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IASON

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Review of climatic data (past & future)

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IHU (Partner) Report

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Contents

1. Introduction

1.1 Significance of climatic factors in driving species distribution

The geographic distribution of species is the outcome of the interaction between species' niches and environmental variables (Soberón and Peterson 2005, Sexton et al. 2009, Brunbjerg et al. 2012). It is well documented that plant growth and geographic distribution of plants worldwide is strongly influenced by climate (Woodward 1987). Unfavorable environmental factors limit both plant's growth and distribution (Mott 2010). Thus, it is well documented that temperature and precipitation are the primary climatic factors that shape plant distribution over large spatial scales.

Globally, regions with climates that are both warm and wet support more species than regions where the climate is either cold or arid (Harisson 2020). The long-term climatic conditions determine the type of vegetation in a region as, either directly or indirectly, environmental stress, caused by poor environmental conditions, can either damage a plant directly or makes it more susceptible to disease or insect attacks (Brown 2014).

Every organism has its ecological niche within which it lives and where its basic needs to survive are met. The abundance and distribution of organisms in an ecosystem is determined by biotic and abiotic factors (Sage 2020). Therefore, each species has a unique distribution based on its own history and tolerance to environmental factors (Wong and Candolin 2015). Plant evolution and distribution are primarily affected by climatic and orogenic events in the past. For example, many plants are believed to have shifted latitude or elevation ranges in response to glaciations (Davis et al 2005), which have led to shifting distribution ranges and have caused the fragmentation of many species (Petrova et al. 2015).

Climate has direct effect on species' physiological processes in a rather short but sensitive periods of their life cycle with severe impact on their ability to colonize or persist in an area (Marini et al. 2012; Allen et al. 2010). The most ecologically important climatic factors, affecting plant growth and distribution, are light, temperature, and patterns of summer precipitation (Hatfield and Prueger 2015). Temperature is an important factor because most plant biological activity and growth occur within only a narrow range of temperatures, usually between 0oC and 50oC (Barbour et al. 1987). Temperature influences most plant processes, including photosynthesis, transpiration, respiration, germination, and flowering. Different plant species have different thermal requirements and adapt in specific regions. As result, higher and lower temperatures affect severely their biological reactions and define the length of the active growing season (Grigorieva et al 2010). Precipitation is also ecologically and biochemically important because it is a major force in shaping climatic patterns and it is a necessary component in physiological processes (Jones 2007). An example of the effects of water on species distribution can be seen in drier areas, where most individuals of a species will gather in the wetter areas, forming a clumped distribution. (Gaviria et al 2017).

Climate change is expected to cause shifts in the geographic distribution of species worldwide as species track their optimal habitat which will likely shift as a result of rearrangement of climate zones (Thomas et al. 2004). Over the last decades, anthropogenic activities such as uncontrolled deforestation have resulted in a series of environmental imbalances that have caused significant changes in complex climate dynamics around the world (Menezes-Silva et al. 2019). With global warming and precipitation reduction in the Southern Europe, species are expected to move towards the poles and higher elevations where temperatures will be lower.

The understanding of climate’s role in driving ecosystem structure and function is essential in developing the knowledge of how climate change will affect the functional composition of communities. Moreover, the study of the geographical distribution of species lies at the heart of ecology (Chen 2009).

1.2 Effects of climate change in species distributions

1.2.1 Climate change in general

Human industrialization has significantly enhanced greenhouse gases emissions causing significant changes in regional and seasonal climate patterns, the so-called Climate change. Such patterns changes can strongly influence plant species distributions and diversity with implications in the overall ecosystems' biodiversity (Parmesan and Yohe2003).

During the last decades the rapid change of the climatic conditions is affecting a wide variety of organisms around the globe including Europe. Most specifically observational data during previous decades indicate that the high climatic divergence during the last 100 years in contrast to past climate changes is already affecting the physiology, distribution, and phenology of some species in way consistent with what the theory predicts (Hughes 2000). However human-induced climate change is considered the most profound factor responsible for the above species shift in their ecological attributes (Hughes 2000; Parmesan and Yohe 2003).

In fact, Global climate change is the driving force determining plants species distribution and performance (Parmesan and Yohe 2003; Lucht et al. 2006). During last decades its severity appears to increase with frequent extreme weather events and an increase in mean annual temperature (Trenberth 2011; Field et al. 2012) affecting European forests resilience and trigger die-offs (Breda et al. 2006; Bigler et al. 2006; Allen et al. 2010; Sánchez-Salguero et al. 2010). Various reports at regular intervals are being published by the Intergovernmental Panel on Climate Change-IPCC, a panel of 195 member countries, assessing the rate of climate change and estimating future climatic variables. The last synthesis report "AR5" from IPCC was published in 2014 and reports a global temperature increase of 0.85^{o}C over the period of 1880 to 2012 (Folland et al. 2001; IPCC 2014)

Temperature and precipitation are modelled to be the deterministic factors for species distribution and survival in European ecosystems (Thomas et al. 2004). Various models and emissions scenarios have been published in the literature

(Radićet et al. 2014). All of them predict 2-4ºC mean temperature increase up to 2100 AD. Additionally an increase in overall precipitation is also predicted to take place especially in the Northernmost Europe due to increase evaporation from water surfaces and gradual melting of glaciers combined phenomenon that it expected to significantly alter the mixed-phase clouds (clouds that consist of both cloud droplets and ice crystals) (Trenberth 2011; Komurcu et al. 2014).

1.2.2 Effect of climate change on species range expansion limits

The forthcoming climate change will affect the range expansion limits of most widely distributed plant species in Europe having significant implication in biodiversity (Moritz and Agudo 2013; Sax et al. 2013). Many endemic species of the high mountains in throughout of Europe are considered to be more prone to climate change due to narrow climatic niche requirements, usually low genetic diversity and a high possibility of becoming isolated (Essl et al. 2009; Dirnböck et al. 2011; Dullinger et al. 2012; Cotado and Munné-Bosch 2020). Many plants species will need to move from one up to thousand kilometers until the end of century (Malcolm et al. 2001; Corlett and Westcott 2013). Under the continuous increase in mean annual temperature most plant species in Europe are predicted to find their climatic niche further North at higher altitudes up to the end of the century (Loarie et al. 2009). Bakkenes et al. (2002), report major changes in biodiversity by 2050. More specifically, by using a grid modeling approach they concluded that 32% of the European plant species that were present in a grid cell in 1990 would disappear from that cell until 2050. The area, in which 32% or more of the 1990 species will disappear, takes up 44% of the modeled European area. However, the shifting in plants distributional limits is not only affected by the climatic variables but it is also depended by the dispersal ability of individual species (Thomas et al. 2004; Engler et al. 2009).

However, the magnitude of the effect it is predicted to differ among European areas with the species populations expanding in the southernmost Europe to be more severely affected, since the increase of temperature will be associated with a decrease of precipitation (Thuiller et al. 2005a; Engler et al. 2011; Pauli et al. 2012) On the other hand, Northernmost species plants populations will be less affected (e.g. Konôpková et al. 2020, Dagnino et al. 2020) while also will be favored from the temperature increment, but this benefit is going to be short-term. In the face of the climate change the populations of many plant species are expected to shift towards higher altitudes to meet their thermal requirements (Engler et al. 2009). This transition could also have increased isolation consequences in the montane populations for example in the Balkans where the mountainous regions have highly heterogeneous topography.

1.2.3 Plant populations response in climate change

The ways the plant species will respond to the changing climatic conditions depend on its severity and rate. For example, if the rate of the climate change is directional most species will try to monitor and genetically adapt to the changing climatic conditions by favoring specific alleles.

Apart from the effect of rate of climate change plant species response is also determined by plasticity in functional traits (incl. changes in physiology, germination timing) or genetic (local) adaptation/change or combination of both (Mátyás 1996; Conner and Hartl 2004; Nicotra et al. 2010; Moritz and Agudo 2013; Alberto et al. 2013; Matesanz and Valladares 2014; Franks et al., 2014; Rehfeldt et al. 2017; Sáenz-Romero et al. 2019; Kijowska-Oberc et al. 2020). However, it should be mentioned that populations plasticity is evolvable having thus genetic basis (Scheiner et al. 2020), and also that high genetic diversity is an important populations' buffer parameter especially for cold-adapted taxa to withstand climate change (Theodoridis et al. 2018). Both plasticity as well as genetic adaptation is significantly affected by landcover changes and the human impact which can cause habitat fragmentation thus limiting population's connectivity through pollen or seed flow (Matesanz and Valladares 2014).

Plant species populations respond to climate change by two ways a) migration to track their suitable niche climatic conditions, b) remaining in the modified climatic environment through adaptation and tolerance mechanisms or by a combination of both (a) and (b) (Davis and Shaw 2001, Jump and Peñuelas 2005). Thus, although the climate change will affect more or less severely the European forest species distribution and survival however this effect can be buffered from the variability of functional adaptive traits at both species and community level locally (O'Neill et al. 2008; Peterson et al. 2019; Estravis-Barcala et al. 2020)

However, there are plant species that are neither able to respond and adapt to climate change nor to migrate fast, and thus they will severely be affected by the modified climatic environment incurred reduction in their distribution range leading them potentially to extinction or quasi-extinction˙a form of isolated relict populations particularly vulnerable to disturbances (Eriksson 2008; Zeidler et al. 2020). But is of high importance to be mentioned that the above species inability to respond to climatic change is not mainly because of climate itself but mainly from human impact and habitat fragmentation that renders the landscape impassable (Pitelka et al. 1997; Thomas et al. 2005) increasing isolation and hampering thus gene flow among populations (Davis and Shaw 2001). Those species have high possibility of becoming extinct in future. Usually, species vulnerable to rapid climate change are species with low dispersal ability, slow growth rate and low phenotypic plasticity. Species with a high degree of endemism on the high mountains of Europe meet these criteria. Maloclm et al. (2006) predict an average extinction percentage of 11,6% endemic biota in Europe in the next 100 years. In a compiled research data Thuiller et al. (2005) projected late 21st century distributions for 1,350 European plants species under seven climate change scenarios and report that many European plant species could become severely threatened and more than half of those species could be vulnerable or threatened by 2080. They also calculated that the expected species loss and turnover per pixel was highly variable across scenarios (27-42% and 45-63% respectively, averaged over Europe) and across regions (2.5-86% and 17-86%, averaged over scenarios). Thomas et al. (2004)

estimate 6-8% and 18-29% of plant species in Europe to extinct under dispersal or no dispersal scenario by the year 2050.

1.2.4 Effect of climate change on plant community composition and ecosystem services

Temperature and precipitation as major driving factors of Climate change not only can alter plant species range limits as mentioned above, but it can also infer changes in the currently dominant species as well as the associated-dependent flora and thus in local or regional biodiversity (Calderaro et al. 2020). Pereira et al. (2010) analyzed quantitative scenarios of changes in biodiversity considering various models (e.g. Species-area models, niche-based models) and parameters (e.g. habitat loss, species abundance, socio-economic aspects) under climate modification and concluded that biodiversity will continue to decline over the 21st century.

Changes in species composition in a given community can take place via two ways either by replacement of the dominant species from subdominant ones or by migration of species from neighboring locations. Severity and rate of climate change are the deterministic factors for whether in situ replacement or migration would take place. This is because each plant has developed a set of functional traits, in the given environment, to counteract the pressure of climate change. If climate change proceeds at a fast rate some species might not “get in time” i.e. adaptation lag, respond and thus lose their functional traits advantage (Sax et al. 2013). The last one can be further accelerated if it is accompanied by any other disturbance leading either in via situ replacement or new migrants’ insertion. Resilience of a plant community to rapid climate change is closely related to the diversity of plant functional/adaptive traits at species level (Loreau et al. 2002). The more diverse the plant community functional traits the more resilient should be the overall ecosystem functions especially under abrupt changes.

The forthcoming climate change can affect the survival and reproductive performance of European forest species. Alongside with the human impact can assist the invasion of alien species in the natural ecosystems at local or regional level with implications on overall biodiversity. Alien species are usually high occupiers as pioneer species often at the expense of the local flora. Alien species invasion apart from its effect in biodiversity is also affecting the overall ecosystem productivity changing nutrient flow and affecting soil composition.

Forests around the globe offer valuable ecosystem services (both economic and ecological- water balance, timber, air quality, food production etc) (e.g. Pan et al 2011; Bonan et al. 2016) which are threatened by the human disturbances and the climate change (Lucht et al. 2006; Houghton and Nassikas 2017; Seidl et al. 2017). However, the effect of climate change on the ecosystem services is not only directional but also bidirectional since the carbon availability especially in the Northern regions of the Europe can also either accelerate or decrease its rate (Cox et al. 2000; Friedlingstein et al. 2003).

Finally, changes in local community species composition resulting from native forest species migration due to climate change and the possible replacement by other species will have consequences on ecosystem services through change in water cycle, carbon balance, nutrient flow and cycling accompanied by changes in the associated (dependent) flora thus reducing the overall biodiversity (Gitay et al. 2001; Viglizzo et al. 2016; Sheil 2018).

1.2.5 Methodological approach in study plat populations distribution under future climate change scenario

Future distribution of plant populations in the face of climate change is being estimated by modeling approach combining published literature data on current species distribution and correlating them with current climatic variables. In a second step they simulate possible migration routes of plant species according projected future climatic variables in their site of origin considering as granted that species will be on the move tracking their suitable niche climate (Guisan and Zimmermann 2000; Malcolm et al. 2002; Thomas et al. 2005; Guisan and Thuiller 2005). A broad range of published material regarding future climatic projections, have already been carried out to forecast future plant species distributions and migration routes, either at large geographical scales with coarse resolution (e.g. 10min arc) (Bakkenes et al. 2002; Thuiller et al. 2005), or with high resolution data but at smaller geographical scale (regional or local) (Guisan and Theurillat 2000; Dirnböck et al. 2003). Although this approach is extensively commented in literature however it does not consider the species adaptive traits and their geographical pattern. A new approach in modeling future plant populations distribution is based in incorporating in the model parameters the species adaptive-functional traits. This approach is being called Dynamic Global Vegetation Models (DVGM) (Neilson et al. 2005; Lucht et al. 2006; Sitch et al. 2008). Dynamic global vegetation models are a more complicated approach trying to simulate changes in species vegetation distribution under changing climatic conditions connecting them, with species ecophysiological traits (e.g. photosynthesis, respiration), changes in carbon productivity and balance alongside with changes in the ecosystem services being used by human society (Costanza et al. 1997, Cramer et al. 2001; Lucht et al. 2006; Sitch et al. 2008). Another limitation in many published references studying future plant distribution by the modeling approach is that in the model parameters they do not consider the species dispersal abilities restricting thus true species estimated migration (Engler et al. 2009). For example, large (heavy) seeded species usually have low dispersal ability itself and their dispersal is depended on biotic factors. On the other hand, light-seeded plant species with modified structures (e.g. wings) are better dispersals. The above-mentioned modeling studies usually consider unlimited species dispersal ability which although might represent a realistic option however omits the true dispersal potential. In this direction new model approaches that consider the dispersal probability of species are published (Dullinger et al. 2004; Iverson et al. 2004; Engler and Guisan 2009; Dagnino et al. 2020).

