THE ORIENTGATE NETWORK

Orientgate

Adaptation measures in Romanian agriculture

SOUTH EAST EUROPE
Jointly for our common future

Programme co-funded by the EUROPEAN UNION

Bucharest – 2014

The project is co-funded by the South East Europe (SEE) Transnational Cooperation Programme under Priority Axes 2 named “Protection and improvement of the environment”, respectively the Area of Intervention related to the improvement prevention of environmental risks.

The South East Europe programme (SEE) is a unique instrument which, in the framework of the Regional Policy's Territorial Cooperation Objective, aims to improve integration and competitiveness in an area which is as complex as it is diverse.

NATIONAL METEOROLOGICAL ADMINISTRATION

SEE Project-OrientGate: A structured network for integration of climate knowledge into policy and territorial planning

BUCHAREST – 2014

European Union
European Regional Development Fund

SOUTH EAST EUROPE
Transnational Cooperation Programme

***Thematic Centre 1*: Forestry and Agriculture**
- *Pilot Study 2:* Climate change adaptation measures in Romanian agriculture

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Foreword

During the 20th century has been a clear trend towards drier conditions, with decreases in rainfall especially in Southern and Eastern European countries. The total area affected by water scarcity and droughts doubled - from 6 to 13 % - during the last 30 years. EU Water Framework Directive (WFD/2000/60/EC) and the Water Scarcity and Droughts EU Policy (EC 2007b) refers to protect and restore the water environment across Europe and to develop adaptation measures and sets out a number of policy options for addressing impacts of water scarcity and droughts in next decades.

In Romania, the 2001-2012 interval was particularly droughty the agricultural production being significantly affected. In July 2013, the Romanian Government adopted the Governmental Decision no. 529/2013 on the National Climate Change Strategy (2013-2020). The National Climate Change Strategy (2013-2020) establishes the post Kyoto objectives, targets and actions for two main components, respectively the reduction in the concentration of greenhouse gases (Mitigation) and the adaptation to climate change (Adaptation). One of the main sectors vulnerable to CC refers to the agriculture. According the integration of the adaptation plans in the sectoral strategies will help to have a comprehensive approach and select appropriate measures for the direct and indirect effects of climate change (including drought and other extreme events). In other words, this gives support to develop the scientific results based on dedicated pilot studies.

The Pilot Study 2 developed in the Orientgate project which is focused on climate change adaptation measures in Romanian agriculture may contribute to a better understanding of impacts of climate change and weather extremes in agricultural production. Increasing resilience to weather extremes and climate change is challenging. The decision makers and practitioners are faced with a wide variety of tools and datasets for the assessment of drought risk and technological measures. In this context, the Pilot Study 2may consolidate existing knowledge and research on this topic.

In the context of the climate change, the best way to find the most appropiate adaptation measures in agriculture is a agrometeorological activity directed towards observing, monitoring and forecasting the extreme events including drought phenomenon, so as to be at the height of the challenges of the 21st century, as regards the adaptation plans and strategies. Adapting to climate change through a better crop system management will benefit mainly from the knowledge given by the responses to severe climate events, when plans to adapt to and mitigate predictable climate change risks are implemented. In practical terms, decisions related to climate change impacts need to encompass several adaptation options to the climate projections. In other words, decision makers and farmers will have to handle different options based on predictable scenarios and combination of technological measures designed to reduce the CC effects.

Dr. Ion Sandu

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1. Introduction

Sustainable development, management, and planning in agriculture benefit from scientific fundaments by using methodologies based on crop-weather relationships and assessment of climate change impacts and extreme climate-related events on crop production.

Drought events have negative effects on the socio-economic condition especially in drough-prone areas through their impact on water scarcity, agricultural production and as well as on land degradation.

The agricultural production is facing multiple challenges of climate change. The potential impact of variability and climate change on yields is different from one region to another. Over the last years the increases losses from weather related extreme events suggest a need for adaptive capacity (Ion Sandu, Elena Mateescu, 2014).

The degree of adaptation depends on the adaptive capacity of each country, region, or exposed sector (e.g. agriculture and food production, water resources, health, urban sector, energy, transport, etc). This is because the adaptive capacity to climate change relies on various factors, such as financial and human resources, scientific knowledge, access to information, technology, social institutions and infra-structure (IPCC- AR5, Chapter 16, 2014).

In many countries, the risks of climate change for the agricultural sector are a particularly immediate and important problem because the majority of the rural population depends either directly or indirectly on agriculture for their livelihoods. The rural poor will be disproportionately affected because of their greater dependence on agriculture, their relatively lower ability to adapt, and the high share of income they spend on food. Therefore, climate impacts could undermine progress that has been made in poverty reduction and could adversely impact food security and economic growth in vulnerable rural areas.

The risks of climate change cannot be effectively dealt with and the opportunities cannot be effectively exploited without a clear plan for aligning agricultural policies with climate change, for developing key agricultural institution capabilities, and for making needed infrastructure and on-farm investments. Developing such a plan ideally involves a combination of high-quality quantitative analysis and consultation with key stakeholders, particularly farmers, as well as local agricultural experts. The most effective plans for adapting the sector to climate change will involve both human capital and physical capital enhancements; but many of these investments can also enhance agricultural productivity right now, under current climate conditions (EEA Reports, 2012, 2013).

The literature on benefits of adaptation suggests that the development of new drought-resistant varieties could have important implications for mitigation targets. Similarly soil moisture conservation technologies e.g., throughtilling systems, crop rotation, etc, can be beneficial for preventing drought and water scarcity in agriculture field (Prutsch A., Grothmann T., Schauser I., Otto S., McCallum S., 2010).

2. The OrientGate Project

Over more than 40 years from the first climate numerical simulations, numerical methods have allowed enormous progress, enlarging the number and type of variables predicted, the range of the predictions and the type of sectors involved. Accuracy, reliability and scope of the forecasts have been steadily increasing.

Society has reaped endless economic social and human benefits. A number of European projects (CIRCE, CLIME, KLIWAS, CLIMWATERADAPT, WATCH, WATER2ADAPT, PRUDENCE, WATER CoRe, ENSEMBLES, STARDEX, CECILIA, CLAVIER, CCWATERs, ENSEMBLES, etc) and international coordinate experiments (CMIP5) have produced vast amounts of data and knowledge for climate evolution and projections. This knowledge is available, but it does not reach the final users and stakeholders with sufficient speed and quantity. It is urgent to overcome the barriers that prevent an efficient exploitation of the knowledge produced by the scientific community so that it can be properly taken into account in the formation of policies and in the development of strategies.

There is a large gain to be achieved by realizing a set of coordinated activities that would build on the existing knowledge, making it available, translating it in more useful terms. It is also urgent that we elaborate effective strategies and practices to insert this rapidly accumulating evidence into the territorial planning and to engage in an effective discourse the local communities.

The scientific knowledge of climate change in South-East Europe (SEE) has improved over the past years. Results of several European research projects and systematic efforts coordinated by the Intergovernmental Panel on Climate Change (IPCC) in the Assessment Reports made it possible to refine our understanding of the ongoing and unavoidable social and environmental changes. The progress in adapting to these changes however is obstructed by fragmented and uncoordinated data services, patchy risk assessment procedures, and low uptake of the available knowledge in territorial development and climate sensitive sectors. Many SEE countries are exposed to sea level rise, increased disaster risk affecting the densely populated and most developed coastal areas.

The already disadvantaged rural areas are facing increases water stress as a result of altered precipitation, runoff and recharge patterns and rates, saltwater intrusion into coastal aquifers, increased domestic water demand, and the demands of the agricultural sector for irrigation of crops. Decline of ecosystem services for livelihood is further exacerbated by deteriorated water quality, land and ecosystems losses, and decline of wild and farmed fish stocks. Natural hazards are a major obstacle to sustainable development. Disaster risk can be framed in terms of changed frequency and/or intensity of extreme climatological and meteorological events such as storms, heatwaves and droughts; hydrological events such as flood and precipitation-triggered landslides; and secondary disasters such as industrial accidents and epidemic/infestation triggered by the above extreme events.

