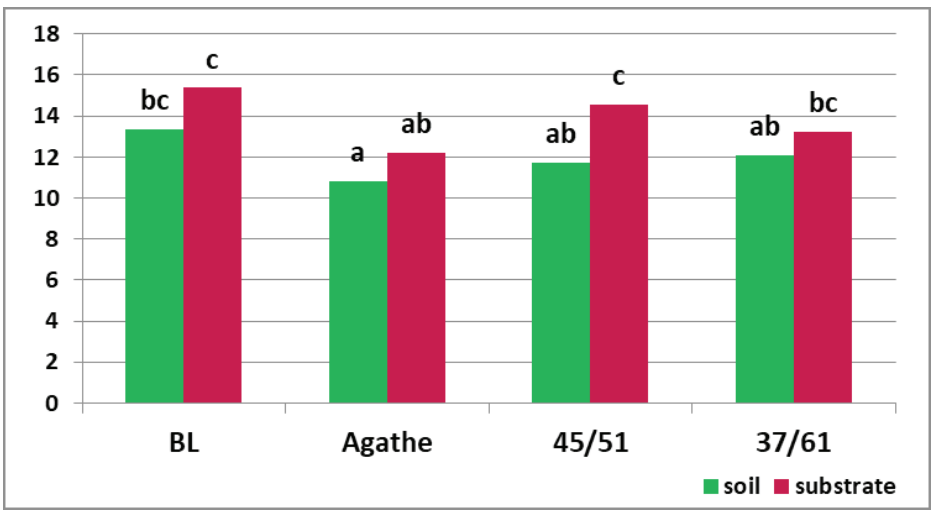
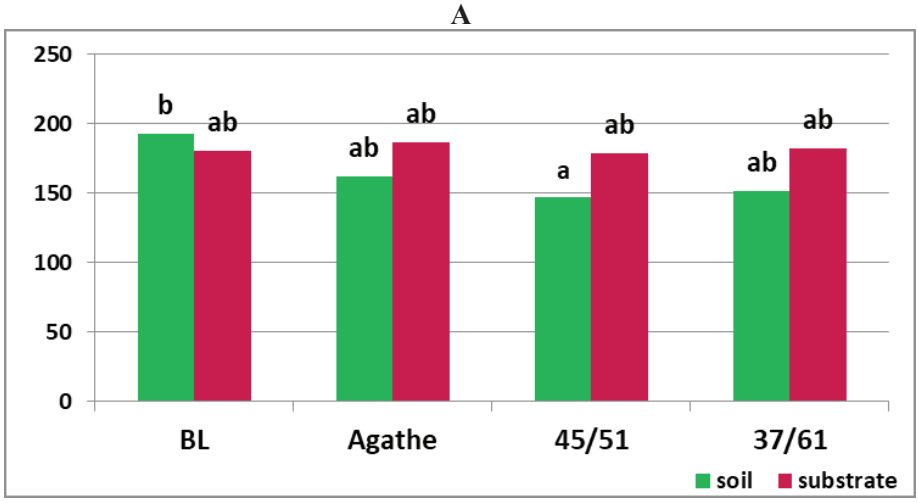


Figure 4. Growing characteristics of 1- year poplar seedlings – compost mixture
Note: Different letters indicate significant differences among means after Tukey's test ($P \leq 0.05$)

Significant differences in growth parameters were also found depending on the growing substrate of poplar seedlings (F = 4.418, Sign. = 0.000; F = 3.086, Sign. = 0.004, for d and H, respectively). The seedlings grown in a compost mixture have better growing characteristics, with better impressed differences in root collar diameter. The most pronounced differences were obtained for poplar clone "45/51" (Figure 5 a, b).



