CLIMATE CHANGE THREAT: WHERE ARE WE HEADING?

Ciprian **ROTARU**[1], Victor-Marian **DUMITRACHE**[2]
[1] PhD Student, Bucharest University of Economic Studies, Romania
Email: rotaruciprian84@yahoo.com
[2] PhD Student, Bucharest University of Economic Studies, Romania
Email: victor.dumitrache@gmail.com

Abstract
Our century is facing a major challenge, with implications that can endanger the existence of humanity - climate change. If hundreds of years ago, these climate changes were perceived as a reaction of nature, now, almost 300 years after the industrial revolution, part of humanity's activities in the struggle for survival are those that generate climate change. The challenges of climate change have become so complex that they require research and understanding of the phenomena in order to have an effective approach and implement the appropriate measures needed to mitigate the negative effects of the consequences of climate change. Agricultural is the one that generates climate change through GHG emissions, but at the same time is the sector most affected by these changes.

Keywords: *standard precipitation index; climate change; sustainable development; environment economic and social impacts; drought; flood; agriculture; risk; loss; climate scenario; temperature; precipitation; drought; effects; adaptive strategies; Romania*

DOI: 10.24818/CAFEE/2019/8/18

1. The climate change and its implications

At the beginning of the millennium, the accelerated development of technologies and the irrational use of resources have led to major concerns such as rationalizing the exploitation of resources and maintaining the balance between the economic, social and natural environment. Aggressive human intervention in ecosystems has been accelerated generating unprecedented environmental problems such as soil and water pollution, atmospheric pollution, biodiversity loss, etc. Also, climate change (global warming) is one of the most important and deeper environmental issue faced by the planet. (Burja, 2012)
Since 1750, global atmospheric concentrations of greenhouse gases have increased significantly (methane, nitrous oxide, carbon dioxide). Global warming generated by human activity remains the root cause of these changes. Since the beginning of global instrumentation recording, namely 1850, the period from 1995 to 2006 has proven to be the warmest.
The Intergovernmental Panel on Climate Change (IPCC) is one of the organizations that builds its global warming agenda. According to the fourth IPCC report, climate scenarios with different global climate models predicted an increase in global average temperature by the end of the 21st century (2090-2099) compared to 1980-1990 between 1.8^{o}C and 4.0^{o}C scenario (Iordan, 2015), depending on the scenario considered for greenhouse gas emissions, this scenario being disastrous for the entire population of the globe (IPCC, 2014). Scenarios are being developed for the global energy system to reach the zero emission carbon emissions by the end of this century, but this requires an increase in decarbonisation to 6.2% per year, limiting heating to 2°C. (The Climate Change Program 2015, pg. 16-17)

If before the 1850s climate change was caused by natural causes such as solar irradiation or volcanic eruptions, since the middle of the nineteenth century, human activity is the main cause of the warming of the planet, generated by diversity in land use, the burning of fossil fuels, agriculture and deforestation. This has contributed to an increase in greenhouse gas (GHG) emissions into the atmosphere, which also appears to be the dominant cause of climate change over the coming decades. (Burja, 2012)

In the figure below we have data gathered from European Environment Agency (**EEA member countries**), data which measures insured economic losses from weather and climate-related disasters. Hydrological, meteorological and climatological events are the types of disasters considered.

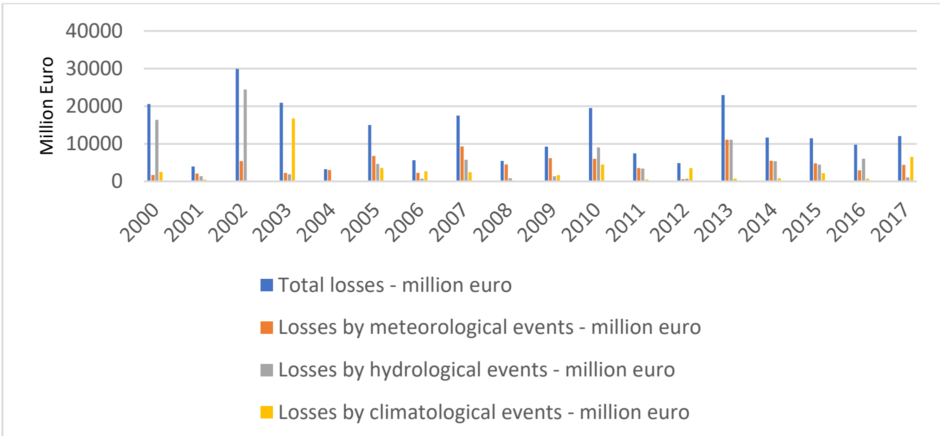

Figure 1. Climate related economic losses by type of event - EU aggregate
Data source: European Environment Agency (EEA)
Data processed by the author

Agriculture is also an economic sector that should consider the consequences of climate change. The most common challenge is to prevent losses caused by climatic and hydrological hazards such as drought, floods, cold / warm waves, heavy snow / heavy rainfall, and more. Estimating these consequences in quantitative terms is hampered by their non-specific nature. Thus, the natural hazards caused by climate change do not differ from the natural hazards in general. (Ioan & Radulescu, 2015)

Both humanity and natural systems are subject to risks, with climate change increasing existing ones and generating new types of risks.

Infrastructure and lower services are expected to affect urban areas, communities in rural areas are at risk of having low availability of water resources and volumes, reduced food security, and reduced farm incomes, a reduction stemming from the relocation of agricultural production in resource-rich areas, possibly generating population movement and regional insecurity. Changes in resource and production management, as well as the changing behaviour and needs of individuals, will have an impact on the economic sectors. (The Climate Change Program 2015, pg. 16-17)

In Europe, reducing greenhouse gas emissions is a key point for sustainable growth and it is necessary to analyse all areas of the economy that produce carbon dioxide and other greenhouse gases, including agriculture as well.

Agriculture is the one that causes climate change and at the same time it is affected by climate change. A strategic approach to this "dilemma" will first consider technical solutions that contribute in both directions. In this respect, it is relevant to show how agriculture is a cause of climate change and what is the nature of the negative consequences of climate change on agriculture. (Ioan & Radulescu, 2015)

Primary greenhouse gases (GHGs) produced by agriculture are methane (CH4), nitrogen oxide (N2O) and carbon dioxide (CO2). Methane and nitrogen oxide have a high potential for global warming, leading to significant climate change that has a negative impact on the environment and, implicitly, on the quality of life. GHG emissions sources in agriculture are diverse: direct use of energy, application of fertilizers, digestion of ruminants, manure management methods, burning of crop residues, etc.

