



Association Milutin Milanković Belgrade

Proceedings of the International Conference

MILANKOVIĆ'S THEORY OF
CLIMATE CHANGES -
HUNDRED YEARS AFTERWARDS

Belgrade, Serbia
4 - 5 November 2024

Proceedings of Conference

**MILANKOVIĆ'S THEORY OF
CLIMATE CHANGES -
HUNDRED YEARS
AFTERWARDS**

Belgrade, Serbia
4 - 5 November 2024

Sponsor:



Ministry of Science, Technological Development and Innovation of the Republic of Serbia

Organizer:



Association Milutin Milanković, Belgrade,

Co-organizers:



University of Belgrade Faculty of Civil Engineering,



University of Belgrade Faculty of Mathematics,



University of Belgrade Faculty of Geography,



University of Belgrade Faculty of Security Studies,



Astronomical Observatory Belgrade

Donors:



Serbian Orthodox
Church in Belgrade



Serbian Chamber of
Engineers Belgrade



Serbian Electric Power
Company Belgrade



Vlatikom Institute
Belgrade



Solar Power Plant Factory
Gornji Milanovac, Belgrade

Scientific Committee



Academician Fedor Mesinger, Chairman Serbian Academy of Science and Arts

Slobodan Simonović, University of Western Ontario, Department of Civil and Environmental Engineering, London, Ontario, Canada

Čedo Maksimović, Imperial College London, Faculty of Engineering, Department of Civil and Environmental Engineering, London, UK

Zoran Stevanović, University of Belgrade – Faculty of Mining and Geology, Department of Hydrogeology – Center for Karst Hydrogeology, Belgrade, Serbia

Dejan Urošević, Faculty of Mathematics, University of Belgrade, Serbia

Petar Kočović, Union University; Belgrade, Serbia

Jelena Luković, Faculty Geography, University of Belgrade, Serbia

Ana Vuković Vimić, Faculty of Agriculture, University of Belgrade, Serbia

Luka Č. Popović, Astronomical Observatory Belgrade, Serbia

Anja Ranđelović, Faculty of Civil Engineering, University of Belgrade, Serbia

Miloš Tomić, Faculty of Security Studies, University of Belgrade, Serbia

Organizing Committee



Slavko Maksimović
Association Milutin Milanković, Belgrade, Serbia

Ljiljana Janković, Faculty of Civil Engineering, University of Belgrade, Serbia

Slobodan Ninković, Astronomical Observatory Belgrade, Serbia

Milan Dimitrijević, Astronomical Observatory Belgrade, Serbia

Milenko Dželatović, Faculty of Security Studies, University of Belgrade, Serbia

Mina Radosavljević, Faculty of Philology, University of Belgrade, Serbia

Nada Đorđević Veselinović, Faculty of Mathematics, University of Belgrade, Serbia

Miloš Krsmanović, Faculty of Mathematics, University of Belgrade, Serbia

Miodrag Dinić, Association Milutin Milanković, Belgrade, Serbia

Nataša Maksimović, Association Milutin Milanković, Belgrade, Serbia

Matija Bošković, Faculty of Civil Engineering, University of Belgrade, Serbia

PREFACE ON THE INTERNATIONAL CONFERENCE

"MILANKOVIĆ'S THEORY OF CLIMATE CHANGE - ONE HUNDRED YEARS LATER"

The Milutin Milanković Association continues its activities to affirm the work of the great Serbian and world scientist Milutin Milanković. The main activities in 2024 were devoted to marking the hundredth anniversary of the publication of his Theory of Climate Change and the celebration of International Climate Change Day - November 4.

This significant anniversary was marked by the organization of the International Conference: "Milanković's Theory of Climate Change - One Hundred Years Later". The conference was held from November 4 - 5, 2024 in the Great lecture theatre, named after Milutin Milanković (Amfiteatar 227) at the Faculty of Civil Engineering in Belgrade. The organizers of the conference were the Milutin Milanković Association, the following faculties of the University of Belgrade: The Faculty of Civil Engineering, The Faculty of Mathematics, The Faculty of Geography, The Faculty of Security and the Belgrade Astronomical Observatory.

The conference was officially opened by academician, professor Zoran Knežević, president of the Serbian Academy of Sciences and Arts, , emphasizing the importance of Milanković's theory for the world science and the importance of this event for Serbia and the international scientific community. "This conference represents an important opportunity to recall the greatness of Milanković's scientific thoughts, which significantly contributed to the understanding of climate patterns and their connection with astronomical cycles. Milanković's work is valuable, because it helps us to understand more deeply the processes that shape the climate, which is more important today than ever".

The goals of the Conference were:

- a. Use the fundamental contribution of Milanković's Theory of Climate Change in order to understand and predict what could be expected in the next 100 years as a result of climate change, both due to natural long-term processes and anthropogenic factors;
- b. Enable understanding of the impact that global changes in nature have on human lives and suggest practical measures that human civilization should take to prevent negative impact on the environment and human civilization, concerning public health and well-being, population migration, land use, food production, soil, water and air pollution and the survival of natural ecosystems.

At the conference some 40 scientific and professional papers were presented by authors from 11 countries: Belgium, Canada, China, Greece, Germany, Hungary, Italy, Poland, Serbia, Sweden, and the UK.

The submitted works are classified into four thematic areas:

1. Quantification of the causes of the impact on climate change and weather extremes
2. Adaptation and resistance (resilience) to climate changes
3. Application of Milanković's Theory of Climate Change to the reconstruction and evolution of the past
4. Climate change and public health and well-being

Based on the presented works, discussions, proposals and recommendations given during the conference, the scientific committee drew up the conclusions of the conference, which were published on the websites of the Milutin Milanković Association (www.milutinmilankovic.rs) and the Faculty of Civil Engineering (www.grf.bg.ac.rs).

At the closing session of the conference, the participants expressed a unique view that Milanković's theory, even after a century of its publishing, is extremely important for understanding today's climate challenges:

"Thanks to the work of a great scientist, we today have a better understanding of planetary processes and opportunities to mitigate climate change. Milanković's vision and scientific contribution remain an inspiration, not only to scientists, but also to the entire society to take responsibility for the preservation of our planet Earth."

"It is the duty of all of us to preserve his legacy and continue to spread the knowledge and contribution of Milutin Milanković for future generations, with the aim of preserving our planet."

"Climate change is no longer a future threat, but a present-day reality, with extreme weather events already significantly affecting human communities and natural ecosystems around the world. All of this represents a clear message that nature is responding / "paying us back" for our relationship with it. Nature is increasingly showing its untamed power, and climate change is warning that we are approaching the dangerous limits of survival."

On behalf of the organizers of the conference "Milanković's theory of climate change - one hundred years later", I express my gratitude to all the participants and authors of this publication - first for their participation in the conference, and then for their outstanding contribution in the respective thematic areas through the presented and published works and their comprehensive discussion. The organizers of the conference would like to especially thank Professor Andre Berger for his exceptional help, support and useful suggestions regarding the organization of the Conference.