A



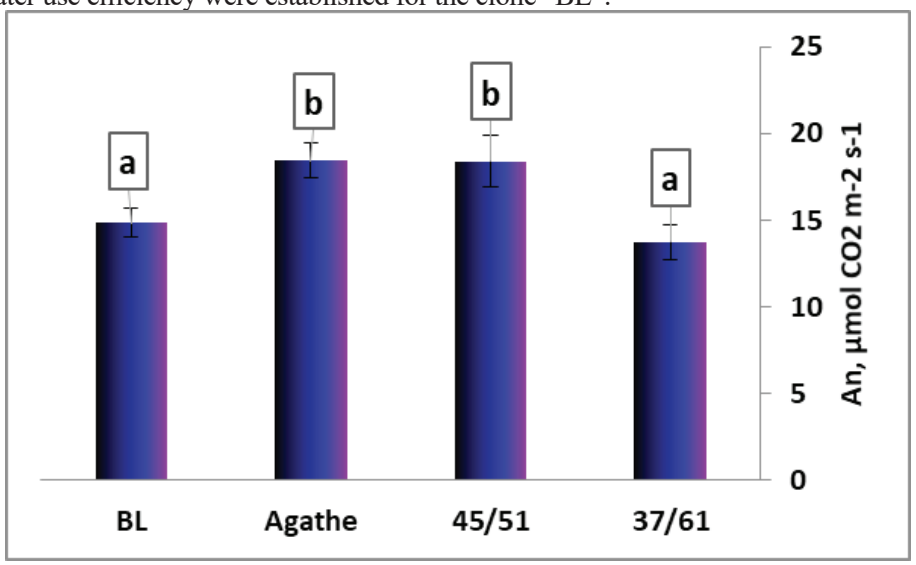
B

Figure 5. Clonal differences in growth parameters depending on the growing substrate (A – diameter, B – height)

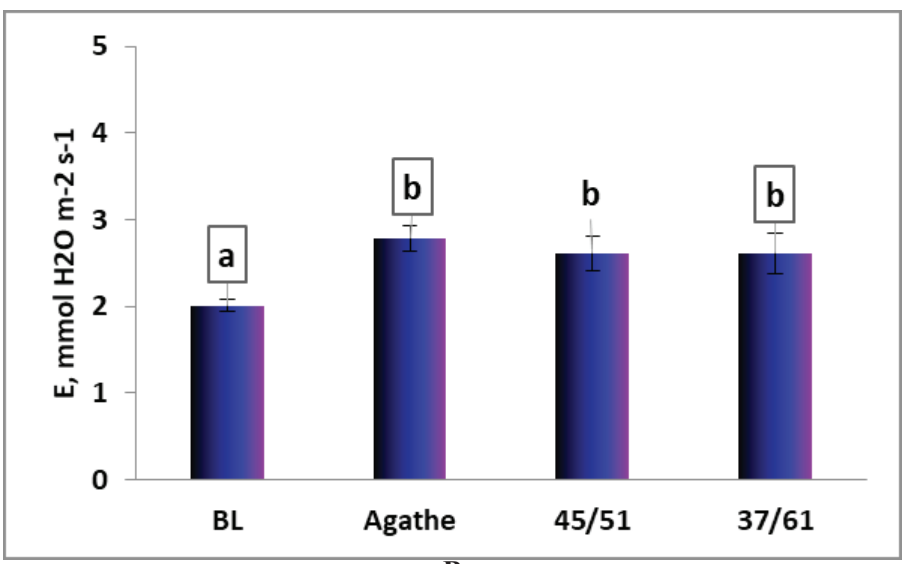
Note: Different letters indicate significant differences among means after Tukey's test ($P \leq 0.05$)

The results from the study of physiological parameters - intensity of photosynthesis, intensity of transpiration and water use efficiency showed the presence of significant clonal differences (Figure 6 a, b, and c, respectively). Poplar clones "Agathe" and "45/51" have a higher level of photosynthesis compared to clones "BL" and "37/61".

For “Agathe”, this reflects intensive growth in height combined with a slow rate of diameter increments, as opposed to “45/51”, where both height and diameter are low. The lowest levels of photosynthesis and transpiration processes and the highest level of water use efficiency were established for the clone “BL”.



A



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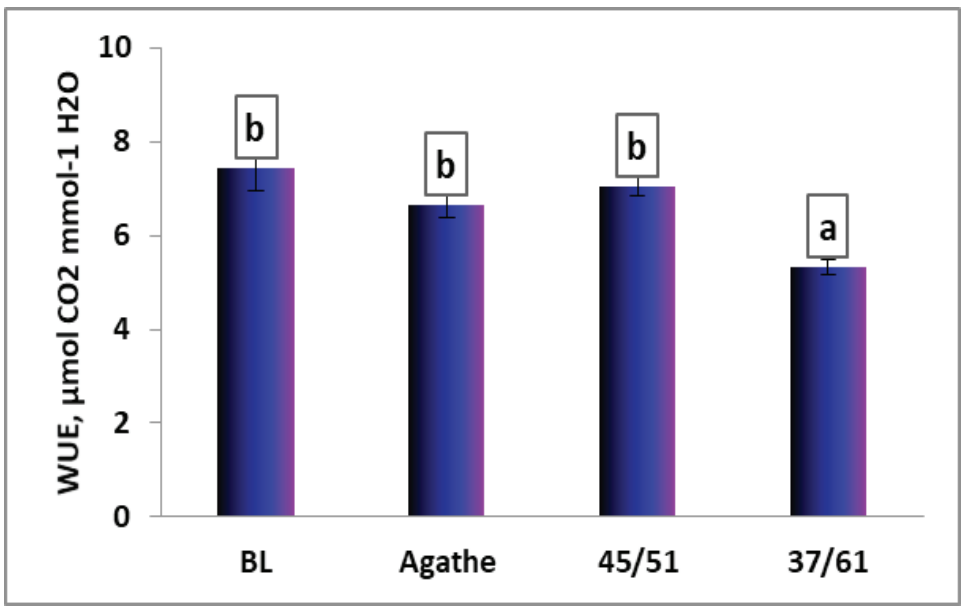

