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DROUGHT INTENSITY ON ARABLE LAND IN ROMANIA – PROCESSES AND TENDENCIES

Olga-Petruta Vizitiu[1], Irina Carmen Calciu[1], Catalin Cristian Simota[1]

Abstract. Drought is one of the factors which may determine land degradation by aridization occurence. Under drought conditions the soil productivity decreases with negative impact on socio-economic conditions. Over 60 % of arable land is affected by drought. In this paper drought risk is evaluated at country level, processes induced by its occurrence and tendencies in future time horizons. Drought intensity was evaluated by using different indicators. Values of Palfay index which was corrected by soil properties, relief and watertable showed that in the south and south-eastern part of the country there is a high intensity of drought. The aridity index showed that there is a high variability during the time. In dry years the highest semi-arid area affected by drought is located in south-eastern part and all the other plain areas under arable use are defined as sub-humid areas. The Bagnouls-Gaussen aridity index showed that the drought occurs mostly in south-eastern part of the country for the time period of 1961-1990. For the future time horizons (2011-2020, 2041-2050, 2071-2080) the drought intensity increases. Within the time horizon of 2041-2050 the predictions show that the entire south part of Romania will be affected by high drought intensity. The environmentally sensitive area to desertification index (ESAI) showed that most of the arable land is classified as critical. The cumulated annual water deficit, the active temperature annual sum over 4 °C, the active temperature annual sum over 10 °C and the number of days with drought increased in the period of 1991-2000, in comparison with 1961-1990 time interval, mostly in western and eastern parts of the country. The same tendency is predicted for the future time horizons. Climate changes lead also in changes of hybrid productivity. Thus, in case of maize, the predictions show that the lately hybrids has higher productivity than early and medium-early ones in the time horizon of 1991-2000 in the most important arable areas. For the future time horizons (2011-2020, 2041-2050) the early and medium-early hybrids are most productive.

Keywords: drought intensity, arable land, index

1. Introduction

Drought years in Romania are repeated every few decades, some of the years in these periods are extremely dry. Even in these dry periods there is currently excess rainfall leading to more or less local floods. But other periods are characterized by rainy or extremely rainy years, producing ample phenomena of soil water excess on agricultural land. Drought is found especially in Dobrogea, southern of Romanian Plain and southern of Moldova, but sometimes

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it is also present in other areas of the country. The effects of drought are largely affected by soil conditions in different parts of the country and also from different areas of a municipality or a village. Drought is somewhat mitigated on deep and medium textured soils prevailing in the affected areas, and on those with watertable at moderate depth, but is more intense on slopes subjected to erosion, on sandy soils from southern Oltenia, on low permeable soils from Teleormanului Plain etc.

United Nations Convention to Combat Desertification defines drought as “complex phenomena with slow manifestation, which affect various components of the environment: hydrological, pedological, vegetal and animal. Consequently, it speaks about different types of drought: hydrological, meteorological and agricultural”.

Common to many geographical areas, the drought is usually associated with the absence of precipitations during long periods of time and provokes visible negative effects on the environment, especially on the vegetation, soil and hydrological resources.

In Romania, during the past years the drought has extended as a result of deep transformations (deforestations, destructions of wind breaks and others) over a most important part of national fund, but also on the basis of climatic unbalance. At the same time, the degradations have knew an alarming intensification both in humid areas and semi-arid as well as in dry-subhumid areas. The meteorological data acquired for the last 100 years within 17 stations situated in southeast of country (Dobrogea, East of Muntenia and South of Moldova) show that these areas are potentially affected by desertification (over the 3 millions ha, where about 2,8 millions ha are agricultural land). Actually, the drought affects almost all agricultural land in our country. In this paper the drought intensity was evaluated by using of different indicators.

2. Methodology

Several indicators used at national level for evaluating drought intensity were calculated using a simulation procedure for long time (30 years) periods covering the reference period for climate change studies (i.e. 1961-1990) and some climate change projections for the next periods (2011-2020; 2041-2050; 2071-2080). The selected indicators have various degree of complexity from indicators based on meteorological data only (Bagnouls-Gaussen ombrothermic index) to indicators based on soil-climate (ESAI Index, number of days with drought) or crop-soil-climate processes (maize hybrids productivity). Such indicators are actually used as technical support in actions derived from implementation of various European environment and agriculture policies. For example, the Bagnouls-Gaussen ombrothermic index is used for the evaluation of erosion risk in Mediterranean region.

The indicators have been calculated for each year using the output data (time step: day) of the agro-climatic simulation model ROIMPEL (precipitation, potential and actual evapotranspiration, crop yields). The yearly values of indicators were then averaged over the 30 year period.

Data available

The key spatially explicit biophysical variables are:

Soil data

Soil input data for agro-climatic simulation model were derived from the European Soil Database v2.0 (ESD) available on http://eusoils.jrc.ec.europa.eu/library/esdac. The components of the ESD used for the needs of this study were: Soil Geographical Database of Eurasia at scale 1:1,000,000 (SGDBE) and the PedoTransfer Rules Database (PTRDB).

SGDBE database divides Europe into Soil Mapping Unit (SMU) polygons, each of which contains a number of Soil Typological Units (STU). STUs are described by variables (attributes) specifying the nature and properties of the soils, e.g. texture, water regime, stoniness, etc. PTRDB database derives rules for the evaluation of soil parameters needed in environmental studies (e.g. hydrological properties: topsoil/subsoil available water capacity, topsoil/subsoil easily available water capacity, saturated hydraulic conductivity).

Climate data.

Baseline data were based on a 10^{o} grid for Europe with monthly time steps using observations for 1961– 1990 (Mitchell et al., 2004).