2.1. Aims and objectives

The OrientGate project aims to build a partnership between communities that produce climate knowledge and communities that apply that knowledge in order to coordinate climate adaptation actions across South Eastern Europe (SEE).

The main objectives refer to:

i) develop a comprehensive and consistent methodology for assessing the risks arising as a result of climate variability and change;

ii) harmonize risk assessment and communication procedures of hydro-meteorological services;

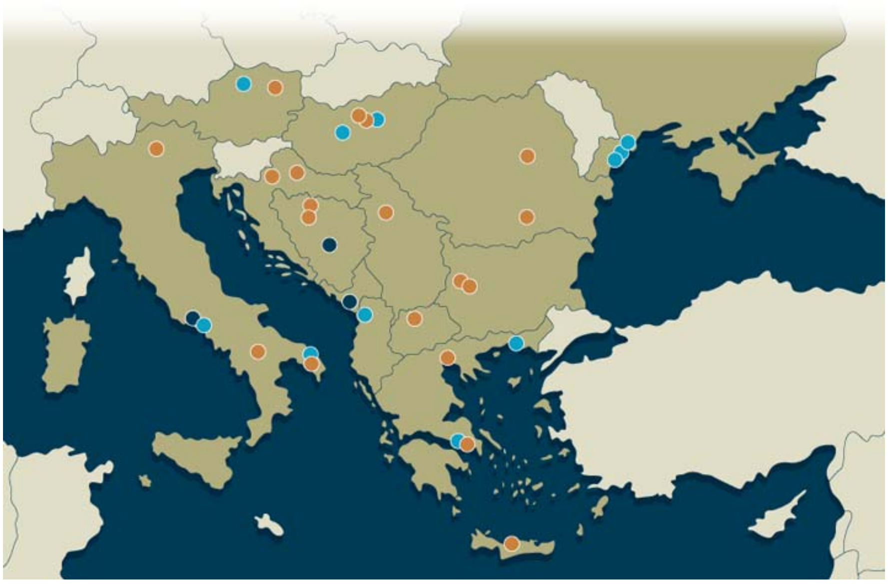
iii) foster the integration of climate adaptation knowledge in territorial planning and development;

iv) enhance capacity to reconcile the risks and opportunities of environmental changes

In summary the project brings a major contribution to connect climate change policy planners and decision makers with the scientific communities in order to find the most appropriate actions to reduce climate change effects in vulnerable sectors at regional and local levels.

The OrientGate partnership (figure 1) comprises 19 financing partners, 11 associates and 3 observers, covering 13 countries. Partners can be grouped into three main categories:

– scientific institutions;
– national hydro-meteorological services;
– institutions responsible for policy planning.



This map is based on the map published on the SEE Transnational Programme website.

Figure 1. *The Orientgate target area*

The project was conducted in the 2012-2014 period and is co-financed by the South East Europe (SEE) Transnational Cooperation Programme under Priority Axes 2 named “Protection and improvement of the environment”, respectively the Area of Intervention related to the improvement prevention of environmental risks.

2.2. Project activities

The activities of the project have been divided into seven (7) strongly interconnected work packages (WP). A part from the predefined 3 WPS, the thematic WPs include 'Mapping and Harmonising Data & Downscaling' (WP3), three WPs dedicated to the set-up of Thematic Centers which who developed pilot studies (WP4, 5 and 6) and one policy related WP aimed at boosting the uptake of the produced knowledge into territorial and sectoral policies (WP7 - Regional Planning Cross Sectoral Study).

The Euro-Mediterranean Centre on Climate Change (CMCC, Italy) as Lead Partner togheter with all partners contributed to outstanding results in order to become a landmark in this research area.

The short description of each work package comprises the following:

- WP2 conducted communication activities of the project;
- WP3 mapping the variety of the methodologies, tools and indicators used by the NMHSs across the SEE countries;
- WP4, 5 and 6 represents 3 Thematic Centers and ensured the implement-tation of 6 pilot vulnerability studies. Each pilot study is meant to demonstrate the use of the harmonized indicators of climate variability and change for the risk and adaptation need assessment in different sectors. Also, these contains the whole 'chain' from the monitoring/surveillance – risk and adaptation need assessment – uptake of the lessons and insights form the assessment exercises in the territorial development policies and planning processes.
- WP7 was dedicated on Regional Planning Cross Sectoral Study including cross sectoral adaptation strategies and vulnerability indicators. Training activities were foreseen in WP3, 4, 5, 6 and 7.

The Thematic Centers and pilot relevant studies are the following:

– *Thematic Centre 1*: Forestry and Agriculture
- ♦ *Pilot Study 1:* Adapted forest management at LTER Zöbelboden, Austria;
- ♦ *Pilot Study 2:* Climate change adaptation measures in Romanian agriculture;

– *Thematic Centre 2:* Drought, Water and Coasts
- ♦ *Pilot Study 3:* Climate change adaptation in the new water regime in Puglia region, Italy;
- ♦ *Pilot Study 4:* Effects of climate change on wetland ecosystems in Attica region, Greece;

♦ *Pilot Study 5:* Water resources and hydroelectric use, Trento, Italy;

– *Thematic Centre 3:* Urban Adaptation and Health

♦ *Pilot Study 6:* Vulnerability assessment in two Hungarian municipalities — 13th district of Budapest and Veszprém.

The implementation of a structured network able to support the cooperation among institutions (e.g. MetServices) and authorities (regional and local administrations) from different countries improved the use of information as a support in planning process for adaptation to climate change. Moreover, the involvement of partners determined the sharing of EU policies and standards by jointly implementing data and tools (e.g. INSPIRE, GMES) for climate vulnerability assessment and identifying adaptation measures (e.g. SET-Plan, WFD, STS, SEA) for climate adaptation plans.

2.3. Expected outputs and results

Adaptation is the "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (Source: IPCC's Five Assessment Report, AR5, Phase I Report Launch, 2014).

As a results, adaptation recommendations and tools are increasingly available to practitioners working in different sectoral, regional and organizational contexts. In other words adaptation requires actions at all levels – local, regional, national and international – and in all sectors. Also, the need for policy planning and development is an urgent issue to implement specific measures, especially in the case of sectors vulnerable to climate change, such as agriculture, forestry, water management, urban area, coasts zones and human health.

In this context, the OrientGate explored climate risks faced by coastal, rural and urban communities; contribute to a better understanding of the impact of climate variability and change on water regimes, forests and agro-ecosystems; and analyses specific adaptation needs in the hydroelectricity, agro-alimentary and tourism sectors. The principal scope of the project is to convey the up-to-date climate knowledge to policy makers who may best benefit from it, that is urban planners, nature protection authorities, regional and local development agencies, territorial and public works authorities.

The key results of project include

i) six pilot studies demonstrating the benefits of data and indicators harmonized across the region for designing specific climate adaptation policies and measures;

ii) a web-based data platform, maintained beyond the project duration and connected to the EU Clearinghouse on Climate Adaptation; and

iii) a series of capacity enhancing seminars and workshops, embedded in the context of each participating country's national platform for disaster risk reduction and climate adaptation.

Additionally, the results from the pilot actions, devoted to identify suitable adaptation measures through the vulnerability assessment of selected territories and themes, will be incorporated into guidance documents supporting the integration of climate change adaptation objectives into regional-level planning and programming. To make sustainable such results, links with sectoral and territorial plans will be identified during the project implementation to suggest synergies with already financed actions and plans at different institutional levels (national, regional and local). The developed guidance documents will be submitted to the already established mechanisms of Open Method of Coordination (OMC) such as the Common Implementation Strategy (CIS) established by Community Water Directors for the sake of a coordinated implementation of the European Water policies (e.g. Water Framework Directive 2000/60/EC and Floods Directive 2007/60/EC).

The "Blueprint" outlines actions that concentrate on better implementation of current water legislation, integration of water policy objectives into other policies, and filling the gaps in particular as regards water quantity and efficiency. The objective is to ensure that a sufficient quantity of good quality water is available for people's needs, the economy and the environment throughout the EU.