Thanks again to everyone

Slavko Maksimović
President of the Milutin Milanković Association

CONTENT

Keynote Talks – Introduction to Thematic Areas of the Conference 15

Qiuzhen Yin - **Astronomically triggered abrupt cooling at the end of interglacials and implication for the future 16**

Slobodan P. Simonović - **Quantitative Measure of Resilience to Climate Change-Induced Flooding..... 17**

Čedo Maksimović - **Advances in quantification of micro-climate conditions' impacts on public health and wellbeing / Extrapolation of the paper: Haotian Zhang, Stanislava Bošković, Anastasios Temenos, Aikaterini Angeli and Čedo Maksimović: *Assessment of health impacts and benefits of vegetation species used in BGS environment*..... 36**

Theme 1: Climate of the Past, What Happened and Why? – Keynote talks 38

Stefano Pierini - **The deterministic excitation paradigm and the late Pleistocene glacial terminations..... 39**

Dragan Latinović, Ute Merkel, and Matthias Prange - **Complex interplay between different forcing factors defines the deglacial AMOC evolution..... 40**

Zhengyao Lu - **Orbital forcing of the El Niño–Southern Oscillation evolution 41**

Hai Cheng - **Milankovitch Theory and Asian Monsoon - Insights from Asian Cave Records 42**

Theme 2: Adaptation and Resilience to Climate Change	44
<i>Ivan Živanović</i> - The relationship between solar activity and climate changes on Earth.....	45
<i>Zhengyao Lu</i> - Impacts of large-scale Sahara solar farms on global climate, terrestrial ecosystem and solar potential.....	54
<i>Francesco Fiorillo</i> - Spring discharge time series and climate change	55
<i>Attila Kovács</i> - Assessment of the impacts of climate change on spring discharge by a combined stochastic-analytical method, Aggtelek karst area, Hungary	56
<i>Zoran Stevanović</i> - Impact of recent drought cycle in Serbia on groundwater – effects and possible mitigation measures	67
<i>Marko Sedlak, Tanja Srejić and Sanja Manojlović</i> - Air temperature trends in Eastern Serbia	86
<i>Milovan Radmanovac, Marina Babić</i> - Distribution of hail and hail damage in Serbia for period 2010-2020	104
<i>Marina Babić, Laura Chica, Milovan Radmanovac, Tin Lukić, Slobodan B. Marković and Ivana Cvijanović</i> - Describing the change in perceived heat stress over Serbia from 1982 to 2021.....	122
<i>Nina Čegar, Stefanija Stojković, Nikola Stančić, Jelena Luković</i> - Earlier onset of the spring in Serbia (1950-2020)	123
<i>Albert Ruman, Anna Ruman</i> - Modelling climate types in South Pannonian Basin, Serbia by applying the Köppen – Geiger climate classification.....	124
<i>Albert Ruman, Anna Ruman</i> - Köppen – Geiger Climate Classification in the Pannonian Basin According to SSP5-8.5 Scenario.....	145
<i>Dušica Jovanović, Vladimir Ćurić</i> - Application of GIS in identifying drought-prone areas – A case study of Vladičin Han municipality	174

**Theme 2: Adaptation and Resilience to
Climate Change - Part 2191**

Zhongbo Yu - **Challenges in water security and sustainable development: science advance and adaptation.....** 192

Gordon McBean - **Addressing the Impacts of a Changing Climate - Adaptation and Resilience Complexities.....** 193

Miloš Tomić, Dušan Kesić - **Modern strategies for mitigating the consequences of climate change.....** 210

Ana Vuković Vimić, Mirjam Vujadinović Mandić, Zorica Ranković Vasić, Dejan Đurović, Željko Dolijanović, Marija Ćosić, Ljubomir Životić, Aleksa Lipovac, Aleksandar Simić, Dragan Stanojević, Danijela Božanić, Ana Repac - **From science to policy: climate change risks assessment and adaptation planning in agriculture in Serbia.....** 211

Anna Domaradzka, Mikołaj Biesaga, Ewa Domaradzka, Magdalena Kołodziejczyk - **The right to a healthy city – from residents’ needs to better planning.....** 228

Ljiljana Brašanac-Bosanac, Tatjana Ćirković-Mitrović, Nevena Čule, Goran Češljarić, Branka Pavlović - **Innovative approach to forest management to mitigate the impacts of climate extremes in forest ecosystems in Serbia.....** 242

Andrijana Stanković - **Strategies for rural area development in the context of changing climate conditions.....** 257

Uroš Davidović - **Utilizing the DesInventar Database for Risk Assessment of Atmospheric Hazards in Serbia.....** 258

Abhishek Gaur - **Projected future potential moisture damage in buildings over Canada.....** 285

Theme 3: Milanković’s theory and evolution of past304

Slobodan Ninković - **On how much Milanković and his climate theory were known in our milieu.....** 305

Stela Filipi Matutinović - **The Influence of Milankovitch Cycles on species geographical distribution, evolution and ecology.....** 312

Dragoljub P. Antić - **Reconstruction and evolution of the past, civilization development, human population development and migration – Using Milankovic’s theory of Climate Change.....** 328

Theme 4: Climate Change, and Public Health and Wellbeing 345

Haotian Zhang, Stanislava Bošković, Anastasios Temenos, Aikaterini Angeli Doulami and Čedo Maksimović - **Assessment of health impacts and benefits of vegetation species used in BGS environment** 346

Sanja Ivanković, Dragana Jovanović, Predrag Savić, Milena Vasić, Vesna Karadžić - **Clinical and non-clinical methods of monitoring the impact of environmental and microclimatic conditions on public health and wellbeing: the HEART project** 387

Maja Stošić, Snežana Jovanović Srzentić - **Review of epidemiological methods of measuring the influence of local microclimatic conditions on public health and wellbeing** 397

Vesna Karadžić, Jelena Knežević, Dragana Jovanović - **Climate changes and winter cyanobacterial blooming in Serbian waterbodies** 402

Anna Domaradzka, Mikołaj Biesaga, Magdalena Roszczyńska-Kurasińska, Ewa Domaradzka - **Measuring the impact of Nature-Based Solutions on citizens' health and well-being: risks and challenges of using wearable devices** 414

Maria Kalpouzani, Anastasios Doulamis, Nikolaos Doulamis, Aikaterini Angeli-Doulami, George Kopsiaftis, Andreas M. Lazaris, Milena Vasić, Dragana Jovanović, Predrag Savić, Sanja Ivanković, Stanislava Bošković and Čedo Maksimović - **Intermediate results of the project: HEALTHIER Cities through Blue-Green Regenerative Technologies: the HEART Approach** 416

Jasminka Smilagić - **Biometeorological forecast as a factor of adaptation to climate change in the domain of health and human behaviour** 426

About Milutin Milanković 451

Association Milutin Milanković 454



Innovative approach to forest management to mitigate the impacts of climate extremes in forest ecosystems in Serbia

