IOSUD –„DUNĂREA DE JOS" UNIVERSITY OF GALAȚI

Doctoral School of Fundamental and Engineering Sciences

DOCTORAL THESIS
-RESUME-
Research regarding the climate variability influence on the agricultural production conditions in Romania

PhD Student,
Mădălina Georgiana BOBOC

Scientific leader,
Prof. dr. ec. dr. eng. habil. Silvius STANCIU

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GALAȚI
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Introduction

Recent studies demonstrated that anthropogenic activities have caused a global warming with approximately 1.0°C compared to the pre-industrial period, and for 2030 – 2052 it is expected a temperature increase of about 1.5°C, this aspect generating in multiple regions an increase in extreme temperatures, a higher frequency, intensity and/or amount of precipitation, as well as the occurrence of drought phenomena. Currently, temperatures higher than the average annual global temperature are recorded in many regions, this increase being more strongly felt on the terrestrial surfaces, compared to oceanic ones [3].

The impact of increased climate variability on plant productivity will generate in future decreases in crop yields. Agricultural crops will be affected by climate change not only directly through changes in agro-climatic conditions, but also indirectly, for example through changes in soil properties or changes in the occurrence of diseases and pests [10].

This study presents an interdisciplinary approach, which brings together terms from the field of statistics with those from climatology and agricultur in order to facilitate the understanding of how they are interconnected.

The original contributions of this study consist in the use of different data sets and statistical methods of analysis with the aim of understanding, on the one hand, the physical processes that govern the climate at European and national level and the impact they may generate on the yield and agricultural production, on the other hand. In this study, it was analyzed whether the various scientific methods of analysis are sufficiently precise in order to answer the various questions related to climate dynamics and the potential impact on the agricultural sector. Within this study, the variability of the main meteorological parameters and the connection with the large-scale mechanisms responsible for the detected changes in their regime were analyzed from a spatial and temporal point of view. Such an analysis is essential so as to be able to identify the real impact of climate change on agricultural production conditions in Romania.

Thus, **in Chapter 1,** a bibliographic study was conducted in which the most recent and relevant published results related to the targeted field were presented.

In order to perform a complex analysis of the influence of the climate regime on agricultural productivity in Romania, in **Chapter 2** were presented the data and methods used. To analyze the temperature and precipitation regime at the national level, data on average temperature and precipitation were used, available within the European ECA&D project [3], in which Romania is a member. A number of 21 meteorological stations were selected, with homogenized and complete data strings, distributed throughout Romania, daily average temperature and precipitation data were extracted, the analysis being performed for the seasons spring (March-April-May, MAM), summer (June-July-August, JJA), autumn (September-October-November, SON) and winter (December-January-February, DJF), for the time period 1961-2018.

For the analysis of the agricultural sector performed in **Chapter 3**, were used and processed the data available on the FAOSTAT platform regarding the production, yields and harvested area, for the time period 1961-2018, for cereal, maize and wheat crops [4]. The data were analyzed for the European continent, Eastern Europe, the European Union (28) and Romania, so that trends recorded in the agricultural sector could be determined. At the same time, in order to highlight the geographical distribution of the crops, the data provided by the National Institute of Statistics [5] regarding the agricultural production and yield of cereal, wheat and maize crops in the development regions of Romania, for the time period 1990-2018, were also analyzed.

In **Chapter 4**, the EOF analysis was conducted on the temperature and precipitation regime at the national level, for the time period 1961-2018. It was retained the first EOF having at least 50% of the explained variance. The analysis of this parameter in the present study is essential because its variation is influencing directly the growth, development and yield of crops. In order to analyze the temporal variability of the data series, the Mann Kendall [45] and Pettitt [46] univariate statistical analysis methods were applied to detect the general trend and the change point, at the 5% significance level.

In **Chapter 5**, was performed the analysis on the changing trend of the temperature and precipitation regime at the national level and the influence on the agricultural sector. The analysis to identify the long-term linear trend in mean air temperature and precipitation was performed for the 21 meteorological stations utilised also in the EOF analysis, for all seasons, being used the Mann-Kendall and Pettitt non-parametric tests for the time horizon 1961-2018. At the same time, data on the growing season length (GSL) [3] were used for four of the 21 analyzed meteorological stations located in different areas of Romania for which the analysis conducted in the present study revealed statistically significant trends. Also, three indicators (Biologically Effective Degree-Days, Number of Tropical Nights and Number of Frost Days) were used, made available by the Climate-ADAPT database [48], which were analyzed under the conditions of two greenhouse gas emission scenarios RCP 2.6 (low greenhouse gas emissions), RCP 8.5 (high greenhouse gas emissions).

For the case studies presented in **Chapter 6**, were performed the synoptic analyzes that generated the occurrence of extreme phenomena in Romania with an impact on the agricultural sector, for the years 2007 (the year with the lowest level of agricultural production) and 2018 (the year with the highest level of agricultural production).

The synoptic analyzes conducted in Chapter 6 showed the dependence of agricultural yields and production on weather conditions, conditions which, on the background of the global warming phenomenon acceleration, tend to present extreme conditions. The amplification of extreme phenomena represents one of the biggest risks for agriculture, making this sector increasingly affected by the positive thermal deviations recorded at the national level, by the uneven distribution of precipitation and the installation of extreme pedological drought.

The present study was developed based on the official data available at national level, with the purpose to facilitate understanding on how climate phenomena may affect directly the agricultural sector. This study could be improved if the volume of available data would be completed, for example, by analyzing a higher number of meteorological stations or by completing information on the irrigated area, for which data are available only from 1997 onwards.

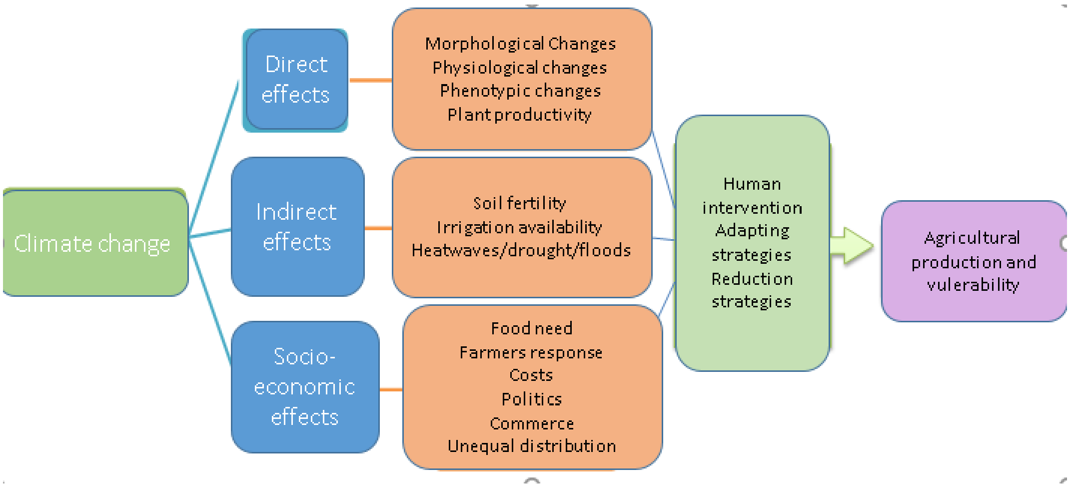
Chapter 1. The main challenges in the agricultural sector under climate change conditions

Greenhouse gas (GHG) emissions are the main cause of climate change. They have increased compared to the pre-industrial period (1850-1900), and are currently at a historical high, due to factors such as economic and global population growth.

Concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrogen oxides (NOX) are at unprecedented levels in the last 800,000 years. About 40% of GHG emissions remain in the atmosphere, while the rest is stored in the land surface (plants and soil) and oceans. Approximately 30% of CO_2 emissions are absorbed by the oceans, this aspect leading to their acidification [1].

Agriculture represents an economic sector directly influenced by climatic conditions, so any change produced will have an immediate effect on it. Climate data in recent years have shown progressive warming of the atmosphere, as well as a higher frequency of extreme events, with rapid heat wave/severe drought/heavy rainfall alternations becoming more and more evident. In this context, water scarcity and pedological droughts, especially those in the south and southeast of Romania, can cause drastic decreases in production, especially in years with excessive drought, and large temperature variations strongly influence the metabolic reactions of plants, which easily lead to the injury of the most sensitive.

A broader picture of what the effects of climate change mean on agriculture was presented by Ali Raza et al. [4], the need for human intervention under this aspect being very well highlighted (Figure 1.1).



Author, through data processing: [4]

Figura 1.1 – Direct, indirect and socio-economic effects of climate change on agricultural production

In plain areas conditions, drought and high temperatures are the most predominant phenomena with a significant influence on plants, their physiology being strongly influenced by temperature fluctuations. Thus, high temperatures negatively affect the yield of grain production, negative temperatures result in plant sterility, and drought negatively influences their morpho-physiology, these climatic problems producing molecular, biochemical, physiological and morphological changes in plants [5]. An analysis of all the effects on crops, dividing them into positive and negative, clearly highlights the fact that there are also advantages, but the number of disadvantages on cereal crops and not only, are twice as high.

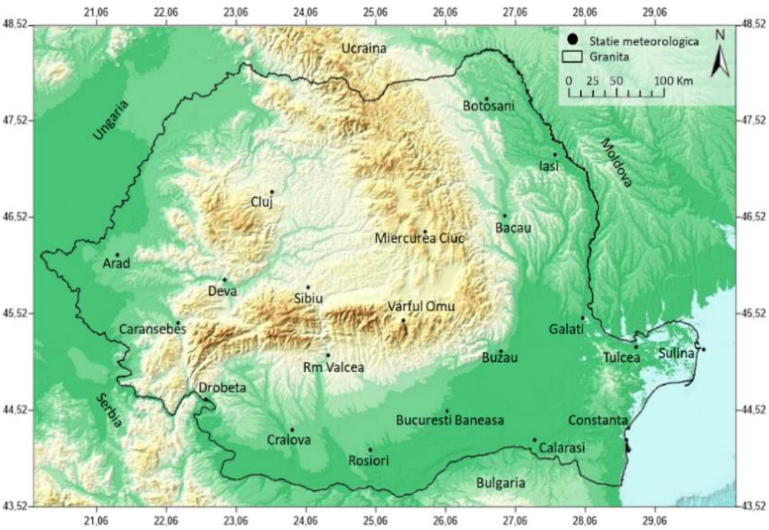
In this context, scientists have developed some stress-resistant varieties [6]. The main cereal crops around the world, such as maize and wheat, are crucial to meet the daily food requirement. Of these, wheat is the staple crop, grown on a large scale (it is harvested on 38.8% of the total agricultural land worldwide and provides a considerably high concentration of protein: 15% per gram compared to maize or rice, which only provides 2 - 3%) [7].

Chapter 2. Data and methods of analysis regarding the influence of the temperature and precipitation regime at the national level on agricultural production conditions

In order to achieve a coherent and complete analysis of agricultural productivity at the national level, an analysis of the available data sets over as long a period as possible is necessary. At the same time, taking into account the fact that in Romania the most representative crops in the agricultural sector are wheat and maize, representing approx. 89% of cereal production at the national level [36], in this study the data provided by the Food and Agriculture Organization of the United Nations (FAO) on the production, yields and harvested area for cereal crops, wheat and maize were processed, for the period 1961-2018. Data were analyzed for the European continent, Eastern Europe, the European Union (28) and Romania, so that trends recorded in the agricultural sector could be determined.

At the same time, in order to highlight the geographical distribution of the crops, the data on the agricultural production of cereal, wheat and maize crops, as well as their average production per hectare (yield) in the development regions of Romania, from the period 1990-2018, were analyzed. , provided by the National Institute of Statistics.

To analyze the temperature and precipitation regime at the national level, average temperature and precipitation data were used, available within the European ECA&D project [38], in which Romania is a member. A number of 21 meteorological stations were selected, with homogenized and complete data strings, distributed throughout Romania. From Figure 2.3 it can be seen that most of the stations analyzed are located in the south and southeast of the territory, this being the area where it is predicted that climate change will increasingly affect Romania from an agricultural point of view [39].



Autor, prin prelucrarea datelor: [40]

Figura 2.1 - Location of meteorological stations used in the present study

Daily average temperature and precipitation data were extracted from the database of the European ECA&D project, the analysis being performed for the seasons spring (March-April-May, MAM), summer (June-July-August, JJA), autumn (September- October-November, SON) and winter (December-January-February, DJF), for the time horizon 1961-2018. At the same time, data on the Growing Season Length (GSL) were extracted for the Arad, Constanța, Drobeta Turnu Severin and Iaşi stations for the period 1961-2018.

In the present study, to analyze the modes of variability of the climatic parameters, the analysis of Empirical Orthogonal Functions (EOF) was used [42]. In climate studies, this mode of analysis is especially used to study possible spatial modes of variability and how they change over time (eg, the North Atlantic Oscillation). In statistical terms, this analysis, which is also known as Principal Component Analysis (PCA), is classified as a multivariate technique.