3. Climate Changes Scenarios and impact on agriculture

3.1. In Europe

Since 1950, high-temperature extremes such as (hot days, tropical nights, and heat waves have become more frequent, while low-temperature extremes (cold spells and frost days) were more less frequent. The period from 2004-2013 was the warmest decade on record in Europe. (Source: EEA, Reports 2012 and 2014). As the climate changes, extreme weather events like heat waves, droughts, heavy rain and snow, storms and floods are becoming more frequent or more intense. Southern and central Europe has seen more frequent heat waves and droughts.

Rainfall patterns are also changing. The Sothern Europe area is becoming drier, making it even more vulnerable to drought and wildfires. As a consequence, the pedological drought may become more severe due to increasing of evapotranspiration. Projected changes in the length of meteorological dry spells show that the increase is large in Southern Europe. Considering these aspects the irrigation needs will increase and will be constrained by the increasing of evapotranspiration and the high demands of crops during the summer time especially. Northern Europe, meanwhile, is getting significantly wetter, and winter floods could become common. Increases in extreme rainfall are projected to further increase coastal and river flood risk in Europe and, without measures to adapt to climate change, will substantially increase flood damage. Climate change is expected to cause significant changes in the quality and availability of water resources (Source: EEA, Reports 2012 and 2014).

Summarizing the results that the climate is changing across the world, and changes in global and regional temperatures are already modifying weather patterns, causing a number of impacts and increasing the vulnerability of regions, economic sectors and communities (figure 2).

In the IPCC WGII AR5 Chapter 23 (Final draft published in March 2014) it is mentioned also that in Europe “the observed climate trends and future climate projections show regionally varying changes in temperature and rainfall with projected increases in temperature throughout Europe and increasing precipitation in Northern part and decreasing precipitation in Southern regions. Climate projections show a marked increase in high temperature extremes, meteorological droughts, and heavy precipitation events with variations across Europe”.

In this context, the Southern Europe is more vulnerable to climate change several sectors will be affected such as: agriculture, forestry, energy, infrastructure, human health, etc.

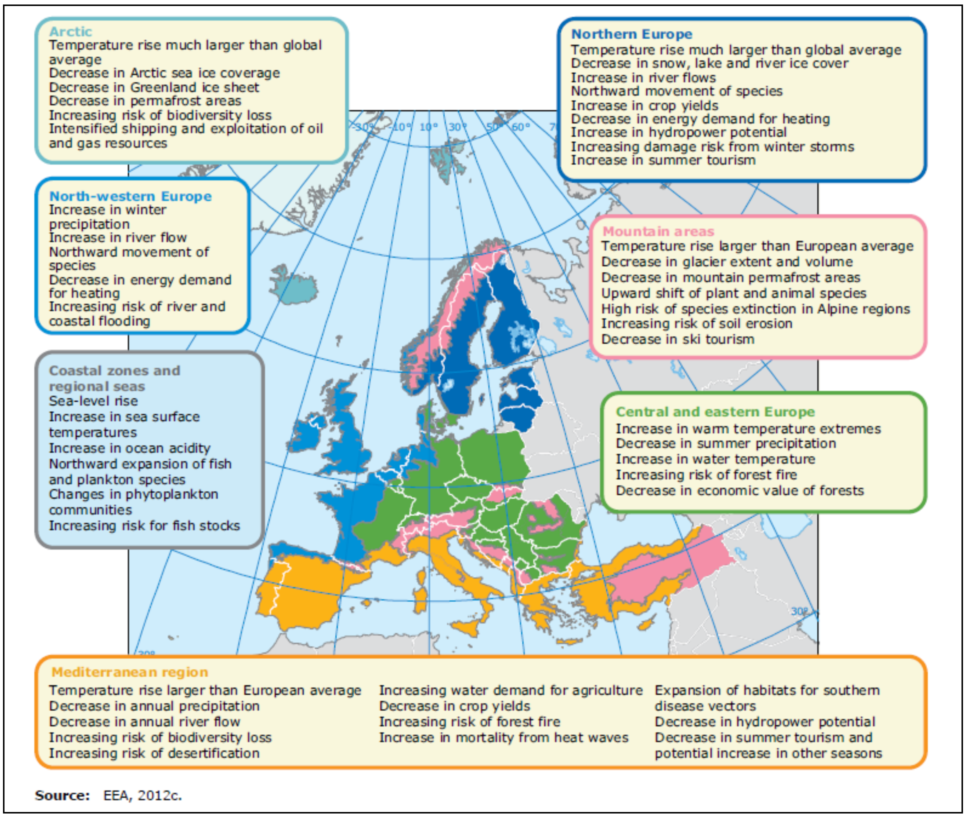


Figure 2. *An overview of regional climate change impacts and vulnerabilities in Europe (Source: EEA Reports, 2012c and 2013)*

3.2. In Romania

Romania's climate is a transitional temperate-continental one with oceanic influences from the West, Mediterranean modulations from the South-West and excessive continental effects from the North-East. Climatic variations are modulated by geographical elements, the position of the main mountain chain; elevation, the location of the Black Sea, etc (figure 3 and 4). The average annual temperature varies with latitude, from 8°C in the North to 11°C in the South, with around 2.6°C in the mountains and 11.7°C in the plains (figure 2). Annual average amounts of precipitations vary between less than 300 mm/sqm*yr and 1200 mm/sqm*yr (figure 4).

During the period 1901-2012, the mean annual air temperature increased by 0.8°C.

In the last 112 years, the warmest year was 2007 (with an average temperature of 11.5°C) and the coldest one, 1940 (with an average temperature of 8°C). An absolute minimum temperature of – 38.5°C was recorded at Bod in Brasov County and an absolute maximum temperature of 44.5°C at Ion Sion in the Baragan

Plain. The evolution by decades of the mean multiannual air temperature over the 1961-2010 period show that the air temperature rose by 0,4...0,6°C in the 2001-2010 interval in comparison with every decade. The increasing trend is obvious especialy begining with 1971.

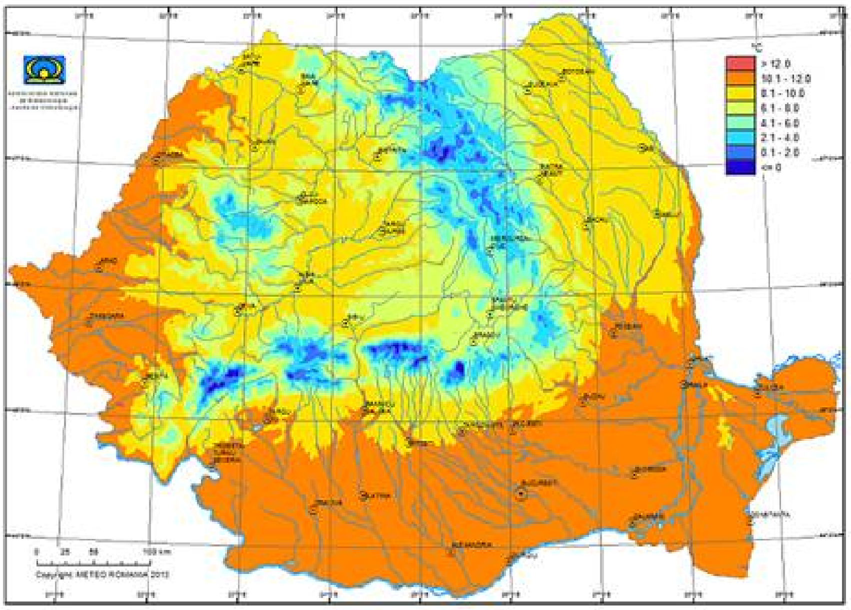


Figure 3. *Multiannual mean of air temperature (in ºC) for the interval 1961-2012*