C

Figure 6. Clonal differences in physiological parameters
A – intensity of photosynthesis, B – intensity of transpiration,
C – water use efficiency
Note: Different letters indicate significant differences among means
after Tukey's test ($P \leq 0.05$)

The measured higher intensity of photosynthesis for clones "Agathe" and "45/51" and their lower productivity can be interpreted as a marker for an increased share in the redistribution of the assimilates produced during photosynthesis, probably to the root biomass, which would explain the relatively high water use efficiency of these poplar clones. Lower levels of photosynthesis and transpiration obtained for "BL" are a potential signal for a more economical and efficient leaf gas exchange regime, especially taking into accounts its higher productivity.

Clone "37/61" is characterized by low intensity of photosynthesis and quite intense transpiration, leading to low water use efficiency, which can be interpreted as either clone - specific productivity or as increased stress. [14] also showed higher positive relation of growth with photosynthesis rate, but lower or lack of significant relation with transpiration rate and water resource conservation in *Populus nigra* clones. Their results also demonstrated that the plasticity of *P. nigra* stem base diameter has a sufficient impact on the stem phenotype produced as a response to the resource availability of the corresponding cultivation medium, which is also

confirmed by our results. On the other hand, in the field experiment, [15] establish lower levels of transpiration rate in "Agathe" and "45/51" compared to "BL", and no significant difference in the photosynthetic rate at the same time.

As a result of the comparative analysis of the two cultivation variants, it was found that poplar seedlings grown in a compost mixture are characterized by significantly higher levels of photosynthesis and transpiration intensity, compared to seedlings grown in soil substrate, which is particularly expressed for clone “BL” (Figure 7).

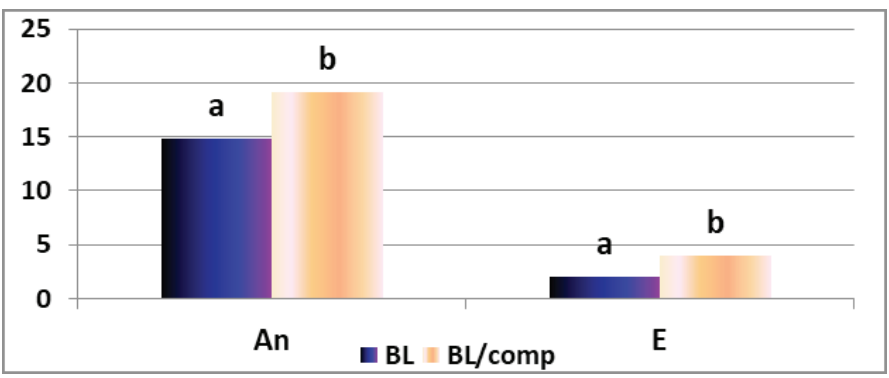

Figure 7. Differences in physiological parameters depending on the growing substrate

Note: Different letters indicate significant differences among means after Tukey’s test ($P \leq 0.05$)

Conclusions

Statistically significant differences were found between studied hybrid poplar clones for growth parameters - root collar diameter and seedling height, grown in soil substrate. For seedlings grown in compost mixture, significant clonal differences are established only for root collar diameter, while the seedling height is not significantly affected by clone.

Significant differences in growth parameters were also found depending on the growing substrate. Poplar seedlings have better growth in compost mixture, with greater differences in root collar diameter and the most distinct from the other - clone “45/51”.

For “Agathe” and “45/51”, the highest values for the studied physiological indicators were measured, but despite its intensive gas exchange, they lag behind in growth. It was found that clone "BL" shows the best growth compared to the others, despite the frugal gas exchange. Clone “37/61” is characterized by clone-specific lower productivity, which is due to low levels of gas exchange.

The growing substrate has also a significant effect on physiological indicators. Poplar seedlings grown in compost mixture have significantly higher levels of intensity of photosynthesis and transpiration, compared to those grown in soil substrate.

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