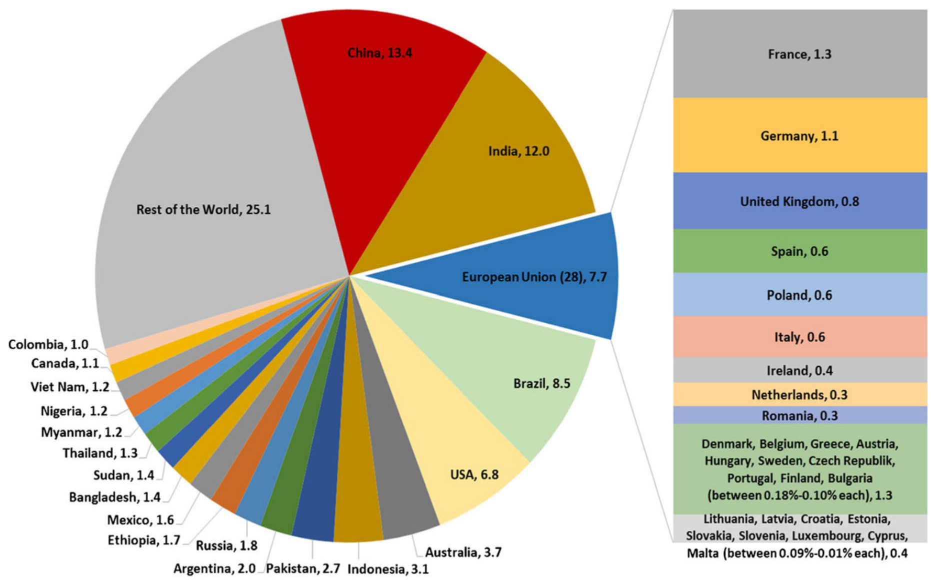

Figure 2. Share in global agriculture GHG emissions (%, 2012)
Source: *FAO (2016)* - *(Fellmann et al., 2018)*

Following the United Nations Climate Change Conference in Copenhagen (2009), the European Union proposed a reduction of at least 20 greenhouse gases by 2020. To achieve this, national strategies include concrete measures reduction of greenhouse gases for all economic activities.

Accordingly, one of the most important tasks of agriculture in each country is to ensure food security. The challenge facing the global agricultural sector is to harmonize the contradiction between the growing demand for agricultural products due to population growth, urbanization and the mitigation of the negative effects of production activities on the environment. (Burja, 2012)

The necessary changes in the management of agricultural activities require more strategies, efforts and concerted actions to address the three dimensions of sustainable development. Firstly, agriculture should offer specific agricultural products in terms of economic efficiency and thus contribute to the biological and economic support of the population. Regarding environmental restrictions, the tasks of this sector should aim at avoiding the degradation of natural ecosystems, maintaining biodiversity and better management of natural resources. (Burja, 2012)

The development of agriculture is often accompanied by negative phenomena: soil pollution, due to the use of synthetic chemicals for plant protection treatments, artificial fertilization of soil, unloading of plant and animal waste; air pollution by crop treatments; water pollution, etc.

A major problem facing European agriculture is the need to adapt it to climate change. The consequences of climate change on agriculture are complex and often negative. These will affect the volume, quality and stability of food production and the natural environment in which agriculture takes place. Climate change will have consequences on the availability of water resources, pests and diseases and soils, which will lead to significant changes in conditions for agriculture and livestock production. In extreme cases, the degradation of agricultural ecosystems could mean desertification, resulting in a total loss of productive capacity of the land concerned. (Burja, 2012)

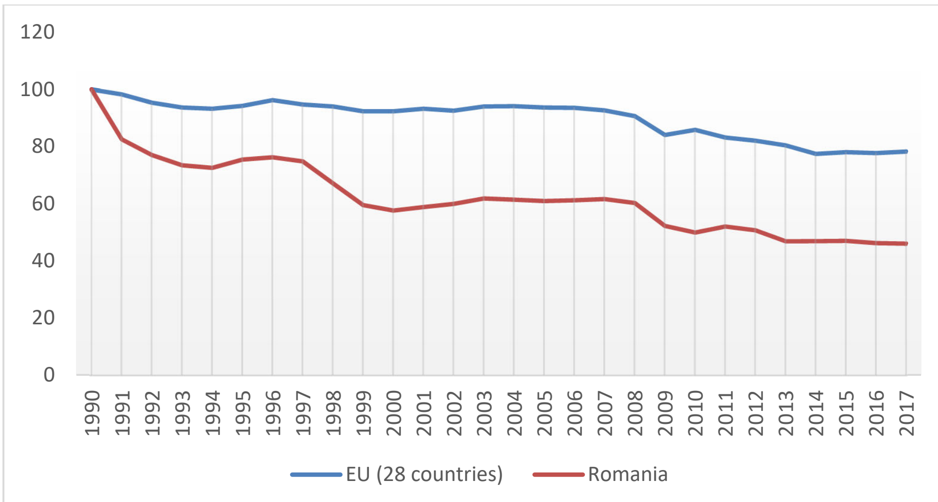

Figure 3. Greenhouse gas emissions (in CO2 equivalent), base year 1990

Data source: European Environment Agency (EEA)

Data processed by the author

In the figure above is represented an indicator (expressed in units of CO2 equivalents) that measures all man-made emissions and integrates all gases of the so called „Kyoto basket" of greenhouse gases (carbon dioxide CO2, methane CH4, nitrous oxide N2O, and F-gases – hydrofluorocarbons, perfluorocarbons, nitrogen trifluoride NF3 and sulphur hexafluoride SF6).

Romania has a growing vulnerability in terms of the intensity and frequency of extreme weather conditions (drought, flood, suffocating heat, etc.), which cause significant losses, especially in agriculture. Thus, from about 14.7 million hectares of agricultural land (of which 9.4 million ha are arable land), the soils affected by the severe drought for long periods and in the years to come cover an area of approximately 7 million ha of land agricultural (48% of the total). Drought becomes a limiting factor that affects plant growth on the largest surface, the extent and intensity of this risk reduces the agricultural output by at least 30-50%. (Hurduzeu et al., 2014)

Climate change is a huge challenge for the RDA sector for agriculture and rural development in Romania. On the one hand, agriculture is a source of greenhouse gas (GHG) emissions and should therefore contribute to achieving the Europe 2020 climate change mitigation targets. On the other hand, the RDA sector is extreme vulnerable to the impact of climate change, as the ability of "rural space" to ensure adequate food supplies; the provision of ecosystem services; supporting economic growth; ensuring a safe living environment for rural communities depends directly on favourable climatic conditions. (Agriculture and Rural Development, 2014)

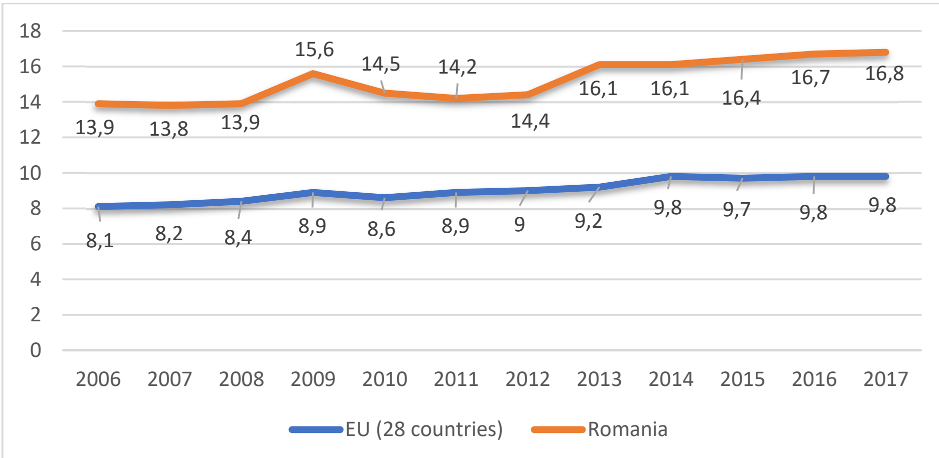

Figure 4. Greenhouse gas emissions from agriculture % of total emissions

Data source: European Environment Agency (EEA)

Data processed by the author

In the context of global warming, Romania has experienced a progressive increase in temperatures, with the results of global climate models analysing for the past 100 years an increase of about 0.8 ° C. (The Climate Change Program 2015, pg. 16-17)

Romania's temperate continental climate is changing and is expected to be significantly different over the next 50-100 years. The average annual air temperature is rising, and Romania should expect a constant steady increase in the annual average temperature, similar to the one predicted for the whole of Europe. There are some variations in the projections of the different models used, but, compared to the 1980-1990 period, an additional increase in the annual average temperature is expected between:

• 0.5 ° C - 1.5 ° C until 2029;

• 2.0 ° C - 5.0 ° C by 2099 (depending on the global scenario) (The World Bank, Disaster risk management development, 2018).