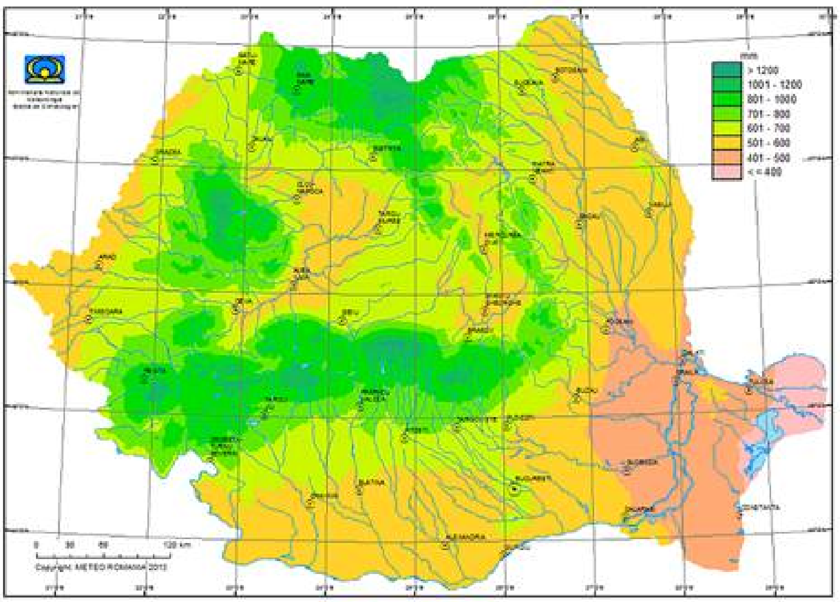


Figure 4. *Multiannual mean of precipitation amount (in mm) for the interval 1961-2012*

As for the precipitation, the analysis of the data recorded during the interval 1901-2012 revealed a slightly decrease in the annual amount of precipitation (23.6 mm) (figure 4). The highest annual rainfall amount recorded in Romania was 2401.5 mm in 1941, Omu weather station. The largest monthly amount of rainfall, 588.4 mm was recorded in June 2011 at the Balea Lac. Absolute maximum amount of rainfall in 24 hours was recorded at the meteorological station Deva, on 07/19/1934.

The climate data recorded over the last decades have therefore shown a progressive warming of the atmosphere as well as a higher frequency of extreme events, rapid alternations of severe heat/drought and heavy precipitation being more and more apparent. As it can be seen, the climate change effects in Romania have been clearly mirrored by modifications in the temperature and precipitation regimes, mainly since 1961 until now, with significant influences upon plant growth and development.

In this context, water scarcity and pedological droughts especially in south and south-east part of Romania can cause drastic yields decreases, particularly during the excessively droughty agricultural years (such as 2006-2007 and 2011-2012), and the higher/lower than optimum temperatures are reflected by metabolically reactions in plants, causing thermal stress especially in summer and winter, while every modification in the trend of their lows can easily aggravate frost injury in sensitive plants.

The 2001-2012 interval was particularly droughty. Average yields of various crops in droughty years in Romania are only 35-60% of the yields which could be obtained under complete provision of crop water requirements by the availability of water sources and maximizing efficiency, in full compliance with the Water Framework Directive. The excessively droughty agricultural years 2011-2012 strongly impacted about 5.9 million hectares, the level of losses varying over different area and culture. The magnitude of the losses range is from -18.6%, for wheat yields to -80.2% for rape, passing through -46.1% below the average for corn yields. From the areas affected by drought, during 2011-2012, over 1.9 million hectares are areas with crops in arable land.

The area subjected to desertification, characterized by an arid, semiarid or subhumid-dry climate is cca 30% of the total surface of Romania, being mostly situated in Dobrudja, Moldavia, the south of the Romanian Plain and the Western Plain (figure 5). This area is prevailingly used for agriculture (cca. 80% of the total, 60% of which is arable land), sylviculture (cca. 8%) and waters (Source: National Strategy for the mitigation of the drought effect, preventing and combating land degradation and desertification in the short, mean and long range, Ministry of Agriculture and Rural Development, 2008).

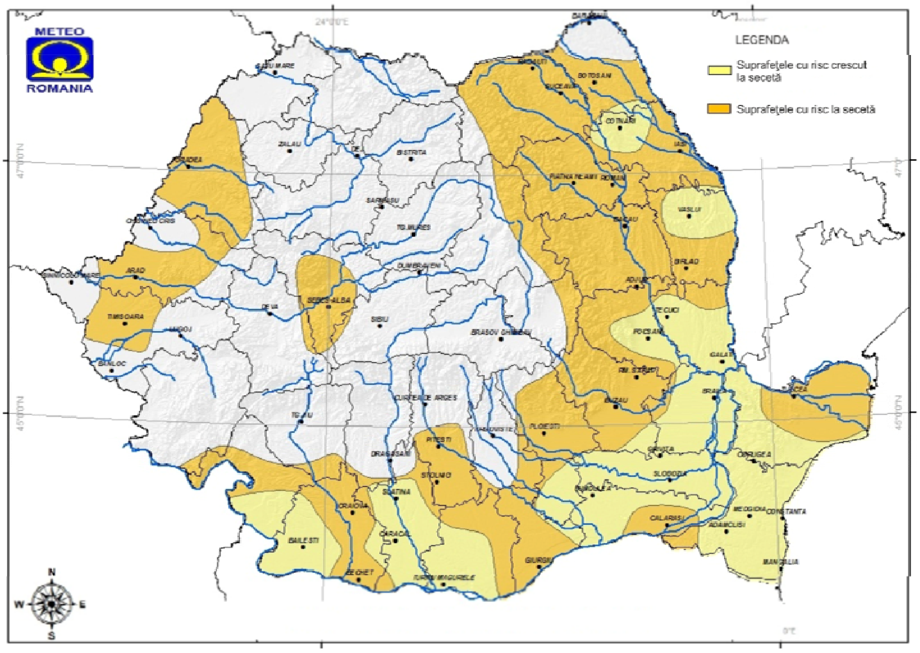


Figure 5. *Agricultural surfaces in Romania affected by drought*

Drought periods and heat waves are of particular interest, the main agricultural crops in Romania, winter wheat and maize, being the most affected crops by the occurrence of these two phenomena. In this context, the adaptation of crop species to limitative conditions can be mainly based on scientific approach.

Every solution aimed to support the actions for climate risk adaptation policies in agriculture should include the complete range of known measures (agro-technical, cultural, irrigation etc.) as well as dedicated technical practices to locate and confine every extreme weather phenomenon in order to avoid aggravated consequences (Mateescu et al, 2010, 2012).

In July 2013, the Romanian Government adopted the Governmental Decision no. 529/2013 on the National Climate Change Strategy (2013-2020). The National Climate Change Strategy (2013-2020) establishes the post Kyoto objectives, targets and actions for two main components, respectively the reduction in the concentration of greenhouse gases (Mitigation) and the adaptation to climate change (Adaptation). One of the main sectors vulnerable to CC refers to the agriculture. According the integration of the adaptation plans in the sectoral strategies will help to have a comprehensive approach and select appropriate measures for the direct and indirect effects of climate change (including drought and other extreme events). In other words, this gives support to develop the scientific results based on dedicated pilot studies.

4. The Pilot Study 2 – concept, description and analysis

The Thematic Centre 1 developed in WP 4 focuses on the assessment of agro- and silvicultural adaptation topics of management and policy in the context of climate change and its impact.

By means of two Pilot Studies, the first is focused on the analisys of climate change adaptation in forest of the Austrian Alps (LTER Zöbelboden) being coordinated by Forestry Department of Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW (Austria), and the second refers to the agricultural adaptation measures in Romania (Covasna and Caracal agricultural area) coordinated by the National Meteorological Administration of Romania in collaboration with Environmetal Protection Agency of Covasna. The Pilot Study regions represent characteristic areas of the respective countries: on the one hand the forest types of LTER Zöbelboden that are typical for the Northern Limestone Alps in Austria. On the other hand, the agricultural areas of Covasna County, situated in the central part and Caracal County in the South, cover the typical range of agroclimatic conditions of Romania.