The EOF configuration, together with the associated PC will define a mode of depending on the variance explained by each. Thus, the closer the explained variance is to 100%, the more faithfully the configuration mode reproduces the real conditions. In this analysis, the input data are represented by the anomalies of the considered variables, calculated against the multi-year average.

This method allows for analyzes using different types of climate data, but it is necessary to establish the optimal number of EOFs used to represent the analyzed field. In the present study, the configuration of the first EOF, which explains at least 50% of the explained variance, was retained.

To check the randomness of the time series associated with the EOF variability modes, the non-parametric Mann Kendall [45] and Pettitt [46] tests were applied. Non-parametric statistical hypothesis testing tests are those in which, under the conditions of the null hypothesis, the probability distribution for the test statistic does not depend on the shape of the distribution underlying the population from which the series is extracted.

In general terms, the Mann-Kendall test verifies randomness character against the alternative hypothesis of the existence of a trend in the analyzed data set, while the Pettitt test verifies the hypothesis "no change" against the alternative hypothesis "there is change".

In the present study, for the analyzed time series, which must be sufficiently long (of at least 30 years), positive values of the Mann-Kendall statistic greater than 1.97 show an increasing trend in the data series, at the level of significance of approximately 5%. For negative values, values less than -1.97 show a statistically significant downward trend at the 5% significance level.

In the case of the Pettitt test, to have a significant upward jump at time T-, the significance level must be less than 0.05 to be significant at the 5% level.

The results regarding the EOF analysis were represented using the Geographic Information System (GIS) which is used for various applications such as data storage, visualization and performing spatial analysis.

Statistical analyzes usually use regression analysis to determine the degree of correlation between two variables. Thus, based on the correlation coefficients, the links between the variables are established, the most used of which are the Pearson coefficient of linear correlation (r) and the Spearman rank coefficient (S).

In the present study, in order to find correlations between different data sets, the Spearman rank correlation coefficient was used, which applies to the ranks of the analyzed values and not to the values themselves. The use of this coefficient allows the analysis of the dependence between the analyzed variables and can have values between -1 and +1, where values close to -1 show a negative correlation of the ranks, while values close to +1 show a positive correlation between them.

The Spearman coefficient is calculated according to the relation:

$$S = 1 - \frac{6\sum_{i=1}^{N} D_i^2}{n(n^2-1)} \qquad (2.5)$$

where Di is the difference between the ranks associated with x and y values, and n shows the number of data associated with x and y values.

Under this study were also utilised available data from the European Climate Adaptation Platform Climate-ADAPT [48], being used a number of agrometeorological indicators, namely: biologically effective degree-days, the number of tropical nights, the number of frost days, for two time horizons 1986-2018 and 2040-2070.

In the present study, synoptic analyzes were also carried out, being analyzed the year 2007, which was mostly characterized by thermal temperature anomalies, and the year 2018, in which excess precipitation was recorded.

Chapter 3. Analysis of the agricultural sector and the productivity of wheat and maize crops in the period 1961-2018

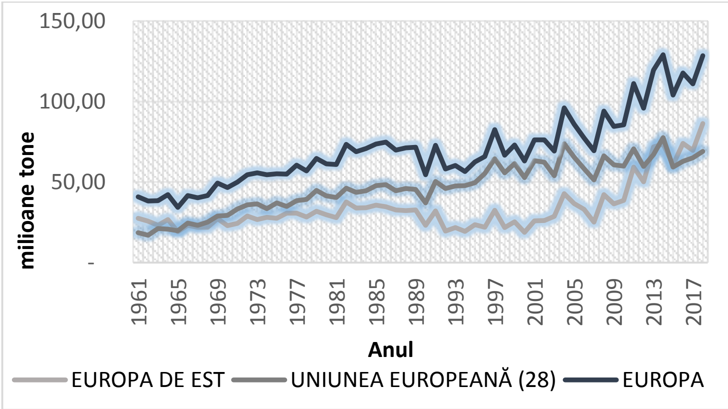
Analysis of the agricultural sector and the productivity of wheat and maize crops at the level of the European continent, the European Union (EU28) and Eastern Europe in the period 1961-2018

Europe's cereal production accounts for about 20% of global production. Eastern European countries show great potential for increasing grain production, and 50% of this growth potential applies to Romania and Poland. Cereals grown in the Member States of the European Union (EU 28) are mainly used for human consumption - 24% and animal consumption - 61%, but are also used for other purposes such as the production of alcoholic beverages -5%, the production of bio-energy - 4% and seeds – 3% [50].

In the present study, data on production, yields and harvested area for cereal crops, wheat and maize, for the period 1961-2018, were analyzed at the level of the European continent, Eastern Europe, the European Union and Romania. At the same time, the data on the agricultural production of cereal crops, wheat and maize, as well as their average production per hectare (yield) in the development regions of Romania, from 1990-2018, were analyzed. For example, information is presented on the production of maize and wheat at the level of the European continent, Eastern Europe, the European Union and Romania, in the period 1961-2018.

Maize production in Europe, European Union (28) and Eastern Europe 1961-2018

In Europe, Eastern Europe and the EU (28), maize production showed a general upward trend (Figure 3.5). In Europe, the lowest amount of maize harvested was 34.18 million tons in 1965, and the highest value was 129 million tons in 2014. In Eastern Europe, the minimum and maximum production values of maize were recorded in the years 2000 (18.75 million tons), respectively 2018 (86.33 million tons), and in the EU (28) they were recorded in 1962 (16.88 million tons), respectively 2014 (77.58 million tons). The year 1990 represented the year with the most significant decreases in maize production in all regions analyzed, both compared to the previous year and to the average of the last 5 years. In 2007, European maize production was around 69.5 million tons, 10.10% lower than in 2006 and 14.14% lower than the average of the last 5 years. This decrease in maize production in 2007 was also found in the other analyzed regions, in the EU (28) the production being 11.91% lower than in the previous year and 18.16% lower compared to the average of the years 2002- 2006.



Author, through data processing:[27]

Figura 3.1 - Maize production in Europe, European Union (28) and Eastern Europe 1961-2018

After the record achieved in 2014, in 2015 maize production recorded a reduction of 19.43% in Europe (103 million tons in 2015 compared to 129 million tons in 2014), with 23.60% in the EU (28) (59.26 million tons in 2015 compared to 77.58 million tons in 2014) and by 17.49% in Eastern Europe (60.68 million tons in 2015 compared to 73.54 million tons in 2014).

Wheat production in Europe, European Union (28) and Eastern Europe 1961-2018

The lowest level of wheat production (Figure 3.6) was recorded in 1963 in Europe (101.71 million tons) and Eastern Europe (58.82 million tons), while the highest level of production was found in 2017 to be 272.38 million tons in Europe and 155.65 million tons in Eastern Europe. In 2003, wheat production fell massively in all analyzed regions, registering the largest decreases compared to the previous year in the entire time period, by 23.53% in Europe (161.81 million tons in 2003 and 211 .61 million tons in 2002), 16.57% in the EU (28) (112.17 million tons in 2003 compared to 134.45 million tons in 2002), and 34.65% in Eastern Europe (mil. tons in 2003 and million tons in 2002. Low levels of wheat production were also recorded in 2012, being harvested 12.94% less in Europe compared to 2011 and 10.71% less than the average of the last 5 years In the EU (28), at the level of 2012 wheat production was only 3.08% lower than the previous year and 2.24% lower than the average of the interval 2007-2011.

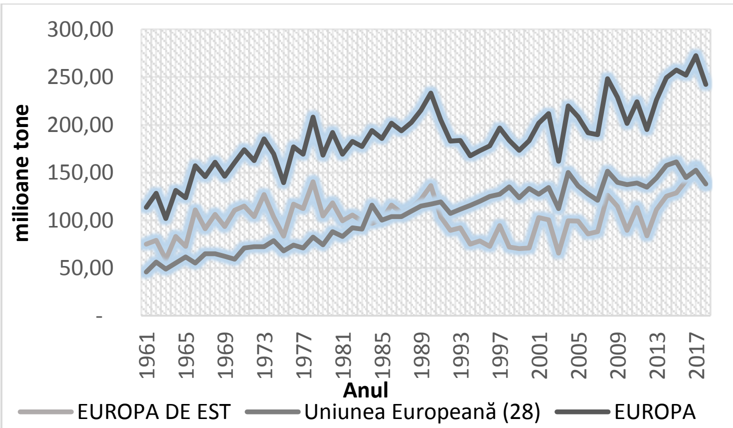


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Figura 3.2 - Wheat production in Europe, European Union (28) and Eastern Europe 1961-2018

In Eastern Europe, wheat production in 2012 recorded very low levels compared to the harvest obtained in the previous year (83.70 million tons of wheat; decrease by 25.98% compared to 2011) and to the average of the last 5 years (-21.23%).

Analysis of the agricultural sector and the productivity of wheat and maize crops at the national level in the period 1961-2018

Maize production in Romania in the period 1961-2018

As in the case of cereal production, in 2017 and 2018, maize production (Figure 3.10) recorded the highest values. In 2018, the production of maize in Romania was 18.66 million tons (the highest value of production in the entire time period analyzed), 30.28% more than in 2017 and 62.61% more compared to the average of the last 5 years. In 2017, also a year with high maize production, 14.33 million tons of maize were harvested, 33.31% more than the previous year and 46.14% more than the average value of the last 5 years.

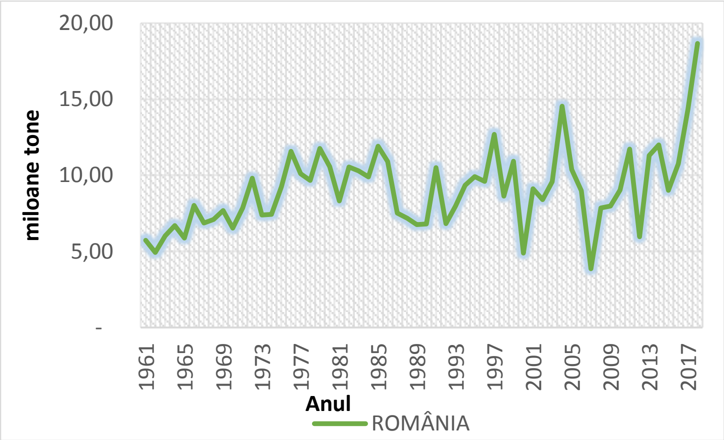

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Figura 3.3 - Maize production in Romania in the period 1961-2018

The most important percentage decreases in production were recorded in the years 2000, 2007 and 2012, only 4.90 million tons were harvested (55.21% less than in 1999 and 52.7% less than the average of the last years 5 years), respectively 3.85 million tons (the lowest level of maize production in the entire time period analyzed) and 5.95 million tons of maize. The extremely low levels of maize production in 2007 and 2012 were closely related to droughts in those years. In 2007, maize production recorded values 57.11% lower than those recorded in the previous year and 62.87% lower than the average of the last 5 years.

Wheat production in Romania during the period 1961-2018

In contrast to maize production, wheat production experienced more significant fluctuations in the analyzed time interval, with the lowest levels of the harvest at the national level being noted in the years 1970, 1992, 1996, 2003 and 2007 (Figure 3.12). In 1992, wheat production in Romania was 3.21 million tons, 41.42% lower compared to the value recorded in 1991 of 5.47 million tons and 55.17% lower than the average production of the last 5 years (7.15 million tons of wheat). The low level of production in 1992 was caused on the one hand by the uncertainties related to the way of land administration after the fall of the communist regime, which implicitly also led to a decrease in the cultivated area compared to the previous year, and on the other hand part, the severe drought in the summer of 1992 had a significant impact on wheat production [61]. In 2003, the lowest level of production was recorded, with only 2.48 million tons of wheat harvested, 43.93% less than in 2002 (4.42 million tons of wheat) and 53 .11% less than the average of the 1998-2002 interval (5.29 million tons of wheat).

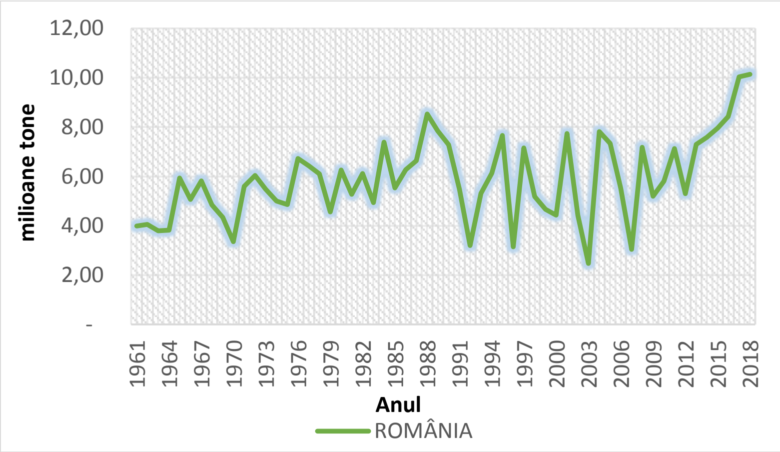

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Figura 3.4 - Wheat production in Romania during the period 1961-2018

It is important to note that the reduced production of wheat in 2003 came against the background of a similarly low level of production recorded in 2002 (reduction of the amount of harvested wheat by 42.85% compared to the previous year and by 24.22% compared to the average of the last 5 years).