1.2.6 Effect of climate change on species populations performance, phenology and survival

Temperature and precipitation climatic variable have driving effect in survival, growth performance, phenology, fruit ripening, and structure of forest plants populations (Hughes et al. 2000; Zeidler et al. 2020; Konôpková et al. 2020; Patsiou et al. 2020; DeSoto et al. 2020; Chamberlain et al. 2021). The magnitude of climate change effect is also differing among the distributional limits of populations at local or regional level (Voltas et al. 2018; Cotado and Munné-Bosch 2020; Patsiou et al. 2020). Mediterranean populations of *Pinus pinaster* showed greater recovery and long-term survival under extreme drought than Atlantic populations of the same species but this could reverse under the forthcoming climate change (Zas et al. 2020). Sánchez-Salguero et al. (2018) found that populations of *Pinus pinaster* from dry sites in western Mediterranean basin were less resistant to drought but recovered faster than trees from wet sites.

Shifting in phenology as a consequence to changing climatic conditions which affects critical driving factors has been observed (Gauzere et al. 2019). Chamberlain et al. (2021) found for six tree species across 11 648 sites in Europe that climate change can reshape the drivers of false spring risk. Fu et al. (2014) and Vitasse et al. (2018) also reported shifting in budburst date as a response to increasing warming trend in Central and Northern Europe. However, spring frost damage possibility estimated up to the current data seems to depend on individual species and its regional distribution and expected to increase (e.g. Chamberlain et al. 2021), remain unchanged (e.g. Scheifinger et al. 2003) or even to minimized (e.g. Vitra et al. 2017) although budburst remains a critical phenological trait for tree fitness under climatic change.

Finally, as stated above the intensity of these effects will differ among the European geographical zones. Performance, growth, and phenology especially in the Southernmost European distribution is expected to be reduced mainly because temperature increment and irregular precipitation (Patsiou et al. 2020; Gárate-Escamilla et al. 2020).

1.2.7 Climate changes gives rise to outbreaks

Increasing climatic change rate could in overall modify the patterns and the magnitude of disturbance caused by herbivores and pathogens through either directly by favoring their survival and colonization or indirectly affecting (a) tree physiological defense, (b) the abundance of their natural enemies (i.e parasitoids, nematoids) and (c) the presence of competitors (Ayres and Lombardero 2000; Hlásny and M. Turčáni 2009).

As stated above climate change is expected to affect forest species performance and growth and will probably benefit biotic factors outbreak as secondary infestation (e.g. Faccoli 2009; Marini et al. 2012; Jaime et al. 2019; Bāders et al. 2020). For example, Netherer et al. (2015) provide evidence of impairing in *Pinea abies* resistance to bark beetle attack under drought stress conditions. Similarly, Dobbertin et al. (2007) also associated increased rate of beetle attack in *Pinus sylvestris* after intense drought summer. In addition, all forest plant populations have a degree of local adaptation in their current habitat. Migration of plant populations outside from their current distributional limits will subject populations to a relative novel environment in which although they will try to adapt however a high chance of secondary infestation from biotic factors do exist.

1.2.8 Human impact on plant migration

Most plant species in Europe (especially the forest ones) have survived many climatic oscillations having their range expansion limits to frequent changes. However, their current range expansion limits are a combination of climate change, species individual resilience and human impact (Kowarik 2003; Meier et al. 2012; Pardi and Smith 2012; Renton et al. 2014).

Human disturbance has either accidentally of incidentally impacted plant migration from their natural locales. One of the main ways is by transferring alien species (e.g. in the form of seeds) which are lie in topsoil and other agricultural or forestry products (i.e timber) (e.g. Hodkinson and Tomson 1997). Those species are deposited outside of their natural habitats in a novel-disturbed environment and can cause severe changes in ecosystem balance since not only alter carbon balance and nutrient flow, but it can also compete the local flora (Mooney and Cleland 2001; Sakai et al. 2001). These alien invasive species can flourish in the novel environment making thus any prediction about future native ecosystems resilience highly uncertain (Lee 2002; Petit et al. 2004).

Another way that human activities impacting on species migration routes is landscape fragmentation, land-cover changes and land abandonment (Higgins et al. 2003; Dullinger et al. 2015; McGuire et al. 2016). These disturbances restrict populations' connection with severe implications on local population effective sizes, introducing bottleneck effects and thus increasing the risk of local extinction.

Habitat fragmentation causes a discontinuation among populations thus restricts (but not impaling) the ability of the offspring to migrate in a suitable habitat meeting their niche requirements even if this habitat do exist (Honnay et al. 2002; Brown et al. 2012; Pachepsky and Levine 2011; Levey et al. 2008; Meier et al. 2012). However, incidentally fragmentation of a habitat when invading alien species can be a way to control its further expansion at the expense of the local flora (Brown et al. 2012).

Finally, the percent of habitat fragmentation as well as the pattern of fragmentation at a given site at local or regional level has significant effect on the rate of migration since for populations of a species with low degree of habitat fragmentation there are less barriers in migrating to a nearby suitable site (Pachepsky and Levine 2011; McGuire et al. 2016).

2. Current climatic conditions across the studied countries

2.1 Romania

The climate proprieties are induced by the general climate-generating factors from which we can mention here the Solar radiation. This radiation is one of the most important factors in the climate. It is the main energy source of physical and geophysical take place in the Earth's atmosphere (Vaduva 2008).

The amount of the Solar radiation is not equally distributed on the land surfaces. Its distribution varies function (firstly) by the position on Earth and (secondly) by the nature of the surface and its altitude. It is well known that there is a relation between the latitude and the Solar radiation. The lower latitude the higher values of the Solar radiation on the surface of Earth.

Thus, Romania is situated in the temperate zone of the general climate on Earth, characterized by the presence of four seasons (two extremes: cold in winter and warm in summer, and two transitional ones: spring from winter to summer and autumn from summer to winter). Being inside of the continent (Europe), the sub-type of the climate is the continental one. This sub-type introduces some specific characteristics to the general climate. One main characteristic is that in winter the temperatures are middle to very low and in summer the temperatures are high and the season usually is dry.

Due to the different quantity of the Solar radiation and different amount of this radiation absorbed differently function of the nature of the surfaces and position in space there are different values of the temperature.

Air temperature is one of the most important parameters of air condition, characterized by a special variability in time and space. The effect of genetic factors is manifested in the distribution of all the characteristics of the multi annual air regime (Vaduva 2008).

In Romania, the distribution of the annual average values of air temperature has distinct peculiarities, differing from one region to another. From the analysis of the annual average values of the air temperature calculated for the period 1961-2000, some particularities of their territorial distribution can be deduced. Between the south and the north of the country the temperature difference is about 4 °C, and between east and west of 1 °C. The distribution of the average annual air temperature values is more uniform in the plain regions than in the mountainous region, because the adjective processes occur on the whole surface of the plain with the same intensity. In the Romanian Plain, the annual values of air temperature are between 10 and 11 °C. Values higher than 11 °C are located in the southern part of this plain, along the Danube (Table 1) (Vaduva 2008) and Figure 1.

Table 1. Air temperature. Multi annual average 1961-2000 (after Vaduva 2008)

Station	T°C	Station	T°C
Alexandria	10,9	Slatina	11,1
Roşiorii de Vede	10,7	Călăraşi	11,3
Giurgiu	11,2	Drobeta-Turnu Severin	11,7
Turnu Măgurele	11,3	Bucureşti Filaret	11,2

High values of the average annual temperature (> 11 °C) are also recorded on the Black Sea coast (due to the moderating role of the sea in winter) and in southwestern Banat (due to the advection of tropical air masses), where the values of the radiative balance and caloric are high (Table 2) (Vaduva 2008) and Figure 1.

In the other plain regions located on the eastern and western peripheries of Romania, the average annual temperature varies between 9 °C and 10 °C. In the hill and plateau regions the average temperature oscillates between 6 and 10 °C. Lower values characterize the northern parts of the sectors respectively, due to the higher frequency of cold air invasions.

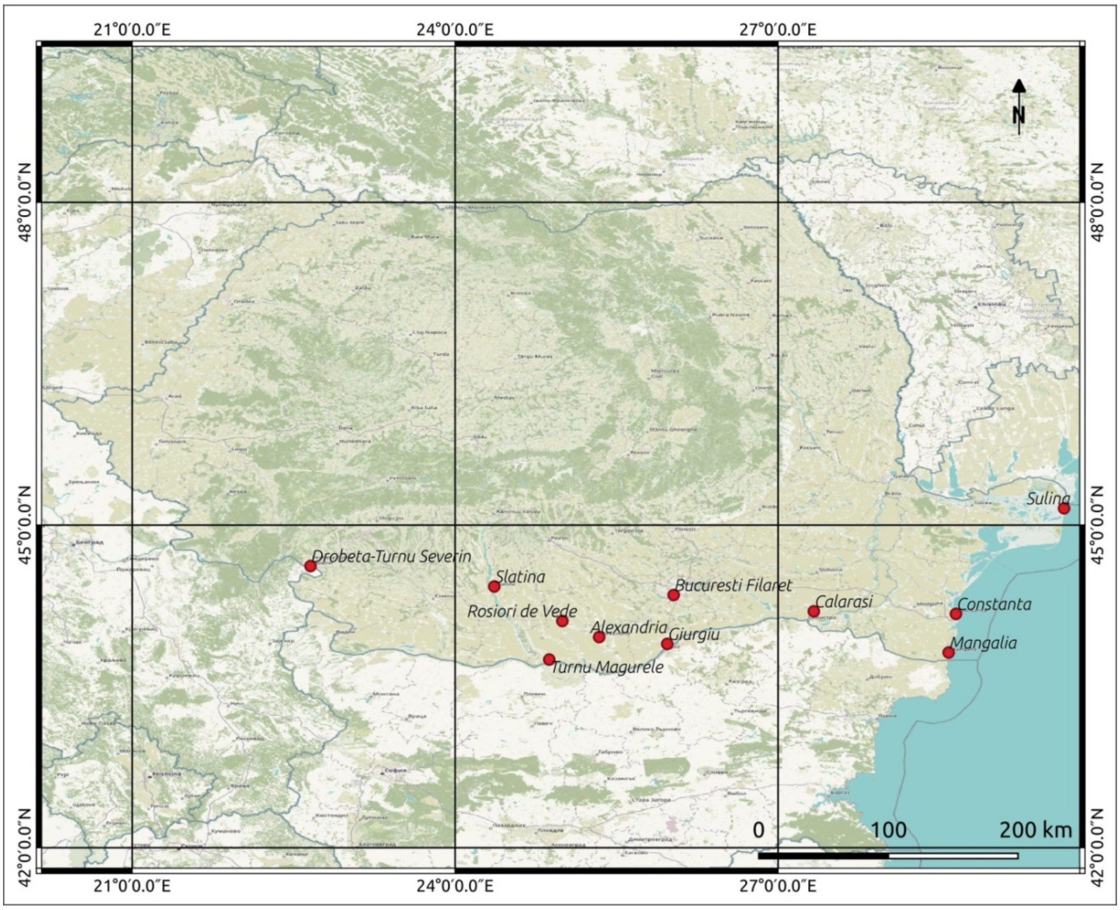

Figure 1. Localities from the Southern part of Romania

Table 2. Air temperature. Multi annual average 1961-2000 South-Eastern part of Romania (after Vaduva 2008)

Station	T°C	Station	T°C	Station	T°C
Sulina	11,3	Constanta	11,6	Mangalia	11,5

Exceptions are also the regions where the föenal processes predominate, which lead to the local adiabatic heating of the air and to the raising of the temperature by 1-2 °C (Vaduva 2008).

Atmospheric precipitation is the climatic element characterized by discontinuity and large variations in time and space. The amount, intensity, frequency, duration and shape of the precipitation it largely depends on the activity and results of the work carried out in a number of fields such as agriculture, construction, transport, balneology, tourism etc. Therefore, the knowledge, at least partial, of the particularities with which they occur in a region or place presents, besides the theoretical importance, also a very important practice (Erhan 1988).

The annual precipitation amounts are unevenly distributed in the territory, in relation to their genetic factors. In the Carpathian Mountains, the distribution of atmospheric precipitation is very uneven, depending on the altitude, the exposure of the slopes and their fragmentation, as well as their concentric arrangement (Vaduva 2008).

The highest annual precipitation amounts are made in the mountainous region at altitudes of over 1900-2000 m (Rodna Mountains, Maramureş, Făgăraş, Apuseni), where they exceed 1200 mm. Peaks play an important role in intensifying frontal activity and thermal convection which creates favorable conditions for the development of cloudiness and falling rainfall.

In general, on slopes with western and northern exposure (exposed to humid air masses), the annual amounts of precipitation are 100-200 mm higher than those with eastern and southern exposure (sheltered, under the advection of continental air masses) (Vaduva 2008).

In the regions with föehnal effects (Huedin-Turda-Alba Iulia-Blaj-Deva area; Focşani-Râmnicu Sărat-Buzău; Mehedinti Plateau and Getic Subcarpathians), the precipitation amounts are lower than in the neighboring regions, due to the descent of the air from the slopes to the western shelters (Pietroasel: 592.0 mm; Buzău: 530.2 mm) (Vaduva 2008).

The lowest annual rainfall occurs on the Black Sea coast (Mangalia, 407.3 mm; Constanta, 407.1 mm) and in the Danube Delta (Sulina, 348 mm; Sfântu Gheorghe, 400 mm), due to the large areas of water that favor currents air down temperature inversions and the disintegration of cloud systems, but also due to the continentalization of oceanic air masses that lose their moisture as it advances to the eastern part of Romania (Vaduva 2008).

There are also quantitative differences between the western sector of the country with oceanic influences and the eastern and south-eastern with continental influences (Vaduva 2008).

In the Western Plain, the average annual rainfall ranges between 600-650 mm (600 mm in Timisoara). In the east of the Romanian Plain, the average annual rainfall decreases from 500 to 400 mm (Vaduva 2008).

In the central part of the Romanian Plain, the annual precipitation quantities are between 500 and 600 mm (Videle: 550 mm; Roşiorii de Vede: 605 mm; Alexandria: 537 mm; Turnu Măgurele: 535 mm), and to the north, in the vicinity of the slopes of the sub-Carpathians and the 600 mm (Pitesti: 672.2 mm) (Vaduva 2008).

In the Subcarpathians and the Moldavian Plateau, the precipitation amounts vary between 630.5 mm at Piatra Neamt; 652.7 in TârguNeamt; 594.9 mm at Buhuşi; 517.6 mm at Adjud; 653.8 mm at Tulnici; 538.4 mm in Bacău; 519.4 mm in Roman and 549.3 mm in Iasi.

Along the Danube, rainfall decreases from west (Drobeta-Turnu Severin: 662.3 mm) to east (Hârşova: 410 mm) (Vaduva 2008).

In the Transylvanian Plateau, the average annual rainfall amounts are between 500-700 mm (Sebeş: 507.4 mm; Blaj: 543.4 mm; Turda: 501.3 mm; Cluj Napoca: 566.5 mm; Târgu-Mureş: 573.5 mm; Dumbrăveni: 631.1 mm) (Vaduva 2008).

2.1.1 Danube (Romania)

The climate in Danube Delta Biosphere Reserve (DDBR) supports three external influences, due to the “buffer” position of the it between the bordering continental land that surrounds it on the north, west and south sides and the Black Sea to the east: continental, pontic and air advection influences, respectively (Bogdan 2006).