Public daily weather data (temperature and precipitations) for the 1961-1990 time periods were provided for Europe region by Klein et al., 2002 (data and metadata available on http://eca.knmi.nl).

Climate scenarios for 2011-2020, 2041-2050 and 2071-2080 were derived from the HadCM3 and ECHAM4 climate model outputs for 2001–2100 (Mitchell et al., 2004). Rounsevell et al. (2006) describes how the scenarios were constructed and describe the patterns for temperature and precipitation. HadCM3 and ECHAM4 were chosen for this study as they represent the extremes in terms of both temperature and precipitation change.

Simulation model - ROIMPEL

General

ROIMPEL agro-climatic simulation model (Mayr et al., 1996, Audsley et al., 2006) was used based on the soil/ terrain information and weather/climate variables to predict the water-, air temperature-, and nitrogen-limited crop yields. The minimum requirement for soils data are the soil texture and organic matter classes. The minimum weather data needed by the model are monthly values of the average daily air temperature and the monthly cumulated precipitation. Links with soil and climate GIS layers, therefore, ROIMPEL is very suitable for applications at national level.

Indicators

Ombrothermic index (Bagnouls-Gaussen)

Ombrothermic index summarizes hydrological stress on plant development and biomass formation (Bagnouls and Gaussen, 1953). The index calculated using formula:

$$BGI = \sum_{i=1}^{12} \left(2T_i - P_i\right) * k$$

where:

BGI is Bagnouls-Gaussen index;

T_i is the mean air temperature for the month i in ^{o}C;

P_i is the total precipitation for month i in mm;

k represents the proportion of month during which $2T_i – P_i > 0$

is used for identifying drought related phenomena (indicated by positive BGI values) for the assessment of the environmentally sensitive areas to desertification in Mediterranean region (Kosmas, et.al, 1999).

Aridity Index

The atmospheric conditions that characterize drought affected areas and desert climate are those that create large water deficits, that is, potential evapotranspiration (ET_o) much greater than precipitation (P). The index defined as P/ET_o is used for designating areas sensitive to drought or desertification (FAO-UNESCO, 1977). The following categories divide the land area based on this index:

I)	The arid zone:	$0.03 < P/ET_o \leq 0.20$
II)	The semi-arid zone:	$0.20 < P/ET_o \leq 0.50$
III)	The sub-humid zone:	$0.50 < P/ET_o \leq 0.75$
IV)	The humid zone:	$0.75 < P/ET_o \leq 1.25$
V)	The extreme humid zone:	$P/ET_o > 1.25$

Environmentally Sensitive Area to Desertification (ESAI) index

To calculate this index is used a method of mediation of indicators calculated by assigning weights to a selection of parameters that characterize the topography (slope, exhibition), soil (texture, edaphic volume, parent material, drainage, skeleton), climate (rainfall, Bagnouls-Gaussen aridity index), vegetation/land use (protection for erosion processes, resistance to drought, soil cover) and the intensity of agricultural management. Depending on the values of this index, the following classes on land degradation and desertification risk were defined:

- *Critical*: areas that is already degraded from the past. These areas represent a danger to the surrounding regions. Examples include areas with strong erosion in which the runoff and soil loss can be considerable;

- *Fraile*: areas in which any changes in the delicate balance between natural processes and those induced by human activity can lead to desertification processes. Droughts in these areas can lead to desertification processes in case of inadequate land management. For example, due to climate change or variability of weather conditions, is possible to reduce the growth potential of biomass particularly in areas sensitive to drought and with implications on soil erosion of those areas which passes in the «critical» category. Similarly, changing the land use or the crops structure can increase the leakage and erosion having consequences in fertilizer losses on the slopes.

- *Potential*: areas threatened by desertification in case of significant climate changes and/or in case of specific structures of land use. In this category can be included also the abandoned land or those that are not properly managed. For these areas a proper management of farm activities is required.

3. Results

Identification of the areas with drought was made taking into account the correlation between the aridity index calculated by the precipitation reference to the potential evapotranspiration and Palfay aridity index, which takes into account the frequency of the drought years. It was considered that the affected areas contain the territories with a severe sensitivity drought for which values of Palfay index is of 6-8 (the frequency of the drought years being of 40-63%). These territories are placed in the southern and eastern part of the country. In the western part of the country, the territories with a risk to drought cover surfaces comparatively restricted (Fig. 1).

A reduced frequency of drought years is in areas with Palfay Index less than 6. The area of Romania with Palfay index in the range 6-8 (see the map) covers 40 % of the agriculture land, mainly in the South, South East and East of Romania; the area with Palfay Index in the range 4-6 is about 20 % of the agriculture land area, mainly in South and South east, but with areas in West and central part of the country. After the evaluation of the National Research-Development Institute for Soil Science and Agro-chemistry and Environment the drought affected area is of about 7.1 million ha (29.8 %).

The intensity of the drought is also dependent on soil, relief, groundwater depth and land characteristics. Therefore, the well developed soils with medium texture, absence of skeleton, high water retention capacity and available water for cops are less vulnerable to drought than extreme sand, clay or skeleton soils with short soil profile depth, having salinisation problems and low soil water capacity. The slope relief increases the vulnerability of the land to drought induced processes due to water losses by runoff. This vulnerability of slope areas is reduced if the groundwater depth is in the range 1-3 m. Considering these aspects in the drought affected area of Romania most of the soils have a small or moderate vulnerability to drought (favorable available soil water and other agrophysical properties, flat area, some areas with shallow groundwater table). Therefore, on these areas the dry farming agriculture is suitable.