Ljiljana Brašanac-Bosanac¹, Tatjana Ćirković-Mitrović², Nevena Čule¹, Goran Češljar², Branka Pavlović³

ABSTRACT: The increase in annual maximum and minimum temperatures, the amount and distribution of precipitation during the growing season, the frequency of extreme weather events (drought, floods, superstorms, ice breaks, snow breaks) and other climate phenomena have a variety of negative impacts on forest ecosystems in Serbia. Most projections of future climate changes scenarios (SRES - Special Report on Emissions Scenarios, IPCC 1990, 2001, 2007, 2018, 2021, 2022, 2023, Climate Change: Impacts, Adaptation and Vulnerability) indicates to temperature and precipitation significant changes, as well as increasing concentrations of greenhouse gases in the atmosphere, that will cause many ecological problems and affected on sustainable development across the world. Results of research on climate parameters in Serbia for the period 1972-2022, normalized deviations and linear trends of air temperature and precipitation amount indicate an increased risk of drying out forest crops and natural forests on larger areas. Unfavorable climatic conditions caused by a further increase in temperatures, occurrences of drought and extreme amounts of precipitation in a short period, can leave long-term consequences on the distribution, function and production of forest ecosystems. The main challenge in the management of forests is the development of innovative adaptation measures to reduce the vulnerability of forests and the consequences due to possible different scenarios of climate change. In order to reduce the vulnerability of forests and the possible consequences of different climate change scenarios and to preserve and protect forest ecosystems, an innovative approach to forest management is needed, applying the principle of integral environmental protection. By afforesting suitable species that are more resistant to climate change, improving the condition of forests and applying appropriate adaptive forest management, it is possible to significantly mitigate the negative effects of climate change.

Keywords: extreme weather events, climate changes scenarios, climate-smart forestry, adaptable forest management, Serbia.

1 Institute of Forestry, Department of Environmental protection, Serbia

2 Institute of Forestry, Department of Forest Establishment, Silviculture and Ecology, Serbia

3 Institute of Forestry, Department of Forest Management Planning, Organizing and Economics, Serbia

1 Introduction

World is become dependent from the source of energy. Consume of natural resources, which sources are reduced, it's unlimited, and from the other side, the necessities of the society are growing. Forest ecosystems have the ability to sequester carbon dioxide, and a large influence on the structure and function of the human habitat, both locally and globally. They can store 20 to 100-fold higher quantities of carbon-dioxide per a unit of area than the agricultural areas, they have a very important role in the decrease of the concentration of this gas in the air, as one of the most important causes of greenhouse effect (Schoene and Bernier 2012). Since numerous studies on the global warming and potential changes of temperature and humidity point to the very wide range of the effects and impacts, both on the forest ecosystems in general (Botkin et al. 1992, Seidl, et al. 2017), and on the individual trees (Ćirković-Mitrović et al. 2013, Stojanović et al. 2014, Češljarić et al. 2022), the knowledge on these interrelations and interactions plant-climate parameter, is of the growing importance. Increased mean annual temperature, changes in the precipitation dynamics and quantity, and increasingly frequent extreme climate events, which occur with varying frequency, directly affect forest ecosystems and forest vitality (Brašanac-Bosanac et al. 2011, Bennett et al. 2015). According to Vacek et al (2023), the most significant consequences of climate change include more frequent and destructive large-scale forest disturbances (wildfire, windstorm, drought, flood, bark beetle, root rot), and tree species migration. Species distribution shifts and changes in tree growth rate have substantial effects on ecosystem carbon storage. Diameter/volume increment changed from -1 to +99% in Central and Northern Europe, while it decreased from -12 to -49% in Southern Europe across tree species over the last ca. 50 years. However, it is important to sharply focus on the causes of climate change and subsequently, on adaptive strategies, which can successfully include the creation of species-diverse, spatially and age-wise structured stands (decrease drought stress and increase production), prolongation of the regenerative period, or the use of suitable introduced tree species.

For forestry resources management in Serbia, the major challenge is development of adaptive measures, and reducing vulnerability under various climate change scenarios. From the need to understand the vulnerability of forests and forest ecosystems to climate change and to facilitate how they adapt to the changes, new challenges arise. As forests are affected by climate extremes and its associated disturbances, adaptation is needed for reducing their vulnerability to climate change. The continuous facilitating the transfer of best know-how, and applying the climate smart forestry and circular bioeconomy concept, are some of innovative methodologies for adequate response on climate extremes impacts.

2 Materials and methods

The non-reactive method, as a special scientific method, was used for the collection of the data on climate characteristics during the period of the research. Collecting and systematization of the existing data, documents and their secondary analysis were used. Based on the collected data of Republic Hydrometeorological Service of Serbia from 28 main meteorological stations for the period 1972-2022, most significant climate parameters on the territory of Serbia and 3 ordinary meteorological stations was analyzed: the data on mean annual air temperature, mean annual air temperature in the growing season, (April-September), extreme maximum and minimum air temperatures, annual sum of precipitation and annual sum of precipitation in the growing season. The multi-decade data obtained by the systematic meteorological measurements are the only way in which the valid assessment of the current condition and the comparison of it with the previous periods can be made.

For the analysis of climatic characteristics in Serbia, the arithmetic mean values of the collected data in terms of time and altitude zone were used. In order to reduce the error rate, a mean value was calculated according to altitude, i.e. according to the altitude zones in which the meteorological stations investigated are located (zone up to 200 m above sea level, zone 200-500 m above sea level, zone 500-1000 m above sea level and zone above 1000 m above sea level). During preliminary data processing, it was found that none of the 28 main meteorological stations are located in the zone of 500 to 1000 m a.s.l, which is important for forestry, so 3 more ordinary meteorological stations were selected: Novi Pazar (545 m), Trgovište (600 m) and Rudnik (700 m). The criterion for their selection was continuity in work and availability of the necessary data.

The normalized deviations, which point how many standard deviations the individual value is above or below the normal level, were used for the presentation of the deviation from the normal level. The territorial distribution of the trend values is based on the trend values in the points with the coordinates of the weather stations. The values between these points were interpolated by using Kriging's method.

The proposed measures are based on the numerous realized projects results, as well as IPCC Reports, the suitable scientific papers, reports, and studies dealing with this problem. However, given the strategic nature of the paper, and the lack of scientific evidence on some of the issues, the analysis on expert knowledge and own understanding and views where based.

3 Results

3.1 Climate change scenarios

Greenhouse gas (GHG) emissions from agriculture, forestry and associated land use changes, are responsible for a significant fraction of anthropogenic emissions, up to 30% according to the Intergovernmental Panel on Climate Change (IPCC 2021). Most projections of future climate changes scenarios (SRES - Special Report on Emissions Scenarios) indicates to temperature and precipitation significant changes, as well as increasing concentrations of greenhouse gases in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC 2018) has reported that if the global temperature continues to increase at the present rate, it may increase by 1.5°C between 2030 and 2052, altering the frequency and severity of natural disturbances and having potentially profound impacts on forest resources and species composition. According to IPCC's Sixth Assessment Report (AR6 WGIII) (IPCC 2022), each of the last four decades has been successively warmer than any decade that preceded it since 1850. Global surface temperature was 1.09°C higher in 2011–2020 than 1850–1900, with larger increases over land (1.59°C) than over the ocean (0.88°C). Global surface temperature has increased faster since 1970 than in any other 50-year period over at least the last 2000 years (high confidence) (IPCC 2023).