In accordance with external influences, the air temperature has moderate values, being, however, in the coastal area, one of the highest in the country. The annual average values increase gradually from west to east, simultaneously with the reduction of land influence and increase of sea influence: Tulcea and Jurilovca 11.0 °C, Gorgova 11.2 °C, Sfântu Gheorghe and GuraPortiţei 11.4 °C, Sulina-dig (located above the territorial waters, at about 6 km offshore) 11.6 °C and the Gloria Platform (located at about 30 km offshore, near the sea coast between Sulina and Sfântu Gheorghe) 12 °C, as a result of the role of thermal water reservoir shallow (10 - 20 m) on the continental shelf (Iliescu 1991).

The average annual temperature registered non-periodic variations, positive or negative, relatively small, of 1.5 – 2 °C. In the warmest years it exceeded 12 °C (12.5 °C in 1951 in Tulcea and 12.7 °C in 1966 in Sulina), and in the coldest years, it dropped below 10°C (9.5 °C in Tulcea and 9.7 °C in Sulina in 1942). During the year, the average monthly temperature is a minimum in January, the only month of the year with negative values and a maximum in July throughout the reserve, except for territorial waters on the continental shelf, where the two main moments are one month behind, in February and August, respectively (Bogdan 2006).

Under the influence of the marine aquarium, in January the air temperature increases from west to east: Tulcea -1.5 °C, Gorgova and Jurilovca -1.4 °C, Sulina-city -0.4 °C, Sfântu Gheorghe and GuraPortiţei -0.3 °C, Sulina-dig -0.2 °C and Gloria Platform, 2.6 °C, the highest value. In the coldest years, the temperature of January can drop below -8 ^{o}C (1942), and in the warmest, it can reach 3 – 5 °C (1936, 1985) (Bogdan 2006).

Likewise, in July, the monthly averages increase in this respect, exceeding 22 °C: Jurilovca 22.6 °C, Tulcea 22.7 °C, Sfântu Gheorghe and GuraPortiţei 22.9 °C, Sulina-dig 23.0 °C and only 22.0 °C at Gloria Platform due to the high humidity of the air. In the warmest years, the averages of this month exceeded 24 – 25 °C (July 1936), but fell below 21 °C, in the coldest months (1902, 1943, 1949, 1969, 1970 etc.) (Bogdan 2006).

Above the territorial waters of the Black Sea, at the Gloria Platform, the annual thermal minimum was registered in February, being of +0.9 °C, and the annual thermal maximum, in August, of 22.4 °C (Bogdan 2006).

Thus, the greatest thermal potential is outlined in the coastal area and on the surface of the neighboring territorial waters (Bogdan 2006).

Under the influence of the neighboring land and the Black Sea, precipitation atmospheric is gradually reduced from west to east (Bogdan 2006).

A significant contribution to the annual amount of precipitation has the local summer rains. Thus, while on the neighboring continental surface, under the influence of thermal convection during the day, risingaircurrentsarisethat generate nebulosityand convective rains, aquatic surfaces, especially above coastal waters, due to evaporation processes involving heat consumption, temperature inversions are formed, characterized by descending air currents, which determines the disintegration of cloudy systems and the decrease or absence of precipitation. In this context, the average annual quantities have the following values:

- in the deltaic space: Tulcea 438.4 mm, Gorgova 406.9 mm, Sfântu Gheorghe 403.6 mm, Sulina-dig 330.5 mm;
- in the Razim-Sinoie lagoon complex: Jurilovca 386.6 mm, Dranov 356.5 mm and Gura Portiţei 327.2 mm (Bogdan 2006).

On the Caraorman and Sărăturile levees, they exceed 400 mm (Sfântu Gheorghe 403.6 mm), as a result of local convective rains. Over the years, the average annual amounts of precipitation have registered large non-periodic variations, the highest rainfall contrasts being right on the coast, at Sulina: 690.5 mm in 1935, the highest annual value, representing twice the multiannual average value and 132.7 mm in 1920, the lowest annual value, which is about 1/3 of the multiannual average (Bogdan 2006).

During the year, the average monthly precipitation amounts to an annual maximum in June (45 - 55 mm) and a minimum in February (18 - 35 mm), with the same downward trend west-east. On the coast, there is also a secondary maximum in November-December, but with lower values (30 - 38 mm), determined by the Mediterranean and Pontic cyclones of this period (Bogdan 2006).

In the warm semester of the year, the average rainfall amounts to 1/2 to 1/3 of the annual value showing the same trend of territorial evolution: about 240 mm in the western extremity and about 170 mm in the eastern, except for the levees, where they exceed 200 mm. The amounts of absolute maximum precipitation in 24 hourswere, in all cases, higher than 90 mm, far exceeding the average value of themonths in which they occurred, July - August; they also represented 1⁄2 to 1⁄3 of the average annual quantity at the respective station. The highest amount in 24 hours occurred on 29.VIII.1924, at CARosetti, totaling 530.6 mm which completed with the rain of the previous day 30.VIII was 690.6 mm, representing 1720% compared to August average; On the same day of 29.VIII, 219.2 mm were recorded in Sulina, representing 2/3 of the annual quantity from the same station, produced in a single day (Bogdan 2006).

The average annual number of days with precipitation (≥0.1 mm) gradually decreases from west to east: Tulcea 104.1 mm, Gorgova 96.4 mm, Jurilovca 90.4 mm, Sfântu Gheorghe 88.0 mm and Sulina 87,3 mm (Bogdan 2006).

The snow cover is temporary, sometimes even ephemeral; only on the reinforced ridges, in the snowy interval. There are rare cases in winter, when violent blizzards occur, and in coastal waters, strong storms (Bogdan 2006).

2.2 Ukraine

Global climate change has caused a number of regional changes in Ukraine: rising average annual temperature; the climate becomes less continental with a significant increase in winter temperatures; in the north-western regions (including the Danube basin) there is an increase in rainfall in the summer months; at the same time, the amount of rainfall in spring and autumn decreases.

In Ukraine, the global warming is known as cause of impact on steppe ecosystem structure; changes in coastal ecosystems; excitation of catastrophic events, desertification process development in southern and southeast regions of Ukraine. It also affects agriculture, aspects of wild bioresources, and economics. Changes in heat and moisture have the main influence on terrestrial ecosystems.

In the phytocenosis of Ukraine's steppes in the second half of the XX-th century and at the beginning of the 21st century the tendency to a degradation of the xeromorphic component by (30 ± 10)% and the reverse tendency to an increase of the mesomorphic component by (20 ± 10)% are established (Tkachenko and Boychenko 2014).

Hydrological study of surface water resources of Ukraine is insufficient to obtain reliable assessments of their state in depending on the scale of anthropogenic transformations. This is due to lack of data monitoring the runoff in natural conditions of its formation and lack of systematic data on water consumption. Modern generalizations of the annual runoff reflect, first of all, the regularities spatio-temporal distribution of household, disturbed economic activities of the runoff, leaving in the form of "white spots" southern and southwestern regions of Ukraine, where there is no information on runoff both natural and transformed conditions (Loboda 2005).

Hydrometeorological observations treated with statistical methods shows a marked increase of mean annual air temperature in Ukraine and adjacent territories of neighboring countries. The largest increasing of temperature is observing in winter and spring, resulting in a marked decrease in the depth of soil freezing. It caused the change of the flow formation conditions and correspondent to it change of inner year distribution. During the observation period from the end of the XIX century mean annual temperature in Ukraine increased by 1.5 °C, that is twice more than in whole on the globe. At the same time the precipitation didn't change essential: somewhere decreased, somewhere increased. Mean annual river flow didn't change significantly, but significantly changed inner year distribution of runoff: maximum spring flood discharges decreased, simultaneously minimum flow increased. The peculiarity of the ice regime of the rivers of Ukraine is the large amplitude of the terms of the first appearance of ice. In some years, in many parts of rivers, the indestructible ice cover may not be installed at all during the winter.

2.2.1 Danube (Ukraine)

Danube waters entering the western part of the Black Sea during the winter months significantly cool its surface layer, which enhances the thermal transformation of the Mediterranean air moving to the region of the Crimean Peninsula. The characteristics of river waters that most significantly affect changes in surface temperatures in the Western Black Sea are river runoff and average temperatures. Climate warming in the Danube basin, as well as anthropogenic impacts on its runoff are factors that can have a transboundary impact on environmental conditions in Crimea and other regions of the Northern Black Sea region, where the state of water resources is determined by winter precipitation (Kholoptsev et al. 2015).

The considerable changes in hydrometeorological conditions were occurred in the Danube River basin over the period from the late 20th century to the early 21st century. These are the air and water temperature rise, softening of ice conditions, and, above all, the noticeable increase in the river water runoff. Particularly, the recent extreme hydrological events in the Danube River basin are important: the disastrous rainfall flood that occurred in August 2002, the extremely high spring – summer floods in 2006 and 2010, and the extraordinary low flow period in summer 2003. Specific features in the development and transformation of flood waves along the Danube River are connected with impact of the Iron Gate1 Reservoir on these processes (Mikhailov et al. 2004, 2008; Mikhailova et al. 2012).

In the border zone between land and sea, many processes are extremely fast. So, the accumulative coast can be cut off by tens of waves in one storm, but after some meters, it can recover and regain its former appearance. Within the coast of Ukraine, significant erosion of the coast is observed near Odessa, in the western part of Crimea in the Yevpatoria region, between Cape Lukull and Sevastopol, and in other areas. The erosion of the unique Azov spits continues, which are of great value in terms of using their recreational opportunities. The natural cause of coastal abrasion is the modern transgression of the sea. Over the past 60 years, the Black Sea level has increased by about 15 cm and continues to rise. The average rate of the current rise in the relative level of the Black Sea can be estimated at 0.25 cm/year. In the area of Odessa, where there is an intense sinking of land, it reaches 0.5 cm/year (Goryachkin and Ivanov 2006, 2008)

Recently, the Black Sea Basin has seen an increase in the number of dangerous hydrological phenomena, in particular the formation of catastrophic floods and the reduction of water resources in large areas. Climate change affects not only the quantitative but also the qualitative characteristics of river runoff, which also affects marine ecosystems (Loboda and Tuchkovenko 2010).

Significant negative linear trends of 80-100-year series indicate a general decrease in the average wind speed and frequency of storms in the coastal zone of the northwestern region of the Black Sea in the 20th century (Repetin and Belokopytov 2008).

The main trends in the change in the average annual values of temperature and salinity in the coastal zone in the northwestern part of the Black Sea in the last 20 years. It was found that the water temperature dropped until the early 1990s, and after that it began to rise. Salinity increased until the early 1990s, and then steadily decreases (Dotsenko 2010).

2.3 Greece

Greece (total area 131 957 km2, land borders 1180.71 km long is located in the most southeastern part of Europe, in the eastern part of the Mediterranean Sea, between latitudes 34–42 ° N and longitudes 19–30 ° E, with coastline length of 15 021 km. It is bordering by the Aegean Sea, Ionian Sea and the East Mediterranean Sea. The main geographical areas are the mainland, the islands and the Aegean basin. The mainland covers about 80% of the total area; the remaining 20% is shared among about 6000 islands and islets. The landscape is mainly mountainous or hilly. The elevation ranges up to 2904 m above sea level (Mamara et al. 2014).

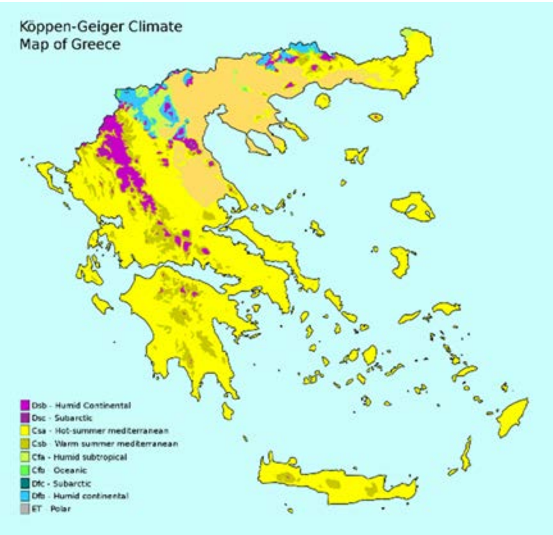

Figure 2. Climatic map of Greece according to Köppen classification

The Greek climate is typical Mediterranean: mild and rainy winters, relatively warm and dry summers and extended periods of sunshine throughout most of the year. It is characterized by a particularly intense topographic relief; with great altitude differences as there are several mountainous volumes (Lagouvardos et al 2007). A great variety of climate subtypes, always in the Mediterranean climate frame, are met in several regions of Greece. This is due to the influence of topography (mountain chains along the central part and other mountainous bodies) on the air coming from the moisture sources of the central Mediterranean Sea. Nine different climatic types according to Köppen classification can be found (Fig. 2), with the Cs class being dominant, i.e. the Mediterranean climatic type, but also including Cf, Df and Ds classes in smaller proportions (Markonis et al 2016).

From the climatic point of view, the year is mainly divided into two seasons: the cold and rainy winter period that lasts from mid-October until the end of March and the warm and dry period that lasts from April until October. The colder months of the first period are January and February, during which the mean minimum temperature varies between 5–10°C in the coastal regions, from 0–5°C in the continental regions and reaches negative values in the northern regions. The winters in the lowlands do not experience particularly low temperatures and snow, while in the mountains usually snow (Lagouvardos et al 2007). The mean annual temperature can be seen in Fig. 3.

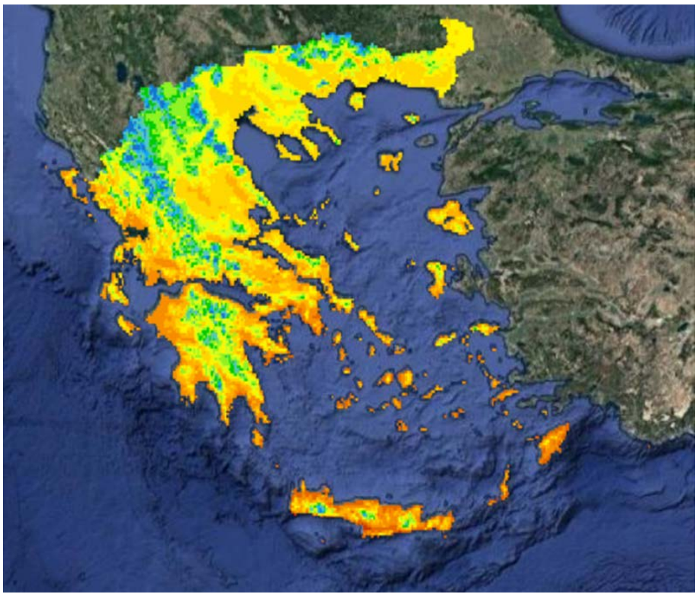

Figure 3. Mean annual temperature in ^{o}C (mean of the years 1971-2000). Climatic Atlas of Greece. (Hellenic National Meteorological Service, HNM, www.hnms.gr)

The warmer period occurs in the last 10 days of July and the first week of August, when the mean maximum temperature varies between 29–35°C. During the warm period the high temperatures are dampened from the fresh sea breezes in the coastal areas of the country and from the north winds blowing mainly in Aegean, well known as Etesianâ (Lagouvardos et al 2007).