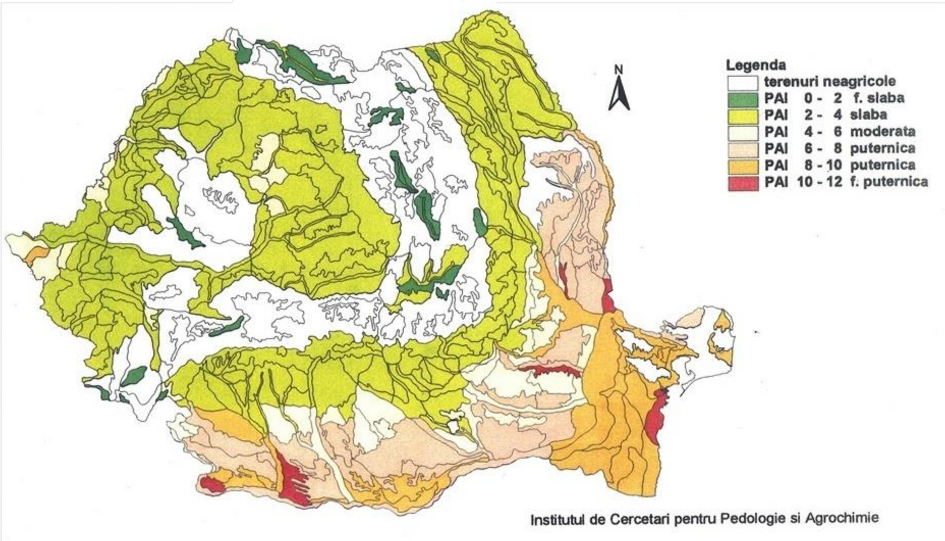

Figure 1: Drought intensity areas according to Palfay index corrected by soil properties, relief and watertable level (0-2: very low; 2-4: low; 4-6: moderate; 6-8: strong; 8-10: very strong; 10-12: excessive)

Figures 2, 3 and 4 show another index for drought intensity evaluation, which is the aridity index. The aridity index showed that there is a high variability during the time. For example, in dry years the highest semi-arid area affected by drought was located in south-eastern part and all the other plain areas under arable use were defined as sub-humid areas (Fig. 3). As it can be seen in Figure 4, in rainy years there was no risk to drought all over the country.

The next index drought intensity evaluation was the Bagnouls-Gaussen aridity index which is used in various European projects related to aridization and desertification (e.g. CORINE, MEDALUS, ENVASSO). This index characterizes water stress which manifests itself on plant growth and biomass formation and is used for evaluating high sensitivity of ecosystems to climate change. In Figures 5-8 are shown the average annual values of the Bagnouls-Gaussen aridity index for the time period 1961-2000 and for estimated periods for climate changes based on IPCC scenario, calculated with global circulation model (GCM) for HadCM3 for the time horizons: 2011-2020, 2041-2050 and 2071-2080. The Bagnouls-Gaussen index showed that the drought occurs mostly in south-eastern part of the country for the time period of 1961-1990. For the future time horizons (2011-2020, 2041-2050, 2071-2080) the drought intensity increases. Within the time horizon of 2041-2050 the predictions show that the entire south part of Romania will be affected by high drought intensity.

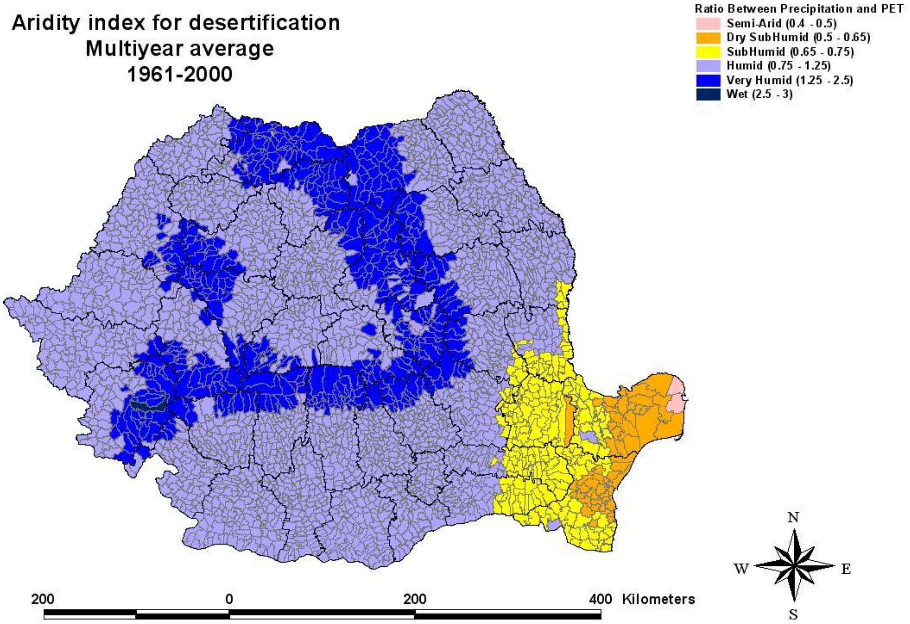

Figure 2: Drought intensity areas according to aridity index evaluated for the time period of 1961-2000. This figure shows the multiannual average values.