Chapter 4. Analysis of the main modes of thermic and pluviometric variability at the national level with the aim of detecting the influence on the agricultural sector

4.1. EOF analysis of the temperature regime at the national level

Air temperature, which undergoes an annual cycle, being an element dependent on solar radiation, can be described based on several climatic parameters, such as averages and extreme values [62]. Air temperature characterizes the state of the weather, being a parameter that is measured both on the ground and in altitude with the aim of examining its distribution over large areas. This parameter, dependent on solar radiation, was analyzed in the present study using the mean values to which the EOF analysis was applied for the interval 1961-2018. The first EOF explaining at least 50% of the explained variance was retained. The analysis of this parameter in the present study is essential because its variation directly influences the growth, development and yield of crops. In order to analyze the temporal variability of the data series, Mann Kendall and Pettitt univariate analysis statistical methods were applied to detect the general trend and the jump in the mean at the 5% significance level.

For example, in the following are presented the results of the EOF analysis and statistical tests for the national average temperature in the summer season, taking into account the fact that for this season, the explained variance of the first EOF was 90%.

From the table below it can be seen that the first EOF for the national mean air temperature in the summer season has a high explained variance of 90%, while the number of modes of variability is low (3). The value of the increase identified for the average temperature is equal to 0.28°C.

Tabel 4.1 Results of the EOF analysis for the national summertime ambient temperature (TMED). The number of EOF configurations, the variance explained by the first EOF, the trend associated with the first PC (jump moment on average) and the value of the detected increase are presented

Author, through data processing: [40]

Parameter	No. EOF (explained variance greater than 1)	explained variance EOF1	Leap year on average	PC1 trend value
TMED	3	90%	2003	0,28°C

The first EOF for this parameter is shown in figure 4.1, while the associated time series is shown in figure 4.2. Based on the 90% explained variance, it can be inferred that large-scale mechanisms may be responsible for the recorded thermal variability. Analyzing the associated time series, it can be seen that a statistically significant upward trend was detected, with a change point, also statistically significant, in the year 2003.

For example, figure 4.3 shows the average air temperature at altitude, at the level of 850 hPa, for the year 2003 in the summer season. This is the average temperature recorded at about 1.5 km above sea level, usually just above the boundary layer. At this level, the diurnal (daily) temperature cycle is generally negligible. Therefore, the temperature at 850 hPa can be used to indicate frontal areas (i.e. areas of high temperature gradient, where the isotherms are tighter), and naturally to distinguish between warm and cold air masses [63].

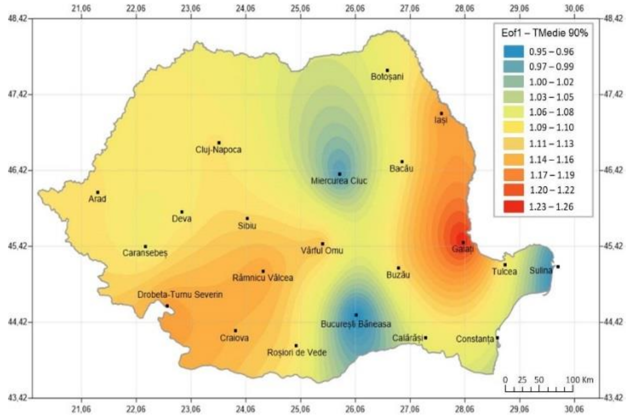

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Figura 4.1 - Configuration of the first EOF associated with the mean air temperature anomaly in the summer season

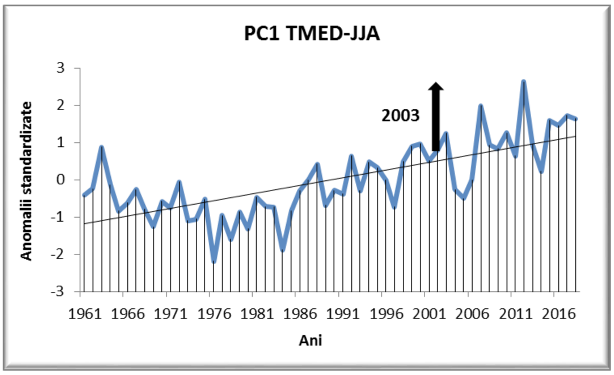

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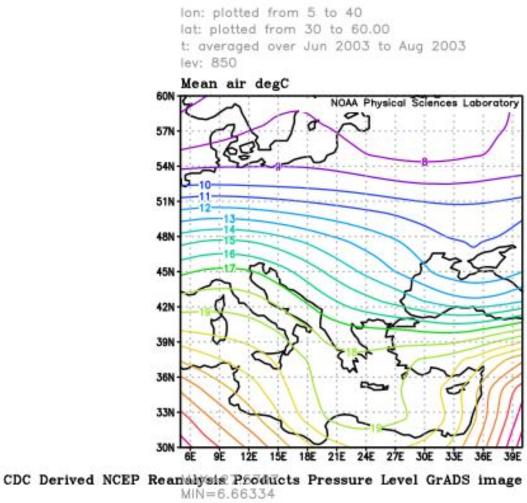
Figura 4.2 - Time series (PC) associated with the first EOF of the summer season. The arrow marks the point of change



Source: [43]

Figura 4.3 - Mean air temperature (in °C) at the 850 hPa level for the summer of 2003

It can be observed that, for the analyzed interval, at the level of our country, the 14 and 15 °C isotherms operate. However, it should be pointed out that in the summer months, the variation of the air temperature at the level of 2m above the ground is less dependent on the air mass located at the level of 850hPa, its value being more influenced by solar radiation. Thus, even if the temperature at the level of 850hPa is not very high, much higher temperatures can be recorded at ground level.

4.2 EOF analysis of the precipitation regime at the national level

Regarding precipitation amounts, the explained variances of the first EOF for the analyzed seasons were smaller, with a higher number of modes of variability. For example, the following presents the results of the EOF analysis and the statistical tests for the amounts of precipitation for the winter season.

Thus, table 4.6 presents the results of the EOF analysis for national atmospheric precipitation in the winter season, from which it is noted that the explained variance associated with EOF1 has a higher value than in summer, of 62%, the number of variability fields being equal to 4. From the first EOF configuration (Figure 4.13), a structure of the same sign can be observed throughout the country, with the highest values in the southwestern part of the territory. Analyzing the associated time series (Figure 4.14), a general downward trend is observed with a significant change point detected following the application of the Pettitt test in 1975 (0.7 mm).

Tabel 4.2 - Results of the EOF analysis for national atmospheric precipitation in the winter season (Precip). The number of EOF configurations, the variance explained by the first EOF, the trend associated with the first PC (jump moment on average) and the value of the detected increase are presented

Author, through data processing: [40]

Parameter	No. EOF (explained variance greater than 1)	explained variance EOF1	Leap year on average	PC1 trend value
Precip	4	62%	1975	-0,7 mm

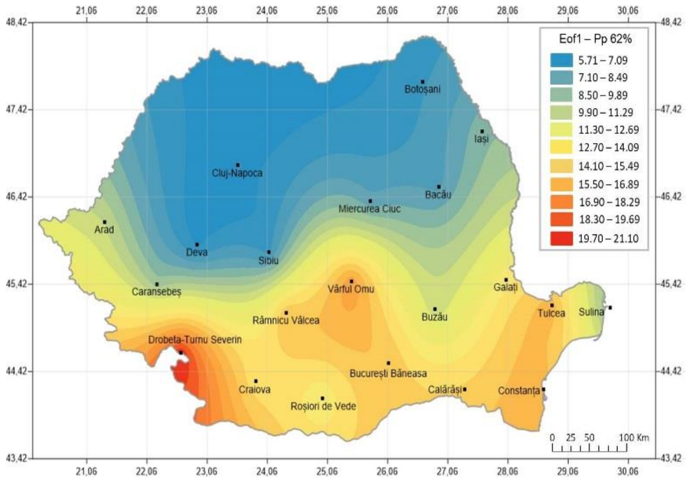


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Figura 4.4 - Spatial configuration of the first EOF associated with precipitation anomalies in the winter season

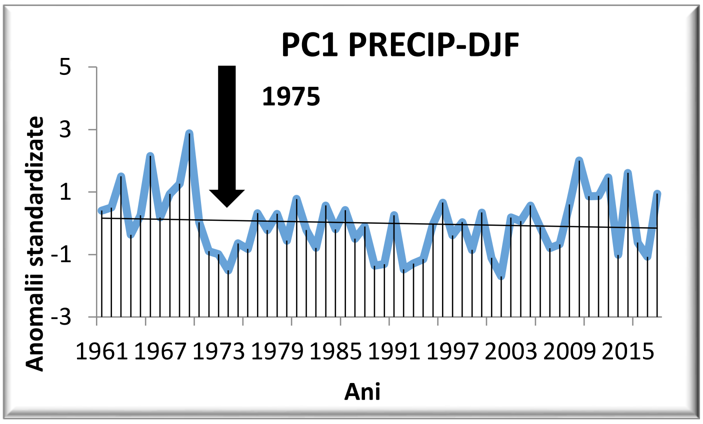
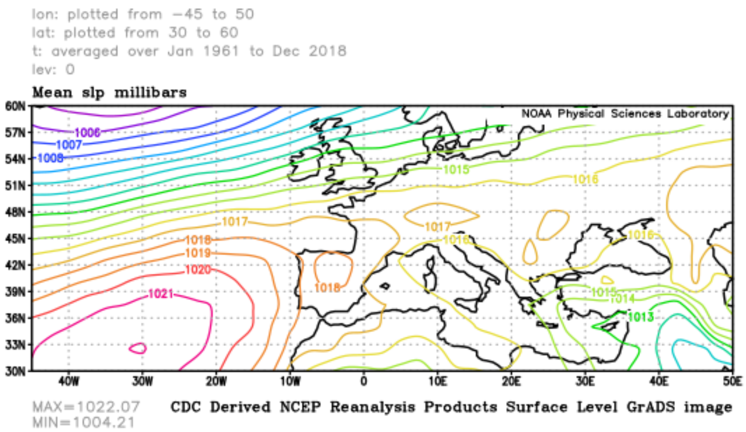


Figura 4.5 - Time series (PC) associated with the first EOF of the winter season

Taking into account the fact that in the winter season atmospheric circulation plays an essential role in modulating the rainfall regime in Romania [64], in 4.15 the pressure field at sea level for the period 1961-2018 is presented in an area that includes the Euro-Atlantic level. From the figure we can see a bipolar structure showing a variability of the opposite sign between the Atlantic region and the rest of Europe, so that at the level of the ocean there is an anticyclonic structure with a pressure center of 1021 mb.



Source: [43]

Figura 4.6 - Sea level pressure field reanalysis data for the period 1961-2018

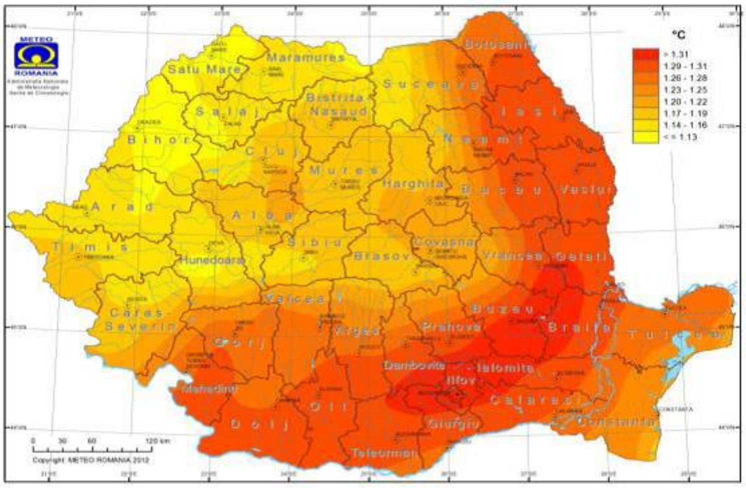
Such a structure reproduces quite well the field of the North-Atlantic oscillation which represents a dominant mode of variability of the atmospheric circulation in the winter season [65]. Extended anticyclonic structures usually produce large amounts of precipitation at the national level, so, from the time series associated with the first EOF that shows a decreasing trend, we can deduce a weakening of their frequency, which causes a decrease in the amount of precipitation over the analyzed interval.