The total annual rainfall is decreasing and by the end of the century a continuous reduction of 10-20% annual rainfall should be expected, although this is likely to differ greatly between

i. the north and south of the country and
ii. mountains and plains.

It is also expected that the precipitation model will continue to change with a higher frequency of shorter, more intense and more localized precipitation events. Rainfall patterns can also become more chaotic and difficult to predict.

Romania is increasingly confronted with the negative impact of climate change (including extreme events), and the shaping of future climate trends suggests that these negative effects will continue to become more severe. These effects include:

- increased incidence of severe floods;
- increased intensity and frequency of drought;
- increased risk of soil erosion and desertification.

Key vulnerabilities are:

- reduced agricultural productivity;
- water supply to rural consumers;
- other social (e.g. human) health and economic risks to rural communities and households;
- the environment and "health" of natural ecosystems. (Agriculture and Rural Development, 2014).

Table 1. Impacts of extreme weather and climate related events in the EEA member countries (1980-2017).

Country	Losses (million Euro)	Loss per capita (Euro)	Loss per sq.km (Euro)	Insured losses (million Euro)	Insured losses (%)	Fatalities
Romania	11065	508	46414	60	1	1310

Data source: European Environment Agency (EEA)
Data processed by the author

2. Statistical data. Agriculture and rural development

Climate factors are risk factors because they can significantly reduce agricultural output when they are severe, especially during critical crop growing periods. The variations of the thermal stress factor are clearly reflected by the evolution of the crops, depending on the intensity and duration of the "heat" phenomenon. It can be associated with the genetic characteristics of cultivated plants, namely high temperature tolerance, restoration capacity and resistance to stress conditions, step growth and development, etc. (Oprea et al., 2018)

Climate change is also a matter of paramount importance in the Carpathian region. Many studies of the Carpathian meteorological characteristics were published before 1990, and many transnational projects (Cheval et al., 2014) and cooperation to preserve biosphere integrity and climate analysis in the Carpathian region have been launched over the last two decades. (Spinoni et al., 2014b)

2.1. Drought

In the context of current global warming (9-IPCC, 2014), the phenomenon of "drought" generates a "hot topic" in scientific literature. Drought is typically classified according to type in: meteorological (takes place over a longer period of time and is manifested by the total or partial absence of rainfall), agricultural (the existence of an insufficient amount of water required for agriculture - precipitation-derived or underground water), hydrological (substantial decrease in water level – underground water reservoir – rivers and downstream waters). (Iordan, 2015)

Drought is among the most destructive natural hazards, with serious consequences for communities and water-dependent sectors such as agriculture and energy. The complexity of the impact is mainly caused by the dependence of a large number of water sectors on the production of goods and the provision of services. Globally, the magnitude of economic costs and losses attributable to natural hazards, drought, have led to increased attention to drought vulnerability. The problem of drought vulnerability can be particularly addressed by different individuals and nations and the factors that make a rural community in a drought-prone developing country might be distinct from that of a prosperous industrialized nation. Thus, vulnerability to drought varies from one region to another and from one family to another. (Dumitraşcu et al., 2018)

Drought monitoring is usually achieved through a large number of indicators: SPI (Chang, et al., 2018) and the most widely used European Index of Evapotranspiration (SPEI). The indicators are based on rainfall and have been implemented and applied in almost all regions of Europe, while SPEI is particularly applicable in the Iberian Peninsula, but its use across Europe is currently increasing. PDSI and sc-PDSI (Spinoni et al., 2013) have also been successfully applied in European drought studies. For more complete information, other indicators are also used: the counterpoint drought indicator (RDI), based on the P / PET ratio (Spinoni et al., 2015); an indicator of drought that reflects ecosystem responses to water availability: Normalized Ecosystem Drought Index (NEDI). (Chang, et al., 2018)

Some agronomic measures (short-term adjustments and long-term adaptation) can be recommended to avoid or mitigate the negative impacts of climate change and exploit possible beneficial options. Short-term adjustments involve changes in planting data, as well as varieties, changes in external inputs such as irrigation and soil water conservation techniques. In Romania, several examples of long-term adaptation measures, including major structural changes to overcome the disadvantages of climate change (land use, reproduction and biotechnology, crop substitution, changes in agricultural systems**.** (Dumitraşcu et al., 2018)

In Romania, the areas most affected by the drought and more exposed to desertification are in Dobrogea, Southern Plain, in southern Moldova and in the west of the Tisa Plain. These areas have a dry, semi-thin and inferior climate and cover 30% of Romania's total land area, 80% of which are used for agriculture. (Bran &Ustinescu, 2018)

The Romanian agricultural sector is facing the threat of climate change, adapting to these changes being a high priority for farmers. The strong impact of adverse weather and hydrological events on the agricultural sector is causing a crop yield volatility from one year to the next. For example, droughts can last from a few weeks to several months, with disastrous effects on agricultural production. The 2007 and 2012 agricultural years were considered the most drained of Romanian agriculture in the last decade, leading to a considerable decrease of the productions.

For example, in 2007, according to national statistics, the drought has reached a very high level, with a negative impact on agricultural productivity, with an average yield per hectare decreasing by over 50%, especially in the case of irrigated land. With a positive thermal deviation of 1.8 ° C compared to the average of the period from 1901 to 2013 (9.7 ° C), 2007 is the warmest year in the history of meteorological measurements.

The drought in the agricultural year 2011 - 2012, according to the data of the Ministry of Agriculture and Rural Development, has caused damage on an area of approximately 5.8 million hectares at the national level, the most affected being crops of corn, barley and barley, wheat, rapeseed, sunflower and potatoes (rapeseed production declined by up to 80.2%).

The associated (pedological and atmospheric) drought phenomena in the agricultural years 2001-2002, 2002-2003, 2006-2007, 2011-2012, 2014, 2015 led to the decrease of autumn and maize wheat crops throughout the agricultural territory of the country (Romania) in respect of the harvested crops. (Oprea et al., 2018)

Table 2. Average production per hectare (kg / ha) for the main crops

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Wheat	2965	2746	1541	3403	2421	2688	3663	2652	3468	3590	3780	3944	4888	4793
Corn	3952	3565	1526	3215	3409	4309	4525	2180	4488	4770	3462	4159	5959	7644
Sunflower	1381	1540	654	1437	1433	1597	1798	1310	1993	2187	1765	1955	2917	3041

Data source: National Institute of Statistics, Romania
Data processed by the author

The table above contains data gathered from National Institute of Statistics, representing the average production kg/ha for wheat, corn and sunflower. Those years highlited in blue were under drought phenomena.