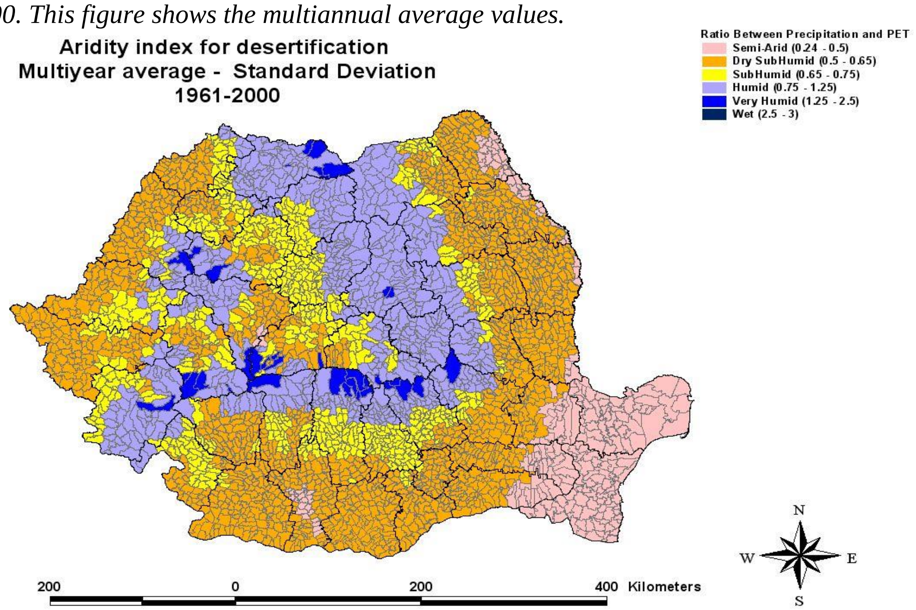

Figure 3: Drought intensity areas according to aridity index evaluated for the time period of 1961-2000. This figure shows the multiannual average values – standard deviation.

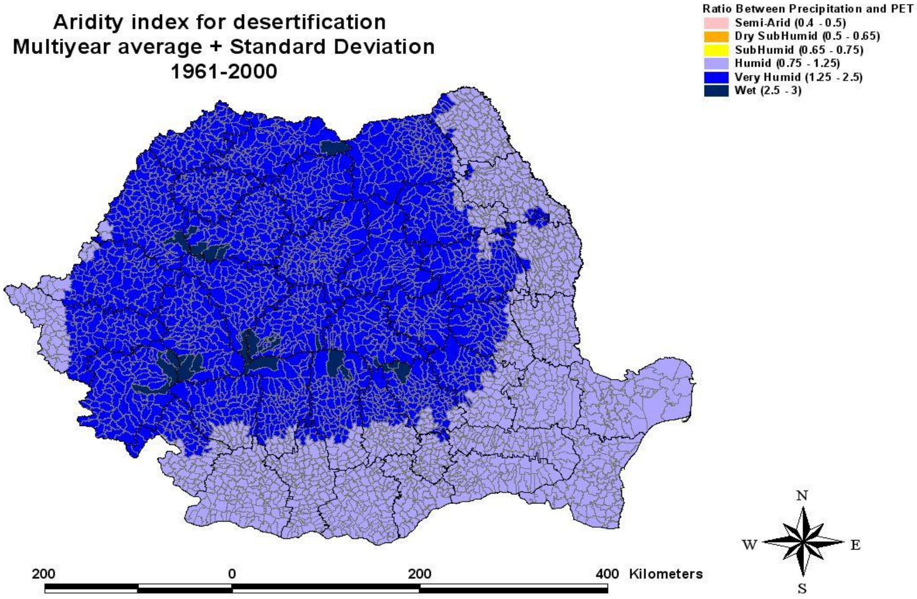

Figure 4: Drought intensity areas according to aridity index evaluated for the time period of 1961-2000. This figure shows the multiannual average values + standard deviation.

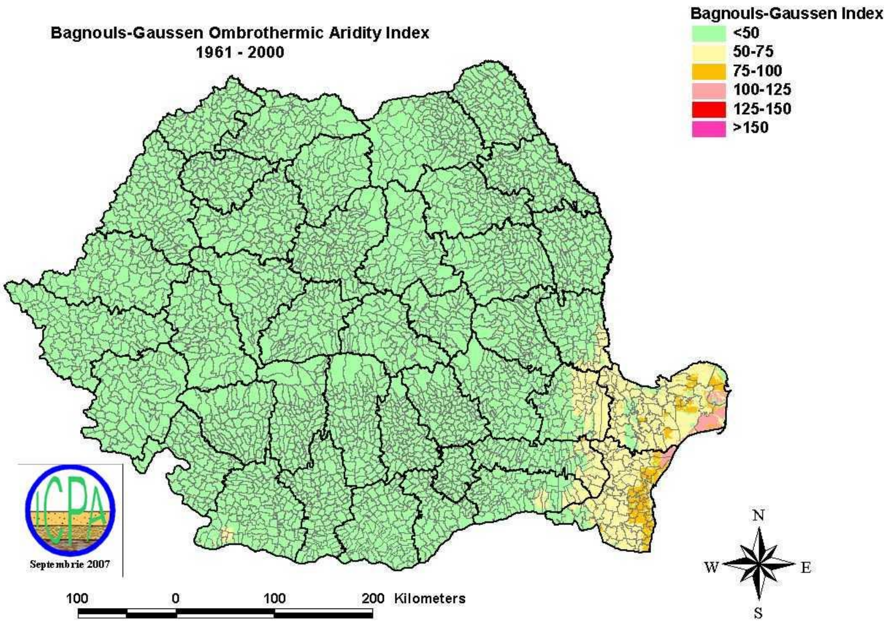

Figure 5: Bagnouls-Gaussen aridity index – average values evaluated for the time period of 1961-2000.