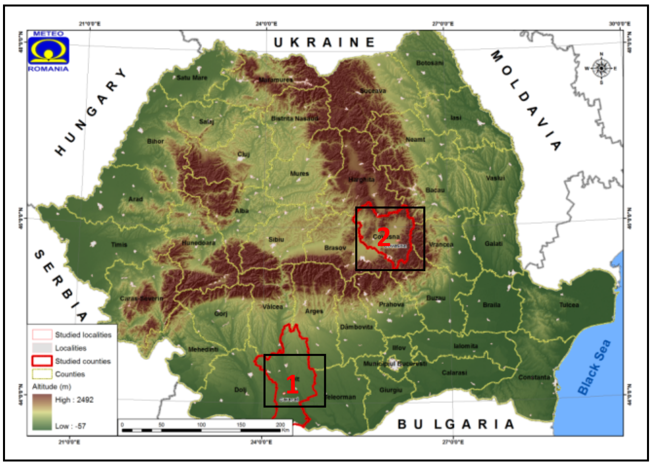
4.1. Objectives

The Pilot Study 2 has as main objective the identification of measures to adapt crops to climate change in two different areas in Romania (Caracal in South of the country and Covasna in the centre). Secondly, the Pilot is creating direct linkages between the researchers and the practitioners (farmers). It is seen as an opportunity by the scientific community to share findings and learn from the practical measures and knowledge in two different sites selected based on historical climatic data how show that these areas where frequently affected especially by drought and periodically by other extreme events (heat waves, heavy rainfall, wind storms, etc). Also, the need to identify critical issues related to climate adaptation was crucial. Another important argument was the structure of crops and the need to find different adaptation options for farmers in the context of current and future climate changes. In these two selected areas the agriculture is traditionally developed by farmers in order to get sustainable production in every year and to provide better crop management systems.

For this reason the linkage between scientific community and practitioners must be correlated with the need to put in practice the scientific climate knowledge according with the necessity to improve the technology and resource management in terms of relation of the crops-water-soil.

4.2. Methodology

The area of interest of the Pilot Study 2 is represented in figure 6 indicating the 2 test areas in the South (Olt County / Caracal area) and Center (Covasna County / Tg. Secuiesc area) of Romania.



1. **Olt County (Caracal area)** is located in the south part of the Oltenia region, in a vulnerable area to extreme conditions (drought/ water scarcity).

2. **Covasna County (Tg. Secuiesc area)** is located in the south-eastern part of the Transilvania region, in a vulnerable area to extreme events (drought/floods).

Figure 6. *The target area of Pilot Study 2*

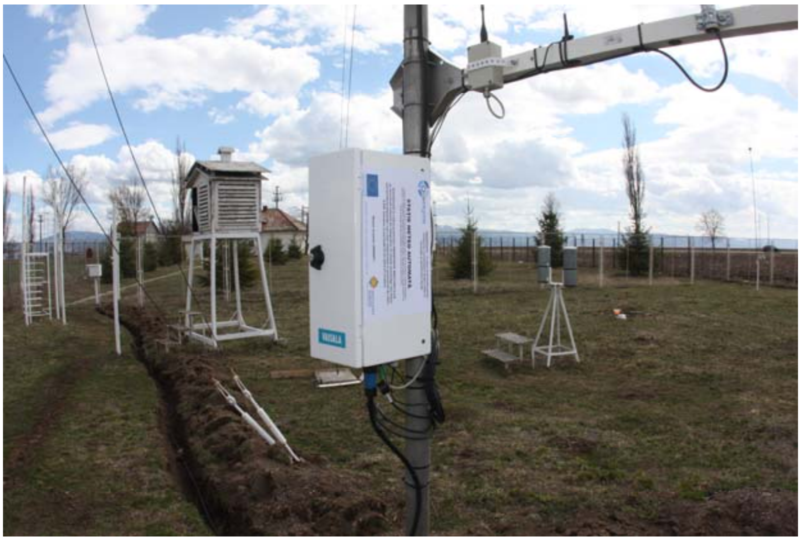
Two Romanian partners were leading the work: National Meteorological Administration (NMA) as responsible for implementing of Pilot Study 2 and Environmental Protection Agency of Covasna (EPA Covasna) as contributor to the implementation process. In order to analyze the historical data (1961-2010) meteo- and agrometeorological information from two weather stations has been used considered as representative of these two test areas: Caracal weather station and Tg. Secuiesc station from Covasna area.

To perform the study different cropping systems (winter wheat and maize) were selected and the CERES models in combination with the climatic predictions [RegCMs/SRES A1B climatic predictions at a very fine resolution (10 km) over 2021-2050 vs. 1961-1990 obtained in FP7 project ENSEMBLES and ensemble mean from CMIP5 experiments - RCP 2.6 and RCP 8.5 scenarios for 2021-2050 period vs. 1961-2000 interpolated at station point]. Also, the DSSAT model was applied to evaluate the potential impact of weather patterns on the productivity of selected crops. Different technological sequences were analyzed by alternative simulations of crop management practices: changes in sowing date, altered genetic coefficients (P1V and P1D) for genotype selection and crop irrigation needs during the vegetation season. Crop model were developed using observed field data (2001-2014) from both sites and were then used to assess climate change impacts. Climate conditions are also monitored through the testing stages of Pilot Study.

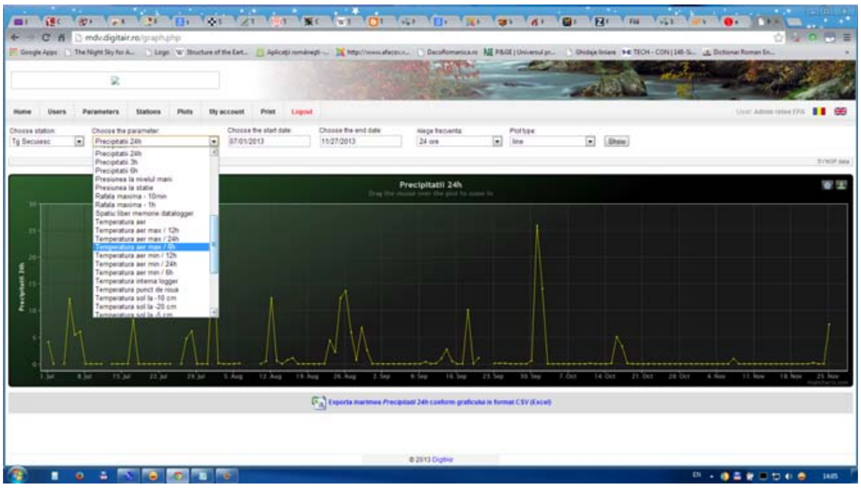
The EPA Covasna acquired weather station and computer software to gather and analyze daily meteorological data of Tg. Secuiesc area. Consequently local data, for example on soil moisture, water demand and rainfalls, air temperature, and phenological data were recorded in regional geographic information system (GIS) maps.

Purchase an Automatic Weather Stations installed in Târgu Secuiesc area.

The meteorological automatic weather station (MAWS) assured the measurements in the Th. Secuiesc area during being equipped with specific sensors (air temperature, relative air humidity, air pressure, wind speed and direction, precipitation) to monitor the climatic condition for the duration of the project with and even after the end of its.



Besides that automatically transmits data stored in the data collection system of NMA, the station allows beneficiaries in Covasna County to access the data recorded the website: http://www.apmcv.anpm.ro



Purchase of portable computer and GIS software for processing specific information.

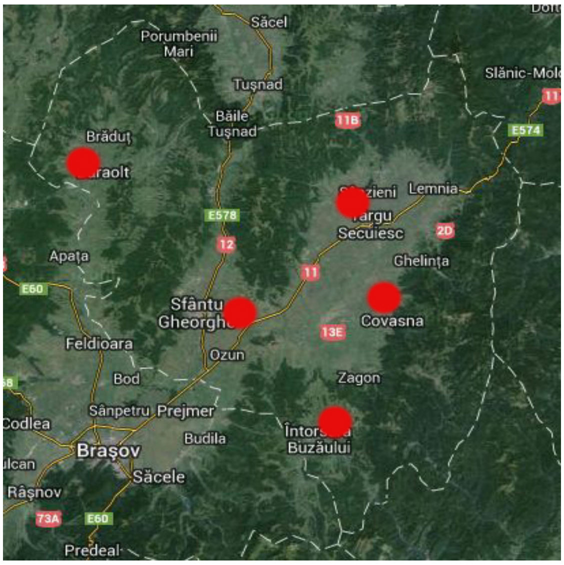
The purchase of a laptop computer for the work in the field during monitoring the crops, and Geographic Information Management software - ArcGIS 10.1, for preparing helpfull maps of agro-metorological data for the local farmers and authorities.