Forests and forestry make a strong and important contribution to meeting the Sustainable Development Goals (UN 2020). They provide natural carbon sinks and their products can substitute for emissions-intensive materials, thereby reducing emissions. The management of carbon flows between reservoirs in the Earth's system forms the basis for climate change mitigation.

3.2 Climate parameters in Serbia

Climate changes are characterized primarily by an increase in temperatures, but also by changes in the precipitation pattern, their annual distribution and their intensity distribution, as well as by an increased frequency of extreme weather events and periods with extreme climatic conditions. Such changes clearly affect the environment, health of people and economy.

It is known that the occurrence and survival of vegetation in certain area, its distribution and altitudinal differentiation, along with the other ecological conditions, to a great extent also depends on the climate characteristics of the area. If any of the climatic factors is not at least on the required minimum, especially during the growing season, a plant will not be able to survive.

As a climate element, temperature has a dominant impact on vegetation and the possibility of the emergence and spread of a fire.

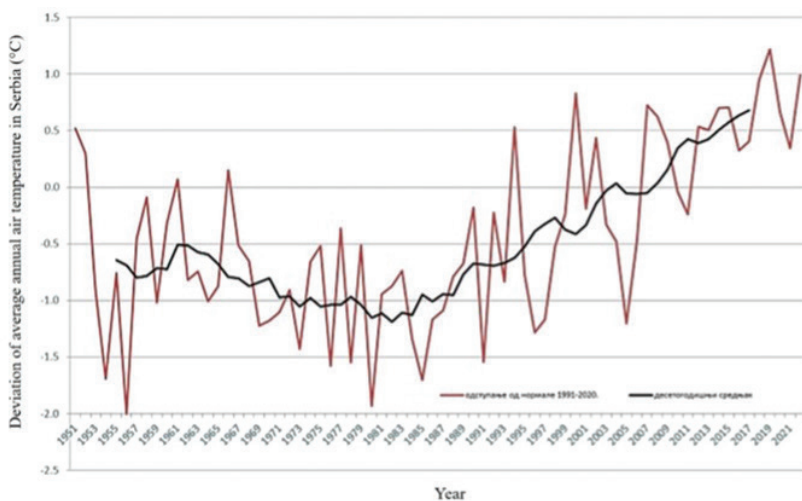


Figure 1. Trend of deviations in the average annual air temperature in Serbia for the period 1951-2021

(Source: www.hidmet.gov.rs/data/klimatologija/latin/2021.pdf)

From 1998 to 2020, every year was warmer than average (except for 2004-2005), so it is estimated that the trend of increasing average air temperatures will continue in the territory of the Republic of Serbia.

In order to study the variability of the mean monthly temperature in Serbia and analyze the deviation of the mean monthly temperatures from the average, the values of the standard deviation of the mean monthly temperatures for 1972-2022 were calculated (table 1).

Table 1: Standard deviation of the monthly, annual and growing season air temperature in Serbia in the period 1972-2022 (°C)

Meteorological station	Altitude (m)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual	Growing season
Negotin	42	2.5	3.0	2.4	1.7	1.4	1.5	1.6	1.9	1.6	1.3	2.2	2.0	0.9	1.6
Zrenjanin	80	2.4	3.2	2.2	1.8	1.6	1.6	1.6	1.9	1.8	1.6	2.4	1.9	0.9	1.7
Veliko Gradište	80	2.1	2.8	2.2	1.7	1.5	1.5	1.5	1.7	1.7	1.4	2.3	1.8	0.8	1.6
Kikinda	81	2.4	3.2	2.2	1.8	1.6	1.6	1.5	1.8	1.7	1.5	2.4	1.9	0.9	1.7
Srem. Mitrovica	82	2.3	3.0	2.1	1.7	1.5	1.4	1.3	1.6	1.7	1.5	2.2	1.8	0.8	1.5
Vršac	84	2.5	3.3	2.3	2.0	1.6	1.6	1.6	1.9	1.9	1.7	2.6	2.0	0.9	1.7
Novi Sad	84	2.4	3.2	2.3	1.8	1.6	1.5	1.4	1.8	1.7	1.5	2.4	2.0	0.9	1.6
Sombor	87	2.4	3.1	2.1	1.8	1.6	1.6	1.5	1.7	1.6	1.5	2.2	1.9	0.9	1.6
B. Karlovac	89	2.1	2.9	2.3	1.8	1.6	1.4	1.3	1.7	1.7	1.5	2.3	1.9	0.8	1.6
Palić	102	2.3	3.0	2.2	1.7	1.6	1.6	1.5	1.8	1.6	1.5	2.2	1.9	0.9	1.7
Loznica	121	2.3	3.0	2.1	1.7	1.5	1.6	1.5	1.7	1.6	1.5	2.2	1.9	0.9	1.6
Smed. Palanka	121	2.2	3.0	2.2	1.8	1.5	1.6	1.5	1.8	1.7	1.5	2.4	1.8	0.8	1.7
Čuprija	123	2.1	2.8	2.1	1.8	1.5	1.5	1.5	1.8	1.7	1.5	2.4	1.8	0.8	1.6
Belgrade	132	2.3	3.1	2.3	1.9	1.7	1.8	1.8	2.1	1.9	1.7	2.4	2.0	1.0	1.9
Zaječar	144	2.3	2.9	2.2	1.6	1.3	1.4	1.4	1.6	1.5	1.3	2.1	2.4	0.8	1.5
Kruševac	166	2.2	2.9	2.2	1.8	1.4	1.5	1.4	1.7	1.6	1.5	2.6	2.0	0.8	1.6
Valjevo	174	2.2	2.9	2.1	1.8	1.5	1.6	1.6	1.8	1.7	1.5	2.3	1.9	0.9	1.7
Kragujevac	185	2.2	2.9	2.1	1.8	1.5	1.5	1.5	1.8	1.6	1.5	2.4	1.9	0.8	1.6
The area 0-200 m.a.s.l.		2.3	3.0	2.2	1.8	1.5	1.5	1.5	1.8	1.7	1.5	2.3	1.9	0.9	1.6
Niš	204	2.1	2.9	2.2	1.9	1.5	1.6	1.6	1.9	1.8	1.5	2.5	1.9	0.9	1.7
Kraljevo	215	2.1	2.8	2.2	1.7	1.4	1.5	1.5	1.8	1.7	1.5	2.4	1.8	0.8	1.6
Leskovac	230	2.2	2.8	2.0	1.7	1.3	1.5	1.5	1.7	1.5	1.4	2.4	2.1	0.8	1.5
Požega	310	2.0	2.6	1.9	1.6	1.3	1.3	1.1	1.3	1.4	1.3	2.0	1.9	0.7	1.3
Kuršumlija	383	2.1	2.8	2.1	1.7	1.3	1.3	1.4	1.6	1.5	1.4	2.4	2.0	0.7	1.5
Vranje	433	2.0	2.6	2.1	1.8	1.4	1.4	1.5	1.8	1.6	1.5	2.4	1.9	0.8	1.6
Dimitrovgrad	450	1.9	2.6	2.0	1.7	1.3	1.3	1.3	1.5	1.6	1.5	2.4	1.9	0.7	1.5
The area 200-500 m.a.s.l.		2.1	2.7	2.1	1.7	1.4	1.4	1.4	1.7	1.6	1.4	2.4	1.9	0.8	1.5
Novi Pazar	545	2.0	2.5	2.0	1.8	1.5	1.6	1.6	1.8	1.6	1.7	2.2	2.0	0.9	1.8
Trgovište	600	1.8	2.6	2.1	1.6	2.4	1.1	1.2	1.5	1.5	1.5	2.5	2.0	0.8	1.6
Rudnik	700	2.0	2.2	2.3	2.0	1.8	1.6	1.7	1.8	1.5	1.8	2.4	2.1	0.9	1.8
The area 500-1000 m.a.s.l.		2.1	2.9	2.2	1.8	2.2	1.6	1.5	1.9	1.9	1.7	2.5	2.0	0.9	1.9
Zlatibor	1028	2.2	2.9	2.3	2.1	1.7	1.7	1.6	2.0	1.8	1.8	2.5	1.9	0.9	1.8
Crni Vrh	1037	2.3	3.3	3.0	2.3	1.9	1.9	1.6	1.8	2.0	1.9	2.5	2.2	1.3	1.9
Sjenica	1038	2.2	3.2	2.8	2.2	2.0	1.7	1.4	1.7	2.0	1.9	2.4	2.3	1.3	1.8
Kopaonik	1711	1.2	2.4	2.3	2.3	1.5	1.5	1.7	1.8	1.7	1.7	2.2	1.8	0.9	1.8
The area above 1000 m.a.s.l.		2.4	3.0	2.6	2.1	1.9	1.7	1.6	1.9	1.8	1.8	2.5	2.4	1.1	1.8