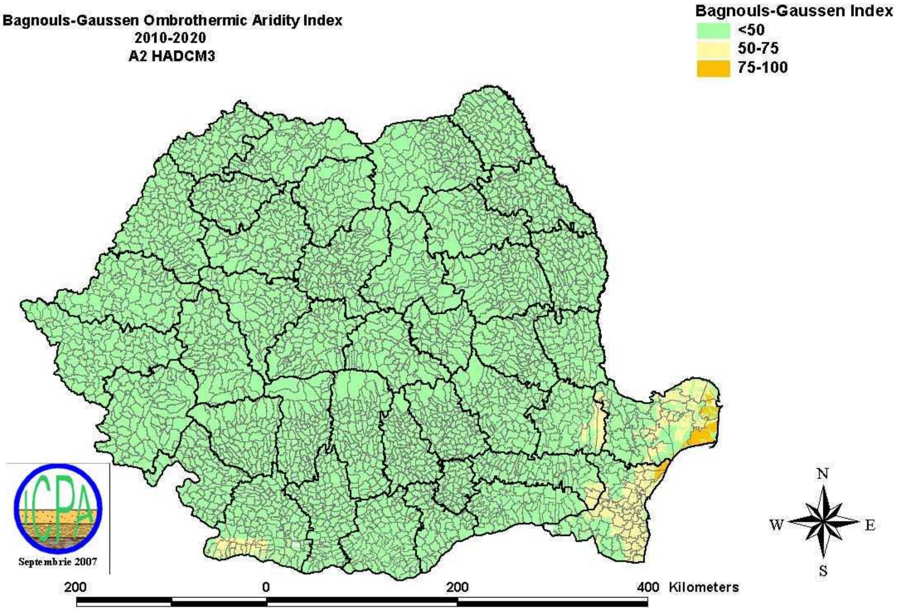

Figure 6: Bagnouls-Gaussen aridity index – average values evaluated for the time period of 2011-2020 (calculated with global circulation model (GCM) for HadCM3).

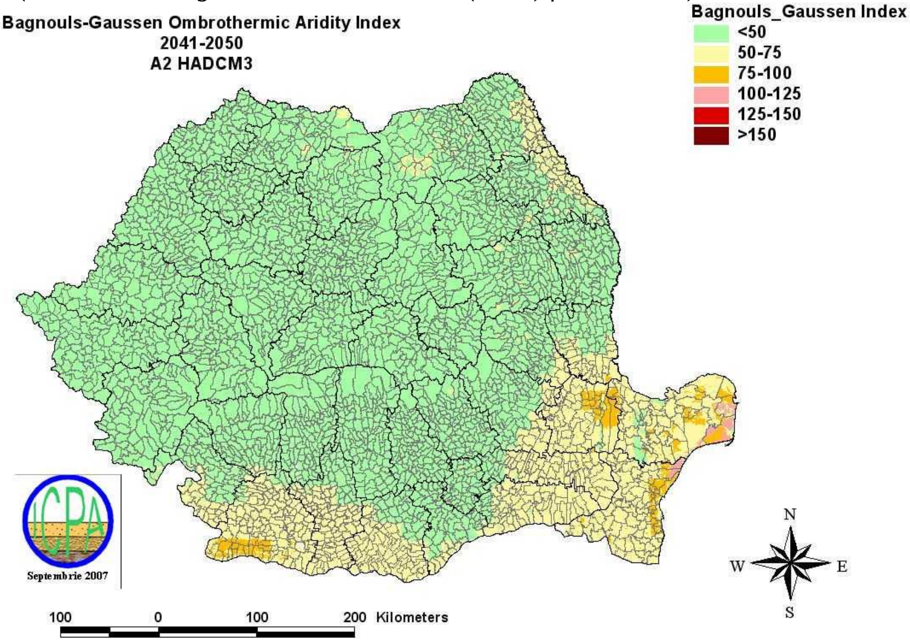

Figure 7: Bagnouls-Gaussen aridity index – average values evaluated for the time period of 2041-2050 (calculated with global circulation model (GCM) for HadCM3).

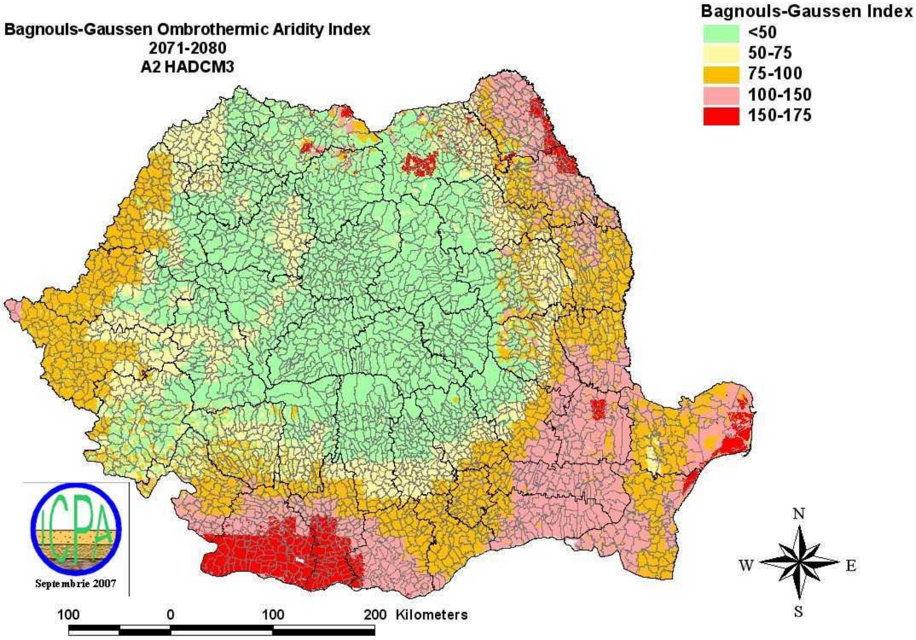

Figure 8: Bagnouls-Gaussen aridity index – average values evaluated for the time period of 2071-2080 (calculated with global circulation model (GCM) for HadCM3).