Rainfall over Greece exhibits strong variability in time in both annual and decadal scale. As an overall trend, there is a clear dependence of winter and annual precipitations on longitude, with a general decrease from western to eastern continental Greece. The central chain of mountains that runs from northwest to southeast through the country creates different precipitation regimes between the western (wettest) and the eastern (driest) parts of the peninsula (Baltas 2008). In terms of spatial variability, higher annual rain is observed to the western part of Greece reaching as high as 1900 mm per year, while dry conditions prevail over the south-eastern part with anhydrate summers and annual rainfall sums, that may fall below 350 mm (Fig. 4) (Markonis et al 2016).

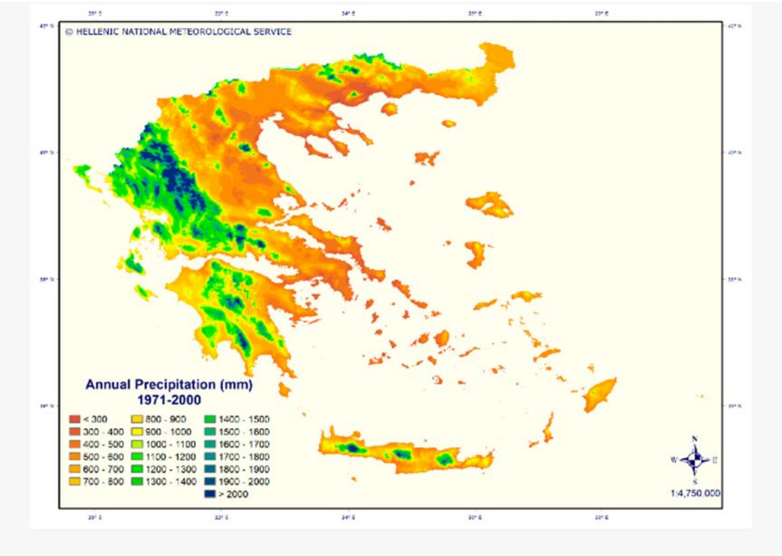

Figure 4. Annual precipitation in Greece (Hellenic National Meteorological Service, HNM, www.hnms.gr)

The rainfall in Greece is mainly associated with disturbances within the zone of westerlies entering the Mediterranean from the Atlantic Ocean and/or disturbances forming mainly in the north-western basin of the Mediterranean and crossing the region during the rainy season (October–April). The rainfall regime in Greece is basically controlled by the latitude and the general circulation of the atmosphere (travelling depressions), but it is modified by the interaction between land and sea and the complex orography of the region. Orographic rains on the mountain ridges contrast markedly with minimum annual rainfalls of less than 300 mm in the southern areas (Pnevmatikos and Katsoulis 2006).

The topography of the Pindos mountain range plays an important role in precipitation in Greece. The Pindos mountain range extends north-south to the movement of weather systems, causing air masses to ascend, their condensation leading to rainfall events. The most intense rainstorms, especially in the summer, are produced by the passage of depressions, usually accompanied by cold fronts (and rarely by warm fronts) approaching from the west, south-west or north-west (Baltas 2008; Markonis 2016).

The maximum mean monthly precipitation amount exceeds 300 mm and occurs in November and December, due to the increase of cyclonic tracks in the region. During these months, precipitation peaks at the highest altitudes (Pindos mountain chain, Peloponnese, Cretan mountain chains). On the contrary, the lowest mean monthly precipitation amount ranges between 21 and 30 mm mainly in Northeastern and Western Macedonia (Gofa et al. 2019).

The minimum mean monthly amount of precipitation is generally less than 10 mm (in July and August in the Aegean Sea islands). During the same months, the maximum mean monthly precipitation amount exceeds 90 mm and occurs in Northern Greece (Figs. 5 & 6) (Gofa et al 2019).

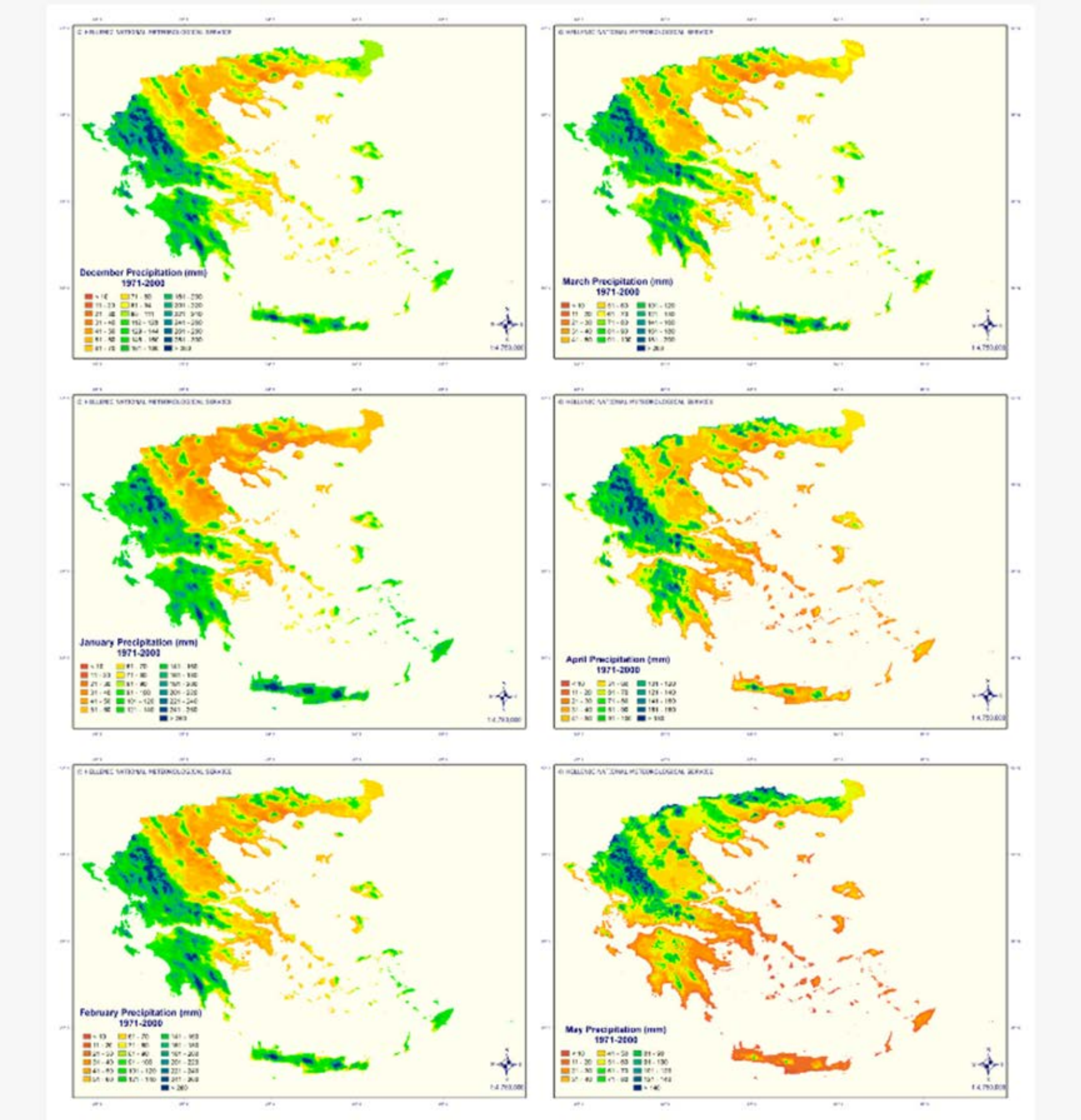

Figure 5. Precipitation maps for the period 1971–2000 for DJF months (left column) and MAM months (right column) (Gofa et al. 2019).

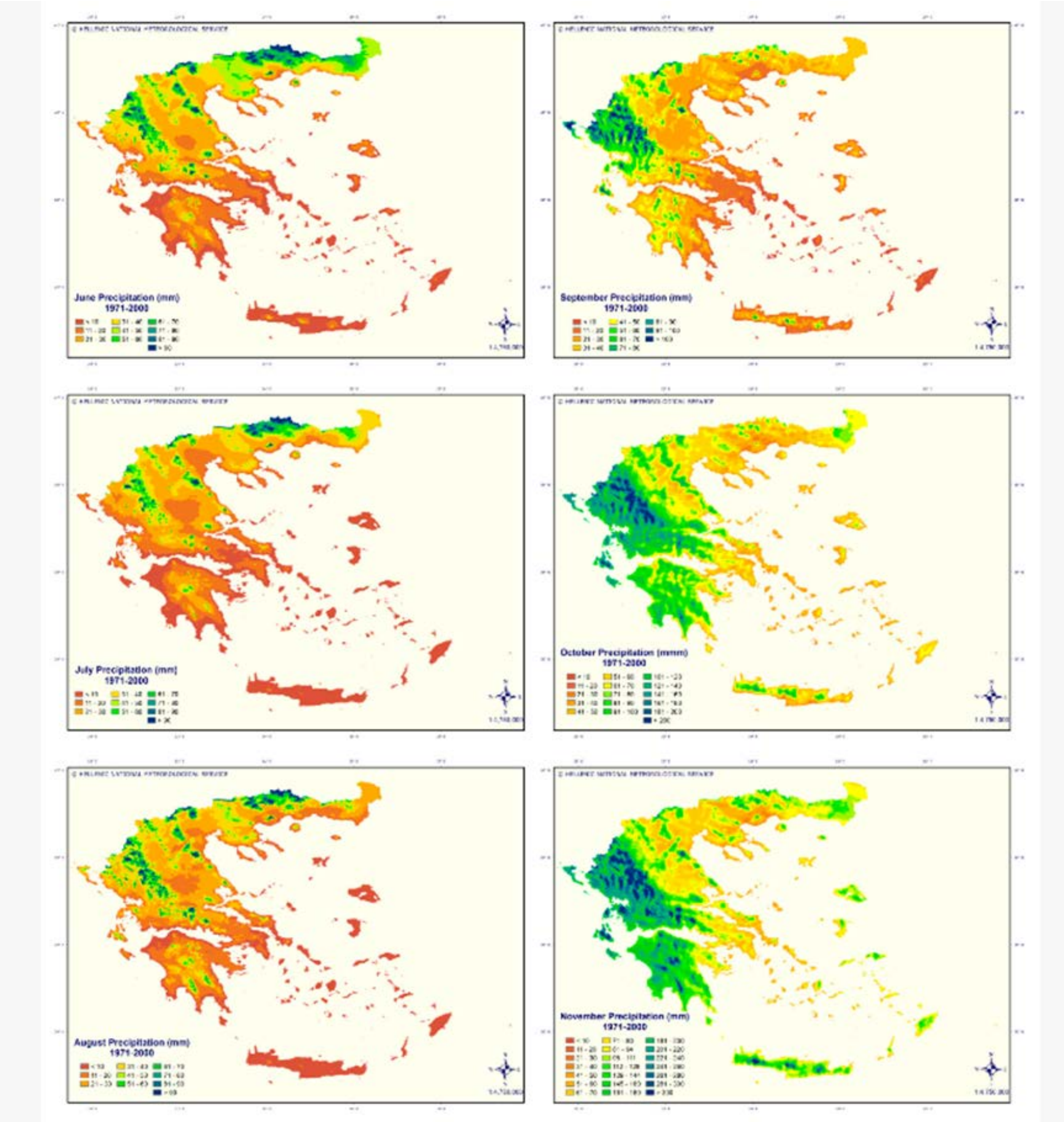

Figure 6. Precipitation maps for the period 1971–2000 for JJA months (left column) and SON months (right column) (Gofa et al 2019).

Earlier analysis of rainfall data over Greece suggests that there is a steady decline in annual rain since 1950 especially during winter months (Xoplaki et al. 2000). Most areas of the Greek peninsula have already undergone shifts in their rainfall regimes. Similar results have been presented for the neighboring regions and the Mediterranean Sea in general, most of them presenting a significant decrease in annual rainfall (Pnevmatikos et 2006, Philandras et al., 2011).

2.3.1 Nestos Delta

The nearest in Nestos Delta meteorological station in located within Megas Alexandros airport, close to the city of Chrysoupolis (Prefecture of Kavala). The general climate of this area is characterized coastal Mediterranean, with mild winters and dry and warm summers.

Precipitation rather constitutes the most significant climatic factor, which affects the vegetation in an area. Except the annual precipitation, the distribution of precipitation, and especially those falling during the period of vegetative growth, are of great significance as rainfalls during this period directly affect plant species by reducing the water stress and make them able to survive and grow.

The mean annual precipitation for the area of Chrysoupolis is c. 425 mm. As it can be seen in Table 3, the maximum value of the mean monthly precipitation is recorded on December (78.4 mm), whereas the lowest value of the mean monthly precipitation is recorded on August (17.0 mm).

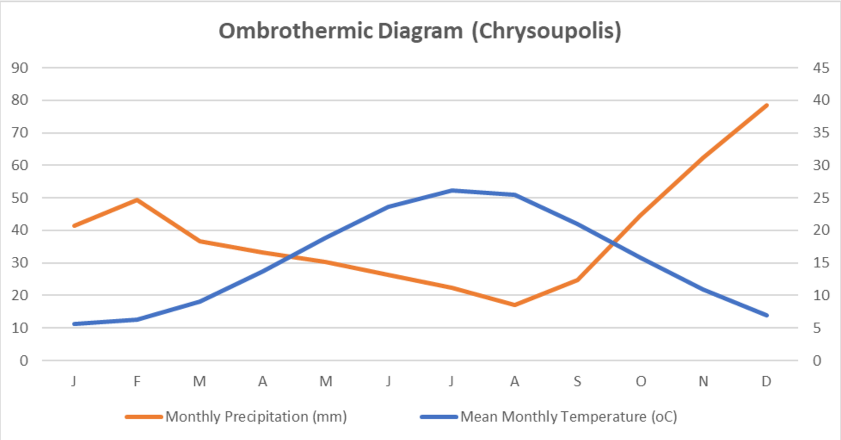

Figure 7. Ombrothermic diagram of the area of Chrysoupolis

Temperature constitutes a very important climatic factor, which plays an important role in shaping the vegetation in an area. Although the mean monthly values of temperature are important, the minimum and the maximum monthly values are important as well. The mean monthly values of temperature obtained from the meteorological station of Chrysoupolis are presented in Table 3, and Fig. 7.

As it can be seen, January is the coldest month (5.6 °C) followed by February and December (6.3 and 6.9 °C, respectively), whereas July, August and June are the warmest ones with 26.1 °C, 25.5 °C and 23.6 °C, respectively. The maximum monthly temperature was observed in August and July with 30.2 and 30.1 °C, respectively, whereas the minimum monthly temperature was measured in January and February with 1.8 and 2.1 °C, respectively. Detailed meteorological data can be seen in Table 3.

Table 3. Monthly values of the climatic data of the meteorological station of Chrysoupolis.

	J	F	M	A	M	J	J	A	S	O	N	D
Mean monthly temperature	5.6	6.3	9.0	13.7	18.9	23.6	26.1	25.5	21.0	15.8	10.9	6.9
Min monthly temperature	1.8	2.1	4.7	88	13.4	17.3	19.5	19.2	15.2	11.0	6.9	3.3
Max monthly temperature	9.5	10.3	12.9	17.5	22.8	27.4	30.1	30.2	25.7	20.4	15.0	10.6
Monthly precipitation	41.3	49.3	36.6	33.2	30.2	26.2	22.4	17.0	24.8	44.5	62.3	78.4

Precipitation and temperature constitute the most significant climatic variables which affect vegetation formations and the way they are arranged in a landscape. Dry season is known for its great ecological significance and is directly related with both these two climatic variables (precipitation and temperature). Dry from an ecological perspective, is considered the month when the total amount of the precipitation that fall this period (in mm) equals or is smaller to the double of the mean temperature for the same month (in ^{o}C) (Bagnouls and Gaussen 1957).