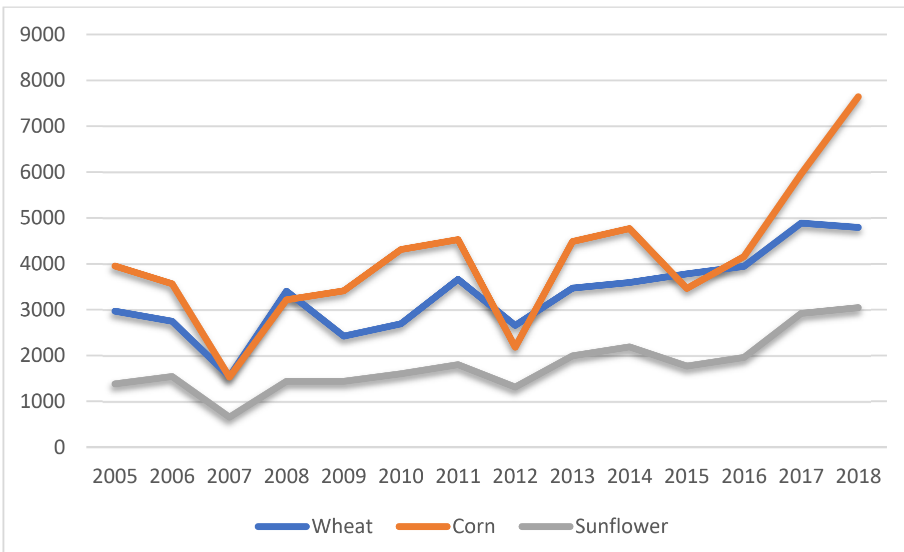

Figure 5. Average production per hectare (kg / ha) for the main crops
Data source: National Institute of Statistics, Romania
Data processed by the author

As we can observe Romania has a major fall in agricultural production for wheat, corn and sunflower in 2007, 2012 and 2015.
The agricultural year 2011-2012 was characterized by insufficient rainfall (below 600 l / m). The precipitation rates recorded in the agricultural year of September 2014-Augus 2015 were optimal (601-700 l / m 2) and high (701 -775 l / m) in most of the agricultural area. (Oprea et al., 2018)

The levels recorded in June-August 2007, 2012 and 2015 for "heat" showed a high intensity (51-90 "burned" units), accentuated (71-90 units) and particularly pronounced 91-296 units), on the entire agricultural area. (Oprea et al., 2018)
The magnitude and intensity of the drought determines an annual reduction in agricultural production of at least 30-50%. Drought represents the natural phenomenon determined by the amount of precipitation below the normal values. The absence of rainfall is due to the predominance of the anti-cyclonic type. The most frequent phenomena occur in the extra-Carpathian agricultural regions of southern and south-eastern Romania. Muntenia is in the drought-sensitive area where the influx of continental anti-cyclones is higher. Although this phenomenon is possible in all seasons and in all agricultural areas, it does not occur simultaneously and does not have the same intensity. In the 21st century, the 2001-2002, 2002/2003, 2006-2007, 2011-2012 and 2014-2015 agricultural years are included in the most recent year list of rainfall, warmth units recorded in the warm season, and the soil moisture reserve available for autumn wheat and maize plants during maximum water consumption**.** (Oprea et al., 2018)
The analysis of the correlation between precipitation and soil water resources, one of the flat areas in 2008-2013, shows a high variability of soil water resources according to the spatial and temporal evolution of precipitation, based on the mass movement of the air. This also shows the dynamic flow of air in Europe, the massive entry of North African tropical air, which generates high temperature air and soil for long periods of time. This leads to drought and drying which, if produced during the development and maturation of crops, threaten agricultural production. (Murărescu et al., 2017)
The Boian area is a subunit of the Romanian Plain affected, at least in the last 20 years, by dry periods and agro-meteorological drought with uneven rainfall and invasions of hot air masses in North Africa. For the period 2008-2013, agro-climatic risk phenomena have been recorded each year. Reducing water resources in the first 20 cm of crops affected by the soil, especially those of grain crops specific to this region. This has had negative repercussions on the quantity and quality of agricultural production. (Murărescu et al., 2017)
Management of water resources in agriculture: the dynamics of the irrigated agricultural area has been influenced by the political and economic context for more than twenty years, when most of the irrigation systems have been systematically abandoned or deactivated, and the area of irrigated agricultural land has diminished. Recently, the increasing incidence of drought has made it necessary to use irrigation to compensate for water deficiency. Currently, the use of irrigation systems is subject to expensive rehabilitation works and high-water costs for irrigation. (Dumitraşcu et al., 2018)

2.1.1. Drought analysis in Romania using DrinC program

Standardized Precipitation Index (SPI) is a drought index first developed by T. B. McKee, N.J. Doesken, and J. Kleist and in 1993 (McKee et al. 1993). Bases on precipitation variable, SPI is used for estimating wet or dry condition and is expressed as standard deviation.

Drought Magnitude (DM) is defined as:
DM= - $\left(\sum_{j=1}^{x} SPI_{xj}\right)$, where j starts with the first month of a drought and continues to increase until the end of the drought (x) for any of the i times scales. The *DM* has units of months and would be numerically equivalent to drought if each month of the drought has *SPI* = 1.0. (McKee et al. 1993)
Calculation of the SPI is based on the long-term precipitation record (longer than 30 years is desirable) for a desired period (three months, six months, 12 months, etc.), (World

Meteorological Organization, 2012). This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero. (Edwards and McKee 1997)

Table 3. SPI values Classification

2.0+	Extremely Wet
1.5 to 1.99	Very Wet
1.0 to 1.49	Moderately Wet
-.99 to .99	Near Normal
-1.0 to -1.49	Moderately Dry
-1.5 to -1.99	Severely Dry
-2 and less	Extremely Dry

Source: Tigkas et al. 2013

Some limitations and unique characteristics must be considered when the SPI is used. The indice is only as good as the data used in calculating it. (Hayes et al. 2000)
McKee et al. (1993) used an incomplete gamma distribution to calculate the SPI. Now, the scientists are in progress to standardize the SPI computing procedure in order to make it easier to SPI users. (Lloyd-Hughes and Saunders, 2002)
DrinC software package (Tigkas et al. 2013) was developed at the Centre for the Assessment of Natural Hazards and Proactive Planning and the Laboratory of Reclamation Works and Water Resources Management of the National Technical University of Athens. DrinC (Drought Indices Calculator) is used to calculate several drought indices: The Reconnaissance Drought Index (RDI), the Streamflow Drought Index (SDI) and the Standardized Precipitation Index (SPI). (Tigkas et al. 2015)
DrinC is giving the user the ability to input the parameters that suit optimally the purpose of each study, the calculating procedure being adaptable. SPI is calculated in a monthly sequential order (McKee et al. 1993), on the other side, RDI is calculated for discrete periods on water year basis. Further, the use of gamma or lognormal distributions may be selected. (Tigkas et al. 2015)
The Standardized Precipitation Index (SPI) is computed following the methodology of McKee et al. (1993) based on gridded precipitation data taken from the monthly set compiled by the World Bank data set for Romania. These data cover the period 1961–2016. A detailed description of the SPI calculation can be found in McKee et al. (1993) and Hayes et al. (2000).