Chapter 5. Analysis of the changing trend of the temperature and precipitation regime at the national level and the influence on the agricultural sector

5.1 The changing trend of the average air temperature

Among the meteorological parameters, air temperature is of great importance due to its dependence on solar radiation. Variations in the air temperature field affect both plant growth and development, as well as wind speed and direction. The higher the air temperature, the more the evaporation process increases and thus the soil is affected.

Our country is experiencing an increase in the average air temperature, so that at the national level for the period 1901-2012 there was an increase of 0.8 °C [66]. Moreover, from the figure below, which shows the changes observed in the multiannual average of the air temperature for the period 2011-2040 compared to the period 1916-1990, it can be seen that especially the regions located in the south and east of the territory are subject to a large percentage of heating (Figure 5.1).

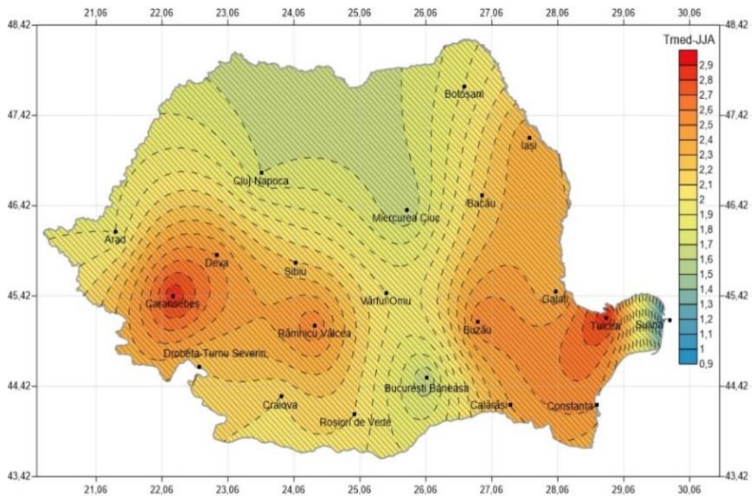


Sursa: [66]

Figura 5.1 - Observed changes in multi-year average air temperature for the period 2011-2040 compared to the period 1916-1990

The following presents the analysis carried out to identify the long-term linear trend in the case of the average air temperature for the 21 meteorological stations also used in the EOF analysis, for the summer season. Mann-Kendall and Pettitt non-parametric tests were thus used for the time horizon 1961-2018..

From Figure 5.2. the linear trend and its statistical significance can be observed for the average air temperature of the summer season. From the figure below, the significant warming signal can be noted at most of the analyzed stations, the highest values being recorded in the eastern and southwestern areas of the territory, a fact also revealed by the EOF analysis discussed in the previous chapter.



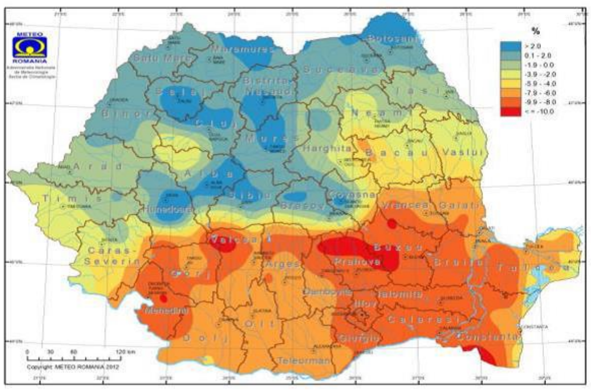
Author, through data processing: [40]

Figura 5.2 - Linear trend of mean summer air temperature (°C) over the period 1961-2018. The hatched areas show statistically significant trends (according to the Mann Kendall test)

It should be noted that at most of the analyzed stations the change point was detected in 2003, the same as in the case of the EOF analysis. This may mean that the detected heating signal is significant due to large-scale atmospheric configurations. According to the report presented by the World Bank in 2014, in 2003 rainy periods were significantly reduced, while 2007 was associated with low harvests.

5.2 The changing trend of the atmospheric precipitation regime at the national level

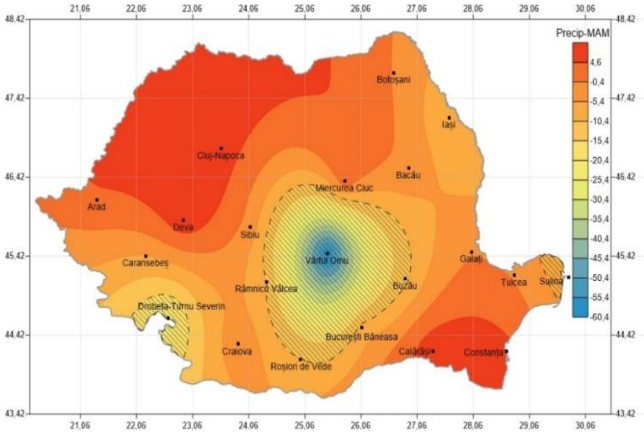
At the national level, the regime of atmospheric precipitation is influenced by several factors, one of which is the orographic one, represented by the Carpathian mountain range. In general, scientific studies have relevant the trend of decreasing the amount of precipitation, this being more pronounced in the warm season [62]. Against the background of the accumulation in the atmosphere of an even greater amount of greenhouse gases, it is expected that the precipitation regime will be affected especially by changing the intensity of the rains that will tend to take on a torrential aspect.



Source: [66]

Figura 5.3 - Observed changes in the multiannual average of atmospheric precipitation for the period 2011-2040 compared to the period 1916-1990

In the case of the spring season, the analysis of the linear trend presented in Figure 5.11., reveals decreasing trends in the amount of precipitation in most regions of the country, but these are statistically significant at a limited number of stations. Significant downward trends are noted at Drobeta Turnu-Severin, Roșiorii de Vede, Vârfu Omu and Sulina.



Author, through data processing: [40]

Figura 5.4 - Linear trend of spring precipitation amounts (°C) over the period 1961-2018. The hatched areas show statistically significant trends (according to the Mann Kendall test)

In the case of the autumn and spring seasons, it is worth noting the more pronounced variability of the precipitation regime. Moreover, in the spring season, characterized by an increase in the amount of precipitation at the national level [62], there are differences in disposition between the intra- and extra-Carpathian regions against the background of the intensification of cyclonic/anticyclonic activities.

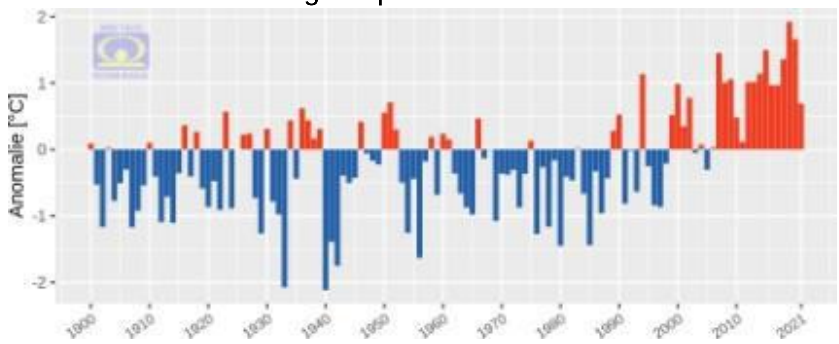
5.3 The influence of detected changes in the temperature and precipitation regime on the agricultural sector at the national level

According to the report prepared by the European Environment Agency in 2019 [68], the agricultural sector at the European level is under the influence of climate change, with crop productivity being strongly affected. The same report also points out that in the short term, the increase in air temperature can favor the agricultural sector by increasing the duration of the growing season, but in the opposite direction, extreme phenomena such as heat waves will lead to a decrease in agricultural production. It is known that the agricultural sector influences the increase of greenhouse gas emissions in the atmosphere, through activities such as the application of fertilizers and the use of land, with important amounts of carbon dioxide, methane and nitrous oxide being emitted into the atmosphere. Instead, as the effects of climate change intensify, the agricultural sector requires new adaptation measures by changing the type of crops, sowing or harvesting period. The most problematic aspect for the agricultural sector is related to the intensification of extreme phenomena that can substantially decrease the water potential needed for agriculture.

From the figures below, it can be seen that starting from the decade 2000-2010, positive thermal anomalies became predominant at the national level, so the table below (Table 5.2.) presents the warmest 15 years at the national level from the point of view of the deviations recorded from the climatological norm from the reference period 1981-2010.

Source: [74]

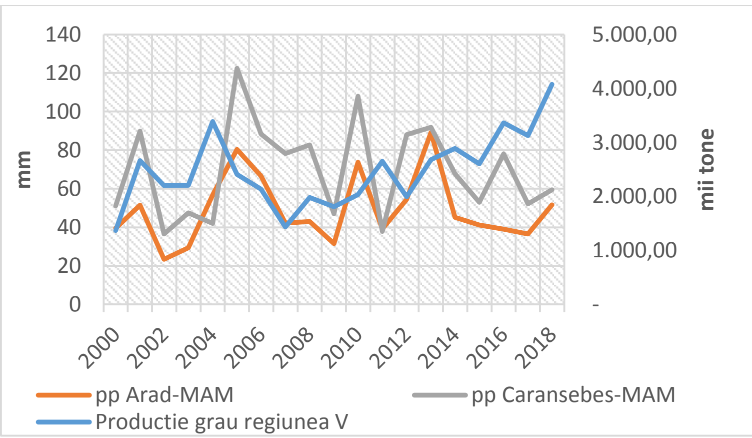
Figura 5.5 - Average air temperature values at the national level during the period 1900-2021



Source: [74]

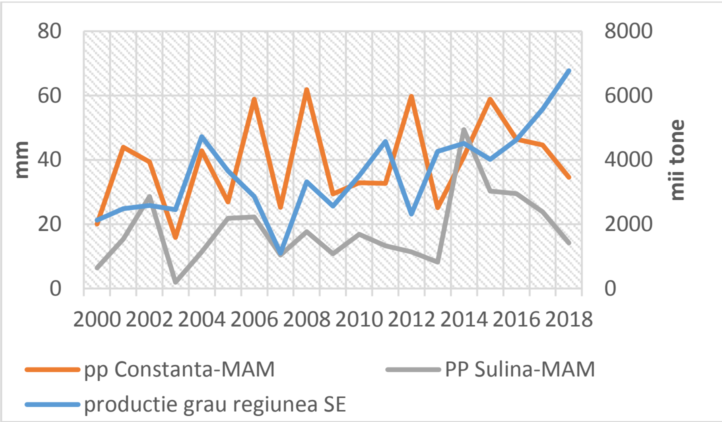
Figura 5.6 - The thermal anomalies recorded at the national level in the interval 1900-2021

In figures 5.16. and 5.17. are represented wheat and corn production for two regions in Romania, the West and South-East region, for the time period 2000-2018, together with the average amount of precipitation at the stations Caransebeș, Arad (West region), Constanța and Sulina (South region -East).



Author, through data processing: [18], [40]

Figura 5.7 - Recorded agricultural production for the wheat crop in the period 2000-2018 for the West region, together with the average amounts of precipitation in the spring season for the weather stations Caransebeș, Arad (West region)

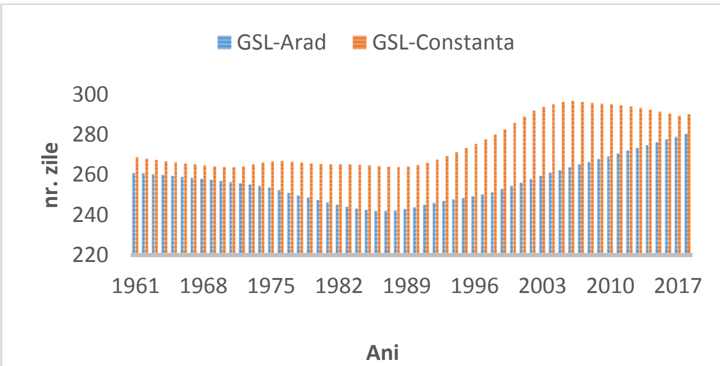


Author, through data processing:[18], [40]

Figura 5.8 - Agricultural production recorded for the wheat crop in the period 2000-2018 for the South-East region, together with the average amounts of precipitation in the spring season for the weather stations Constanța and Sulina (South-East region)

For wheat, lower values of agricultural production can be observed in the Western region of the country, but for both regions the lowest value was recorded in 2007, although the lowest values of the amount of precipitation were recorded in 2003 (for weather stations in the Southeast region) and 2002-2003 (for weather stations in the West region). It should be pointed out that analyzing the amounts of precipitation in the spring season is essential in this case, since the optimal sowing period for spring wheat occurs in the first part of March.