The dry season of an area can be observed in the ombrothermic diagraph, which is created on the basis of the climatic data of the specific area. Thus, based on the ombrothermic diagram (Fig. 9), the dry season for the area of Chrysoupolis lasts at least six months, from mid-April to the ends of October.

Based on the climatic data of the meteorological station of Chrysoupolis (temperature and precipitation) Vasilopoulos (2005) calculated the ombrothermic Quotient of Emberger (Q2). Specifically, based on the Emberger-Sauvage bioclimatic graph [created for Greece by Mavromatis (1980)] and the climatic conditions, Chrysoupolis is included in semi-arid class with cold winter (Vasilopoulos 2005).

2.4 Turkey

The Turkish Black Sea Region, climate is warm and dry in the summers and, mild and wet in winters (Ozesmi 1999). The average annual temperature is 14°C and the annual rainfall is 741.5 mm. The coldest months are January and February and while the warmest months are July and August (Acar et al. 2004).

Samsun has a humid subtropical, warm and temperate climate (Köppen: Cfa), like most of the eastern Black Sea coast of Turkey (Url 1). Spring temperatures can vary by over 10 degrees from one day to the next. Summers are warm and humid, and the average maximum temperature is around 27 °C in August. Winters are cool and damp, and the lowest average minimum temperature is around 3 °C in January. The average annual temperature in Samsun is 14.1 °C (Fig.8; and Fig.9).

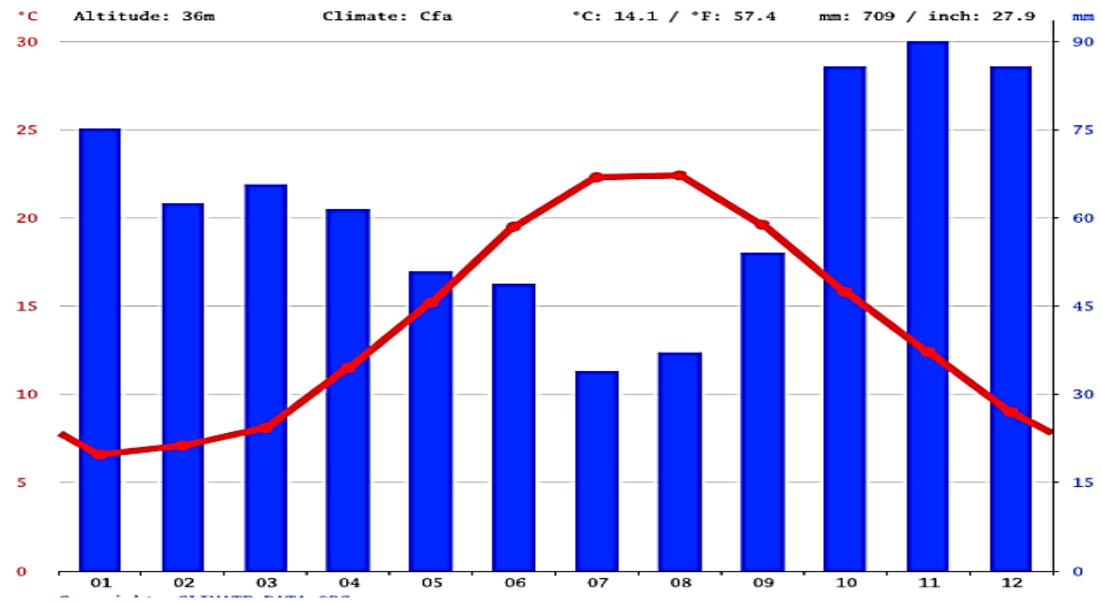

Figure 8. Samsun climate graph (yearly mean air temperature and precipitation) (Url-1, 2020; Url-2, 2020; Url-3, 2020; Url-4, 2020)

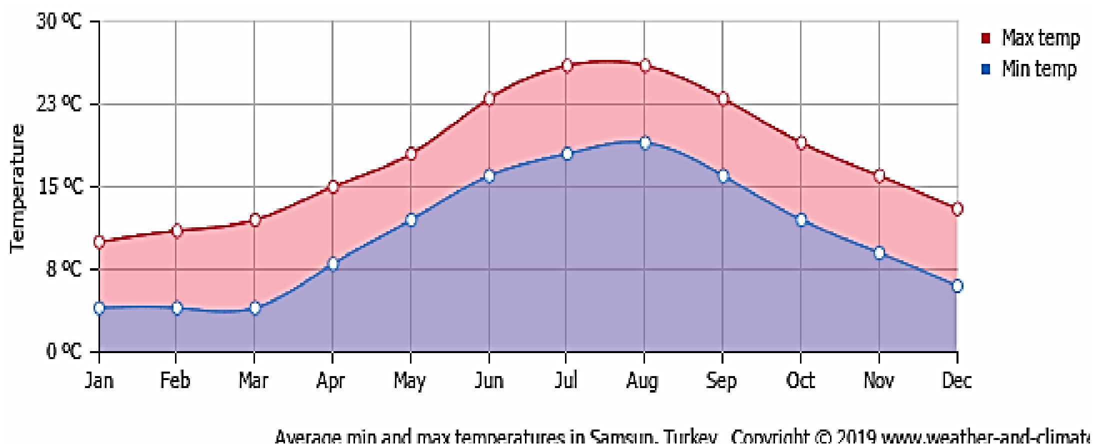

Figure 9. The mean minimum and the maximum temperature over the year in Samsun, Turkey (Url-4, 2020)

The heaviest precipitation rate is in late autumn and early winter. Snow precipitation sometimes occurs between the months of December and March, but never more than a few centimeters of snowfalls in the seashore, and the temperature is below the freezing point rarely, and snow stays on the earth for no more than a couple of days. Precipitation is about 709 mm per year. Black Sea and Samsun (Kızılırmak) region rainfall climate zones was given at Fig. 10 and Fig. 11.

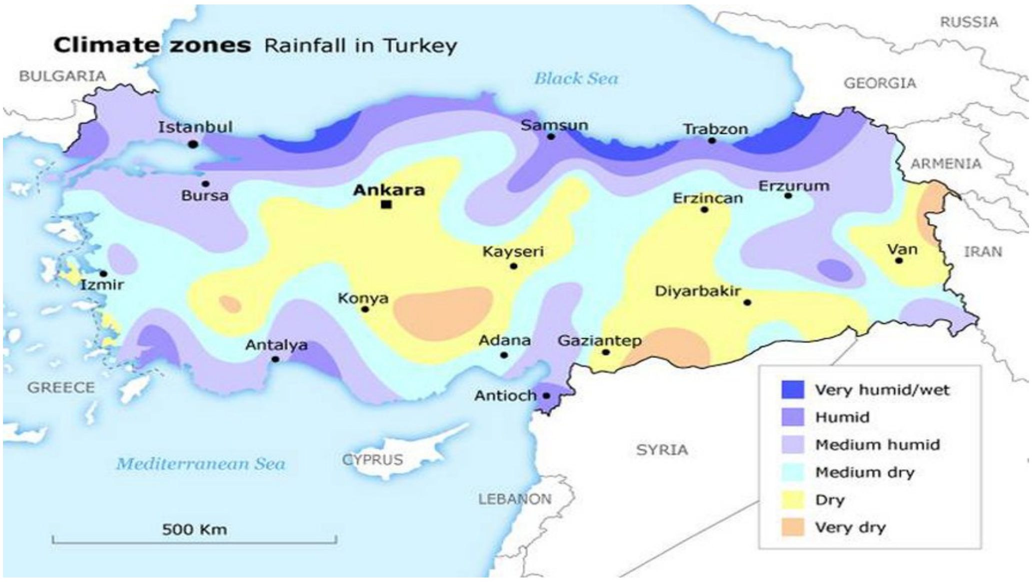

Fig 10. Black Sea and samsun (Kızılırmak) region rainfall climate zones (Url 6, Kibaroğlu, 2011; DSI, 2013)

Samsun region montly precipitation (mm) and rainy days are given in Fig 12. Samsun (in the Black Sea coastal area) average air water temperature during the year at 16.2 °C and the maximum sea water temperature is about 25.7 °C in August. The lowest sea water temperature is about 8 °C in February.

The climate of the Kızılırmak Delta bears all the characteristics of the climate in Samsun. Having a temperate climate in general, there are two different climates in the hinterland and coastal parts of Samsun. İnfluence of the Black Sea climate is seen at the coast. Therefore, summer is hot and dry, winter is warm and rainy, and spring is foggy and rainy at the coast.

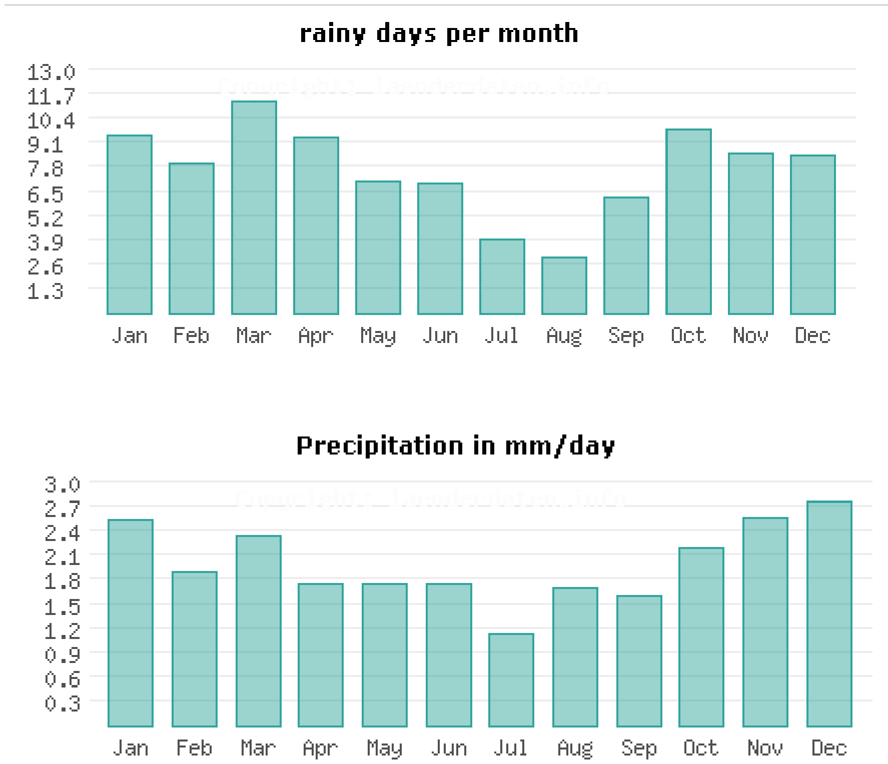

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Figure 11. Central Black Sea Region, Samsun region monthly rainy day and precipitation values (Url5, 2020)

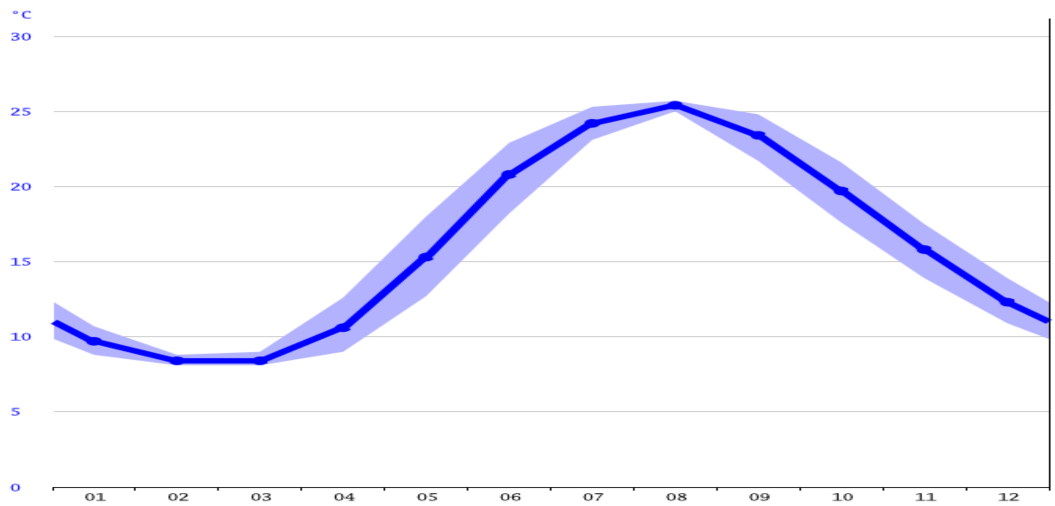
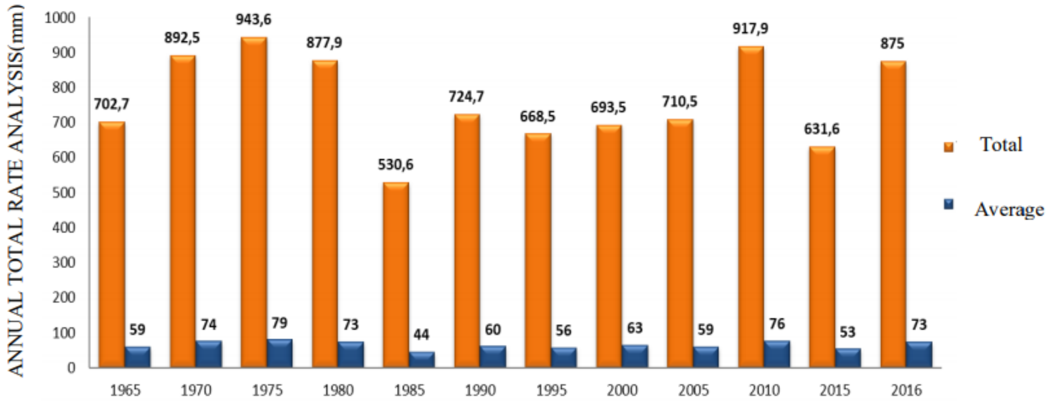


Figure 12. Yearly water temperature of Samsun (Kızılırmak) region (Url-1)

Figure 13 showed that long term meteorological data taken from two meteorological stations (Bafra and Samsun Meteorology stations). These data are cover Black Sea region region where Natural Protected Areas of the Wetland and Bird Paradise in the Kızılırmak Delta in Samsun Province. The annual average rain (mm) precipitation values were examined according to the data obtained from Bafra meteorological station since 1965 and the maximum precipitation was 943.6 mm in 1975 (Fig. 13) (Tavsanoğlu et al. 2019).