Training course of EPA team project.

The project team from EPA Covasna was trained by the specialists from NMA to use the GIS methods for presenting the available weather data in an accesibile shape for the beneficiaries in Covasna County.

Monitoring of crop vegetation during 2013 year.

Within the Pilot Study no. 2 activities, EPA Covasna selected and start to monitorizing specific crops (potatoes, winter wheat, maize), in different areas of the county (Sfântu Gheorghe, Târgu Secuiesc, Covasna, Întorsura Buzăului and Baraolt), over a whole vegetation cycle, during the 2013 year.



Monitorized croplands disposal in Covasna County

During the monitorizing period, the crops were checked every two weeks, and were recorded the vegetation stadium, the meteorological conditions, the technologies applied and the production achieved.

Images from the monitoring activities in different locations and crops, in the Covasna areas

Applying questionnaires

In order to evaluate the knowledge's of the local authorities and of the farmers regarding the climatic changes and the counter measure they apply, we applied questionnaires.

From the more than 50 questionnaires sent, we received back answers from 25 stakeholders and local farmers, most of them being representatives for the county agriculture.

Conclusions resulting from analyzing the questionnaires:

– The cultivated cropland have very different areas: from 1-2 ha to 30-40 ha;

– The seed used is sorted or from his own production, in variable proportions;

– The cultivation technologies are applied if there are enough money for that;

– The issue of water access, to their own well or to the irrigation systems, is widely spread;

– All of them are facing the phenomenom of climate changes and they all fight against the effects;

– Measures taken by farmers to prevent the effects of drought:

- Provide water as needed for crops!
- Changing the crop growing season!
- Changing the varieties used, with others more resistant to drought: with a shorter growing season
- Introduction of crops with low water requirements, to spare potato production
- Performing surface mechanical works, for soil crust cracking
- Performing mechanical work to decrease soil evaporation through capillary destruction
- Increasing the coefficient of soil organic matter through cultivation of green manure, after harvesting grain cereals, which then returns in the soil in the autumn plowing
- Using $CaCO_3$ amendments to adjust soil acidity (above pH> 6)
- Use of NITROCALCAR type fertilizer, instead of ammonium nitrate, not to increase soil acidity

– Measures required by farmers to be taken by the authorities to prevent and minimize the effects of climate change:

- Provide sources of cheaper electricity for agriculture
- Drilling of water wells in areas where needed
- Making the accumulation of water in unproductive lands, over water, etc.
- Easier Legal Access to drill their own wells for irrigation
- Facilitating access to existing irrigation systems
- Upgrading existing irrigation systems
- Massive, organized, systematic afforestation, including the establish-ment of shelterbelts against wind
- Creation of ponds (retention basins) with large areas of water surface, to collect water from periods of surplus and to humidify the air in summer
- Develop plans for efficient use of water resources at national level for agricultural purposes
- Making technical works in areas prone to flooding
- Conduct research to create new varieties of plants, adapted to the climate of excessive

Additionally, the NMA used satellite-derived indicators for the evaluation of crops vegetation state in the interest zones of the Pilot Study 2 such as: NDVI, NDWI, NDDI, ET and LAI. In order to highlight the land cover / use categories of the test area an unsupervised image classification for the Pleiadés images at different dates (10 May 2013, 03 July 2013 and 26 August 2013) was applied. By regrouping the classes, a map with 6 main land cover / use classes (water, winter crops, summer crops, pastures, barren soil, urban), was finally obtained. A set of dedicated indicators (1961-2010) was used for the risk assessment like: Standardized Precipitation Index 3 months (SPI3), Soil Moisture reserve – Rf (SM), Heat stress (HT), Aridity Index (AI), total precipitation in wet days (PRCPTOT), and consecutive dry days (CDD). Also, satellite derived indices such as: Normalized Difference Vegetation Index (NDVI), Normalized Difference Drought Index (NDDI), Normalized Difference Water Index (NDWI) was applied.

4.3. Stakeholders involvement

Local municipalities in Caracal and Covasna were involved during the whole project-period. They provided technical support for the implementation of results in order to develop drought-risk management tool and adaptation measures and contacts with local farmers for testing techniques and implementing results. Also, the Agricultural Research-Development Station of Caracal will use the findings of the pilot results to develop own research on obtaining varieties and hybrids with high adaptability to local climate and soil conditions. To ensure transfer of knowledge 3 thematic seminars and 3 scientific meetings among *OrientGate* partners and Romanian stakeholders were planned: local, regional and national authorities in the sectors of agriculture, farmers, water, environment, emergency response, education and public administration; urban planners; academic institutions; and representatives from civil society. We can say so that project results are useful to a better understanding of the climate change impact and adaptation actions as a good example at regional and local level helping the authorities to implement measures and actions resulted from the Study Pilot 2.

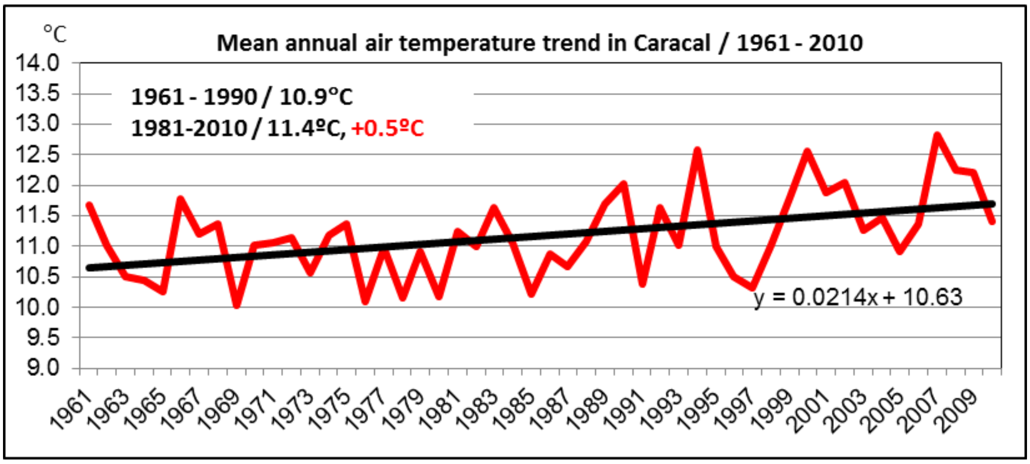
The training activities with stakeholders and local authorities and managers will raise also the awareness of CC issue. Finnaly, the seminars were an excellent opportunity to exchange experiences with the experts of the Federal Ministry of Agriculture, Forestry, Environment and Water Management, Forest Department from Austria (BMLFUW/PP13), which is the coordinator of the TC1.

Finnaly, the Orientgate project can be considered as scientific support for Romania's climate adaptation regional policy, given the National Climate Change Strategy for 2013-2020 recently adopted by the Romanian Government (GD 529/July 2013). Basically, the project results aimed to support the actions and procedures for climate risk prevention and mitigation in agriculture should include the complete range of known measures (agro-technical, cultural, irrigation etc.) as well as actual interventions to locate and confine every extreme weather phenomenon in order to avoid severe consequences.

4.4. Results

4.4.1. Observed changes and future scenarios on climate conditions in the Pilot Study 2 areas

In Caracal area, the mean annual air temperature rose by 0,5°C and in Tg. Secuiesc area by 0.4°C in the 1981-2010 period in comparison with climatic period of reference (1961-1990), figure 7. As regards precipitation, a trend of decreasing in the annual precipitation amounts in Caracal area (526.1 mm/1981-2010 vs. 565.9/1961-1990) and a slight increase in the Tg. Secuiesc area (513.1 mm/1981-2010 vs. 500.8 mm/1961-1990) could be observed.