The next index for drought intensity evaluation is the Environmentally Sensitive Area to Desertification Index (Kosmas et al., 1999). This index is used at European level to characterize the sensitivity of agricultural ecosystems to desertification. According to Figure 9, the environmentally sensitive area to desertification index (ESAI) calculated for the time period of 1961-1990, showed that most of the arable land is classified as critical.

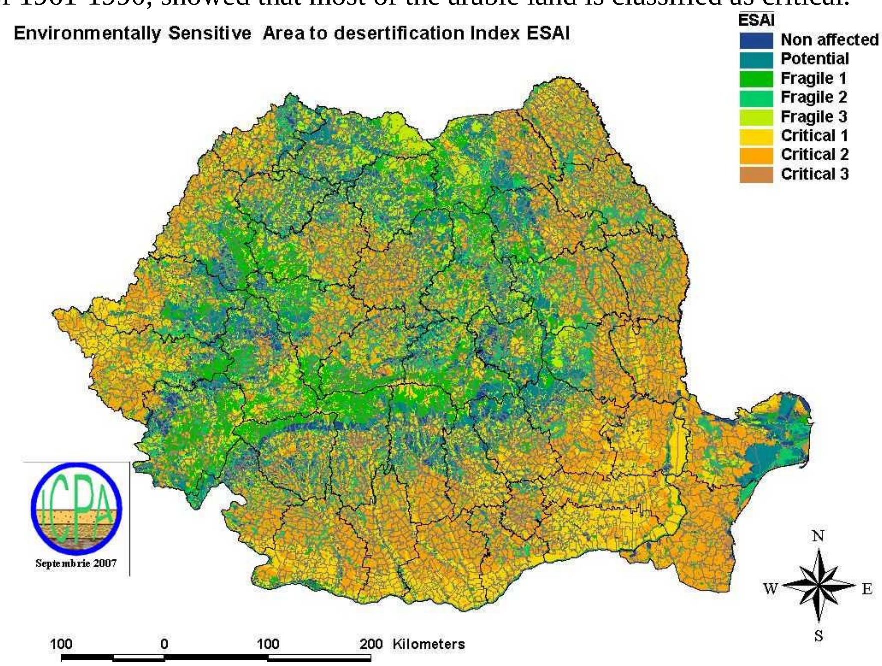

Figure 9: Environmentally Sensitive Area to Desertification index – values evaluated for the time period of 1961-1990.

The cumulated annual water deficit, the active temperature annual sum over 4 °C, the active temperature annual sum over 10 °C and the number of days with drought increased in the period of 1991-2000, in comparison with 1961-1990 time interval, mostly in western and eastern parts of the country (Figures 10-12). The same tendency is predicted for the future time horizons.

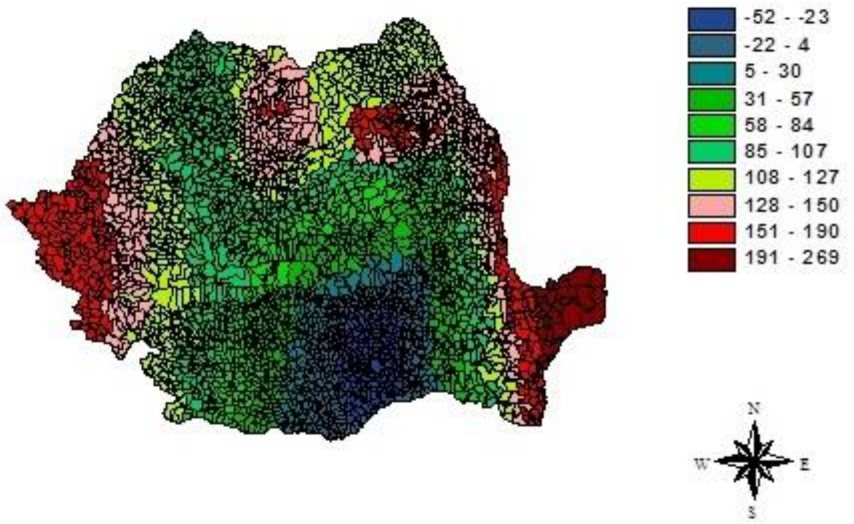

Figure 10: Change of active temperature annual sum over 4ºC in the period 1991-2000 in comparison with 1961-1990 (data based on FP5 projects – ATEAM, ACCELERATES, ACCELCEEC).

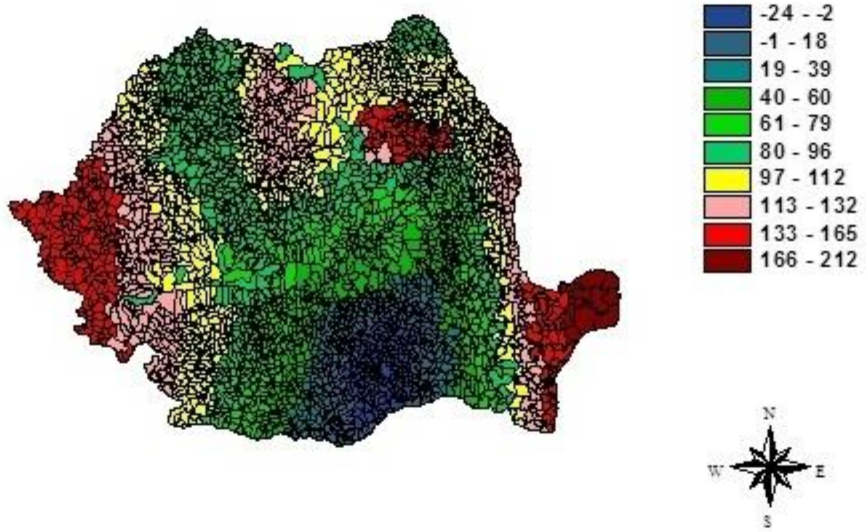

Figure 11: Change of active temperature annual sum over 10ºC in the period 1991-2000 in comparison with 1961-1990 (data based on FP5 projects – ATEAM, ACCELERATES, ACCELCEEC).