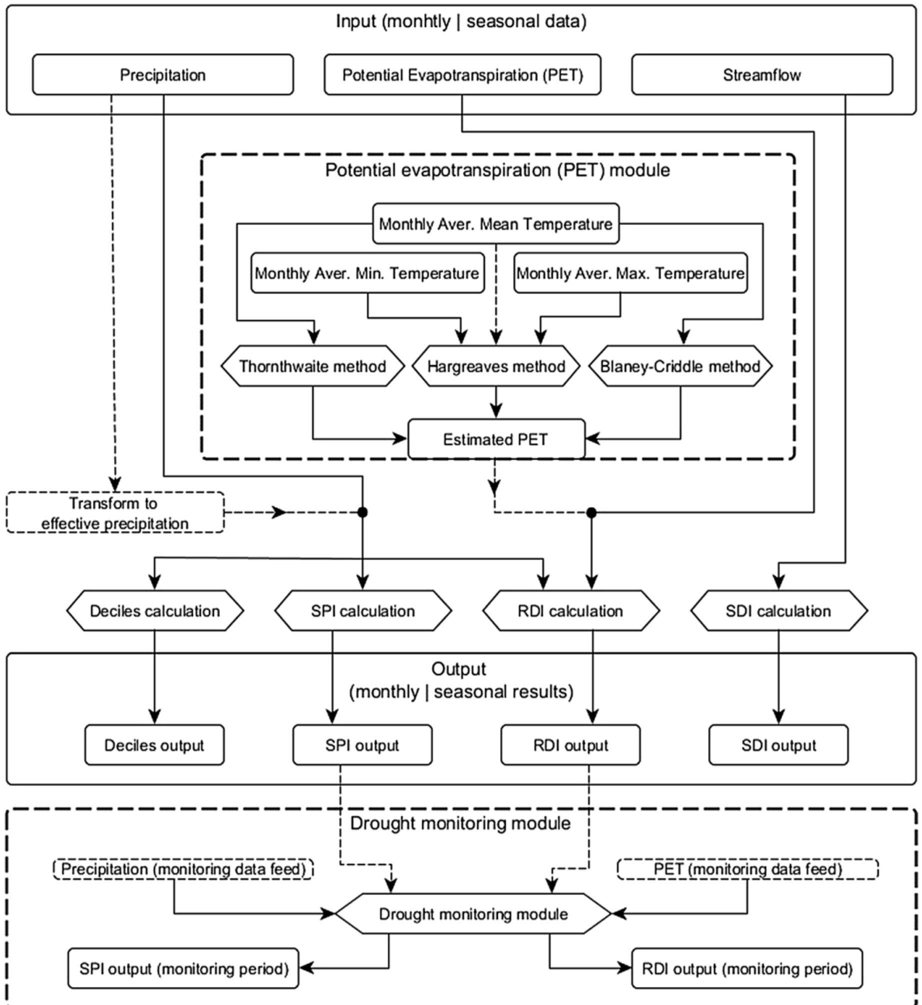

Figure 6. The flow chart of DrinC software
Source: Tigkas et al. 2015

Figure below indicates the changes of annual precipitation and temperature in Romania, between 1961 and 2016. Looking at the linear regression curves, the temperature rises from a mean temperature of 9 °C in the 60' to a temperature above 10 °C in 2016. As the data show us the period between 2012-2016 has a mean temperature above 10 °C for each year. Following the precipitation curve, we can figure it out what were the droughts period between in the period analyzed.

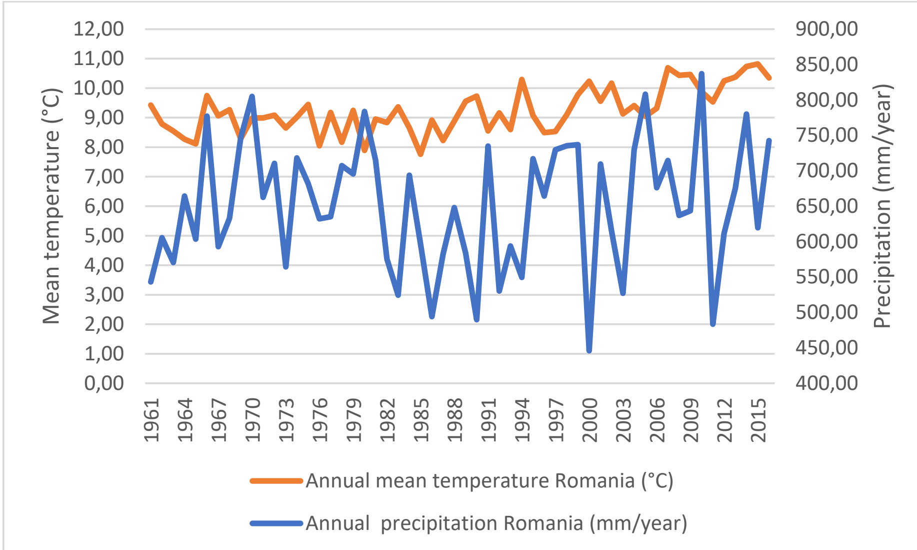

Figure 7. Annual precipitation and annual mean temperature in Romania 1961-2016

Data source: World Bank data set for Romania (1961-2016)

Data processed by the author

Results obtained with DrinC Program

For our study we will use data sets records from World Bank Group. We computed the primary data, in order to analyse the monthly and annual data for 55 years (1961-2016). Using the values obtained for precipitation, were calculated the SPI values (3, 6, 9, 12 months) results which are presented in the next tables and figures, but our attention will be focused on the annual SPI values.

Table 4. SPI calculated for 3, 6, 9, 12 months

Year	3-month SPI	6-month SPI	9-month SPI	12-month SPI
1961 - 1962	-0.65	-0.88	-0.39	-1.19
1962 - 1963	-0.14	-0.17	0.19	-0.45
1963 - 1964	-0.40	-0.49	-0.39	-0.86
1964 - 1965	0.12	0.16	-0.34	0.2
1965 - 1966	-0.21	-0.24	0.47	-0.47
1966 - 1967	0.84	1.18	1.71	1.36
1967 - 1968	-0.28	-0.43	-0.24	-0.59
1968 - 1969	-0.16	-0.05	-1.59	-0.14
1969 - 1970	0.63	0.83	1.02	1.05
1970 - 1971	0.85	1.17	1.77	1.62
1971 - 1972	0.08	0.04	-0.19	0.19