Source: www.mgm.gov.tr

Figure 13. Long term, yearly total and monthly average precipitation rates of Samsun region (Tavsanoglu et al. 2019)

Global warming may determine with some indicators such as air and water temperature organism distribution etc. In the sea, some fish species could be an indicator for determining global warming. Seawater temperature is a major determining parameter because it intervenes in reproduction and living area optimum events. Fish are very sensitive to seawater temperature during their larval and juvenile stages. This is why it is inevitable for fish that migrate between sea and rivers to be affected by this circumstance. Fish like, Sardine, Bogue, and Salema live in the Mediterranean Sea and were rare in the Black Sea and the Marmara Sea until 20 years ago. The fact that they are observed in these seas and are even being exploited in western Black Sea regions such as İğneada is associated with rising in seawater temperatures. The quickening of Mediterranization of the Black Sea, introduction of many new species, and alteration of the tropic web, as a result, can be more pronounced in forthcoming years (URL-7, 2020)

2.5 Georgia

Georgia is located in the South Caucasus region, between the Black Sea to the west, the Greater Caucasus Mountains to the north and the Lesser Caucasus Mountains to the south. The total area occupied by the country is 69,700 km^2 and 80% of the territory is mountainous. On the north, Georgia is bordered by the Russian Federation, with the borderline running along the crest of the Greater Caucasus mountain range (maximum elevation 5,000 m asl (above sea level), and on the east and southeast by Azerbaijan, and on the south and southwest by Turkey and Armenia, respectively. The western edge of the country is the 310-km long Black Sea coastline.

The country has a diverse and complex terrain, with its northern parts characterized by high mountains and the central and southern parts by medium height to lower mountains, covered with alpine and sub-alpine meadows and forests. Western Georgia's landscapes range from lowland plains, marsh-forests, swamps and temperate rainforests to eternal snows and glaciers, while the eastern and south-eastern and southern parts of the country contain floodplain valleys and forests, light (savannah type) forests, steppes and semi-deserts.

Georgia's climate is predetermined by its complex terrain and the movement of regional air masses. Much of western Georgia is located within the northern periphery of the humid subtropical zone, with annual precipitation ranging from 1,000 to 4,000 mm. In low to middle-mountain regions, the climate varies from humid sub-tropical to alpine. At some places (high mountains) the humid-subtropical climate zone abruptly changes to permafrost. Eastern Georgia is characterized by the climate transition from humid subtropical to continental, and has considerably lower annual precipitation (400 to 1,600 mm).

Almost every climate zone is represented in Georgia, except for deserts, savanna and tropical forests.

The Greater Caucasus protects the country from direct cold air intrusion from the north. Peculiar circulation of these air masses largely determines the precipitation regime on the whole territory of Georgia.

Likhi Range contributes to having completely different climate in Georgia divided by west and east parts.

Climate in West Georgia is very diverse and in some places sharply changes from a humid subtropical zone to the zone covered with permanent ice. Climate here is determined by the Black Sea coast from the west, as well as by the Kolkheti Lowland located inside three large mountain ranges.

In 1960-1990, Georgia's climate was characterized by the following parameters: The Black Sea coast is characterized by humid subtropical climate. The average annual temperature here is 14- 15 ^oC, while the sums of precipitation vary in the range of 1 400-2,700 mm. The temperature extremes are: +45 and -16^oC. The impact of the Black Sea on the climate in West Georgia is expressed in mild winter, hot summer and excess precipitation. Here, the annual average air temperature varies in the range of 9-14 and (-2) - (+ 7) ^oC in the hilly and high mountainous areas, with the absolute minima of -31 and -35 ^oC and accordingly, annual precipitation varies in the range of 1,100-2,300 mm and 900-1,900 mm.

Climate is drier in East Georgia: Dry subtropical in the lowlands and Alpine in mountain regions. The average annual temperature in the lowlands equals to 10-13 ^oC and (-6) - (+ 10) ^oC in the mountains, respectively with the absolute minima of -28 and -36 ^oC. The absolute maximum temperature reaches +43 ^oC and the absolute minimum -42 ^oC on glacier slopes. Sums of annual precipitation are 400-1000 mm in the plain, while they reach 500-1300 mm in mountainous districts.

During the last 50 years average annual temperature has increased, with the maximum increase in average annual temperature observed in Dedoplistskaro (0.70 ^oC), Kakheti region, between the periods 1961-1985 and 1986-2010. The maximum increase in West Georgia was observed in Poti (0.60 ºC). A relatively small but important warming trend was revealed in the Mtskheta-Mtianeti and various parts of the Kakheti region.

2.5.1 Chorokhi and Kolkheti

Western Georgia has prevailing subtropical climate, influenced mainly by dry air masses from the Caspian and Central Asia in the east, and humid air from the Black Sea in the west. The Caucasian ridge, located north-east to the site protects the area from cold air masses coming from the north. At the same time high ridges favor condensation and therefore humidity is rather high. The area is known for high level of precipitations. According to climatic characterizations, the project region belongs to III-b climatic sub-region. Seasonal pattern of wind direction is predetermined by location of Lesser Caucasus and Likhi ridges which are responsible for regulation of air circulation regime. Wind directions are characterized by seasonal variations and depend on topography of the area.

The climate of central part of Georgian black sea coast is warm and humid. Total annual precipitation mainly in the form of rain, amounts to 1500-1600 mm and is roughly equally distributed throughout the four seasons. The average monthly temperature in January, the coldest month, is about 4.5 - 4.7ºC, while that of August, the warmest month is 22.4 – 22.6 ºC. However, the maximum temperature in August has been known to reach 34 ºC. The region is characterized by relatively high humidity and strong winds.

The air flow regime is greatly affected by local circulation, resulting from the uneven heating of sea and land surfaces, manifested in breezes, monsoons, and mountain-valley winds. According to multi-year hydrometeorological observations, until the 1990s the mean annual air temperature in the coastal area varied in the range of +14.4-14.5 ºC and annual sums of precipitation from 1400 mm to 2600 mm (Batumi). In the last half-a-century, hydrometeorological parameters of the Black Sea coastal zone underwent certain changes in relation to the global climate changes. During the past century until the beginning of the 1990s, the air temperature decreased by 0.2-0.3 ºC though, for the last 16 years it increased by 0.2 ºC. Compared to the 1960s, the precipitation in Poti for the last 15-20 years has grown by 13%, but in Batumi it has declined by five percent. Quite similar to the air temperature, the sea surface temperature had decreased by 1 ºC throughout 1924-1996. However, in 1990-2006 it had grown by 1.3 ºC, as a result of which the cooling of the sea surface at present equals 0.8 ºC, compared to the 1924 value.

According to meteorological stations in Poti, east winds dominate in this area. The winds have a seasonal character: in winter is characterized north-east whereas in summer south-west winds are prevailing. The wind regime in Poti follows a regular annual cycle. Seasonal \ wind direction patterns are predetermined by location of Lesser Caucasus and Likhi ridges which are responsible for regulation of air circulation regime. Because of its geographic location Poti is usually subject to east winds (air masses coming from Caucasus ridge). In summer south-west and west winds are prevailing, whereas in winter east winds are frequent. Winds directions are characterized by seasonal variations and depend on topography of the area.

For Poti area east-west direction monsoon winds are typical, however, west, and south-west winds dominate. Average wind speed is 4.3 m/sec, maximum speed may reach 26 m/sec. In the coastal area of Poti in October-March, strong east winds are common. These winds can be very strong and last several days reaching speeds of 40 m/sec. Such winds are registered in the area from Supsa to Enguri River and in the can be observed off land 10 miles from the shoreline.

Soil temperature is maximal in July and August and reaches 26-25ºC respectively. The soil temperature exceeds the average air temperature value by several degrees. In winter, soil and air temperatures are similar which presumably is conditioned by the presence of the Black Sea. Soil freezing depth is zero cm.

Climatic characteristics of the central part of Georgian black sea coast are given below:

Air Temperature

Location	Average Monthly												Average Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Poti park	5.2	5.8	8.7	12.0	16.6	20.3	22.9	23.0	19.8	15.9	11.8	7.1	14.1
Poti port	5.7	6.4	8.8	11.9	16.4	20.3	23.1	23.5	20.5	16.5	11.9	7.9	14.4

Location	Abs min	Abs max	Aver max, hottest month	Coldest month 5-day aver	Coldest month aver	Coldest period average	Period with average monthly T<8C		Aver T at 13:00	
							Duration day	Aver T	Coldest month	Hottest month
Poti Park	-13	41	27.3	-2	-5	5.0	91	5.9	7.9	26.2
Poti Port	-11	41	26.9	-3	-5	5.3	83	6.5	7.9	26.2

Air Temperature Amplitude

Location	Average monthly °C												Max monthly °C											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Poti park	7.0	7.5	8.5	9.2	8.6	8.0	6.7	7.2	8.5	9.1	8.3	7.0	14.5	14.7	16.9	18.6	17.6	15.8	14.0	15.1	16.7	18.5	17.0	15.1
Poti port	6.5	7.0	7.9	8.0	7.7	7.2	6.3	6.9	7.9	8.5	7.8	6.8	16.5	17.2	18.0	18.5	17.6	17.0	16.8	17.0	17.5	19.0	18.0	17.2

Relative Humidity

Location	Relative air humidity, %													Average relative humidity at 13:00		Aver. daily amplitude of relative humidity	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Aver Annual	Coldest month	Hottest month	Coldest month	Hottest month
Poti park	74	74	75	78	80	82	83	84	85	81	75	72	79	65	74	14	16
Poti port	72	73	75	78	82	82	83	83	83	79	73	70	78	64	73	15	15

Precipitation

Location	Precipitation per year, mm	Daily maximum, mm
Poti park	1865	223
Poti port	1720	268

Snow Cover

Location	Weight of snow cover, kPa	Days with snow cover	Water content in snow layer, mm
Poti park	0.50	6	-
Poti port	0.50	6	-

Ground freezing depth. 0

Wind Characteristics

	Max speed once in 1,5,10,15,20 yrs, m/sec					Recurrence of direction (%) January, July								Aver. max & min velocity, m/sec		Wind direction and calm recurrence (%) per year								
	1	5	10	15	20	N	NE	E	SE	S	SW	W	NW	Jan	Jul	N	NE	E	SE	S	SW	W	NW	Calm
Poti park	21	27	29	31	33	2/2	17/8	53/8	5/4	3/11	6/31	9/26	5/10	7.8/2.4	3.5/1.7	4	12	30	5	7	17	17	8	14
Poti port	26	32	34	37	38	1/2	8/3	62/12	4/4	3/10	7/37	11/27	4/5	8.3/3.5	4.6/2.0	3	7	37	4	6	21	17	5	8

3. Future climatic conditions across the studied countries

3.1 Romania

Atmosphere-ocean general circulation (AOGCM) models are the most plausible techniques for simulating the characteristics of the global climate system, as well as for designing the system's response to scenarios of the influence of external factors (natural or anthropogenic). By the nature of their construction, these models provide direct information on regional climate and regional climate change. The degree of spread of estimates obtained across a set of AOGCMs is often used to characterize uncertainties in projections of future climate change. A larger spread (both in terms of intensity of change and the sign of increase or decrease) shows greater uncertainty. The average of the changes on a set of multi-models is considered the optimal value (IPCC 2007).

Due to their complexity, the horizontal resolution of the atmospheric component of these global models is quite coarse (from 400 to 125 km), which is insufficient for the practical needs of any study. In order to obtain finer Oscar information (downscaling) two main methods are known, summarized in the latest IPCC Report (Christensen et al. 2007): a) the dynamic method represented by regional climate models (RegCM) lateral conditions with global climate models and b) the statistical method which is based on certain statistical relationships established on the basis of observational data between climatic variables on the local / regional scale and atmospheric variables on skimming. In both cases, the quality of the products obtained by downscaling depends on the quality of the global models. Both methods have advantages and disadvantages, on which we do not go into many details, they being summarized, among others, in the work mentioned above. For a given region, it is ideal to use both methods to better estimate uncertainties.

The projections of the changes in the Romanian climate regime (air temperature and atmospheric precipitation) for the period 2001-2030 compared to the current period 1961-1990 were made by the two downscaling methods applied to global (AOGCM) or regional (RegCM) climate models, under the scenario conditions. IPCC emission A1B, which assumes a weighted rate of increase in the concentration of greenhouse gases for the 21st century. Details of this scenario can be found in the IPCC Assessment Report 4 (IPCC 2007). According to this report, the differences between the climate scenarios for the beginning of the 21st century, based on different greenhouse gas emission scenarios, are insignificant. These differences increase as we approach the end of the 21st century. The changes in climate parameters mentioned for the period 2001-2030 are calculated as differences between their average over the period 2001-2030 and the average over the period 1961-1990. This chapter presents the results obtained by both methods: statistical downscaling and dynamic downscaling within the PCMDI program (The Program for Climate Model Diagnosis and Intercomparison), in order to have a general idea about the dependence of the result on the use of several models in the analysis (Busuioc et al. 2008).

The performance of the statistical models of downscaling is expressed in several quantities: the correlation coefficient between the values observed and those estimated by the model, the percentage of the variance explained by the statistical model of the total variance observed or the mean square error (RMSE). The first quantity is sensitive to the presence of a significant linear trend in the data, which is why the second and third quantities were used. Testing the credibility of these models for estimating future climate change was done by applying them to predictors corresponding to a data set independent (1991-2007) of the one for which the models were calibrated (1961-1990). It was found that the models reproduce very well the observed variability of the monthly thermal anomalies during this period, including the extreme events. It is worth noting the ability of the model to reproduce the extreme thermal anomalies of summer 2007. Using the 1961-1990 interval as a calibration interval, these models were applied to the predictor anomalies simulated by 3 global climate models (BCM2, INGV, FUB), of whose simulations for the period 2001-2030 under the conditions of the A1B emission scenario and for the current period 1961-1990, were taken from the CERA archive of the Max-Planck Institute of Meteorology in Hamburg, within the ENSEMBLES project. These scenarios were used, among others, in the elaboration of the 4th IPCC Report (IPCC 2007). Although

5 global models were analyzed, it was found that two of them present unrealistic simulations for predictors (identical values for pairs of 2 months or multiannual averages approximately equal for all months) (Busuioc et al. 2008).

Projections of changes in the average monthly air temperature at the 94 weather stations for the period 2001-2030 made using statistical downscaling models applied to the three global climate models show the same air temperature rise signal, with some differences in signal strength. The average of the projections of the three models is the optimal value (the most probable). For the period 2001-2030, compared to 1961-1990, a higher average monthly air temperature is projected in November-December and in the warm period of the year (May-September), of approximately 1°C, slightly higher values (up to 1.4 °C -1.5 °C) being in the mountains, in the south and west of the country. In the cold period of the year the heating does not exceed 1 °C. The average annual heating, at the level of the whole country, is between 0.7 °C and 1.1°C, the highest values being in the mountain area (Busuioc et al. 2008).

In the case of seasonal rainfall, during the analyzed interval, no clear significant trend of change was identified throughout the country, even if it had the same sign. However, there are linear trends for the 4 seasons. The analysis was performed on data from 104 weather stations. In the case of winter and spring, decreasing trends of precipitation have been identified in most regions of the country, but these have been statistically significant at a confidence level of at least 90% only in certain areas of the south and east of country (winter) and in some points in Oltenia (spring). Significant trends in increasing rainfall over larger areas are observed in the autumn season. In summer, although large areas show an increasing trend, it is not statistically significant and in some remaining areas it shows a decreasing trend, this being significant only in a few isolated points. An important feature of the temporal variability of precipitation amounts is the pronounced interdecenial component which makes it difficult to separate the long-term climate signal, the same conclusion being mentioned in the IPCC report (IPCC 2007) on precipitation variability globally (Busuioc et al. 2008).