For an even better example, the figures below show the growing season length (GSL) at two of the 21 analyzed meteorological stations located in different areas in Romania for which the analysis carried out in the present study revealed significant trends in terms of statistical view. Data on the duration of the growing season, an indicator with great applicability in the agricultural sector, being used both to characterize plant phenology and to predict the conditions that favor the emergence of pests, were extracted from the ECA&D project and calculated according to the algorithm explained in the chapter 2.



Author, through data processing: [40]

Figura 5.9 - Duration of the vegetation season for the Arad and Constanța stations for the period 1986-2018

An increase in the duration of the growing season can be observed for the interval analyzed at the two stations, especially starting from the decade 2000-2010, which is consistent with the results obtained in the case of the average air temperature where increasing trends were detected throughout the country (except for small areas in the autumn season for which decreasing trends were detected).

In table 5.3. the level of the Spearman correlation coefficient between the analyzed agricultural production values and the multiannual air temperature values is also presented.

Tabel 5.1 - Correlation between multiannual average temperature values and wheat and corn production for three representative development regions in Romania

Author, through data processing: [18], [40]

Crop type	Region and meteorological station	Spearman Rank Coefficient
Wheat	North-East Region/ Iași meteorological station	-0,35
	South-East Region/ Călărași meteorological station	-0,38
	South-Muntenia Region/ Roșiori meteorological station	-0,35
Maize	North East Region/ Iași meteorological station	-0,37
	Regiunea Sud Est/ Călărași meteorological station	-0,39
	Regiunea Sud Muntenia/ Roșiori meteorological station	-0,39

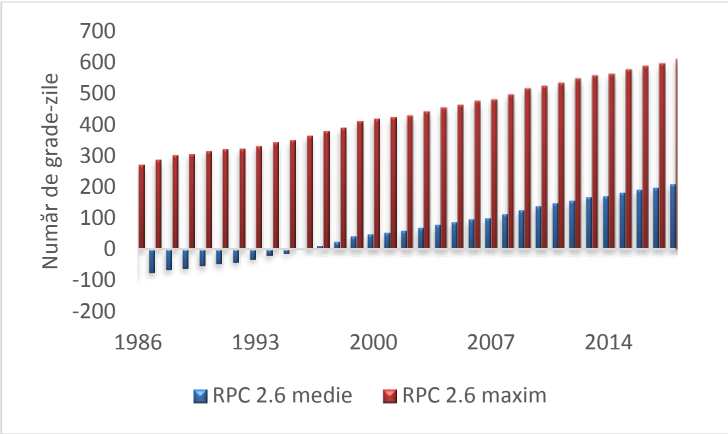
It can be seen that their values are inversely proportional, the Spearman coefficient revealing a not very close negative correlation, which means that as one variable increases, the other tends to decrease. Regarding the values of this coefficient, close to -1 or +1 should be scored, representing stronger relationships than values closer to zero.

5.4 Analysis of agroclimatic indicators in different greenhouse gas emission scenarios

In the present study, a number of three agroclimatic indicators available from the Climate-ADAPT database [48] were used, under the conditions of two greenhouse gas emissions scenarios RCP 2.6 (with low greenhouse gas emissions) , RCP 8.5 (with high greenhouse gas emissions), as presented in Table 5.6.

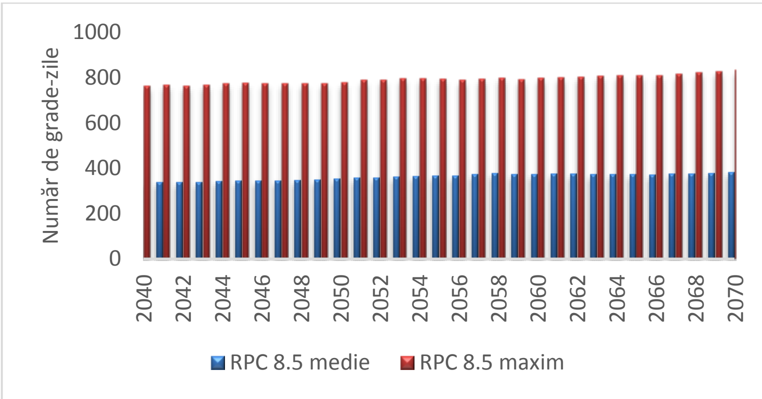
Climate indicators were projected from the ensemble of five global climate models available from the CMIP5 database, and projections were calculated relative to the reference period 1981–2010. The values of the indicators used in the present study are represented as the average for the entire country. Projections on the change of each indicator are presented as the 30-year average for each of the two scenarios used.

In the following, for example, the results obtained for the biologically effective degree-days indicator are presented in the case of both emission scenarios considered. Thus, from figure 5.26. it emerges that in the case of the RCP 2.6 scenario, the average and maximum values show a significant increasing trend as we approach the end of the analyzed interval.



Author, through data processing: [48]

Figura 5.10 - The trend of the number of degree-days in Romania (average and maximum values) for the period 1986-2018 in the case of the RCP 2.6 scenario



Autor, prin prelucrarea datelor: [48]

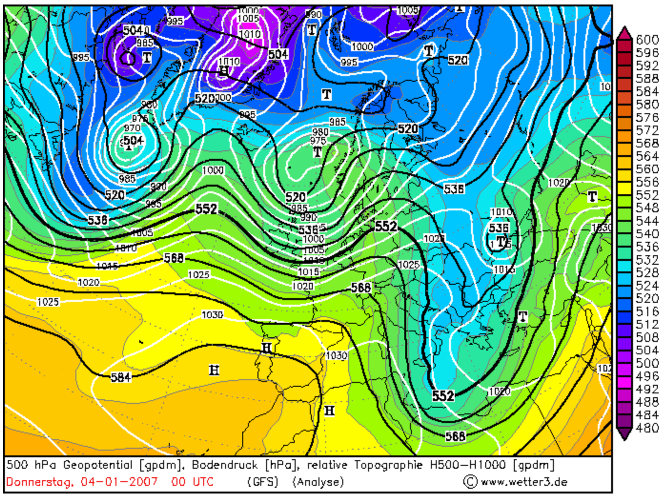
Figura 5.11 - The trend of the number of degree-days in Romania (average and maximum values) for the period 2040-2070 in the case of the RCP 8.5 scenario

In the case of average values, the detected increase is less, starting from negative values and continuing with positive values starting from 1996. In the case of maximum values, the general trend of growth can be observed for the entire analyzed interval. Regarding the analysis carried out for the RCP 8.5 scenario for the time horizon 2040-2070 (Figure 5.27.), both in the case of average and maximum values, general increasing trends can be observed.

Chapter 6. Analysis of the synoptic conditions that generated the occurrence of extreme phenomena in Romania with impact on the agricultural sector - Case studies

6.1 Analysis of the synoptic conditions that generated the unusually warm weather of the winter and summer of 2007

At the national level, the persistence of hot days manifested itself more and more frequently, with the year 2007 registering deviations from the normal values of the average air temperature both in the warm season and in the cold season. From a meteorological point of view, the year 2007 was one of temperature records on the one hand, but also of extreme phenomena on the other. Since January, the year 2007 stood out as a warm one (Table 6.1), even though the beginning of the month was manifested by the deepening of a valley of the Icelandic Depression in an area that also includes the territory of our country (Figure 6.2), the structure that determined the registration low temperatures.



Source: [49]

Figura 6.2 Relative baric topography, ground clearance and geopotential at 500 hPa level on 04.01.2007

Table 6.1 The top of the years with the warmest January months in Romania, from the period 1961-2021

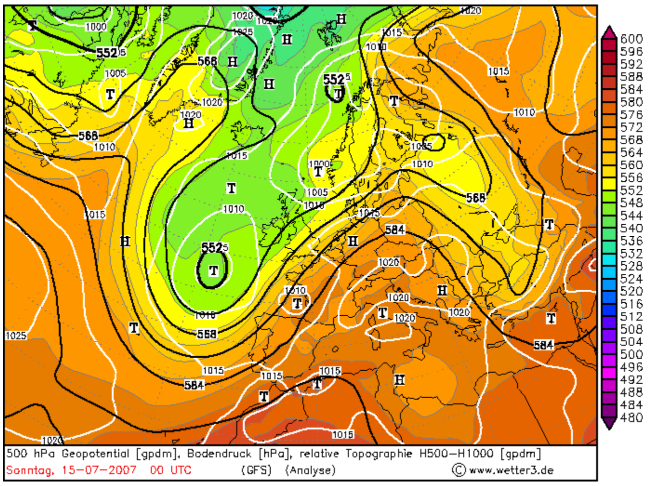
Source: [94]

No.	**Year**	**Mean monthly temperature (ºC)**	**Deviation from the median of the reference interval 1991 – 2020 (ºC)**
1	**2007**	**3,0**	**5,1**
2	1994	1,3	3,4
3	1983	0,7	2,8
4	1988	0,6	2,7
5	2014	0,3	2,4
6	2018, 2021	0,1	2,2
7	1975, 2001	0,0	2,1

8	1971, 1998	-0,3	1,8
9	1984, 2015	-0,4	1,7
10	2005, 2020	-0,7	1,4

According to the results presented in Chapter 3, in 2007 agricultural productions of 3.04 million tons for wheat and 3.85 million tons for corn were recorded. Compared to the average of the analyzed interval 1961-2018 of 5.88 million tons for the wheat crop and 9.07 million tons for the corn crop, the values recorded in 2007 were much lower. Taking into account the fact that in the agricultural year 2006/2007 the soil registered a significant deficit of moisture, as a result of the lack of precipitation in the form of rain and snow [95], the considerable decrease in the production of the analyzed crops can be explained.

The year 2007 continued to be one of positive thermal extremes during the summer as well, so that since June 2007 the persistence of heat waves during which high daytime and nighttime thermal values were recorded was noted. During the summer of 2007, four major heat waves were recorded in our country, one in June, two in July and one in August [20]. Among them, the heat waves registered at the national level in July 2007 were severe and were dominated by the expansion of an anticyclone of North African origin over the south and southeast of the European continent, also affecting Romania (Figure 6.6).

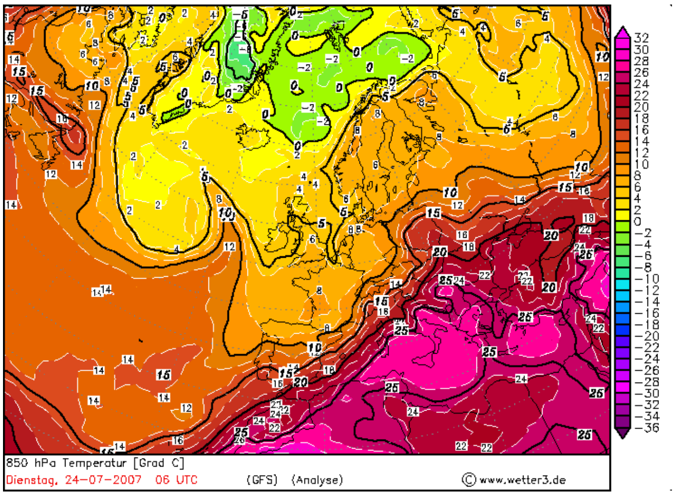


Source: [49]

Figura 6.6 Relative baric topography, ground clearance and geopotential at 500 hPa on 15.07.2007

From figure 6.6 it can be noted that the Icelandic Depression was blocked by a vast anticyclonic structure that determined the advection of warm tropical air from the north of Africa, being recorded at the level of 850 hPa (1500 m altitude), temperatures that exceeded the threshold of 20°C.

The peak of the heat wave was recorded, according to the records, on July 24 when the 30 °C isotherm was located in the air temperature field at the level of 850 hPa above our country (Figure 6.8), which led to the ground record of temperatures exceeding 40 °C.



Source: [49]

Figura 6.8 Air temperature field at the isobaric level of 850 hPa on 24.07.2007

The month of July of 2007 is ranked as the warmest in the period 1961-2021, according to the multi-year climatological characterization carried out by the National Meteorological Administration [94] (Table 6.2), the deviation from the average of the reference interval 1991-2020 being 2.6 ºC . In fact, on July 24, 2007, the National Meteorological Administration issued the first red heat wave code for the municipality of Bucharest and five counties (Ilfov, Giurgiu, Olt, Dolj, Teleorman), for the rest of the country, orange and yellow discomfort codes were established thermally accentuated. The maximum temperature on that date exceeded 43 °C in the areas where the red heat code was established, the temperature-humidity index (ITU) exceeding the critical threshold of 80 units in almost the entire country, which marked the summer of 2007 in Romania, an exceptional character.

According to Dima and others [20], the temperatures recorded both in the warm season and in the cold season of 2007, but especially against the background of the recording of extreme temperatures in July 2007, led to the recording of average temperature values of 10, 6°C, which at the time constituted an absolute record at national level.

