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THE USE OF SATELLITE IMAGES AND THE STANDARDIZED PRECIPITATION INDEX FOR THE ANALYSIS OF DROUGHT AND RAINFALL EXCESS IN ROMANIA

PHD THESIS SUMMARY

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Atmospheric precipitation represents one of the most important climatic parameters, their distribution in different periods of time representing the subject of numerous studies and researches, due to the practical and applied interest they have. Therefore, the study of all the extreme and complex conditions of precipitation formation and accumulation in certain areas is necessary taking into consideration the use of the water resource but also ~~of~~ preventing and combating their negative effects. The significant amounts of water produce increasingly significant financial losses for the agricultural sector, in the context of the increase in the economic value of agricultural crops or the expansion of the areas inhabited and used by humans.

Droughts can also be considered complex, considering that several factors contribute to their triggering, such as the lack of atmospheric precipitation, the reserve of soil water accessible to the plant, humidity and air temperature or wind speed, to which are added factors that define the characteristics of the active surface, factors that define the physiological particularities of the plant or the anthropic influence on the environment.

According to the IPCC (International Panel of Climate Change) reports from 2014 and 2022, in the southern part of Europe, including the geographical area of Romania, it is expected that the phenomenon of drought will occur more and more often, affecting more and more extended areas within Romania's territory. It is also expected that the drought will have an increasing impact on socioeconomic sectors, requiring the application of measures and policies to reduce its effects.

In other words, the occurrence of the drought phenomenon as well as the rainfall surplus is inevitable, so strategies and actions must be developed to adapt to their impact, especially in the eastern, southern and south–eastern regions of Romania, considering that they are among the most vulnerable, according to the results presented during this thesis. The better prepared a region is to deal with adverse weather conditions, the more it can contribute to the development of the entire country.

Although there are barriers, limits and costs, the unwanted effects of these meteorological phenomena must be limited as much as possible, and strategies, projects, laws, etc. must be developed. Also, through this research, solutions must be found to better anticipate possible future episodes of meteorological phenomena, which cause damage and potentially catastrophic effects.

The results of this study suggest that water resource management strategies should be adjusted according to the time of year and the spatial and temporal extent of drought and excess rainfall. Thus, several analyzes were carried out in order to better estimate the variability and trend over time of these phenomena over Romania.

This work is primarily based on the calculation of the SPI index with the help of which an analysis of the degree of severity of the drought phenomenon and of the pluviometric excess in Romania was carried out, but also of the territorial extension of these phenomena at the seasonal, semiannual and annual level during 1951–2020. Drought is an extremely complex climatic phenomenon characterized mainly by the lack of precipitation, a series of other factors contributing to its production such as soil water reserve, air humidity and temperature, evapo-transpiration, wind speed, water table depth, coverage with ground vegetation, etc.

Regarding the territorial distribution of the drought phenomenon according to the SPI, it has been proven that the most affected regions are those in the east and south–east of Romania, especially the east of the Moldavian Plain, the eastern half of the Barlad Plateau, the Dobrogea Plateau and the eastern half of the Romanian Plain. In other words, the greatest risk of drought is not necessarily recorded in the southern area of Romania every time, but also in the curvature area, this area being frequently affected. Also, among the most affected regions are the intra Carpathian area, especially the south–west of the Tarnavelor Plateau and the eastern half of the Apuseni Mountains. On the other hand, among the most frequently affected regions by the pluviometric excess, the central area of the Eastern Carpathians, the north-western part of the Barlad Plateau, the north-west of Romania, but also the entire central-southern and south-western area of Romania should be mentioned.

Also, the variability of the values resulting from the calculation of the SPI index, did not indicate a clear trend of increase/decrease in the frequency of droughts. However, an increase in the intensity of the phenomena and a faster succession from extremely dry periods to periods with a pluviometric excess can be taken into account.

Thus, according to SPI, in the spring season the most affected by drought were the years 1952, 1968, 1969, 1983, 1986, 1992, 2002, 2003 and 2009, while the largest areas affected by excess rainfall were recorded in the years 1970, 1978, 1980, 1984, 2012, 2014 and 2016, these being the years with more than 50% of the Romanian territory affected.

In the summer season, the most affected drought years were 1952, 1987, 1990, 1996, 2000, 2003, 2012, 2015 and 2020, while the summers in which the highest percentages of the Romanian territory were affected by excess rainfall, are those from 1969, 1972, 1975, 1979, 1991, 1997 and 2005.

In the autumn season, drought affected significant percentages of our country's surface in 1951 with 100% of the affected territory and in 2011 with 98.8%, but also in 1953, 1963, 1969, 1982, 1983, 1986 and 2006. On the other hand, when it comes to the years in which the rainfall surplus recorded the highest values, the years 1964, 1972, 1998, 2001, 2007, 2015 and 2016 can be mentioned.