Year	3-month SPI	6-month SPI	9-month SPI	12-month SPI
1972 - 1973	0.16	0.34	-0.41	0.69
1973 - 1974	-0.47	-0.66	-0.29	-0.93
1974 - 1975	0.20	0.45	0.57	0.77
1975 - 1976	0.00	-0.02	0.22	0.39
1976 - 1977	-0.05	-0.09	-0.78	-0.14
1977 - 1978	-0.07	-0.17	-0.37	-0.12
1978 - 1979	0.24	0.29	0.46	0.66
1979 - 1980	0.32	0.39	0.48	0.53
1980 - 1981	0.82	1.15	1.73	1.42
1981 - 1982	0.50	0.70	0.99	0.74
1982 - 1983	-0.43	-0.69	-1.24	-0.8
1983 - 1984	-0.87	-1.33	-1.55	-1.42
1984 - 1985	0.28	0.44	0.89	0.51
1985 - 1986	-0.29	-0.46	-0.17	-0.55
1986 - 1987	-0.93	-1.30	-1.58	-1.81
1987 - 1988	-0.29	-0.42	-0.06	-0.71
1988 - 1989	0.08	0.13	0.54	0.03
1989 - 1990	-0.57	-0.87	-0.92	-0.7
1990 - 1991	-1.00	-1.34	-1.26	-1.87
1991 - 1992	0.33	0.43	0.56	0.94
1992 - 1993	-0.76	-0.99	-0.5	-1.35
1993 - 1994	-0.22	-0.37	-0.55	-0.58
1994 - 1995	-0.56	-0.83	-1.09	-1.11
1995 - 1996	0.46	0.59	0.56	0.76
1996 - 1997	0.18	0.21	-0.17	0.2
1997 - 1998	0.42	0.59	0.37	0.89
1998 - 1999	0.54	0.72	0.74	0.94
1999 - 2000	0.57	0.76	0.77	0.96
2000 - 2001	-1.35	-1.82	-2.76	-2.47
2001 - 2002	0.32	0.38	0.27	0.68
2002 - 2003	-0.23	-0.25	-1.31	-0.34
2003 - 2004	-0.70	-0.89	-1.6	-1.39
2004 - 2005	0.53	0.71	0.3	0.89
2005 - 2006	0.85	1.15	0.7	1.65
2006 - 2007	0.09	0.15	0.04	0.33

Year	3-month SPI	6-month SPI	9-month SPI	12-month SPI
2007 - 2008	0.46	0.71	0.39	0.73
2008 - 2009	-0.05	-0.15	-0.18	-0.1
2009 - 2010	0.09	0.15	0.54	-0.02
2010 - 2011	1.07	1.50	2.44	1.92
2011 - 2012	-1.05	-1.54	-1.72	-1.95
2012 - 2013	-0.16	-0.19	0.52	-0.38
2013 - 2014	0.21	0.31	0.79	0.33
2014 - 2015	0.78	1.09	1.5	1.39
2015 - 2016	-0.04	-0.06	0.15	-0.29

Data source: World Bank data set for Romania (1961-2016)
Data processed by the author

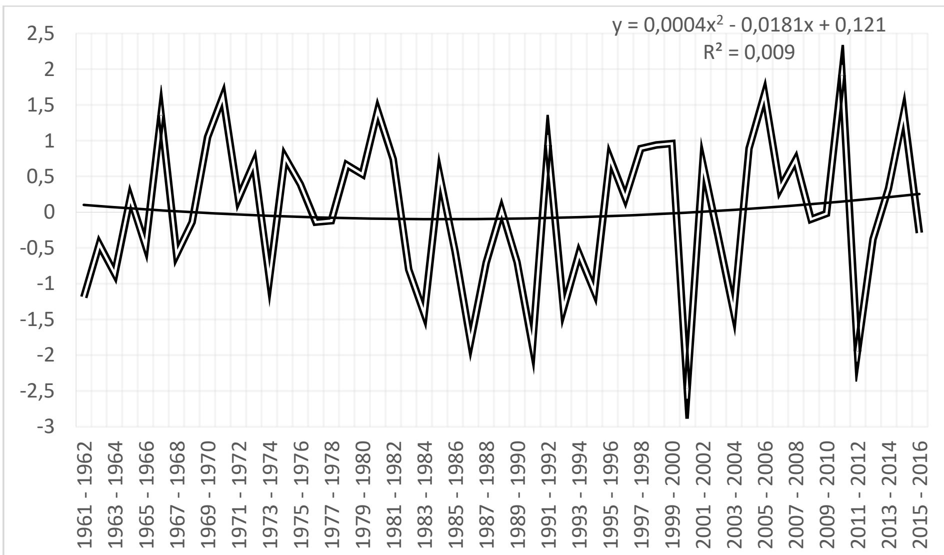

Figure 8. 12-month SPI values for Romania, 1961-2016
Source: World Bank data set for Romania (1961-2016)
Data processed by the author

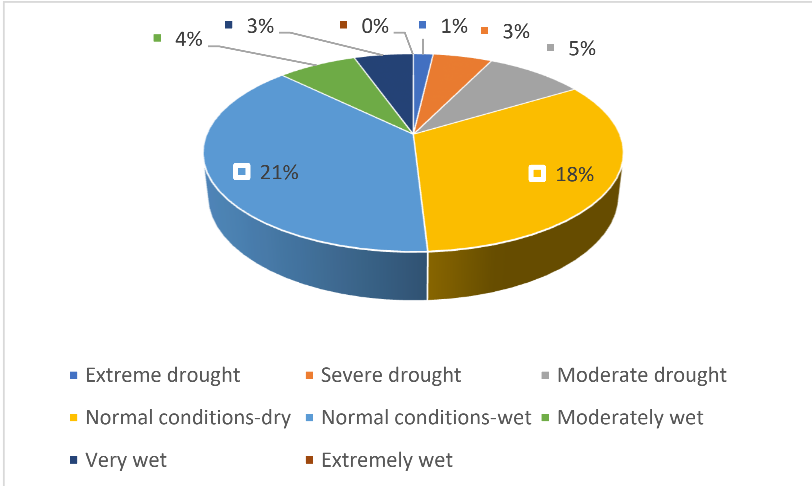

Figure 9. Frequency of drought periods (SPI 12 – month)
Source: World Bank data set for Romania (1961-2016)
Data processed by the author

It can be observed, analysing the previous graphs and tables, that the actual climate tendency in characterized by increasing of normal and wet periods.
As we can observe in the figure 9, SPI 12 indicates that only 23% of the last 55 years are characterized by normal (18%) and moderate (5%) drought, the draughtiest period being the one between 1983 and 1995. As we know in this period were implemented a lot of drainage system to assure the necessary water level for irrigation in the agricultural area. The agricultural year 2000-2001 was characterized by an extreme drought (-2,47), followed by 2003-2004 with a moderate drought (-1,34) and a severe drought (-1,95) in 2011-2012.

2.2. The floods

Another recurring problem in Romanian agriculture is the floods. Products either after snow melt or torrential rains, the number of floods has increased in recent decades as a result of climate change. (The Climate Change Program 2015, pp. 76-86)
Normally, in the area of Romania, rainfall is moderate and falls in quantities ranging from 400 l / year in the Danube Delta and 1400 l / year in the mountain area. The average annual rainfall across the country is 638 mm / year.
Floods as natural phenomena are the most common disasters in Romania, and major floods such as 1970, 1975, 2005, 2006 (The World Bank, 2018) and 2010 (Romanescu et al., 2018) marked and marked the development of society, leading to a change in strategy, to find the right solutions to prevent such events and to set up defence strategies if they occur.
In a chronological order, there were floods in the river basins of the Someş, Cris and Mureş rivers between December 1995 and January 1996. In April 2000 the basins of Timiş, Mureş and Crasnei were affected, in 2001 the Tisa basin; 2002 - Siret catchment area.
The most disastrous floods occurred in 2005, producing for a long period of time (February - September), affecting extensive areas: the Bega, historical flows were recorded on the rivers Putna, Trotuş (Ţîncu et al., 2018), Râmnicul Sărat, Cricovul Sărat and Banat rivers.