The analysis of the values of standard deviations for 1972-2022 period, it indicates that trend of the increase of the main air temperature (about 0.9°C) and main air temperature in growing season (1.7°C) in most parts of the territory of Serbia, except for Belgrade, Crni Vrh i Sjenica. Higher temperature variability in the winter months is a consequence of the penetration of cold and warm air masses in certain years. It is expected that these trends of climate change in Serbia will continue in the future, which will significantly alter the structure and function of forest ecosystems, thereby imposing the need for the change of the previous forest management.

Together with the air temperature, precipitation is a necessary condition for the unhindered growth and development of plants.

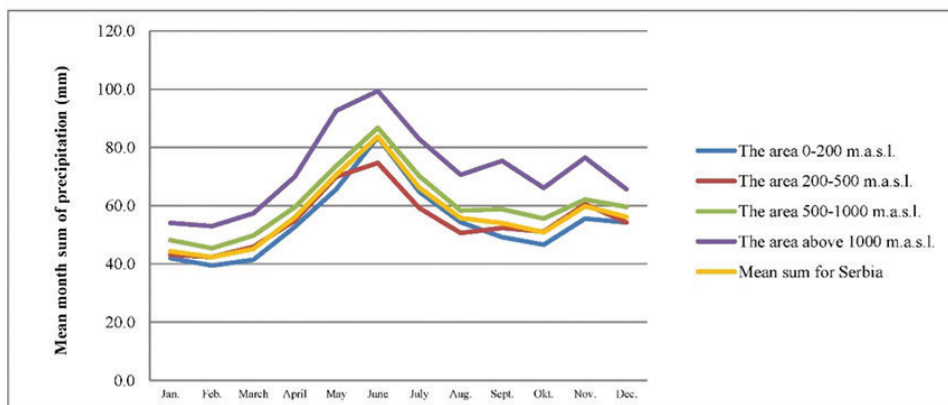


Figure 2. Mean month sum of precipitation in Serbia for the period 1972-2022

The occurrence of forest desiccation to a great extent depends on the high temperatures and amount of precipitation. More than 50% of the total annual precipitation occurs during the growing season. Along with the amount of precipitation and their distribution in the growing season, the lack of moisture in the soil has a great impact on the process of forest of desiccation. Fighting against the heavy drought, forest trees decelerate transpiration, which implies absorption of lower quantities of nutrients from the soil and deceleration of all other physiological processes. Under such conditions, if the period of drought is extended, the trees physiologically weaken and become less tolerant to the other anthropogenic, abiotic and biotic causes of forest desiccation. The increase in growth increment of vegetation occurs due to the increase in the amount of precipitation, while, on the other hand, drought which is the most common cause of damages and die-back of both individual trees and larger forest areas occurs due to insufficient amount of precipitation over a long period.

3.3 Impacts of climate changes on forest ecosystems in Serbia

Serbia is considered to be a medium forested country (Brašanac-Bosanac et al. 2011). According to Ćirković et al. (2013), the beech, as the most dominant broadleaf species in Serbia, is a mesothermal species, well-adapted to the moderate temperatures, quantities of moisture, and shady conditions (sciophytes). In contrast to the beech, most oaks in Serbia are xerothermic (they grow at dry and warm sites) and light-loving species (heliophytes). Regarding conifers, pines are light-loving species, adaptable to the ecological condition of temperature, moisture and soil. The spruce and fir are sciophilic, i.e. shade-loving species. Serbian forests are characterized by the relatively high potential carbon-dioxide absorption from

the atmosphere and thereby they significantly contribute to the alleviation of the adverse effects of the climate change (Stojanovic et al. 2014).

The possibility and rationality of using some forest functions, as well as the rate of achieving the goals related to the forest management, depend on the pre-existing conditions, particularly in regard to the functional optimum determined for some primary purposes. The condition of forests in Serbia is unsatisfactory in several regards. There are the following disturbing factors of planning and permanent use of forest ecosystems: forest desiccation, wildfires, strong winds and storms, climate change, polluted air, as well as the process of soil acidification.

Climate changes cause numerous problems and changes in forest ecosystems: degradation, deforestation, increased mortality rates, biodiversity loss, reduced forest ecosystem vitality due to cumulative impact of different stresses, changes in tree level processes (productivity), changes in species distribution, changes in site conditions (soil condition), changes in stand structure (density, height), changes in disturbance regimes (fires, pests and diseases). The vulnerability of a forests depends on its adaptive capacity. Even if the adaptive capacity of forests remains uncertain, many scientists are concerned that this innate capacity will not be sufficient to enable forests to adapt to unprecedented rates of climatic changes.