The driest winters are those of 2001–2002 with 92.5% of the Romanian territory affected, 1973–1974 with 88.4% and 1991–1992 with 81.6%. Other winters are 1971–1972, 1972–1973, 1988–1989, 1989–1990, 1992–1993, and 2013–2014. In the case of the pluviometric surplus, the years 1969–1970 with 95.9%, 1952–1953 with 88.5%, 1965–1966 with 84.9%, but also 1962–1963 and 2009–2010 are noteworthy.

Regarding the situations in the two semesters of the year, in the cold semester, those of 1971–1972, 1973–1974, 1988–1989 and 1989–1990 stand out, while in the warm semester of the year the driest cases were those of the years 1952, 1956, 1963, 1990, 1992, 2000, 2003 and 2020. In the case of the pluviometric excess, in the cold semester the highest values occurred in 1952–1953, 1954–1955, 1965–1966, 1969– 1970, 1980–1981, 2009–2010, 2017–2018 while in the warm semester, the highest values of rainfall surplus occurred in 1970, 1972, 1991, 2005 and 2010.

On an annual level, the most affected drought years were the years 2000 with 94.5% of the Romanian territory affected, 1990 with 94.2%, 2011 with 70.2%, 1992 with 70%, 1983 with 66.4%, 2003 with 55.5% and 1986 with 50.9 % while the years in which the highest percentages of rainfall surplus were recorded are 2005 with 89.9%, 2010 with 88.4%,

2014 with 67.9%, 1966 with 66.5%, 1969 with 65.1%, 1972 with 63.1 %, 1970 with 61.4% and 2016 with 55.3%.

Also, considering that drought is an extremely complex phenomenon, in the analysis of which several indices and methods must be used, several products of the Terra MODIS satellite were used in this work, more precisely 3 spectral bands included in the MOD13Q1 product, with the help of which the NDVI and NDWI indices were calculated, from the calculation of the two indices resulting the NDDI index, in an attempt to analyze and monitor the general characteristics of the drought phenomenon that affected the arable lands in Romania. Drought assessment was based on the calculation of the relative frequency of NDDI values indicating moderate, severe and extreme drought conditions.

The analysis focuses on the March–August period from 2001–2020, in order to identify exactly the most affected regions of Romania at a very good spatial resolution. This interval was used in an attempt to include the period of vegetation greening up to the maximum vegetative stage. NDDI values were later correlated with precipitation amount values to observe the relationship between them.

From a methodological perspective, certain indices such as NDVI and NDWI can be used singularly for the analysis of the drought phenomenon, but it is recommended to use products that include multiple indices, such as NDDI.

The main conclusion is that the NDDI is a valuable tool to assess drought from both a temporal and a spatial perspective. However, drought assessment using the NDDI should be interpreted with caution, as the NDDI is the result of both meteorological and non-meteorological conditions, which are constantly changing over time. This aspect is particularly emphasized by the weak significant correlation we obtained between NDDI and the amount of precipitation at the level of the whole country. Furthermore, when used over longer periods of time, NDDI provides a comprehensive picture of the degree of aridity for the analyzed region.

Regarding the territorial distribution of the drought, it was observed that the most affected regions are the eastern part of the Romanian Plain and the southern and northeastern part of the Moldavian Plateau. Also, the entire Dobrogea Plateau, most of the Western Plain and the central and western part of the Romanian Plain are constantly affected by moderate drought. It should be emphasized that these are the arable regions in Romania for which drought should not be considered an extreme event, but a main climatic characteristic, which can only be treated by permanent irrigation.

Last but not least, the results do not indicate a clear long-term trend regarding the frequency of drought events as expressed by NDDI values. Therefore, discussions about a possible desertification that manifests itself in some parts of Romania are doubtful.

Thirdly, a classification of the main types of atmospheric circulations in Romania, both cyclonic and anticyclonic, was carried out, their frequency being analyzed at the multiannual, semiannual and seasonal level in the period 1951–2017. Thus, it was shown that at the multiannual level the highest frequencies have the NVa, Va, SEc, Na and Ec circulations and the lowest frequencies are recorded by the Vc, NVc, Sa, Nc and SEa circulations.

In the cold half of the year, the Sc, C, Na and NW circulations predominate and to a lesser extent the SEc, NWc, Ec or NEa and Va circulations, while in the warm half of the

year the Ec and SEc circulations predominate, but also the NWa circulations, Va, Na but also A.