Compared to a flood in 1895, the Danube flood in 2006 was one of the most destructive.
The floods from the Danube in April-May 2006 were the biggest flood event in the Romanian Danube sector over the past 150 years, having the longest water flow over the flood thresholds. A combined effect of snow melting with liquid precipitation in the upper and middle parts of the basin and very well-saturated soils led to the recording of peak water levels and discharge on the Danube (eg 15800 m3 / s at Baziaş compared to 7900 m3 / s is the mean value of the spills in April) and most of the major tributaries in the upper, central and lower basin (eg Tisa 3790 m3 / s, Sava 470 m3 / s, Velika Morava 1740 m3 / s, Jiu 1020 m3 / s Siret 1200 m3 / s). The return period of these peak spills is about 100 years. The recorded levels have caused longitudinal failures of the dam in several locations across the Romanian Danube sector, causing significant losses. More than 15,000 people have been evacuated and some of the affected areas have been flooded for many years**. (**Craciunescu et al., 2016)
Equally destructive were the floods recorded in the summer of 2010 in the Siret basin. (Romanescu et al., 2018)

2.3. Risk management

Flood risk management is the result of an extensive combination of pre-crisis preventive actions, operational actions during the event, and post-crisis restoration and recovery actions. Traditional measures to reduce the negative impact of floods include building or strengthening existing flood defences.
However, there are very cost-effective alternatives to flood protection that appeal to the ability of nature to absorb water excess: improving land use to prevent rapid leakage, exploiting natural infiltration capacities to reduce or mitigate the impact of floods. (Craciunescu et al., 2016)

2.4. Measures to reduce the impact of climate change Romania

- Awareness, information and advice campaigns among farmers on the danger of climate change;
- Major investments in modernization of farms – modern facilities, state-of-the-art equipment for storing and using manure, using green energy using biomass or biogas as well as other renewable energy sources;
- Setting up of green crops, quantifying the amount of vegetal biomass resulting from afforestation (The Climate Change Program 2015, pp. 76-86);
- Supporting farmers by adopting low carbon technologies to encourage them to adopt farm management technologies and practices that directly contribute to reducing emissions – and nitrogen flows into the agricultural ecosystem;
- Encourage and support farmers to adopt farm management technologies and practices that directly contribute to reducing soil carbon leakage and increased carbon sequestration;
- Priority actions for support include afforestation of inferior and non-productive land, especially in those areas where soils are most vulnerable to degradation and loss; organic farming;
- Support for increased renewable energy production in rural areas to encourage farmers, rural businesses and communities to invest in renewable energy production, including energy crops; production of rural biogas from manure; investments in small and large-scale technologies available to produce solar and wind power;
- Investments in irrigation infrastructure in the most vulnerable regions. Priority actions are

needed at national level to improve / rehabilitate economically viable irrigation infrastructure in southern, south-eastern and eastern Romania, where drought is believed to be the most common;

- o Better climate risk management in the ARD sector, introducing relevant risk management tools to support farmers' confidence in continuing to manage and invest in their farms, in the face of the uncertainty associated with extreme weather events; Specific tools that can be considered include:
  - ✓ systems of insurance against natural disasters and against pests and diseases of animals and crops; and
  - ✓ creating farmers' mutual funds to stabilize incomes in the event of price volatility or losses caused by natural disasters. (Agriculture and Rural Development, 2014)
- o Investments in agricultural research and experimental production to modify crop structure and select varieties with drought resistance;
- o Developing and implementing local action plans for adaptation to climate change (Mateescu et al., 2013)

Conclusions

Agriculture is the economic activity with the longest history and has a major influence on the development of civilization and accumulation of wealth. In spite of the technological development and process that consistently supported productivity gains, agricultural added value has not increased. In fact, the value diminished, the farmers' profit margin becoming smaller.

Climate change is one of the greatest environmental threats that must face mankind, which could trigger catastrophic events with unpredictable developments. Agriculture is at the forefront of the economic sectors and has to deal directly with the adverse weather conditions that will accompany climate change.

The physical impacts of climate change and technological adaptation measures are well known both in theory and in practice.

In Romania, the negative consequences of natural hazards and climate change have an increasing effect. Large areas in the south of the country are affected by drought and soil degradation processes, with extremely negative economic consequences.

Environmental imbalance, forest destruction and limitation are the cause of floods, landslides, water erosion and wind erosion.

Sustainable development should be focused on the specialization of agricultural production by cultivating and growing in each region the corresponding crops that have the greatest benefit from the natural potential for agriculture, which is assessed by analysing the pedoclimatic conditions.

References

1. Bran, V., Ustinescu, G., 2018. *Reflections on the phenomenon of desertification and its influence on the natural ecosystems in Romania*, “Ovidius” University Annals, Economic Sciences Series Volume XVIII, pp. 133-138.
2. Burja, C., 2012. *Greenhouse gas emissions from agriculture: a comparative analysis between countries that recently joined the EU*, Annales Universitatis Apulensis Series Oeconomica, 14(2), pp. 589-598, online at : http://www.oeconomica.uab.ro/upload/lucrari/1420122/25.pdf, accessed 30.10.2018.