The fact that the climate change occurs much more rapidly than it was anticipated has pointed out to the need to conduct the continuous researches and monitor the influence of the climate change on the vertical and horizontal zoning of vegetation, alternations in the current forest ecosystems and effects of this change during the establishment of new forests. The future activities aimed at reforestation, tending and regeneration of forest ecosystems must be based on the climate parameters from the previous multi-annual period but also on the recent climate extremes which was reported in Serbia as well.

Table 2. Negative impact of climate changes on forest ecosystems

Area of negative impact	Implications / disturbances
Forest ecosystems	Rapid deforestation and forest degradation Increased use of forest trees as a source of energy
Forest ecosystems biodiversity	Change in distribution of plant and animal communities Biodiversity loss Occupation of habitats by allochthonous species Change in pollination system Change in plant dispersion and regeneration
Forest ecosystem productivity	Change in forest growth and ecosystem biomass Change in relation between species / habitat Change in ecosystem nitrogen cycle
Forest ecosystems health condition	Increased mortality due to climatic stress Reduced forest ecosystem vitality and health due to cumulative impact of different stresses
Land and water	Changes in seasonality and intensity of humidity Changes in flood flow regime Increased possibility of extreme draughts occurrence Increased terrain instability and soil erosion due to increased humidity Early snow melting leading to change of period of maximum flow and amount of water in streams
Carbon cycle	Changes in forest CO ₂ reservoirs and increased emission of CO ₂ from forest ecosystems due to change in forest growth and productivity
Direct forest benefits for people	Change in woodiness degree Socio-economic changes Changes in specific forest products availability (timber, wood fuel, medicinal plants, fungi, etc)
Indirect forest benefits for people	Change in frequency of conflicts between people and nature Income changes for forest owners and local population Socio-economic changes Changes of cultural, religious and spiritual values

3.4 Climate-Smart Forestry concept

In order to mitigate the effects of extreme weather events on the forest ecosystem in Serbia and to eliminate the resulting consequences, innovative approaches to forest management should be applied. One of these is the concept of climate-smart forestry.

Climate-Smart Forestry (CSF) is an integral approach of sustainable forest management that focuses on forest management in response to climate change (Bowditch et al. 2020). The fundamental focus of the CSF concept is on adaptation, mitigation and social dimensions. CSF is being interpreted in a number of ways, which mostly focus on adaptive forest management, the decrease of GHG emissions, and effective carbon sequestration (Nabuurs et al. 2018; Yousefpour et al. 2019).

Nabuurs et al. (2018) presented the following three pillars of the CSF approach:

- active forest management aiming to sustainably increase productivity and provide all benefits that forests can provide
- adapting forest management to build resilient forests
- reducing and/or removing GHG emissions to mitigate climate change.
- According to Verkerk et al. (2020), the concept of CSF goes beyond forest management measures, including GHG mitigation opportunities of wood use, carbon storage and substitution in its targets:
- increasing carbon storage in forests and wood products, in conjunction with the provisioning of other ecosystem services;
- using wood resources sustainably to substitute non-renewable, carbon-intensive materials;
- enhancing health and resilience through adaptive forest management.

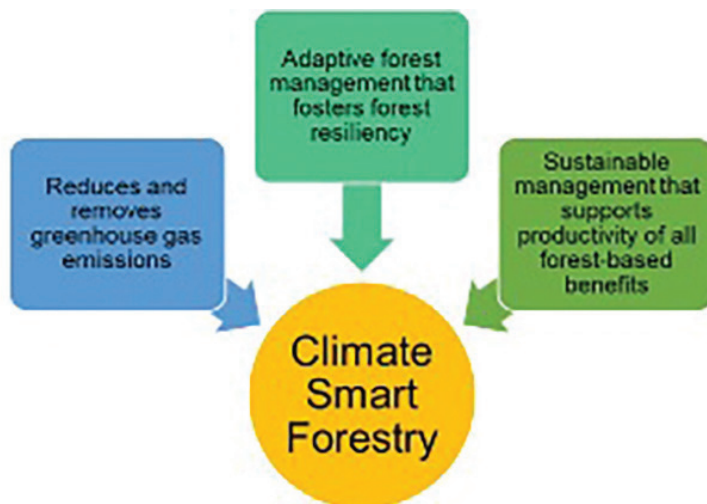


Figure 2. A framework of climate smart forestry
(Source: Chizmar & Parajuli, 2022)

These components aim to increase the total forest area and avoid deforestation, connecting mitigation with adaptation measures to enhance the resilience of forest resources, and using wood for products that store carbon and substitute emission-intensive fossil and non-renewable products and materials.

The integral nature of the CSF concept acknowledges all carbon pools and integrates forest management and wood use strategies to maximise mitigation benefits. Therefore, it should be considered that forest growth declines in aging forests, which leads to diminishing removals of CO₂ from the atmosphere (Nabuurs et al. 2013). Secondly, many existing climate impact studies suggest an increasing risk from abiotic and biotic disturbances (Seidl et al. 2017). Besides harvesting wood, active forest management allows for quicker and more controlled adaptation of forests to climate change (e.g., selection of tree species and provenances) to ensure resilience of forest ecosystems (Schoene and Bernier 2012).

It is important to note, that CSF includes a more efficient use of wood is needed, using the substitution potentials to maximise the positive climate impact that forests and the forest value-chain provide.

4 Conclusion

Forest management activities are largely focused on providing desirable forest ecosystem functions, e.g. wood production, biomass, biodiversity, economic, wildlife habitat, etc., through the provision of forest structure in the present and the future. Comprehensive understanding of natural disturbance regimes, stand development pathways, and their combined effects on structural aspects that provide for forest functions is critical because the heterogeneity of natural disturbances influences a variety of ecosystem properties and processes.

Based on the obtained results and assessment of the different scenarios of climate change (global, regional), it was concluded that the territory of Serbia is one of the areas in which, due to the climate change, the sustainable use of natural, particularly forest, resources, is endangered. Due to the direct impact of higher temperatures, and changing precipitation patterns will change the composition of forests, and this will affect the provision of ecosystem services. Together with the air temperature, precipitation is a necessary condition for the unhindered growth and development of plants. If any of the above climatic factors is not at least on the required minimum, especially during the growing season, a plant will not be able to survive. Recent observations of elevated tree mortality following climate extremes, like heat and drought, raise concerns about climate change risks to global forest health. We currently lack both sufficient data and understanding to identify whether these observations represent a global trend toward increasing tree mortality. Extreme events underscore the fact that climate change may affect forests with unexpected force in the future.

The latest results of research studies indicate that climate change has a direct impact on the following aspects of forestry and forest-based goods and services:

Forest health: climate-stressed trees will not be able to defend themselves as well against native and non-native pests and diseases.

Timber production: while increased atmospheric carbon dioxide may increase timber growth, this growth will be dependent on the availability of water.