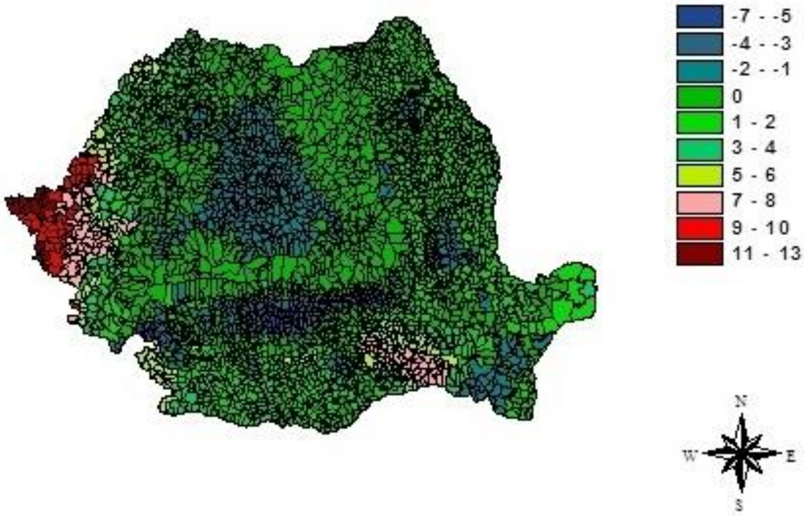

Figure 12: Change of number of days with drought in the period 1991-2000 in comparison with 1961-1990 (data based on FP5 projects – ATEAM, ACCELERATES, ACCELCEEC).

Climate change conditions also lead to changing in relative yields of maize hybrids with different classes of precocity. Thus in the case of maize hybrids which in the actual climate scenario (1991-2000) the lately hybrids (FAO Class 6) have higher production than early and medium-early maize hybrids (FAO Class 2) in the main agricultural areas of the country (Figure 13). For the time periods of 2011-2020 and 2041-2050 the productivity of the maize hybrids, as measured by simulation models coupled with databases developed for studying of climate change impacts are reversed (figures 14-15).

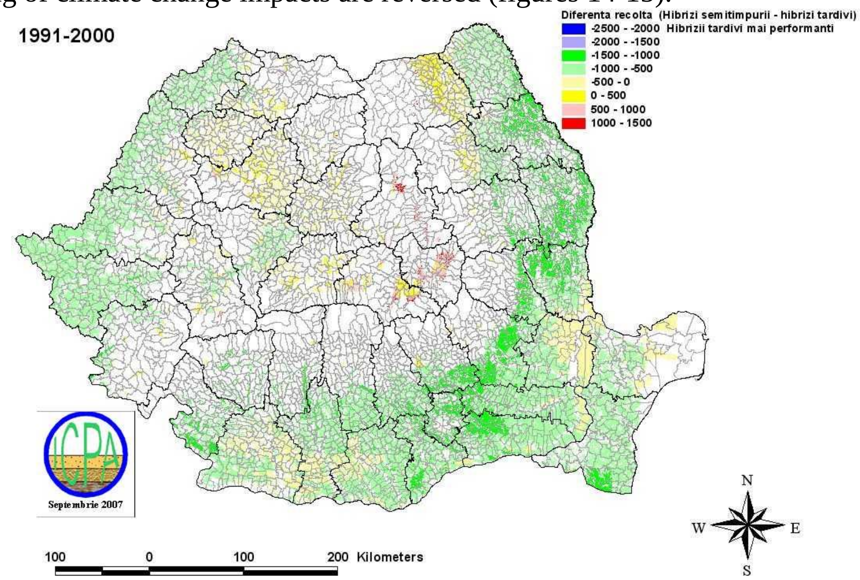

Figure 13: Difference between the average multiannual productions (1991-2000) of medium-early maize hybrids (FAO Class 2) and of lately maize hybrids (FAO Class 6) estimated by ROIMPEL simulation model.