3. Chang, K.Y., Xu, L., Starr, G., Kyaw Tha Paw U., 2018. *A drought indicator reflecting ecosystem responses to water availability: The Normalized Ecosystem Drought Index*, Agricultural and Forest Meteorology 250–251, pp. 102–117, Published by Elsevier B.V., https://doi.org/10.1016/j.agrformet.2017.12.001
4. Cheval, S., Birsan, M.V., Dumitrescu, A., 2014. *Climate variability in the Carpathian Mountains region over 1961-2010*, Global and Planetary change 188: 85–96, DOI:10.1002/joc.4059.
5. Craciunescu, V., Stancalie, G., Irimescu, A., Catana, S., Mihailescu, D., Nertan, A., Morcov, G., Constantinescu, S., 2016. *MODIS-based multi-parametric platform for mapping of flood affected areas. Case study: 2006 Danube extreme flood in Romania,* Journal of Hydrology and Hydromechanics, 64, 2016, 4, 329–336, DOI: 10.1515/johh-2016-0040.
6. Dumitraşcu, M., Mocanu, I., Mitrică, B., Dragotă, C., Grigorescu, I., Dumitrică, C., 2018. *The assessment of socio-economic vulnerability to drought in Southern Romania (Oltenia Plain),* International Journal of Disaster Risk Reduction, Volume 27, pp. 142-154, https://doi.org/10.1016/j.ijdrr.2017.09.049, Elsevier LTD.
7. Edwards, D.C. and McKee, T.B., 1997. *Characteristics of 20th Century Drought in the United States at Multiple Time Scales*. Climatology Report 97-2, Department of Atmospheric Science, Colorado State University, Fort Collins.
8. Fellmann, T., Witzke, P., Weiss, F., Van Doorslaer, B., Drabik, D., Huck, I., Salputra, G., Jansson, T., Leip, A., 2018. *Major challenges of integrating agriculture into climate change mitigation policy frameworks*, Mitig Adapt Strateg Glob Change, 23:451–468, DOI 10.1007/s11027-017-9743-2
9. Hayes, M. J., Svoboda, M. D., Wilhite, D. A., 2000. *Chapter 12 Monitoring Drought Using the Standardized Precipitation Index*. Drought Mitigation Center Faculty Publications. 70. htp://digitalcommons.unl.edu/droughtfacpub/70, Published in Drought: A Global Assessment, Vol. I, edited by Donald A. Wilhite, chap. 12, pp. 168–180, London: Routledge.
10. Hurduzeu, G., Kevorchian, C., Gavrilescu, C., Hurduzeu, R., 2014. *Hazards and risks in the Romanian agriculture due to climate changes*, Procedia Economics and Finance 8, pp. 346 – 352, Published by Elsevier B.V., https://doi.org/10.1016/S2212-5671(14)00100-2
11. Ioan, I., Radulescu, C.V., 2015. *New Challenges for Agriculture within the Context of Climate Change*, Theoretical and Applied Economics, Volume XXII, No. 4(605), Winter, pp. 253-262.
12. Iordan, L.H., 2015. *Drought in Romania. Effects and adaptive strategies*, Scientific Papers. Series A. Agronomy, Vol. LVIII, ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785, pp. 391-397.
13. IPCC, 2014. Summary for policymakers. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.
14. Lloyd-Hughes, B., and Saunders M. A., 2002. *A drought climatology for Europe*. Int. J. Climatol, DOI:10.1002/joc.846
15. Mateescu, E., Smarandache, M., Jeler, N., Apostol, V., 2013. *Drought conditions and management strategies in Romania*, Initiative on “Capacity Development to support

National Drought Management Policy" (WMO, UNCCD, FAO and UNW-DPC) Country Report, http://www.droughtmanagement.info/literature/UNW-DPC_NDMP_Country_Report_Romania_2013.pdf

16. McKee, T.B., N.J. Doesken and J. Kleist., 1993. *The relationship of drought frequency and duration to time scale*. Proceedings of the 8th Conference on Applied Climatology, Anaheim, California, 17–22 January 1993. Boston, American Meteorological Society, 179–184.
17. Murărescu, O., Murătoreanu, G., Nouaceur, Z., Frînculeasa, M., 2017. *Agro-Meteorological Drought in Boian Plain (Romania). Case Study: Years 2008-2013*, Târgovişte: Valahia University. DOI: 10.1515/agr-2017-0012, De Gruyter.
18. Oprea, O., A., Mateescu, E., Barbu, A., Tudor, R., 2018. *Extreme dry years in the 21st Century at the level of the agricultural areas of Muntenia, Romania*, pp. 101 – 109. DOI: 10.2478/alife-2018-0015
19. Programul privind schimbările climatice și o creștere economică verde, cu emisii reduse de carbon, 2015. *Strategia națională privind schimbările climatice și creșterea economică bazată pe emisii reduse de carbon*, online at: http://www.mmediu.ro/app/webroot/uploads/files/2015-08-20_CRESC_Strategia_climatica_V3%281%29.pdf, accessed 30.10.2018.
20. Romanescu, G., Pintilie, A.M., Stoleriu, C.C., Carboni, D., Paveluc, L.E., Cimpianu. C.I., 2018. *A Comparative Analysis of Exceptional Flood Events in the Context of Heavy Rains in the Summer of 2010: Siret Basin (NE Romania) Case Study,* MDPI *Water*, *10*, 216; doi:10.3390/w10020216
21. Romania, Climate Change and Low Carbon Green Growth Program, 2014. *Agriculture and Rural Development Rapid Assessment,* The World Bank Europe and Central Asia Region, online at: https://openknowledge.worldbank.org/handle/10986/17571
22. Spinoni, J., Antofie, T., Barbosa, P., Bihari, Z., Lakatos, M., Szalai, S., Szentimrey, T., Vogt, J.V., 2013. *An overview of drought events in the Carpathian Region in 1961–2010*, Adv. Sci. Res. 10 (1), 21–32.
23. Spinoni, J., Naumann, G., Vogt, J.V., Barbosa, P., 2015. *The biggest drought events in Europe from 1950 to 2012*, Journal of Hydrology: Regional Studies 3, pp. 509–524, Published by Elsevier B.V. http://dx.doi.org/10.1016/j.ejrh.2015.01.001.
24. Spinoni, J., Szalai, S., Szentimrey, T., Lakatos, M., Bihari, Z., Nagy, A., Nemeth, A., Kovacs, T., Mihic, D., Petrovic, P., Krzic, A., Hiebl,J., Auer, I., Milkovic, J., Stepanek, P., Zahradnicek, P., Kilar, P., Limanowka, D., Pyrc, R., Cheval, S., Birsan, M.V., Dumitrescu, A., Deak, G., Matei, M., Antolovic, I., Nejedlik, P., Stastny, P., Kajaba, P., Bochnicek, O., Galo, D., Mikulova, K., Nabyvanets, Y.,Skrynyk, O., Krakovska, S., Gnatiuk, N., Tolasz, R., Antofie, T., Vogt, J.V., 2014b. *Climate of the Carpathian Region in the period1961–2010: climatologies and trends of 10 variables*, Int. J. Climatol., http://dx.doi.org/10.1002/joc.4059., https://www.academia.edu/11597668/Climate_of_the_Carpathian_Region_in_the_period_1961-2010_climatologies_and_trends_of_10_variables
25. Tigkas D., Vangelis H., Tsakiris G., 2013. *The Drought Indices Calculator (DrinC)*. In: Proceedings of 8th International EWRA Conference "Water Resources Management in an Interdisciplinary and Changing Context", R. Maia et al. (eds.). Porto, Portugal, 26-29 June 2013, pp.1333-1342.
26. Tigkas D., Vangelis H., Tsakiris G., 2015. *DrinC: a software for drought analysis based on drought indices*. Earth Science Informatics, 8(3):697-709. doi: 10.1007/s12145-014-0178-y
27. Ţîncu, R., Zêzere J.L., Lazar, G., 2018. *Identification of elements exposed to flood hazard*

in a section of Trotus River, Romania, Geomatics, Natural Hazards and Risk, 9:1, 950-969, DOI: 10.1080/19475705.2018.1486891
28. The World Bank, 2018. *Disaster risk management development policy loan with a catastrophe deferred drawdown option,* Building Disaster and Climate Resilience Program, Report No: PGD23, online at: http://projects.worldbank.org/P166303?lang=en
29. World Meteorological Organization, 2012: *Standardized Precipitation Index User Guide* (M. Svoboda, M. Hayes and D. Wood). (WMO-No. 1090), Geneva.
30. National Institute of Statistics – ROMANIA, http://www.insse.ro/cms/en
31. European Environment Agency, https://www.eea.europa.eu
32. World Bank Group, https://climateknowledgeportal.worldbank.org/country/romania