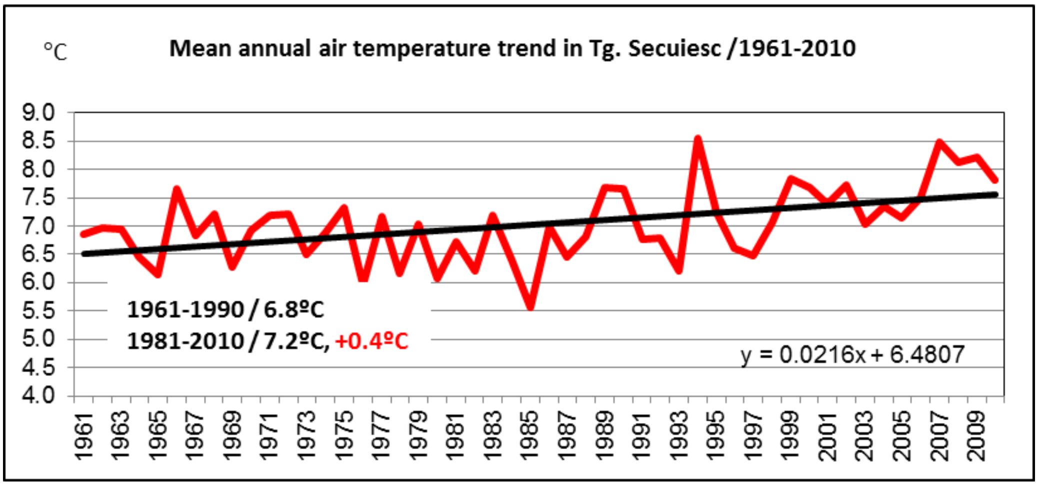


Figure 7. *Air temperature trend in Pilot Study 2 agricultural area*

Plants' need of heat depends on plant species (thermophilic, mezophilic) and phenological phases (germination, emergence, leafing out, grain/seed formation and filling etc.).

Air temperature highs associated with high levels of humidity deficits in air (atmospheric drought) and soil (pedological drought) define a complex phenomenon – the agricultural drought – with severe effects upon plants:

► in *winter wheat*, especially during May and June, fertilization-pollination is affected, with a poor dry matter accumulation in grains, pronounced grain scorching, forced maturation and ripening, and finally a significant decrease in yields;

► in *maize,* particularly through July and August, such conditions cause a hydric stress that is highly unfavorable when it lasts for several consecutive days (at least five). It is in these conditions that pollen is shed before tassel emerged, which hastens male inflorescence development and its emergence several days (10-12 days) before stigmata, many plants becoming sterile or having cobs with many missing grains.

In addition, in the warmest years the physiological processes in crop plants could be affected due to significantly higher thermal stress especially over the critical interval for crops (May-August).

In the table below are presented the warmest years since 1961 until 2010. Notice that the 10 and 9 warmest years were recorded in the period 2000-2010.

***Table 1.** The warmest years in* Pilot Study 2 agricultural area

Warmest years in Caracal, over 1961 – 2010 period (1961-1990 / 10.9℃)			*Warmest years in Tg. Secuiesc, over 1961 – 2010 period (1961-1990 / 6.8℃)*		
	Annual air temperature	Deviation		Annual air temperature	Deviation
1. 2007	12.9°C	1.9°C	1. 1994,	8.6°C	1.8°C
2. 1994, 2000	12.6°C	1.7°C	2. 2007	8.5°C	1.7°C
3. 2008, 2009	12.2°C	1.3 °C	3. 2009	8.2°C	1.4°C
4. 1990, 2002	12.0°C	1.1°C	4. 2008	8.1°C	1.3°C
5. 2001	11.9°C	1.0°C	5. 1999	7.8°C	1.0°C
6. 1966, 1999	11.8°C	0.9°C	6. 1966, 1989, 1990, 2000, 2002	7.7°C	0.9°C
7. 1961, 1989	11.7°C	0.8°C	7. 2006	7.5°C	0.7°C
8. 1983, 1992	11.6°C	0.7°C	8. 2001, 2004	7.4°C	0.6°C
9. 2004	11.5°C	0.6°C	9. 1975	7.3°C	0.5°C
10. 1968, 1975, 2006, 2010	11.4°C	0.5°C	10. 1971, 1972, 1968, 1977, 1983	7.2°C	0.4°C
11. 2003	11.3°C	0.4°C	11. 1998, 2005	7.1°C	0.3°C

We can note that in terms of monthly air temperature data the highest values were recorded in winter and summer months at Caracal and as regards precipitation the mean monthly values register in general a decrease in ten months out of the twelve month also (table 2). In Tg. Secuiesc area the air temperature has a tendency to increase in nine months the highest values of over 1ºC in descending order by registering it in the coming months: January, August and July. The monthly rainfall have registered positive or negative deviations throughout the year (table 2).

Table 2. *Mean monthly air temperature and monthly rainfall amounts in Pilot Study 2 area over 1981-2013, compared with baseline climate period (1961-1990)*

CARACAL												
Interval	Monthly air temperature (ºC)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961-1990	-2,3	0,1	5,2	11,7	17,1	20,5	22,5	21,8	17,8	11,4	5,3	0,2
1981-2013	-1,2	0,7	5,8	11,7	17,5	21,4	23,5	22,9	17,8	11,7	5,0	0,0
Deviation	1,1	0,5	0,6	0,0	0,5	0,9	1,0	1,2	0,0	0,3	-0,3	-0,2
	Monthly rainfall amounts (mm)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961-1990	38,7	38,9	40,0	47,9	63,1	73,2	60,4	46,3	32,1	32,4	47,7	45,2
1981-2013	31,9	29,6	36,9	43,9	51,6	60,2	51,8	41,0	38,5	39,3	41,0	40,5
Deviation	-6,8	-9,3	-3,1	-4,0	-11,5	-13,0	-8,6	-5,3	6,3	6,9	-6,7	-4,7
TG. SECUIESC												
	Monthly air temperature (ºC)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961-1990	-5.8	-3.5	1.4	7.6	12.8	15.7	17.1	16.6	12.9	7.3	2.1	-2.9
1981-2013	-4.6	-3.7	1.6	7.7	13.4	16.5	18.2	17.8	13.0	7.7	1.8	-3.2
Deviation	1.3	-0.2	0.2	0.1	0.6	0.7	1.0	1.1	0.1	0.4	-0.2	-0.3
	Monthly rainfall amounts (mm)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1961-1990	20,7	18,8	19,8	44,9	64,4	79,8	79,2	68,8	39,3	27,4	20,1	17,5
1981-2013	17,0	18,5	22,6	44,7	69,0	82,6	74,3	67,4	42,0	31,8	20,7	22,6
Deviation	-3,7	-0,3	2,8	-0,2	4,6	2,8	-4,9	-1,4	2,7	4,4	0,6	5,1

The frequency of droughty/rainy years recorded in the two test areas is shown in figure 8. Notice that in both of these areas dominated by the droughty years which recommend specific measures for the adaptation of agricultural technologies to water deficit.

CARACAL / 1961 – 2010	TG. SECUIESC / 1961 – 2010
⇒ 2 years / 4.0% - excessively droughty years (<350.0 mm/year) ⇒ 9 years/18,0%-dry years (351.0–450.0 mm/year) ⇒ 25 years/50,0% - moderate dry years (451.0– 600.0 mm/year) ***TOTAl years - 36 years / 72,0% excessively droughty, dry and moderate dry years*** ⇒ 6 years/12,0%-optimal years (601.0– 700.0 mm/year) ⇒ 8 years/16,0% - excessive rainy years (701.0 – 800.0 mm/year)	- ⇒ 14 years/28,0%-dry years (351.0 – 450.0 mm/year) ⇒ 28 years/56,0% - moderate dry years (451.0– 600.0 mm/year) ***TOTAl years - 42 years / 84,0% dry and moderate dry years*** ⇒ 6 years/12,0%-optimal years (601.0–700.0 mm/year) ⇒ 2 years / 4,0% - excessive rainy years (701.0 – 800.0 mm/year)

Figure 8. *The frequency of droughty/rainy years in Pilot Study 2 agricultural area*

Within the context of present climate change, in Romania, the frequency of occurrence of droughty years was higher in the last decades. It can be seen that from 1901 until now in the Pilot Study 2 agricultural area in every decade one to five extremely droughty/ rainy years occured and an increasing number of droughts being more and more apparent after 1981 (tables 3 and 4).