Water quantity and quality: surface and ground water availability and usability will fluctuate with changes in precipitation.

Wildfire risk: increased instances of drought, extreme weather events, and forest stress will likely contribute to higher risks of wildfires.

Wildlife: temperature changes will alter wildlife populations through the timing and availability of forage.

Soil productivity: higher temperatures and increased instances and intensity of droughts can facilitate soil compaction if forestry best management practices are not used.

Emerging forest-based bioproducts and technology: the forest products industry continues to evolve through emerging products and technologies (applying the circular bioeconomy concept).

The complexity of forest ecosystems and numerous ways in which the society use and misuse them, as well as the fact that the forest ecosystems in Serbia are endangered by different factors, requires the application of the range of different protective measures and innovative approach to the problem. These measures, above all, include the suitable normative-legal and organizational-institutional mechanisms, suitable standards and practice in the domains of forestry, agriculture, water management, civil engineering, spatial planning, etc.

Strengthening resilient of forest ecosystems in Serbia on future climate change and possible extreme weather conditions is possible to achieve through the improving knowledge, applying of the new methodologies, as well as defining of specific resilient forest types. In that purpose it is necessary to conduct an analysis of afforestation success by species, type and age of seedlings and planting technology in the conditions of climate change. The future researches and analysis aims to improve the knowledge necessary for adequate planning of the different forest species taking into account climate change vulnerability and risk assessments. In order to achieve this, it is necessary to develop models of different types of forests over the next 50 years under the conditions of climate change.

By integrating all these measures and climate-smart forestry applying it is possible to achieve the higher degree of the environmental protection and sustainable forest management, even under the altered climate conditions, which are the results of the global warming.

Acknowledgment

This study was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, Contract No. 451-03-66/2024-03/200027.

References

1. Bennett, A., McDowell, N., Allen, C., Anderson-Teixeira, K. (2015) Larger trees suffer most during drought in forests worldwide. *Nature Plants*. 1, 15139. <https://doi.org/10.1038/nplants.2015.139>
2. Botkin, D.B., Nisbet, R.A., Simpson, L.G. (1992) Forests and Global Climate Change. In: Majumdar, S.K., Kalkstein, L.S., Yarnal, B.M., Miller, E.W., Rosenfeld, L.M. (eds.): *Global Climate Change: Implications, Challenges and Mitigation Measures*, Philadelphia, Pennsylvania Academy of Sciences, Chapter 19, 274-290
3. Brasanac-Bosanac, Lj., Filipovic, D., Cirkovic-Mitrovic, T. (2011) Measurements for the adaptation of forest ecosystems on negative impacts of climate change in Serbia, *Fresenius Environmental Bulletin*, Germany, Vol.20- No 10-2011, 2643-2650 <https://www.researchgate.net/publication/289715385>
4. Chizmar, S., Parajuli, R. (2022) What is Climate Smart Forestry? A Brief Overview, NC State Extension Publications <https://content.ces.ncsu.edu/what-is-climate-smart-forestry-a-brief-overview>
5. Češljarić, G., Jovanović, F., Brašanac-Bosanac, Lj., Đorđević, I., Mitrović, S.; Eremija, S.; Ćirković-Mitrović, T.; Lučić, A. (2022) Impact of an Extremely Dry Period on Tree Defoliation and Tree Mortality in Serbia. *Plants* 11(10), 1286; <https://doi.org/10.3390/plants11101286>
6. Ćirković-Mitrović, T., Popović, V., Brašanac-Bosanac, Lj., Rakonjac, Lj., Lučić, A. (2013) The impact of climate elements on the diameter increment of Austrian pine (*Pinus nigra* Arn.) in Serbia, *Archives of Biological Sciences*, Belgrade, Vol. 65 (1), 161-170, doi:10.2298/abs1301161c

7. IPCC (1990) *Climate Change: The IPCC Scientific Assessment*, edited by: Houghton, J. T., Jenkins, G. J., and Ephraums, J. J., Cambridge University Press, Cambridge, Great Britain, New York, NY, USA and Melbourne, Australia, pp. 410 https://archive.ipcc.ch/publications_and_data/publications_ipcc_first_assessment_1990_wg1.shtml
8. IPCC (2001) *Climate Change 2001: Mitigation. A Report of Working Group III of the Intergovernmental Panel on Climate Change*, edited by: Banuri, T., Barker, T., Bashmakov, I., Blok, K., Bouille, D., Christ, R., Davidson, O., Edmonds, J., Gregory, K., Grubb, M., Halsnaes, K., Heller, T., Hourcade, J.-C., Jepma, C., Kauppi, P., Markandya, A., Metz, B., Moomaw, W., Moreira, J. R., Morita, T., Nakicenovic, N., Price, L., Richels, R., Robinson, J., Rogner, H. H., Sathaye, J., Sedjo, R., Shukla, P., Srivastava, L., Swart, R., Toth, F., and Weyant, J., Cambridge University Press. <https://archive.ipcc.ch/ipccreports/tar/wg3/index.php?idp=0>
9. IPCC (2007) *Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by: Metz, B., Davidson, O. R., Bosch, P. R., Dave, R., and Meyer, L. A., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, ISBN 978-0521-88011-4, https://archive.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4_wg3_full_report.pdf
10. IPCC (2018) *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change*, edited by: Masson-Delmotte, V., Zhai, P., Pörtner, H. O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J. B. R., Chen, Y., Zhou, X., Gomis, M. I., Lonnoy, E., Maycock, T., Tignor, M., and Waterfield, T., <https://doi.org/10.1017/9781009157940>
11. IPCC (2021) *Summary for Policymakers*, in: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., Maycock, T. K., Waterfield, T., Yelekçi, O., Yu, R., and Zhou, B., Cambridge University Press, <https://doi.org/10.1017/9781009157896.001>
12. IPCC (2022): *Annex III: Scenarios and modelling methods*, in: *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by: Shukla, P. R., Skea, J., Slade, R., Khoualdjia, A. A., van Diemen, R., McCol-lum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., and Malley, J., Cambridge University Press, Cambridge, UK and New York, NY, USA, <https://doi.org/10.1017/9781009157926.022>