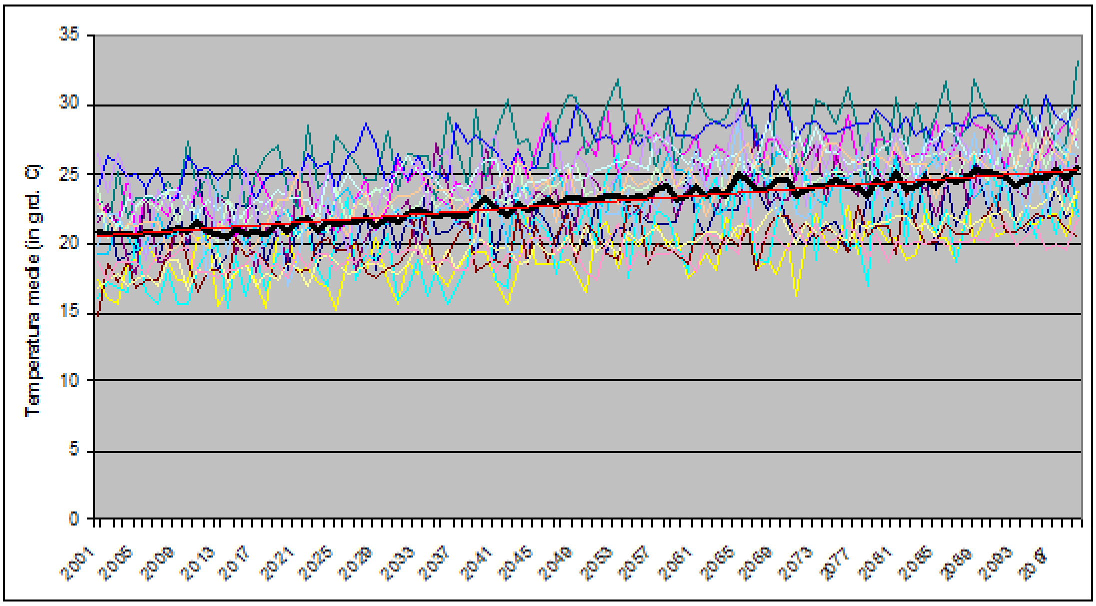


Figure 14. The evolutions in the case of the August temperature, mediated for the Romanian territory (in º C), for 16 climatic models and for the average of the whole (in black). The trend was represented in the case of the multimodel average (with red line). The scenario used is A1B. The averages of all 17 climate models extracted from the CMIP3 database were used

The changes observed in the climate of the last decades pose the problem of evaluating the probable climatic evolutions in the decades and even the next centuries with mathematical models of the climate. The complexity of the climate system, the different nature of its components (atmosphere, ocean, cryosphere, biosphere, lithosphere) and the interactions between them, require the use of extremely complex numerical models, but based on systems of equations associated with the laws of physics. The influence of the anthropogenic factor introduces an uncertainty related to the evolution of greenhouse gas emissions in the future.

The studies of Romanian researchers have contributed to the refinement of regional projection projections of the global warming signal. Statistical modeling methods applied to the results of global climate models were used (Figs. 14-16) but also numerical experiments with regional climate models and analysis of their results together with observed data to highlight mechanisms by which local factors modulate the global signal of climate change.

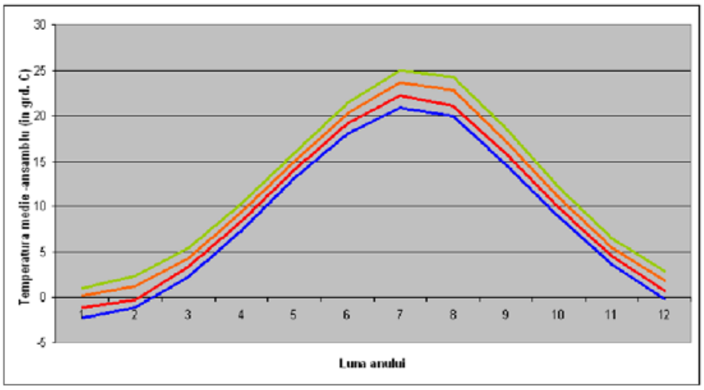


Figure 15. The seasonal cycle of temperatures corresponding to the intervals 1961-1990 (blue), 2001-2030 (red), 2031-2060 (orange) and 2061-2090 (green) in the case of the average for the Romanian territory (in º C). The scenario used is A1B. The averages of all 17 climate models extracted from the CMIP3 database were used.

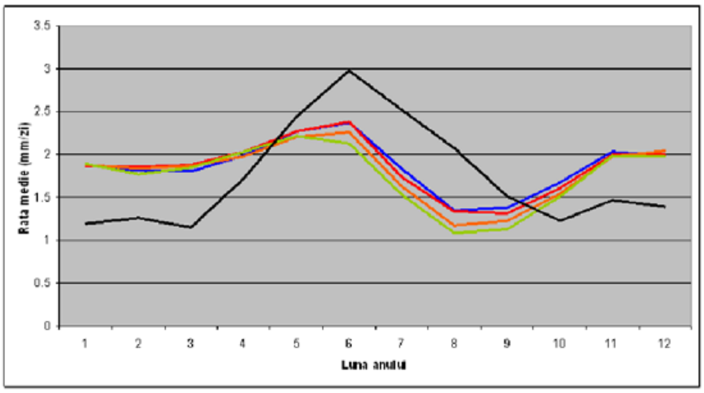


Figure 16. Seasonal precipitation cycle corresponding to the intervals 1961-1990 (blue), 2001-2030 (red), 2031-2060 (orange) and 2061-2090 (green) in the case of the monthly average, mediated for the territory of Romania, of the daily rate of precipitation (in mm). The scenario used is A1B. The seasonal cycle of the daily precipitation rate for the Romanian territory, calculated from the observation data at the meteorological stations, was represented in black. The averages of all 17 climate models extracted from the CMIP3 database were used.

The analysis of air temperature projections and precipitation amounts for Romania was made using the results of numerical experiments conducted for the 20th and 21st centuries with global climate models, archived at Lawrence Livermore National Laboratory, USA. This is the CMIP3 set from the PCMDI program (The Program for Climate Model Diagnosis and Intercomparison), from which the available data from 16 climate models were extracted. Using these data, the averages for all 16 models were first calculated and the changes in air temperature and precipitation amounts for Romania were expressed as differences between the respective values averaged by country for the period 2001-2030 (scenario A1B) and the reference range. 1961-1990 (control), using the grid points available for the Romanian area. In the case of precipitation, the changes are given in percentages. Due to the rather coarse spatial resolution of these models, the country average of the climate signal was calculated to have a general idea of the effect of using more climate models in estimating this signal. the biggest difference between the scenario and the control run was in July (1.31 °C). It is interesting to note that in the case of precipitation, their largest reduction (of almost 6%), in the type horizon 2001-2030, also takes place in July. The change in the quantities of monthly precipitation, in the time horizon 2001- 2030, for the territory of Romania, is different during the seasonal cycle. Thus, there is an increase in the spring months, with a maximum of about 4% in March. In the summer and autumn months, the averages of the set of 16 models indicate a decrease, the most important being in July (approximately 6%). In the winter months, in case of precipitation, a clear signal does not appear.

An explanation could be related to the dependence of winter precipitation on the variability of the North Atlantic oscillation, also revealed by the observation data, to which is added the effect of the natural variability of some local factors, such as the surface temperature of the Black Sea water (Busuioc et al. 2008).

3.2 Ukraine

The climatic conditions of Ukraine have definitely reacted to global warming (the annual temperature increased and insignificant increase of the annual sums of precipitations for 100 years). The features of transformation of seasonal course of climatic fields of Ukraine of the temperature and atmospheric precipitations considered also. The analysis of the basic ecological consequences of global warming, which can be in the nearest future in Ukraine is carried out: the spatiotemporal transformation of steppe phytosystem structure; changes in Northern Sea of Azov maritime spits ecosystems; excitation of catastrophic events in Ukraine, desertification process development in southern and southeast regions of Ukraine, climate change impacts on agriculture, aspects of water resources (Adamenko 2007, Boychenko 2005, Polevoy et al. 2007, Tkachenko and Boychenko 2014).

The climatic catastrophic phenomena, such as droughts, floods, extremely cold or warm winter, occurring at a large scale and great intensity are rather rare events. These phenomena, typically, occur only a few times per century. On the basis of the criteria's equation the scenarios of increase of frequency of occurrence of different catastrophic climatic phenomena in territory of Ukraine, East European plain and the Western Europe in 21th century are constructed. Validity of the semi-empirical models are checked up by the decision of a return problem: comparison of results ofmodeling calculations with the fact for last millennium (11—13 century). By the developed scenarios it is possible to draw a conclusion, that the expected average amount of the considered catastrophic climatic events in 21th century in territories of Ukraine, the Western Europe and Russian plain in 1.5—2 times will exceed their fixed quantity in 12th century — for epoch of known global warming in the last millennium. It is found that the repeatability of the considered events is a non-monotonic function of temperature fluctuations, namely: repeatability of catastrophic climatic phenomena in the territory of Ukraine was higher, when the global temperature was deviating in either direction from some optimum level (at global warming or cooling from some optimum level of global temperature). A scenario of possible dynamics of repeatability of climatic catastrophic phenomena in the territory of Ukraine at the further global warming is considered (Boychenko 2010).

In general, various prognoses show that by the middle of the 21st century reducing of water resources is expected on the plain territory of Ukraine. In the geographical zone of the Ukrainian Carpathians, especially in the Tisa river basin, its stability or growth is possible. Analysis of changes in the ratio of moisture and heat resources showed that climate aridity will be intensify and the insufficient moisture zone and the semiarid zone will be widen (Gopchenko and Loboda 2000; Loboda and Bozhok 2016; Loboda 1998; Loboda et al. 2014, 2015).

Climate change and human use of water abstracted from rivers and groundwater are projected to alter river flow regimes worldwide in coming decades. Consequently, community structure in many rivers is expected to change because river flow is fundamental in determining conditions required by organisms, and processes on which they depend. Future flows in pan-European rivers were computed for baseline conditions (period 1961–1990) and for different combinations of climate and socio-economic scenarios (2040–2069). Depending on scenario, about 30–50% of the river network length remained of the same type, whilst c. 40–50% transformed to an existing type; a third group of rivers (c. 10–20% of network length) formed new types, not present under baseline conditions, with potential to create novel river ecosystems. According to the IPCM4 EcF 2050s scenario, a new type of river with winter dominated flow, medium flow magnitude and variability, and low extremes and limited high extremes will appear in Europe. It will be distributed in Northern Germany, Romania and southern Ukraine (significant part of the rivers). Map of the distribution – Laize et al. (2017).

3.2.1 Danube Delta (Ukraine)

The results of calculations of possible state of water resources within the Danube River basin in the 21st century were based on the model "climate-runoff", developed in Odessa State Environmental University. As the input to model data of climate scenario A1B (model REMO) were used. Average long-term annual flow values using meteorological data (air temperature and precipitation) from the scenario for different climatic periods of 21st century were calculated. Projection of changes in water resources was given by comparing the calculation results in the past (before 1989) and in the future (1990-2030, 2031-2070, 2071-2100). The major trends in climatic factors of the flow formation and water resources were established. It is shown that the climatic conditions in the 21st century on the Danube River catchment is unfavorable for the formation of runoff. The positive component of the water balance (precipitation) remains unchanged and the negative component (evaporation) increases. Isolines of norms of climatic annual flow within the whole basin were constructed. It is established that by 2030 a significant reduction of water resources will not occur; during the 2031-2070 diminution will be 17,9 %; during the 2071-2100 – 22,0 % (Loboda and Bozhok 2016).

Directly in the Danube delta, the following processes are possible (Cheroi, 2013):

1. In the coming decades, the Danube Delta will see an increase in air temperature. The average annual air temperature will increase by 0.5 °C, to 2030 will reach 11.0 - 11.8 °C. It is likely that the intensity of warming will be increase and by 2050 the average annual temperatures will already be 12.0-12.8 °C. The maximum annual air temperature will increase by 2.0 °C by 2050, and the minimum - by 1.5 °C. The number of days with snow will be significantly reduced;

2. Annual precipitation is likely to increase slightly. The intensity and frequency of weather phenomena associated with convection will also increase: thunderstorms, tornadoes, squalls.

3. Flood risk associated with local runoff will increase due to increased rainfall. The intensity and height of the Danube floods will increase.

4. The frequency of floods on the maritime edge of the Danube Delta will increase due to further rise in the Black Sea level, an increase in the number of squalls, tornadoes and associated extremely high surges.

5. The water temperature will increase in all water bodies of the estuarine area of the Danube. The greatest increase in temperature should be expected in the Danube lakes and on the estuary seaside. The frequency and duration of ice phenomena will decrease in all reservoirs and watercourses of the delta. An increase in the total mineralization in the Danube lakes and deterioration of water quality for most indicators.

The general trend towards the rise in the Black Sea level is predicted to continue. This trend is clearly expressed in the area between the mouths of the Danube and Dniester. The probable reason for the revealed patterns is the change in the features of synoptic processes over the North-Western Black Sea, which affect the wind speed field and the characteristics of its surface currents, which can cause surges (Schuiskiy et al. 2001, 2013).

The emerging trend of an increase in the annual runoff of the Danube and Dnieper at the end of the 90s. will contribute to a further decrease in salinity in the Northwestern Black Sea (Dotsenko 2010).

3.3 Greece

The Mediterranean region is vulnerable to climate change particularly due to its sensitivity to drought and rising temperatures (Giannakopoulos et al. 2011). Climate change is related to changes in the frequency and intensity of extreme climate events, which may adversely affect vital economic sectors, such as agriculture and tourism, and have substantive impacts on local communities. Moreover, it is expected that climate change will negatively affect biodiversity and ecosystem services.

By analyzing the up-to-date data about the forest fires across the EU countries, and especially the average burnt area per fire, it has been found that Greece has the most severe forest fire problems among the European Union countries (Giannakopoulos et al. 2011). Forest fires, as any other ecosystem process, are highly sensitive to climate change because fire behaviour responds immediately to fuel moisture, which is affected by precipitation, relative humidity, air temperature and wind speed. Thus, the effects of climate change and specifically the increase in temperature will increase fuel dryness and will reduce relative humidity and this effect will worsen in those regions where rainfall decreases. Accordingly, increases in climate extreme events are expected to have a great impact on forest fire vulnerability. Thus, it has been estimated that in some areas of Greece, the fire risk period will be extended for at least 15 days, which means that Greek forests will greatly suffer the consequences of fire events (Giannakopoulos et al. 2011).

There is large number of studies the changes in the climate of different areas across the globe and at regional scale, whereas a large number of studies is focused in predicting the future climatic conditions of several areas (Kovats et al. 2014). Up to now, it has been observed that the average temperature in Europe has continued to increase, with regionally and seasonally different rates of warming being greatest in high latitudes in Northern Europe. Since the 1980s, warming has been strongest over Scandinavia, especially in winter, whereas the Mediterranean warmed mostly in summer (Kovats et al. 2014).

In their study, Zanis et al. (2009) used nine RCMs (Regional Climate Models) to simulate the future climatic conditions over 11 regions in Greece. In general, all nine RCMs they used, predicted a dramatic increase of the mean near surface air temperature for the future climate during winter, summer and the whole year for all the 11 sub-regions of Greece. They found that the air temperature future changes will be higher during summer than during winter, as well as for the continental regions than for the maritime ones. The mean temperature change of the nine RCMs (ΔT 2mean) between the future period 2071–2100 and the control period 1961–1990 for the integrated Greek domain for the whole year is 3.7°C, for winter 3.4°C and for summer is 4.5°C. Almost all RCMs predict an increase of the inter-annual temperature variability in summer and decrease in winter.