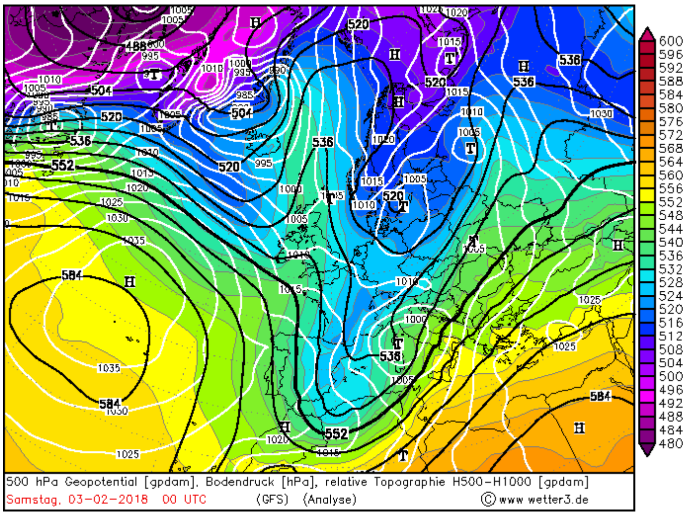
6.2 Analysis of the synoptic situations that generated the weather conditions of 2018

In 2018, Romania had the largest corn production in the European Union (18.66 million tons), surpassing for the first time France, which recorded a harvest of approx. 12 million tons of corn [85]. It should be noted that the other states of the European Union were far below the level of corn production in Romania, harvesting less than 8 million tons in 2018 [98]. Also in 2018, Romania ranked 3rd in the European Union in terms of cereal production, with a harvested quantity of over 31 million tons. and 4th in terms of wheat production [86].

The very rich harvest of 2018 was due to very favorable climatic conditions, although there were unfavorable episodes for crop development. In February 2018, temperatures between -15°C and -25°C were recorded, and precipitation was evenly distributed, forming a thick layer of snow especially in the southern and southeastern regions of the country. Snow melting starting in March 2018 led to the replenishment of the soil water reserve [99]. The second part of March was characterized by excessive rains, causing delays in the sowing campaigns for spring and summer crops [100]. The period between April 1 and May 15 was warmer than usual, speeding up the development of winter crops by up to two weeks. During this period, temperatures of up to 30°C were also recorded. The lack of rainfall in April created favorable conditions for the completion of sowing campaigns for maize crops [101]. In May-June 2018, the number of days with temperatures above 30°C was 2-3 times higher than the usual level for this period. Precipitation exceeded the average limit by 15-60 mm in western Romania, ensuring an adequate level of soil water reserves, but remained below average in the eastern and central regions, with the total precipitation deficit reaching 20-90 mm. Thus, the climatic conditions from May to June 2018 led to the acceleration of the crop development process and the reduction of the reproductive phase for winter cereals [102].

In the first half of June, temperatures were 2°C to 4°C above the multi-year average, followed by cooler-than-normal temperatures. The harvesting campaign for winter crops was started much earlier than normal, but heavy and frequent rainfall from 1 June to 15 July (Figure 6.13), with record values of 80mm to 330mm (the highest levels of rainfall since 1975).

Next, it will be analyzed the synoptic situation that generated the formation of a thick layer of snow in February 2018, a fact that led to the replenishment of the soil water reserve and implicitly the favorable development of agricultural crops. The month of February 2018 started with higher than normal temperatures due to the presence of air of tropical origin in the south-east of Europe, the rest of the continent being dominated by the presence of air of polar origin.

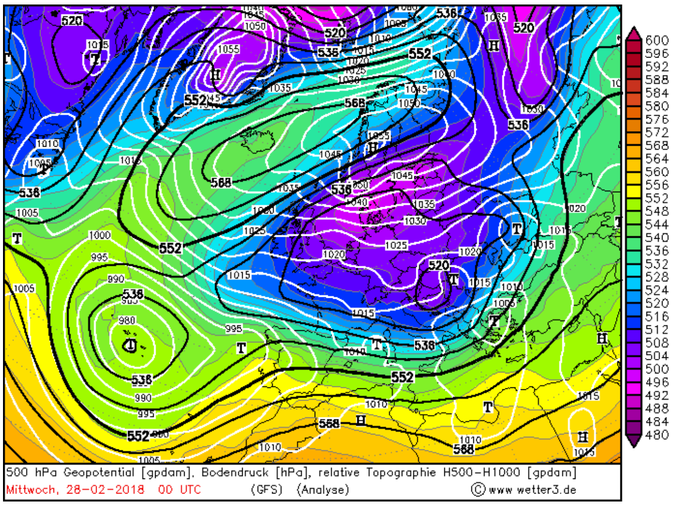


Source: [49]

Figura 6.14 Relative baric topography, ground clearance and geopotential at the 500 hPa level on 03.02.2018

At the national level, on that date, the lack of snow cover was also reported on extensive areas, a fact that can be attributed to the high temperatures recorded.

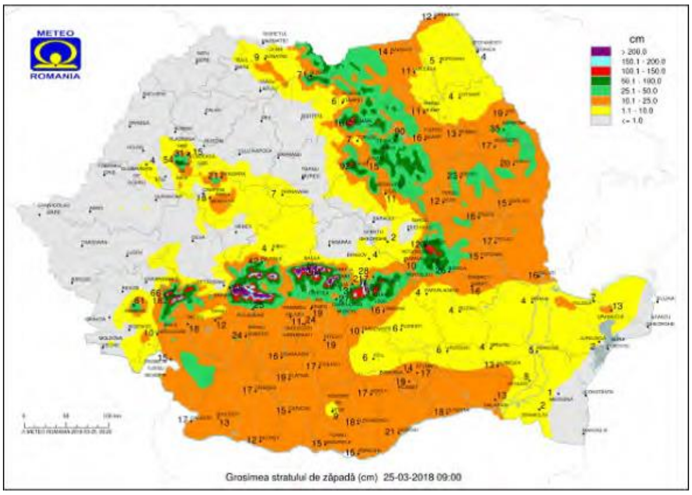
Compared to the beginning of February, its end is marked by the advection of air of polar origin over most of Europe, except for the south and southwest of the continent (Figure 6.16). It is worth noting that our country is under the influence of the air of polar origin, which determined for March 1, 2018 the registration of absolute minimum temperatures in Romania [105].



Source: [49]

Figura 6.16 Relative baric topography, ground clearance and geopotential at the 500 hPa level on 28.02.2018

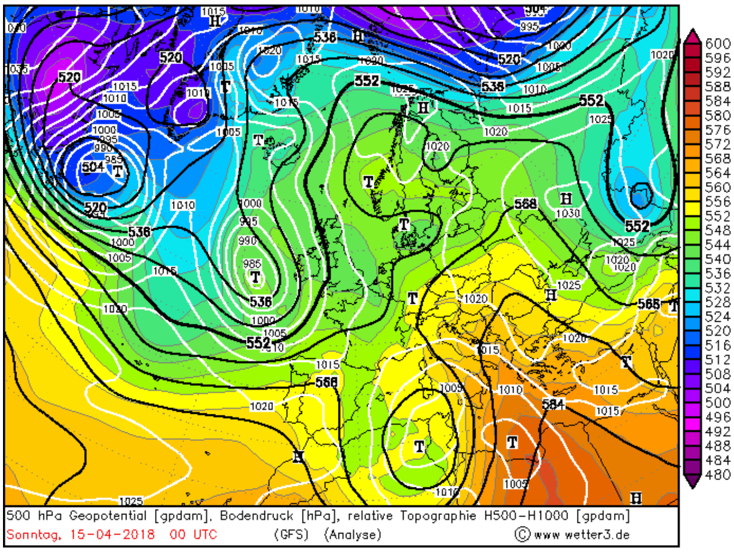
Following this particularly cold weather episode, the first spring month of 2018 was marked by thermal oscillations such that both mild and very cold weather episodes were recorded. At the same time, it should be noted that at the end of February, a consistent layer of snow was recorded in Romania, favoring the establishment of freezing conditions, with extremely low temperatures.



Source: [105]

Figura 6.17. The thickness of the snow layer on 25.02.2018

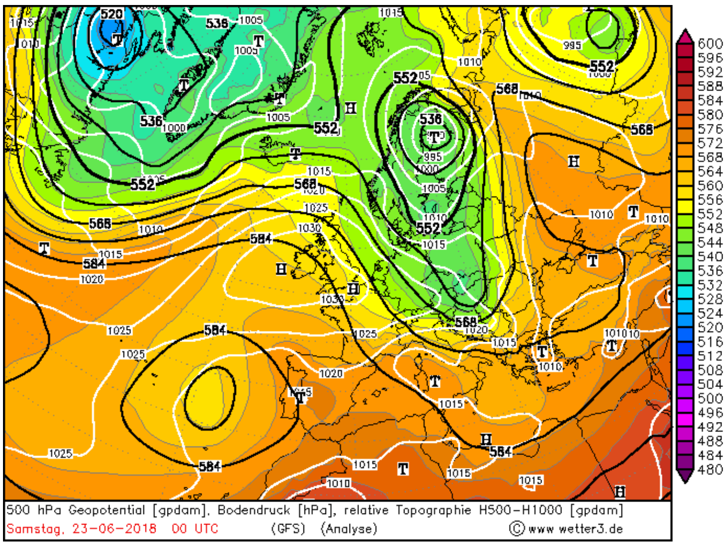
The month of April was dominated by intrusions of tropical air of North African origin in most of Europe, except for the north and northwest of the continent where polar air advections are noticeable (Figure 6.18).



Source: [49]

Figura 6.18 The relative baric topography, ground clearance and geopotential at the 500 hPa level on 14.04.2018

From the figure above, you can see the high values of the geopotential field over the territory of our country, a fact that favored the recording of increased temperatures at the national level. Instead, June of 2018, as can be seen from the data presented in table no. 6.3, was the month in which precipitation in the form of rain was present in considerable amounts. This situation was caused by intrusions of polar air that also reached over our country, which led to the recording of abundant amounts of precipitation (Figure 6.19).



Source: [49]

Figura 6.18 Relative baric topography, ground clearance and geopotential at the 500 hPa level on14.04.2018

Overall, 2018 was a favorable year for the development of agricultural crops, which, compared to the year 2007 analyzed in the first part of this chapter, recorded both precipitation in the form of rain and precipitation in the form of snow, but also temperatures favorable to the development of crops agricultural, as was the case in April and May. Compared to 2018, 2019 did not have the same agricultural productions, being a year in which there were either late spring frosts or excessive floods or droughts.

The synoptic analyzes carried out in this chapter showed the dependence of yields and agricultural productions on weather conditions, conditions which, against the background of the acceleration of the global warming phenomenon, tend to take on extreme aspects. The amplification of extreme phenomena represents one of the biggest risks for agriculture, causing this sector to be increasingly affected by the positive thermal deviations recorded at the national level, by the uneven distribution of precipitation and the installation of extreme pedological drought.

General conclusions, original contributions and perspectives

Climate change is caused by the increase in the concentration of greenhouse gases in the atmosphere as a result of the anthropogenic factor. It is estimated that human activities have so far caused a warming of approximately 1.0°C compared to the pre-industrial period, and for the period 2030 - 2052 it is expected that this increase in temperature will be up to 1.5°C, this aspect generating in multiple regions an increase in extreme temperatures, a higher frequency, intensity and/or amount of precipitation, as well as the occurrence of drought phenomena. Currently, many regions are experiencing higher temperatures than the global average annual temperature, with this increase felt more strongly over land surfaces than over oceans.

Agriculture represents an economic sector directly influenced by climatic conditions, so any change produced will have an immediate effect on it. Climate data in recent years have shown a progressive warming of the atmosphere, as well as a higher frequency of extreme events, with rapid heatwave/severe drought/heavy rainfall alternations becoming more evident.

The original contributions of this study consist in the use of different data sets and statistical methods of analysis with the aim of understanding, on the one hand, the physical processes that govern the climate at the level of the European continent and at the level of Romania and the impact they can have on the yield and agricultural production, on the other hand. In this study, it was analyzed whether the various scientific methods of analysis are sufficiently precise to answer the many questions related to climate dynamics and the potential impact on the agricultural sector. Therefore, the paper presents an interdisciplinary approach, which brings together terms from the field of statistics with those from climatology and agriculture. Within this study, the variability of the main meteorological parameters and the connection with the large-scale mechanisms responsible for the detected changes in their regime were analyzed from a spatial and temporal point of view. Such an analysis is essential to be able to identify the real impact of climate change on agricultural production conditions in Romania.

Thus, in **Chapter 1**, a bibliographic study was carried out in which the most recent and relevant published results related to the targeted field were presented.

In **Chapter 2**, the data and methods used to carry out a more complex analysis of the influence of the climate regime on agricultural productivity in Romania were presented.