In the winter season, a predominance of cyclonic circulations, both northern and southern or eastern, is observed. These high frequencies are explained by the normal fact that in this season the cyclonic activity of Mediterranean and Atlantic origin is higher than in other seasons. In the spring season, being a transitional season, almost all types of atmospheric circulation have equal values, although lower values are noted in the case of Nc and NWc circulations but also in the case of SVc, Vc and SEa circulations.

In the summer season, the predominant absence of cyclonic circulations is noted, except for those Ec and SEc produced by cyclones of Mediterranean origin in the first half of the season. At the opposite pole, the NVa, Va, Na and A circulations have very high values, this being explained by numerous periods with anticyclonic regime produced by extensions of the ridge of the Azorean anticyclone to the interior of the continent.

In the autumn season, the Va and NWa circulations record lower multiannual average values than in the summer season, the extensions of the ridge of the Azoric anticyclone are still frequent, while the Na and NEa circulations show higher values especially at the beginning of the interval. It is also noticeable the increase in the multiannual average values for the Sc and SVc circulations due to the increase in the frequency of cyclones of Mediterranean origin, but also the increase in the values for the Nc, NVc or NEc circulations due to the increase in the number of cyclones of Atlantic origin, as the cold semester of of the year.

Regarding the relationship between the types of atmospheric circulation and the degree of severity of the drought or of the pluviometric excess at the multiannual level, ~~the~~ positive correlations can be seen between the SPI values and the Nc, NWc and NEc circulations that generate pluviometric excess in the western, northern and north–eastern Romania. Also noteworthy are the SEc, Sc, SVc, C, and Vc circulations that produce excess rainfall and implicitly positive values of the Pearson index in the southern, southeastern and eastern parts of Romania, due in large part to the high frequency of cyclones of Mediterranean origin that affect especially the southern and eastern regions of Romania. On the other hand, NVa, SVa, Na or A circulations produce negative values of the Pearson correlation index.

In the warm semester, the positive values recorded in the case of circulations Va, Na, Ea, A and on smaller areas NEa are noted, while circulations Sa, SEa and SVa produce negative correlations on extended areas in the southern regions of Romania. In the cold semester, the circulations Nc, NVc, Vc and to a lesser extent NEc and Ec produce quantitatively greater precipitation in the regions of the west, northwest and north of Romania and implicitly positive values of the Pearson index but also the circulations SVc and Sc. On the other hand, the anticyclonic circulations NVa, Na and NEa are noticeable through the negative correlations at the level of the entire country.

In the winter season, from the positive correlations point of view, mainly cyclonic circulations Nc, NWc, NEc, Ec, SEc, Sc, Vc and C stand out, while negative correlations are recorded especially in the case of circulations Sa, SVa, Va, NVa, Na, NEa and A.

In the spring season, the convective activity and cut-off low altitude cyclones are increasing again, so quantitatively significant precipitations produced in an anticyclonic

regime are more and more frequent, in this case highlighting the positive correlations of Sa type circulations, SEa, SVa and Va. Also, Nc, NVc, NEc, Vc but also C must be mentioned, through high values of positive correlations, cyclonic activity in the spring season being again on the rise. At the same time, it can be noted that in the case of NVa, Na, NEa, A types and in most of the Ea territory, negative correlations prevail over extended areas. This confirms that in the spring season, the increased activity of these types of circulations inhibits cyclonic circulations and leads to conditions for the emergence of the drought phenomenon.

In the summer season, cyclonic activity is much reduced compared to the winter or spring seasons, especially in the months of July and August. This is particularly noticeable in the case of circulation types Nc, NVc, NEc, SVc and Vc. Somewhat higher values are recorded in the southern half of Romania, in the case of type C, especially in its southern central part, being produced by the more significant cyclonic activity of Mediterranean origin since the beginning of summer. Also in the summer season, circulation types Va, Ea and partially A but also type Na are noticeable. The correlations of these types are strongly influenced by the high convective activity during the summer, the advections of cold air masses from the north of the continent that meet warm and dry air masses from the south of Romania, generating accentuated atmospheric instability and quantitatively significant precipitation.

In the autumn season, significant positive correlation values are observed in the case of circulation types Nc, NEc and even C, in the south-west, west and north-west regions of Romania. These values suggest the very good relationship between these types of circulations and significant amounts of precipitation. Regarding the correlations produced by the anticyclonic circulations, the types Sa, SVa, Va and Ea stand out on the one hand. This fact is due to the significant convective activity in the first half of the autumn season when cold air masses from high latitudes are advected towards the interior of the European continent. On the other hand, the types of NWa, Na, NEa and A circulations are noted whose significant activity leads to negative values of the Pearson correlation index at the level of the entire territory of Romania, thus suggesting the fact that they produce a significant pluviometric deficit.