However, the same authors state that the increase of the inter-annual temperature variability in summer for almost all RCMs and sub-regions of Greece is a common finding for the whole European domain. Climate models consistently predict an increase in the variability of summer temperatures in European mid-latitudes, but the underlying mechanisms responsible for this increase remain uncertain.

Moreover, the almost all nine RCMs that were used by Zanis et al. (2009) simulate a decrease of the precipitation for the future climate during all seasons and for all the 11 sub-regions of Greece. For the integrated Greek domain in winter Zanis et al. (2009) calculated an overall precipitation decrease of −15.8% (about−0.20 mm/day) for the whole year, −14.2% (about−0.30 mm/day) for winter and −57.3% for summer (about −0.18 mm/day) from the nine RCMs. However, this was not the first study that showed a decrease in the mean precipitation in the future. Such a trend was also reported by others regarding most of the Mediterranean regions (e.g. Pal et al. 2004; Tapiador et al. 2007). The reliability of the future projections of precipitation for Mediterranean can be assessed by the fact that the majority of the AOGCMs participated in IPCC AR4 show consistently strong precipitation decreases in the Mediterranean region for both winter and summer for the 21st century (Tselioudis et al. 2006).

Another study, that of Tolika et al. (2012), who calculated future changes in temperature and precipitation for Greece with respect to the data of the period 1961-1990, showed that the climate in Greece will be warmer and drier in the future. Specifically, their key findings are the following:

The warming during winter is in range of about 2.5 to 4.5 oC (there are fluctuations among the different scenarios they used) and generally it increases from the coastal areas to the central and northern continental interiors. High winter temperatures, yet in high altitudinal areas could result to changes in the hydrological balance due to reduced snowfall, whereas the different sea – land warming could be attributed to the differences in heat capacity and the fact that the evaporation of the sea water results to energy expenditure which due to the constant undulation and the vertical currents is transferred to lower depths. Thus, the surface temperature above the sea will not increase so much.

The warming is even higher during summer. The projections showed an increase from 3 to 6 ºC. As in winter, over land the temperature rise will be more intense. The results of their study are generally consistent with previous studies indicating that the Mediterranean region and southern Europe will exhibit an amplified temperature increase in comparison to the rest of the continent.

Winters are estimated to be drier by the end of the 21st century. Two scenarios (A2 and A1B) estimate a decrease in the annual precipitations up to -30% in southern Greece, while for the B2 scenario the precipitation reduction is almost half (up to -15%) and moreover some parts of northeastern Greece will have a small rainfall increase.

The drier future summers is also one of the common features in all the models used in their study. The expected changes of summer precipitation due to the anthropogenic emission of greenhouse gases in Greece showed a prevailing decrease or rainfall heights up to -60% with respect to the reference period. This maximum drying was assessed from a specific group of models they used (A2 PRUDENCE group of models) and characterizes mainly the areas of Peloponnese and eastern Aegean Sea. The other projections estimated a quite smaller decrease.

It is worth mentioned that independently of the study we are referring to, all studies estimate an increase in the temperature, which will be higher in the southern part of Greece, whereas the increase in temperature is expected to be lower towards the northern parts of the country. Similarly, annual precipitations are expected to decrease, with the southern parts of Greece being much drier, whereas in the northern parts of the country the decrease in is expected to be lower and in specific mountainous areas a small increase in the precipitation is estimated.

3.3.1 Nestos Delta

In their study, Skoulikaris et al. (2017) found that Nestos river basin is expected to swift to a warmer climate during the period 2030-2049, in comparison to the reference period they used in their simulations (1970-1989). In total, they used three climate models and they found that the RCM-CLM (Max Planck Institute for

Meteorology, Germany) was the model that predicts the less intense temperature increase especially for the stations in the Greek area of the basin (Greek part of Nestos area). The percentages of this future temperature raise are expected to vary from 7.2% up to 21.5% and all three models the used agree that the future temperature time series will present a small positive trend.

The up to now analysis of the climatic data of the period 1970-1989, revealed that the annual rainfall increases towards the northern parts of the basin which are located in Bulgaria. The maximum increase was found in the Bulgarian parts of Nestos Basin (with an increase from west to east), whereas a minimum increase was observed over the Greek region (Skoulikaris et al. 2017).

As for the future estimations of the annual precipitation, all models used by Skoulikaris et al. (2017) agree that the climate of the Nestos basin will swift to a dryer one. They found that the rainfall decrease varies from -50 mm up to -150 mm compared to the values during the reference period (1970-1989). The KNMI (Royal Netherlands Meteorological Institute) climate model showed that the decrease in the annual rainfall over the Nestos Basin will be more uniform (decrease from -7% to -10%), while for RegCM (National Center for Atmospheric Research, Pennsylavia State University) and especially CLM, the most intense precipitation decrease will happen over the Nestos basin (up to -19% rainfall decrease). Finally, during this future period (2030-2049), the calculation of the variance coefficient and the standard deviation values demonstrated that precipitation is expected to increase its variability gradually, especially during the summer months. This finding can be interpreted as a future increase of the extreme rainfall episodes.

3.4 Turkey

Demir et all (2008) studied to contribute to the ongoing researches about the assessment of climate change impacts in Turkey and other region by obtaining the climate projections (http://climatechangeinturkey.com/climate-change-basics-how-does-the-climate-of-turkeychange.html. Accessed on 10.02.2019). For dynamical downscaling, British Met Office, Hadley Centre for Climate Prediction and

Research's Regional Climate Model, PRECIS (Providing Regional Climates for Impacts Studies) was chosen. In that research, for the present-day simulations, European Centre for Medium-Range Weather Forecasts's reanalysis data (ERA40), for the future, Hadley Centre's Atmospheric General Circulation Model, HadAMP3's A2 scenario has been selected. The results of past 30 years run were compared with CRU's (Climate Research Unit) global observational land data, which have 0,5°x0,5° grid resolution, for the verification. Changes in maximum, minimum, mean surface temperature values and precipitation amounts for the period of 2071-2080 have been evaluated seasonally and annually with the corresponding values of 1961-1990. Generally in Turkey, 4-5 °C increase was projected in mean temperatures for the period of 2071-2080. For the same period, mean maximum temperature increase rate in Eastern Turkey was 5-6 °C, for the other regions it was 4-5 °C. In the seasonal temperature analysis, the highest increases were in summer. The changes in total annual precipitation amounts had generally decreasing tendency over Turkey in the projections. Especially in winter season, along the Toros Mountains, decreases in precipitation was apparent. Additionally, along the Eastern Mediterranean coastal zone and in the Eastern Black Sea region, there is an increase in the locally scattered precipitations.

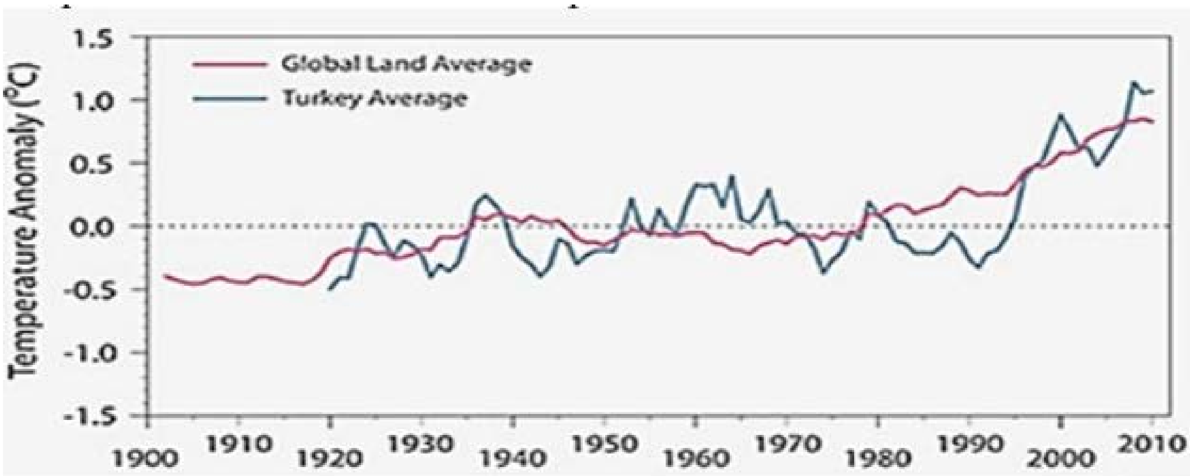


Figure 17. Developments in the average annual temperatures in Turkey (Sen, 2018).

Figure 17 shows that, in Turkey, there had been a parallel trend in the temperature anomaly. While global trend seems to begin since 1980s, there had been an increasing trend in the temperature anomaly of Turkey since 1990s. Despite this delay, the temperature increase in Turkey was higher than the global temperature increase for the same period (Bozoğlu et al. 2019).

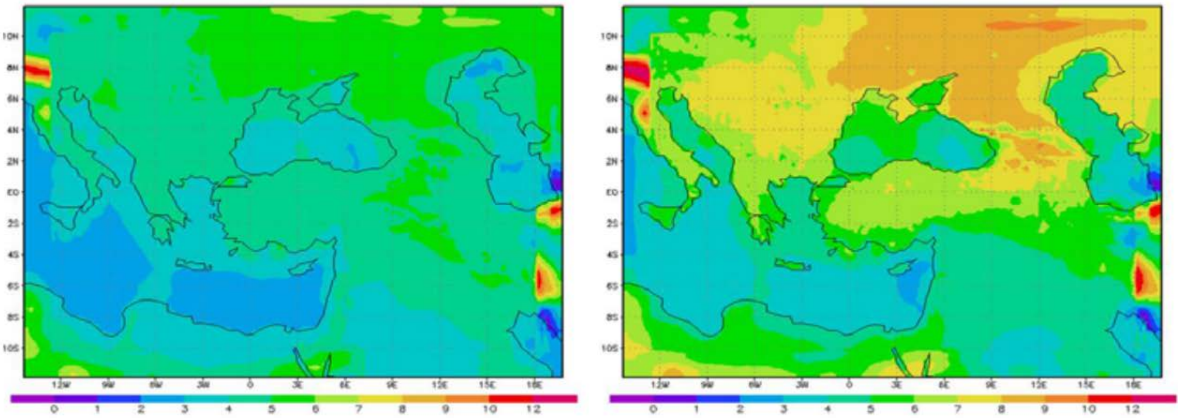


Figure 18. According to HadAMP3 A2 scenario, average (right) and summer (left) temperature difference map of 2071-2080 and ERA 40 1961-1990 years (Demir et al. 2008)

Based on the average of 1961-1990, the estimated annual mean temperatures in Turkey for the periods of 2010-2039, 2040-2069 and 2070-2099 show that the temperature will increase in all over Turkey. The temperature increase from 1960s or 1970s to the 2000s was close to 1.5 ^{o}C. By 2050, it was estimated that while annual mean temperature would increase by 1.5 °C and precipitation would decrease by 1.5 mm. At the end of this century, it was expected that temperature would increase 1.8 °C at the low emission scenario and 4 °C at the high emission scenario and the temperature increases would rise the sea level about 26 cm and 59 cm, respectively (IPCC 2007). However, Cline (2007) projected that there would be 5 ^{o}C temperature increase in 2099 compared with the base period of 1961-1990 and average daily precipitation would decrease from 1.57 mm to 1.33 mmThe least temperature change is projected as changing from 1.6 °C to 2.5 °C for the Black Sea Region. The highest and the least changes in precipitation were projected for the period of March and April in the Mediterranean Region and the South-eastern Anatolian Region, respectively (IPCC 2007). Summer season would witness the largest temperature increase and the temperature increase would affect more the South East, Central Anatolia, Aegean and Mediterranean regions. While the temperature would further increase, there would not be a single trend regarding prospective changes in precipitation patterns. Still the primary factors that shape the climate of Turkey can give us hints about prospective changes in precipitation patterns. Estimation results show clearly that climate change will be intensified more in the future and Turkey will be one of the most affected country (Fig.18) (Bozoğlu et al. 2019; Demir et al. 2008).

3.5 Georgia

During the last 50 years average annual temperature on the whole territory of Georgia showed an increasing trend. Its maximum increment in West Georgia (+0.60 ºC) was registered in Poti. According to forecast, by 2050, as compared with 1986-2010, warming will mostly occur in coastal zone and mountainous regions of Adjara (1.6-1.7 ºC), and by 2100 the biggest increment of temperature (+4.2 ºC) is anticipated in Batumi. In general, precipitation increased in most regions of West Georgia. Up to 2050, according to the forecast, sustainable trends of increase of precipitation is anticipated. Decrease by 10-20% will begin until 2100. Relative humidity of air in the period of 1961- 2010 increased by two percent on the entire territory of Georgia, although change of this trend in declining direction is anticipated in the region under consideration in 2050-2100. Average annual wind speed significantly decreased on the whole territory and according to the forecast, this decrease will continue till the end of the century.

A recent U.S. Agency for International Development (USAID) publication assessed future climate change (years 2020-2050) for the Lower Rioni Pilot Watershed Area according to the regional PRECIS model, in which the ECHAM4 global model and two (A2, B2) scenarios of the world socio-economic development were used. Mean values of total average air temperature and total precipitation were calculated by ECHAM4 and HADCM3 models. The scenarios of climate parameter changes were reviewed through ECHAM4, A2, B2 and HADCM3 A2 models. Results indicated the following:

- According to both scenarios, **yearly values of average temperature** show an increase in all seasons. Increased temperature is projected especially in summer (2.50 ºC). In other seasons average temperature rises by 2.0 ºC.
- Values of **average maximum of atmospheric temperature** also increase according to both scenarios in all seasons and, accordingly, yearly. The minimum increment in spring equals 0.90 ºC, while in other seasons this parameter is 2.0 ºC. According to the B2 scenario, the annual increase of average maximum temperature is 2 ºC, and by the A2 scenario, maximum temperature increase is greatest in autumn (1.4 ºC), while it warms up by 1 ºC in other seasons.
- **Average minimum temperature**, except transitional seasons, experiences more warming in all seasons than the maximum temperature. The annual minimum is expected to rise by 1.3-1.9 ºC. By both scenarios, in winter minimums will warm up by 2-2.4 ºC. In all other seasons minimum parameters repeat the character of the maximum variations. According to the B2 scenario, this parameter raises more than according to A2 one. In this case winter and summer experience more warming. By the A2 scenario, this warming is less than 1 ºC per each season, and annual minimum rises by 1.3 ºC.
- **Total annual precipitation** that increases between two observation periods, according to the B2 scenario and A2 will be increased by 8% and 21% respectively. Precipitation in winter and summer will increase by 30-37%. According to the B2 scenario rainfalls intensify by 4% in autumn and lessen similarly in spring. In winter and summer, the value of total seasonal precipitation raises by 21-16%.
- **Winters** will become warmer with fewer freezing days and with increased total and intensive precipitation.

- **Spring** is expected to be warmer and moderately dry, with an increased amount of extreme precipitation.
- **Summers** will be much hotter and extremely rainy.
- **Autumn** is expected to have considerable risk of heavy precipitation; though it will be warm with less risk of freezing.

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