13. IPCC (2023) Summary for Policymakers. In: Climate Change 2023: IPCC Sixth Assessment Report -AR6, https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf
14. Nabuurs, GJ, Verkerk, P.J. Schelhaas, MJ, Olabarria, J.RG., Trasobares, A., Cienciala, E. (2018) Climate-Smart Forestry: mitigation impacts in three European regions. From Science to Policy 6. European Forest Institute. https://efi.int/sites/default/files/files/publication-bank/2018/efi_fstp_6_2018.pdf
15. Nabuurs, GJ., Lindner, M., Verkerk, P.J., Gunia, K., Deda, P., Michalak, R., Grassi, G. (2013) First signs of carbon sink saturation in European forest biomass. *Nature Climate Change* 3: 792-796. <https://doi.org/10.1038/nclimate1853>
16. Schoene, D.H.F., Bernier, Y.P. (2012) Adapting forestry and forests to climate change: A challenge to change the paradigm, *Forest Policy and Economic*, Vol. 24, November 2012, 12-9 doi: 10.1016/j.forpol.2011.04.007
17. Seidl, R., Thom, D., Kautz, M. et al. (2017) Forest disturbances under climate change. *Nature Climate Change* 7, 395-402. <https://doi.org/10.1038/nclimate3303>
18. Stojanović, D.B., Matović, B, Orlović, S, Kržič, A, Trudić, B., Galić, Z., Stojnić, S., Pekeč, S. (2014) Future of the Main Important Forest Tree Species in Serbia from the Climate Change Perspective. *South-east Eur for* 5 (2): 117-124. doi: <http://dx.doi.org/10.15177/seefor>.
19. UN (2020) The Sustainable Development Goals Report 2020, <https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf>
20. Vacek, Z., Vacek, S., Cukor, J. (2023) European forests under global climate change: Review of tree growth processes, crises and management strategies, *Journal of Environmental Management*, Volume 332, 2023, 117353, ISSN 0301-4797, <https://doi.org/10.1016/j.jenvman.2023.117353>
21. Verkerk, P.J., Costanza, R., Hetemäki, L., Kubiszewski, I., Leskinen, P., Nabuurs, G.J., Potočník, J., Palahí, M. (2020) Climate-smart forestry: the missing link. *Forest Policy and Economic*, Volume 115, June 2020, 102164, <https://doi.org/10.1016/j.forpol.2020.102164>
22. Yousefpour, R., Nabel, J.E.M.S., Pongratz, J. (2019) Simulating growth-based harvest adaptive to future climate change, *Biogeosciences*, 16, 241-254, <https://doi.org/10.5194/bg-16-241-2019>
23. www.hidmet.gov.rs/data/klimatologija/latin/2021.pdf

Milutin Milanković



28 May 1879–12 Dec 1958

The beginning of the life story of Milutin Milankovic is on 28 May 1879 in Dalj, a place near the Danube, in the vicinity of Osijek, the then capital of Slavonia, one of the southern provinces of the Habsburg Monarchy. Due to its size and flow, the Danube became an obsession of time and space for Milanković. The river near which he spent his whole life gave him the necessary security in life, in it he found sources of inspiration for his creative work.

Milankovic completed his primary education in his hometown. He continued his education in Vienna at the Technical High School. He completed his studies in civil engineering in 1902, and defended his doctoral dissertation on 3 December 1904, at the age of twenty five.

For Milankovic, Vienna was a place of growing up and maturing into a mature man and scientist. It was a meeting place of the scientific elite of the whole of Europe at that time and a centre for the exchange of scientific thoughts, which young Milankovic used extensively to acquire a broad education.

Although a civil engineer by education, a university professor of celestial mechanics by profession, Milankovic, with the strength of his talent, but above all with persistent and systematic work, expressed himself and created in various scientific disciplines and fields. Construction mechanics and civil engineering, astronomical theory of climate change, calendar reform, popular science works

and the history of natural sciences are the areas in which Milankovic's scientific thoughts are reflected.

He had a very successful career as a civil engineer in Vienna, but his wish was to become a professor at a university, because there he could dedicate himself completely to scientific work.

In 1909, he accepted an invitation from the Faculty of Philosophy of the University of Belgrade, which offered him a position as a lecturer at the Department of Applied Mathematics, which included rational mechanics, celestial mechanics and theoretical physics.

Having chosen the climate of the distant past as the subject of his scientific research, he carefully planned his scientific journey through the "distant worlds and times". That journey he set out on will last for a full thirty years.

One of Milankovic's stops on his journey through the "distant worlds and times" was Budapest, where he spent the First World War (1914–1918) in internment as a Serbian citizen. As an already established scientist, he was enabled to work unhindered in the libraries of the Hungarian Academy of Sciences and the Central Meteorological Institute. The results of his four-year work are presented in the book "Mathematical Theory of Thermal Phenomena Caused by Solar Radiation", which was published in Paris in 1920. In it, Milanković presented the basics about the astronomical influence of solar energy and their connection with climate change on the planet Earth. The results of this research were the foundation of his world-renowned theory of climate change.

Milankovic continued his further work on the development of the theory of climate change in cooperation with one of the world's most famous climatologists, Wladimir Koeppen and his son-in-law, a well-known geophysicist, Alfred Wegener. After four years of successful cooperation in their voluminous work "Paleoclimatology" in 1924, Milankovic's insolation curves, later known as "Milankovic's cycles", were published. With this, it can be considered that Milankovic's work on the development of his theory of climate change was completed.

In 1941, the Serbian Academy of Sciences printed 600 copies of Milankovic's major work "The Canon of Insolation and the Ice Age Problem". It contains his entire long-term work and all the results of his work on the theory of climate change.

In 1923, the Congress of Eastern Orthodox Churches was held in Constantinople (today's Turkey), at which Milankovic's proposal for the reform of the Julian calendar was accepted. This calendar has given the highest accuracy so far, whereby the calendar year differs by only 2 seconds from the current length of the tropical year.

Milutin Milankovic was not only a scientist, but also a historian of natural sciences, a chronicler of scientific events of his time, a writer of popular science and literary works. Although he described different times, places of events, phenomena and personalities in his works, Milankovic's desire to vividly and clearly present the lives of great scientists, the most complex problems of science, the time in which they are born, as well as their application in the field of technology one can truly feel.

The end of the life story about Milanković is in his native Dalj, on the bank of the Danube - the paradise river Fison, from where he set out on a journey through the "distant worlds and times".



Association Milutin Milankovic

The Association Milutin Milankovic is a scientific-professional association formed in 2007. It gathers members from the activities that Milankovic was engaged in (geophysical and technical sciences), but also a large number of deputies from the humanities (artists, writers, philosophers, journalists, film workers). The association was founded with the aim of popularizing the personality and valorization of the scientific work of Milutin Milankovic.

Since Serbia does not have a museum dedicated to Milutin Milankovic, the basic task of the Association is to collect, process and make Milankovic's legacy available to the domestic and foreign public.

Namely, behind Milankovic there is a rich legacy, which is still in archives, museums, libraries, establishments and institutions in the places where he lived and worked (Dalj, Osijek, Vienna, Budapest, Belgrade) as well as in other places, primarily in territories of Austria and Germany (Graz, Hamburg, Freiburg, Munich).

So far, over 1,500 different documents have been collected and digitized from these sources, as well as other artifacts about Milankovic's life and work (originals of old books, personal documents, paintings, drawings, photographs, diagrams, charts, professional and popular publications, video segments, newspaper articles, numerical databases and many other things).

The Association used the collected archival and museum material to organize 10 scientific and professional gatherings, publish 15 publications, and shoot 10 feature-length documentaries of various content and duration.

For further information about the Association Milutin Milankovic, please visit website www.milutinmilankovic.rs.