The analysis of the aforementioned data for the agricultural sector, carried out in **Chapter 3**, revealed very low values of cereal, wheat and maize production in years such as 2000, 2003, 2007 and 2012 and very high values in 2017 and 2018.

In **Chapter 4**, the EOF analysis was carried out on the temperature and precipitation regime at the national level, for the period 1961-2018.

The results of the EOF analysis and statistical tests for the national mean summer temperature show a high explained variance of 90%, while the number of modes of variability is low (3). The value of the increase identified for the average temperature is equal to 0.28°C. Based on the 90% explained variance, it can be inferred that large-scale mechanisms may be responsible for the recorded thermal variability. Analyzing the associated time series, it can be seen that a statistically significant upward trend was detected, with a change point, also statistically significant, in the year 2003.

The results of the EOF analysis for atmospheric precipitation at the national level in the winter season, from which it is noted that the explained variance associated with EOF1 has a higher value than in summer, of 62%, the number of variability fields being equal to 4. From the first configuration EOF, a structure of the same sign can be observed throughout the country, with the highest values in the southwestern part of the territory. Analyzing the associated time series, a general downward trend is observed with a significant change point detected following the application of the Pettitt test in 1975 (0.7 mm).

In **Chapter 5**, the analysis of the changing trend of the temperature and precipitation regime at the national level and the influence on the agricultural sector was carried out.

The analysis to identify the long-term linear trend in the mean air temperature was performed for the 21 weather stations also used in the EOF analysis. Mann-Kendall and Pettitt non-parametric tests were thus used for the time horizon 1961-2018.

For the summer season, the signal of significant warming was observed at most of the analyzed stations, with the highest values being recorded in the eastern and southwestern areas of the territory. It should be noted that at most of the analyzed stations the change point was detected in 2003, the same as in the case of the EOF analysis. This may mean that the detected heating signal is significant due to large-scale atmospheric configurations.

Regarding the amount of precipitation, in the case of the spring season, the analysis of the linear trend reveals decreasing trends in the amount of precipitation in most regions of the country, but these are statistically significant at a limited number of stations, respectively at the Drobeta Turnu-Severin stations , Roșiorii de Vede, Vârfu Omu and Sulina.

From the analyzes carried out in the present study, a significant warming signal emerged at most of the analyzed stations, the highest values being recorded in the eastern and southwestern areas of the territory, a fact also relevant to the EOF analysis.

From the analysis of growing season length (GSL) data, an increase in growing season length was observed for the interval analyzed at all four stations analyzed in the PhD thesis, especially starting from the decade 2000-2010, which is consistent with the results obtained in the case of the average air temperature where increasing trends were detected throughout the country (except for small areas in the autumn season for which decreasing trends were detected).

The application of the Spearman coefficient for multiannual average temperatures and wheat and corn production, revealed that their values are inversely proportional, with a not very close negative correlation. The negative correlation shows that as multiannual average temperatures increase, agricultural production for the two analyzed crops tends to decrease.

Within the case studies presented in **Chapter 6**, synoptic analyzes were made that generated the occurrence of extreme phenomena in Romania with an impact on the agricultural sector, for the years 2007 and 2018. In 2007, production recorded the lowest values, while the harvests obtained in 2018 were the highest in the time period analyzed.

The synoptic analyzes carried out in Chapter 6 showed the dependence of yields and agricultural productions on weather conditions, conditions which, against the background of the acceleration of the global warming phenomenon, tend to take on extreme aspects. The amplification of extreme phenomena represents one of the biggest risks for agriculture, causing this sector to be increasingly affected by the positive thermal deviations recorded at the national level, by the uneven distribution of precipitation and the installation of extreme pedological drought.

The present study was developed on the basis of official data available at the national level, with the aim of facilitating the understanding of how climate phenomena can directly affect the agricultural sector. The study could be improved if the volume of available data would be supplemented, for example by analyzing a higher number of meteorological stations or completing the information on the irrigated area, for which data are available only from 1997 onwards.

Chapter 7. List of published papers

Published books:

1. Monografie „Monitorizarea impactului asupra mediului a lucrarilor de imbunatatire a conditiilor de navigatie pe Dunare intre Calarasi si Braila, km 375 si km 175”, volumul 1, Anexa 1, Universitas Petroșani, ISBN: 978-973-741-506-6, 2016

Author: DEÁK György, Ilie Mihaela, Bâdiliță Alin Marius, Raischi Marius, Raischi Natalia Simona, Ionescu Petra, Ivanov Alexandru Anton, Anghel Ana Maria, Monica Matei, Mărcuș Iuliana, Mițiu Mihaela, **Boboc Mădălina,** Ciobotaru Irina, Dumitru Florina Diana, Holban Elena, Laslo Lucian, Mincu Mariana, Moncea Andreea, Olteanu Marius, Radu Violeta Monica, Sîrbu Cristina, Tociu Carmen

2. Monografie „Monitorizarea impactului asupra mediului a lucrarilor de imbunatatire a conditiilor de navigatie pe Dunare intre Calarasi si Braila, km 375 si km 175”, volumul 2, Anexa 2, Universitas Petroșani, ISBN: 978-973-741-506-6, 2016

Authors: DEÁK György, Ilie Mihaela, Bâdiliță Alin Marius, Raischi Marius, Raischi Natalia Simona, Ionescu Petra, Ivanov Alexandru Anton, Anghel Ana Maria, Monica Matei, Mărcuș Iuliana, Mițiu Mihaela, **Boboc Mădălina**, Ciobotaru Irina, Dumitru Florina Diana, Holban Elena, Laslo Lucian, Mincu Mariana, Moncea Andreea, Olteanu Marius, Radu Violeta Monica, Sîrbu Cristina, Tociu Carmen

3. Ghid de bune practici privind cartarea şi evaluarea ecosistemelor zonelor umede şi a serviciilor oferite de acestea, Universitas Petroşani, ISBN 978-973-741-533-2, 2017

Autori: Monica Matei, Lucian Laslo, DEÁK György, Nicu Ciobotaru, **Mădălina Boboc,** Marius Raischi, Cristina Mușat, Theodor Lupei, Simona Raischi, Andreea Moncea, Diana Dumitru, Gabriel Badea, Lampros Lamprinakis, Divina Gracia P. Rodriguez, Anne Strøm Prestvik, Asbjorn Veidal, Bjørn Klimek

4. Best practices guide on mapping and assessing wetland ecosystem and their services, Universitas Petroşani, ISBN 978-973-741-534-9, 2017

Autori: Monica Matei, Lucian Laslo, DEÁK György, Nicu Ciobotaru, **Mădălina Boboc**, Marius Raischi, Cristina Mușat, Theodor Lupei, Simona Raischi, Andreea Moncea, Diana Dumitru, Gabriel Badea, Lampros Lamprinakis, Divina Gracia P. Rodriguez, Anne Strøm Prestvik, Asbjorn Veidal, Bjørn Klimek

5. Deșeuri periculoase – Gestionare și riscuri pentru mediu și sănătate, ISBN 978-973-741-535-6; Autori: Magdalena Chiriac, Fredrik Gaustad, Petra Ionescu, DEÁK György, Eirik Rudi Waerner, Ana Maria Anghel, Gina Ghiță, Cristina Maria, Goran Vujicic, Monica Silvia Matei, Monica Niculina Radu, **Mădălina Georgiana Boboc**, Marian Tudor, Valentin Logodinschi, Veronica Ilie, Lavinia Stancu, Cornel Loghin

6. Hazardous waste: Management and Risks for Environment and Health, ISBN 978-973-741-536-3; Autori: Magdalena Chiriac, Fredrik Gaustad, Petra Ionescu, DEÁK György, Eirik Rudi Waerner, Ana Maria Anghel, Gina Ghiță, Cristina Maria, Goran Vujicic, Monica Silvia Matei, Monica Niculina Radu, **Mădălina Georgiana Boboc**, Marian Tudor, Valentin Logodinschi, Veronica Ilie, Lavinia Stancu, Cornel Loghin

Scientific articles published in ISI indexed journals:

1. Olteanu M.V., Baraitaru A., Panait A.M., Dumitru F.D., **Boboc M.G.**, Deak Gy., Advanced SiO2 Composite Materials for Heavy Metal Removal from Wastewater; Journal of Water Air and Soil Pollution (2019) 230: 179. https://doi.org/10.1007/s11270-019-4225-7;

2. Florea A.M., Capatina A., Radu R.I., Serban (Bacanu) C. 1, **Boboc M.G.,** Stoica (Dinca) C., Munteanu (Pila) M, Ion (Dumitru) I.M., Stanciu S.; Limiting Factors that Influence the Formation of Producer Groups in the South-East Region of Romania: A Fuzzy Set Qualitative Comparative Analysis (fsQCA); Journal of Sustainability, 2019, 11, 1614, 2019, https://doi.org/10.3390/su11061614;

3. Ciobotaru, N., Laslo, L., Matei, M., **Boboc, M.,** Moncea, A., Lupei, T., Ghita, G., Szep, R., Popescu, I., Stroie, O.; 2018; Factors controlling hydrological processes and characteristics in the Șușita catchment area; Journal of Environmental Protection and Ecology 19, No. 1, p. 25-38; ISSN 1311-5065, 2018, http://www.jepe-journal.info/journal-content/vol-19-no-1;

4. Raischi M. C., Oprea L., Deák Gy., **Boboc M.,** Matei M., Raischi N.; 2017; Investigation of sturgeon migration routes using the most adequate monitoring techniques in difficult hydrological conditions of the Danube river, Journal of Environmental Protection and Ecology 18, No. 1, p. 142–157, ISSN 1311-5065, 2017, http://www.jepe-journal.info/journal-content/vol-18-no-1;

5. Daescu A.I., Holban E, **Boboc M. G**., Raischi M. C, Matei M., Ilie M., Deák Gy., Daescu V.; 2017; Performant technology to remove organic and inorganic pollutants from wastewaters, Journal of Environmental Protection and Ecology 18, No. 1, p. 304–312, ISSN 1311-5065, 2017, http://www.jepe-journal.info/journal-content/vol-18-no-1;

6. Matei M., Raischi M., Ciobotaru N., Laslo L**., Boboc M**., Zamfir A.S., Deák Gy.; 2017; Flood Protective Measures in Divici–Pojejena Wetland, Caras-Severin County, Romania; Journal of Environmental Protection and Ecology 18, No. 1, p. 235–245, ISSN 1311-5065, 2017; http://www.jepe-journal.info/journal-content/vol-18-no-1;

Scientific articles published in international databases (BDI)/ISI Proceedings

1. Bara, N., Deák, Gy. Laslo, L., Rotaru, A., Matei, M., **Boboc, M.,** Enache, N., Yusuf, S.Y., (2022). Changes of Carbon in a Hardwood Forest by Forecasts Using a Forest Model. Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology. Lecture Notes in Civil Engineering, vol 214. Springer, Singapore. https://doi.org/10.1007/978-981-16-7920-9_3;
2. Christine, C.S.M., Tengku Izhar, T.N., Zakarya, I.A., Yusuf, S.Y., Azhari, A.W., **Boboc, M**. (2022). A Study on the Environmental Impact During Distribution and Disposal Stages for the 3-Ply Face Masks by Using Life Cycle Assessment (LCA). Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology. Lecture Notes in Civil Engineering, vol 214. Springer, Singapore. https://doi.org/10.1007/978-981-16-7920-9_9;
3. Amat, R.C., Ibrahim, N.M., Rahim, N.L., Ismail, K.N., Hamid, A.S.A., **Boboc, M.** (2022). Influence of Cement Paste Containing Municipal Solid Waste Bottom Ash on the Strength Behavior of Concrete. Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology. Lecture Notes in Civil Engineering, vol 214. Springer, Singapore. https://doi.org/10.1007/978-981-16-7920-9_33;
4. Enache, N. Deák, Gy., Laslo, L., Rotaru, A., Matei, M., **Boboc, M**., Rahim, N. L., (2022). Comparative Evaluation of the Thermal Efficiency Between Rehabilitated and Non-rehabilitated

Blocks by Using Thermography. Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology. Lecture Notes in Civil Engineering, vol 214. Springer, Singapore. https://doi.org/10.1007/978-981-16-7920-9_10