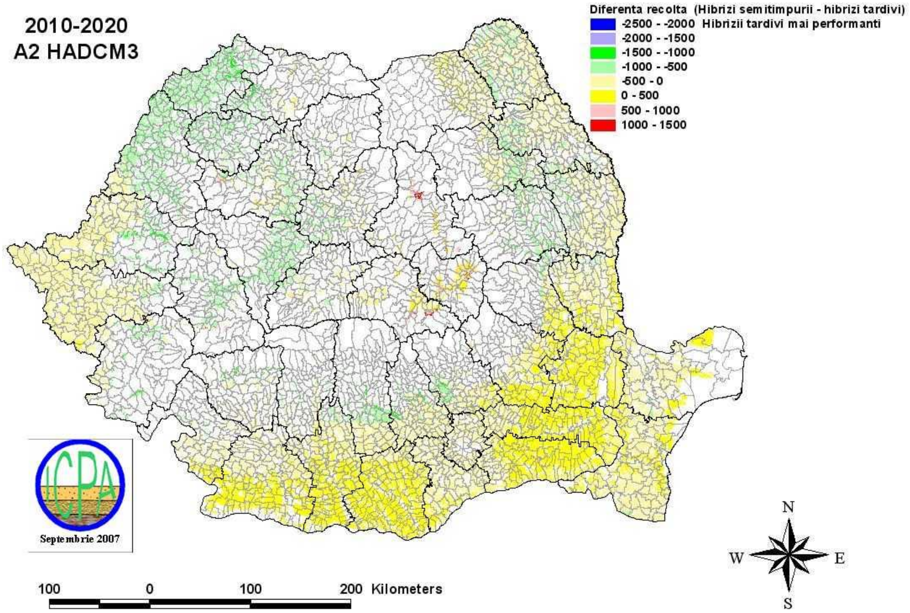

Figure 14: Difference between the average multiannual productions (2010-2020, calculated with global circulation model (GCM) for HadCM3) of medium-early maize hybrids (FAO Class 2) and of lately maize hybrids (FAO Class 6) estimated by ROIMPEL simulation model.

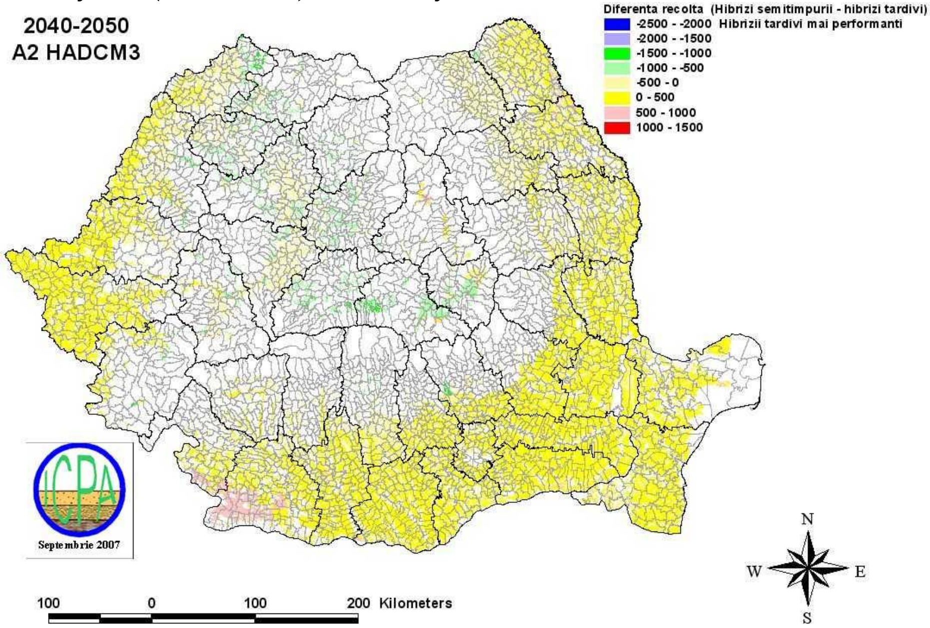

Figure 15: Difference between the average multiannual productions (2040-2050, calculated with global circulation model (GCM) for HadCM3) of medium-early maize hybrids (FAO Class 2) and of lately maize hybrids (FAO Class 6) estimated by ROIMPEL simulation model.

Besides the effects on agriculture ecosystems the drought has a negative impact on animal stocks by decreasing food and water supplies. At the same time, in drought periods are affected surface and groundwater reserves with negative consequences on hydropower plants and fluvial navigation. Reducing the river water flows could induce the increase of pollutant concentration. Direct negative effects on human health were also reported in the drought periods.

The drought has a significant effect on socio-economic sector. The income of farmers is significantly reduced and the production costs are not recovered. Considering that in the last years the drought affected large and compacted areas almost all the population involved in agriculture or agriculture-related economic activities is affected. The insurance system is not able to cover the damages of drought due to the fact that in these years the damages are very high and generalized over large areas.

A very negative consequence of the land degradation processes is the altering of the physical and biological soil functions and the decreasing of soil productivity with 20 – 100 % on an area of about 2 million ha, and with up to 20 % on a slope land area of 3.7 million ha with agriculture land use. In the same time, the degraded lands have a 20 – 90 % decreased water storing capacity with very negative consequences during the drought periods.

Measures for preventing, limiting and combating the drought:

- Land reclamation through:
  - shelter-belt establishment;
  - reforestation of some arable lands up to 10 % in the plain area;
  - reforestation of degraded land;
  - use of the Code of good practices for soil water conservation either in dry farming or irrigated conditions;
  - use of minimum soil tillage;
  - water reservoirs establishment with multiple functions, including irrigation in small local systems;
- Analysis of crop and hybrid efficiency in the context of new climatic conditions;
- Classification of the irrigation systems taking into account its technical and economic efficiency, improving the economic systems;
- Use of some techniques for merging the lands in order to apply the irrigation.

Conclusions

The following **conclusions** can be drawn:

- no single index must be used as criteria for designation of areas affected by drought. Each indicator shows different patterns over the country;
- considering that the indicators will be used for the next future in implementing Community polices their values for climate change scenarios are very useful in designing proper measures. The uncertainty induced by climate change predictions (different Global Circulation Models, different emission scenario), procedures for evaluating soil parameters needed for calculation, evaluation tools (simulation models) make this evaluation a difficult task. The best solution is to show the range of variation of indicators over all the possible climate and soil values;
- all different indexes used for drought intensity evaluations showed that for the future time periods there will be an increase of the drought intensity at the country level.

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