5. Ilie, M. Deák, Gy, Marinescu, F., Ghita, G., Tociu C., Matei, M.S., Savin, I., **Boboc, M**., Raischi, M. C., Arsene, M., (2022) Identification of Antibiotics as Emerging Contaminants and Antimicrobial Resistance in Aquatic Environment of the Arges-Vedea, Buzau-Ialomita, Dobrogea-Litoral River Basins in Romania. Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology. Lecture Notes in Civil Engineering, vol 214. Springer, Singapore. https://doi.org/10.1007/978-981-16-7920-9_47;
6. Baharom, N.A., Yusuf, S. Y., Za'aba, S. K., Mohd Noor, N., Ahmad, N. A., Amneera, W. A., Ahmad, W, **Boboc, M,** (2022), Carbon Footprint Assessment from Purchased Electricity Consumption and Campus Commute in Universiti Malaysia Perlis (UniMAP): Pre- and During COVID19 Pandemic. Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology. Lecture Notes in Civil Engineering, vol 214. Springer, Singapore. https://doi.org/10.1007/978-981-16-7920-9_2;
7. Danalache, T., Holban, E., Deák, Gy., Matache R., Prangate R., Matei, M., **Boboc, M.,** & Zainon Najib, N., W., A., (2022). Identification and Validation of a Method for Determining the Age of Sturgeons. Proceedings of the 3rd International Conference on Green Environmental Engineering and Technology. Lecture Notes in Civil Engineering, vol 214. Springer, Singapore. https://doi.org/10.1007/978-981-16-7920-9_18;
8. Bratfanof E., Deak Gy., Tudor G., Dănălache T., Holban E., **Boboc M.** (2020), Synthesis of Studies Conducted to Reveal the Impact of the Bastroe Canal on the Physico-Chemical Conditions and Biodiversity in Danube Delta Biosphere Reserve (DDBR), IOP Conf. Ser.: Earth Environ. Sci. 616, (2020) 012022, doi:10.1088/1755-1315/616/1/012022;
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10. Voicu M., Coman V., Enache N., Laslo L., Matei M., Rotaru A., Bara N., **Boboc M.**, Stanciu S., Deak Gy., (2020) Experimental Determination of Carbon Dioxide Flux in Soil and Correlation with Dependent Parameters IOP Conf. Series: Earth and Environmental Science 616 (2020) 012010, doi:10.1088/1755-1315/616/1/012010;
11. Moncea M.A., Dumitru F. D., Baraitaru A. G., **Boboc M. G.**, Deák Gy., Razak R. A., (2020) Assessing the Recovery Opportunities of Different Types of Wastes by their Embedment in Inorganic Binders, IOP Conf. Series: Earth and Environmental Science 616 (2020) 012044, doi:10.1088/1755-1315/616/1/012044
12. Bara N., Rotaru A., Laslo L., Matei M., **Boboc M.,** Coman V., Voicu M., Enache N., Deak Gy. (2020) Carbon Dynamics Projection for the Quercus petraea and Robinia pseudoacacia Species - Case Study IOP Conf. Series: Earth and Environmental Science 616 (2020) 012007, doi:10.1088/1755-1315/616/1/012007
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Model, Designed For Wetland Protection, AIP Conference Proceedings 2129, 020076 (2019); https://doi.org/10.1063/1.5118084;

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17. Laslo L., Matei M., Ciobotaru N., Deák Gy., **Boboc M.,** Mohamed Noor, N., Rozainy, M. R. 2019, Analysis of satellite vegetation indicators, meteorological and water use data for sustainable management of irrigations in Romania, IOP Conference Proceedings 2129, 020071 (2019); https://doi.org/10.1063/1.5118079

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20. Deák Gy., Panait A.M., Moncea A.M., Dumitru F.D., **Boboc M.,** Matei M., Olteanu M.V., 2019, Influence of Water to Binder Ratio on Mechanical Properties of Blended Cements with Brick Powder Waste, AIP Conference Proceedings 2129, 020091 (2019); https://doi.org/10.1063/1.5118099;

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23. Deák Gy., Dumitru F.D., Moncea A.M., Panait A.M., Baraitaru A.G., Olteanu M.V., **Boboc M.G.,** Stanciu S., 2019, Synthesis of ZnO Nanoparticles for Water Treatment Applications International Journal of Conservation Science; Iasi Vol. 10, Iss. 2, (Apr-Jun 2019): 343-350;

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30. Lupei T., Ciobotaru N., Badea G., Zamfir S., Matei M., **Boboc M.;** Mapping of Tourism Suitability Regarding Wetlands. International Journal of Tourism, 2, 1-9, 2017, ISSN: 2367-9131; https://www.iaras.org/iaras/journals/caijt/mapping-of-tourism-suitability-regarding-wetlands "

31. **Boboc M.,** Laslo L., Ciobotaru N., Matei M., Velcea A.M., Deák Gy. Hydrological modelling for Divici – Pojejena wetland's tributaries, Proceedings of International Symposium Agricultural and Mechanical Engineering, 26-28 octombrie 2017, București, ISSN 2344 – 4118, pp 615-620 https://www.researchgate.net/publication/323698594_HYDROLOGICAL_MODELLING_FOR_DIVICI-POJEJENA_WETLAND'S_TRIBUTARIES

32. Ciobotaru N., Matei M., Laslo L., **Boboc M.,** Velcea A.M., Deák Gy Assessment of pedological stress in Romania based on drought indices, Proceedings of International Symposium Agricultural and Mechanical Engineering, 26-28 octombrie 2017, București, ISSN 2344 – 4118, pp 621-628; https://www.researchgate.net/publication/323699931_ASSESSMENT_OF_PEDOLOGICAL_STRESS_IN_ROMANIA_BASED_ON_DROUGHT_INDICES

33. Badilita A.M., Danalache T., Raischi M., Deák Gy., Cristea A., Holban E., Zamfir St., Badea G. , Gheorghe I., **Boboc M.,** Matei M., Uritescu B., Cirstinoiu C., Tudor G., Boaja (Popescu) I., Stefan D. Identification of anthropogenic factors and assessment of their possible impact on preservation of sturgeon species from the Lower Danube, Proceedings of International Symposium Agricultural and Mechanical Engineering, 26-28 octombrie 2017, București, ISSN 2344 – 4118, pp 701-706;

34. Ciobotaru N., Laslo L., Matei M., Muşat C., Lupei Th., **Boboc M**., Deák Gy., Mapping Romanian wetlands – a geographical approach. WATER RESOURCES AND WETLANDS, ISSN: 2285-7923; Pages: 220-227, 2016; https://www.limnology.ro/wrw2016/proceedings/30_Ciobotaru_Nicu.pdf"

35. Matei M., Raischi M., Laslo L., Ciobotaru N., Muşat C**., Boboc M**., Deak G - Assessment of Ecosystem Condition in Romania Using MAES Methodology. Case study: Divici – Pojejena

Wetland- Proceedings of International Conference on Biological Engineering and Natural Sciences, ISBN 978-986-5654-13-9, 2016; https://www.researchgate.net/publication/305309072_Assessment_of_Ecosystems_Condition_in_Romania_Using_MAES_Methodology_Case_Study_Divici_-_Pojejena_Wetland"

36. Matei M., Laslo L., Ciobotaru N., Musat C., **Boboc M.,** et. al.; 2016; Assessment of Pressures Caused by Climate Changes on Wetlands in Romania Based on MAES Framework.; International Journal of Environmental Science, 1, Pages 265-271, ISSN: 2367-8941, 2016; https://www.iaras.org/iaras/journals/caijes/assessment-of-pressures-caused-by-climate-changes-on-wetlands-in-romania-based-on-maes-framework "

Projects

1. Studies for achieving shore protection of wetland area Divici-Pojejena, Caras-Severin County, Romania
No. Contract: 2013/S 175-301310/ 4839 din 09.04.2014
Beneficiary: Consiliul Județean Caraș Severin
Period: april 2014-april 2015
Work team member

2. Nucleu Programme – MADED (Environment, Water, Sustainable Development)
PN 09 06 03 52: Research on the corrosion exerted by the marine environment on coastal constructions
Faza PN 09 06 03 52. 2 - Corrosion potential of coastal lakes
Beneficiary: National Authority for Scientific Research (ANCS).
Project Responsible

3. Nucleu Programme – MADED (Environment, Water, Sustainable Development)
PN 09 06 01 21: Elaboration of scenarios at the national level to reduce CO2 emissions by using renewable energy resources
Project Responsible

4. Nucleu Programme – MADED (Environment, Water, Sustainable Development)
PN 09 06 03 65: Study on the hydraulic modeling of sediment transport on the Danube tributaries, in the Baziaş - Moldova Noua area
Faza: PN 09 06 03 65.1: Field studies performed in order to obtain the volume of information necessary to run the hydraulic modeling software
Project Responsible

5. Nucleu Programme – MADED (Environment, Water, Sustainable Development)
PN 09 06 01 14: Research on the modeling of the dispersion of pollutants in the atmosphere based on the intercomparison of new generation models
Faza PN 09 06 01 14.2: Study on the assessment of the impact of greenhouse gas emissions on the environment at the regional level: the costs and benefits obtained from the reduction of GHG through the use of innovative technologies
Project Responsible

6. Cartarea și evaluarea serviciilor de ecosisteme din zona umedă Divici-Pojejena și identificarea contribuției acestora la sectoarele economice (WETECOS)
Contract number: 6329/14.09.2015
Beneficiary: Ministry of Environment, Waters and Forests
Period: September 2015 – December 2016
Implementation expert

7. Training and awareness campaigns regarding the potential environmental and public health risks associated with hazardous substances and waste (TARCHS)

Project code RO04-0009
Beneficiary: Ministry of Environment, Waters and Forests
Perioda: July 2015 – December 2016
Implementation expert

8. Nucleu Programme – MEVAS (Environment, Green Energy, Water, Sturgeons)

PN 16 04 01 07: Research on the possibility of utilizing different types of waste with/without the content of dangerous substances, in inorganic binders
PN 16 04 01 07.1: Identification and characterization of waste with/without the content of hazardous substances, originating from industrial activities, constructions, demolitions with the potential to be recycled into inorganic binding materials
Phase Responsible
PN 16 04 01 07.2 The influence of technological factors for obtaining binder materials, with/without content of dangerous substances, on their properties
Responsible
PN 16 04 01 07.3: Durability of binder materials obtained by using different types of waste with/without the content of hazardous substances
Responsible

9. Monitoring the environmental impact of works to improve navigation conditions on the Danube between Călăraşi and Brăila, km 375 and km 175

Numar contract: 53/30.03.2011
Beneficiar: AFDJ R.A. Galaţi
Perioada: martie 2011- aprilie 2019
Membru în echipa de lucru

10. Research in support of the development of the capacity to assess and mitigate the impact of climate change and other stress factors on the state of forest ecosystems and viticultural crops

Contract: no. 3PS/02.11.2017
Beneficiary: Ministry of Research and Innovation
Period: November 2017 – December 2018,
Scientific Researcher

11. National register of secondary reserves of economically important raw materials resulting from mining residues

Contract: no.: 9PS/2017
Beneficiary: Ministry of Research and Innovation
Period: October 2017 – December 2018
Scientific Researcher

12. Technologies for valorization of sludge resulting from urban sewage treatment plants and waste from landfills

Contract: no: 7PS/2017
Beneficiary: Ministry of Research and Innovation
Period: October 2017 – December 2018
Financial responsible

13. Research in support of the development of the capacity to monitor, evaluate and capitalize on the natural resources offered by wetlands of international importance in Romania and the Black Sea coastal area

Contract: no: 4PS/2017
Beneficiary: Ministry of Research and Innovation
Perioad: October 2017 – December 2018

Scientific Researcher

14. Innovative Technologies for Reducing the Negative Impact of Climate Change in Vegetable Crops

Beneficiary: UEFISCDI
Period: March 2018 – September 2020
Work team member

15. Integrated and sustainable environmental depollution processes, wastewater reuse and waste recovery

Beneficiary: UEFISCDI
Period: March 2018 – September 2020
Work team member

16. Innovative Technologies for the Production of Renewable Energy from Natural Sources Integrated in Complex Installations

Beneficiary: UEFISCDI
Period: March 2018 – September 2020
Work team member

17. Technologies for valorization of agricultural works using ecological machinery

Beneficiary: Ministry of Education and Research
Period: August 2019 – December 2020
Expert

18. Determination of the methodology and coefficients specific to Romania in order to quantify GHG emissions and absorptions in order to quantify climate change

Beneficiary: Ministry of Education and Research
Period: September 2019 – December 2020
Expert

19. Completing the level of knowledge of biodiversity by implementing the system for monitoring the state of conservation of species and habitats of community interest in Romania and reporting based on Article 17 of the Habitats Directive 92/43/CEE – Evaluation of the state of conservation for fish species community interest at national level and the determination of their favorable/unfavorable status, based on article 17 of the Habitats Directive 92/43/EEC in order to carry out country reporting

Beneficiary: Ministry of Environment, Waters and Forests
Period: March 2019 – March 2022
Financial expert

20. Recirculating aquaculture systems used in the stage preceding the repopulation of natural waters with fish material

Beneficiary: Ministry of Agriculture and Rural Development
Period: September 2019 – October 2022
Partner Responsible

21. Research on the use of composts obtained from sludge resulting from the processing of domestic wastewater as fertilizer in fruit growing in compliance with the Environmental Acquis

Beneficiary: Ministry of Agriculture and Rural Development
Period: September 2019 – October 2022
Expert

Chapter 8. References

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