Table 3. *The frequency of droughty/rainy years in Caracal agricultural area*

DECADE	CARACAL area / OLT County XX-TH CENTURY	
	EXTREMELY DROUGHTY YEARS	EXTREMELY RAINY YEARS
1961-1970	1961-1962, 1967-1968 / 2 years	1968-1969, 1969-1970 / 2 years
1971-1980	1973-1974, 1975-1976 / 2 years	1972-1973, 1978-1979 / 2 years
1981-1990	1982-1983, 1984-1985, 1986-1987, 1989-1990 / 4 years	-
1991-2000	1992-1993, 1994-1995,1995-1996, 1999-2000 / 4 years	1990-1991 / 1 year
	XXI-ST CENTURY	
2001-2010	2000-2001, 2001-2002, 2002-2003, 2006-2007, 2008-2009 / 5 years	2004-2005, 2005-2006, 2009-2010 / 3 years
2011-2020	2011-2012, …………..	2013-2014, …………..

***Table 4 .**The frequency of droughty/rainy years in Covasna agricultural area*

DECADE	TG. SECUIESC area / COVASNA County XX-TH CENTURY	
	EXTREMELY DROUGHTY YEARS	EXTREMELY RAINY YEARS
1961-1970	1961-1962, 1962-1963, 1963-1964 / 3 years	1969-1970 / 1 year
1971-1980	1973-1974, 1975-1976 / 2 years	1972-1973, 1974-1975, 1978-1979 / 3 years
1981-1990	1984-1985, 1985-1986, 1986-1987, 1989-1990 / 4 years	-
1991-2000	1991-1923, 1993-1994,1997-1998 / 3 years	1990-1991 / 1 year
	XXI-ST CENTURY	
2001-2010	2000-2001, 2002-2003, 2005-2006, 2006-2007 / 4 years	2009-2010 / 1 year
2011-2020	2011-2012, ……….	2013-2014, ……….

The RCP 2.6 and 8.5 projections from the CMIP5 experiments for 2021-2050 periods vs. 1971-2000 indicate an increase of the average annual air temperature, more pronounced in the case of 8.5 scenarios and a decrease of annual rainfall in both scenarios, especially in the Southern and Eastern regions of the country (figure 9). The data represent the ensemble mean consisting of 21 models from CMIP5 experiments, the annual air temperature differences being expressed in ºC and rainfalls in percentage (%).

For the summer season the projections indicate also an increase of air temperature more pronounced in the case of RCP 8.5 scenario in most part of the country. As to precipitation, both scenarios indicate a decrease in the Pilot Study 2 area, respectively Caracal (1) and Covasna (2) areas (figure 10).

In the context of global warming, changes in the climate regime of Romania are modulated by regional conditions. Also, projections show that changes in mean temperature and precipitation occur along with changes in extreme phenomena statistics. Extremes related to temperature increase are spatially and temporally prevailing under climate change.

The climate in Romania is expected to undergo significant changes over the coming decades. In near future term (2021-2050), the most pressing consequences are those related to thermal changes (e.g. hotter summers with more frequent and persistent heat waves) over entire country (more pronounced over Southern and Eastern regions) and to reduction in mean precipitation in Southern part of Romania. Estimates based on analysed projections suggest that on the longer terms

(2021-2050) the temperature increase will continue to grow and the reduction in mean precipitation will extend over majority areas of the country, especially in warm season. The rainfall reduction seems to be more pronounced in the Southern and Eastern regions of Romania.

RCP 2.6 Scenario RCP 8.5 Scenario

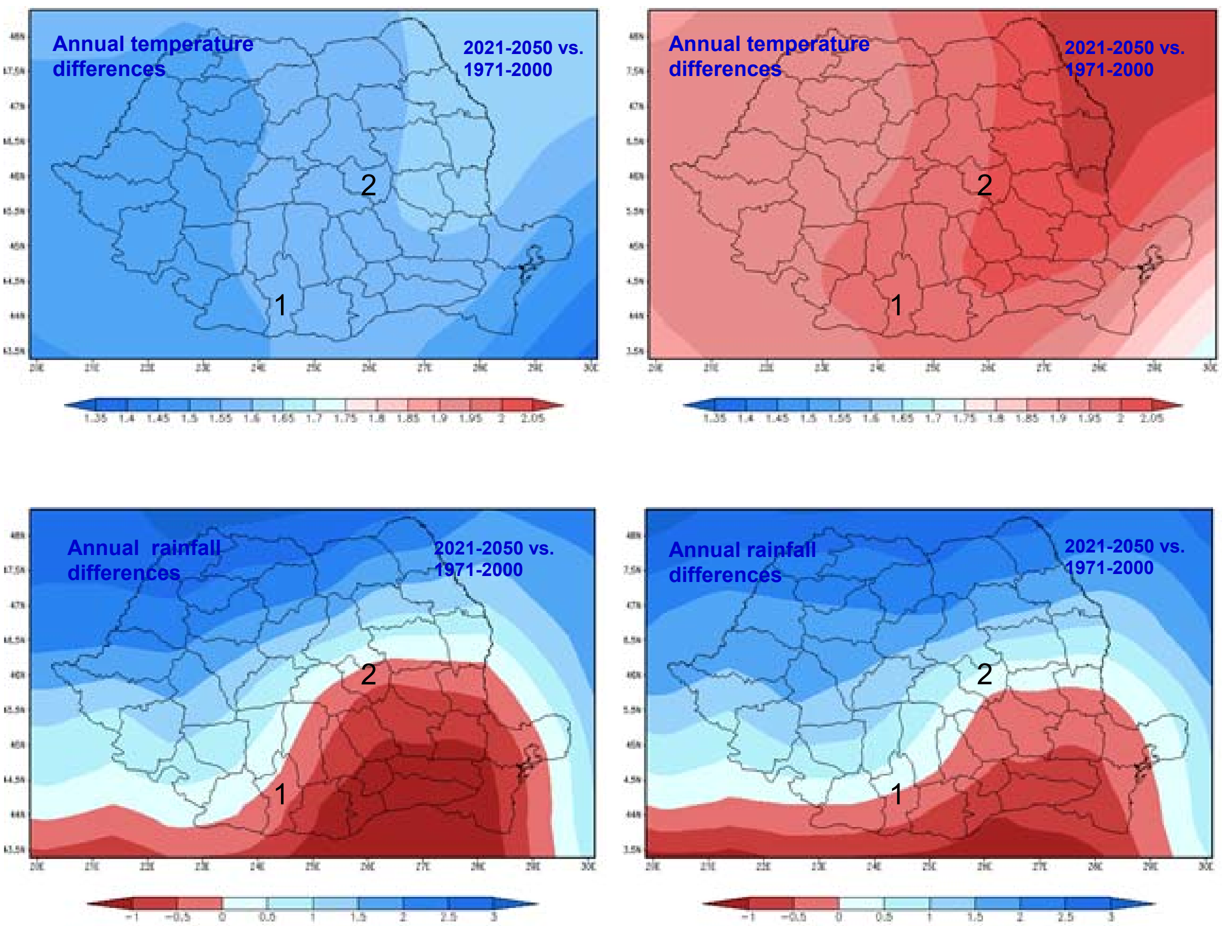


Figure 9. *The average annnual air temperature and rainfall projections from the CMIP5 experiments for 2021-2050 vs.1971-2000* (1- Caracal and 2- Covasna area)

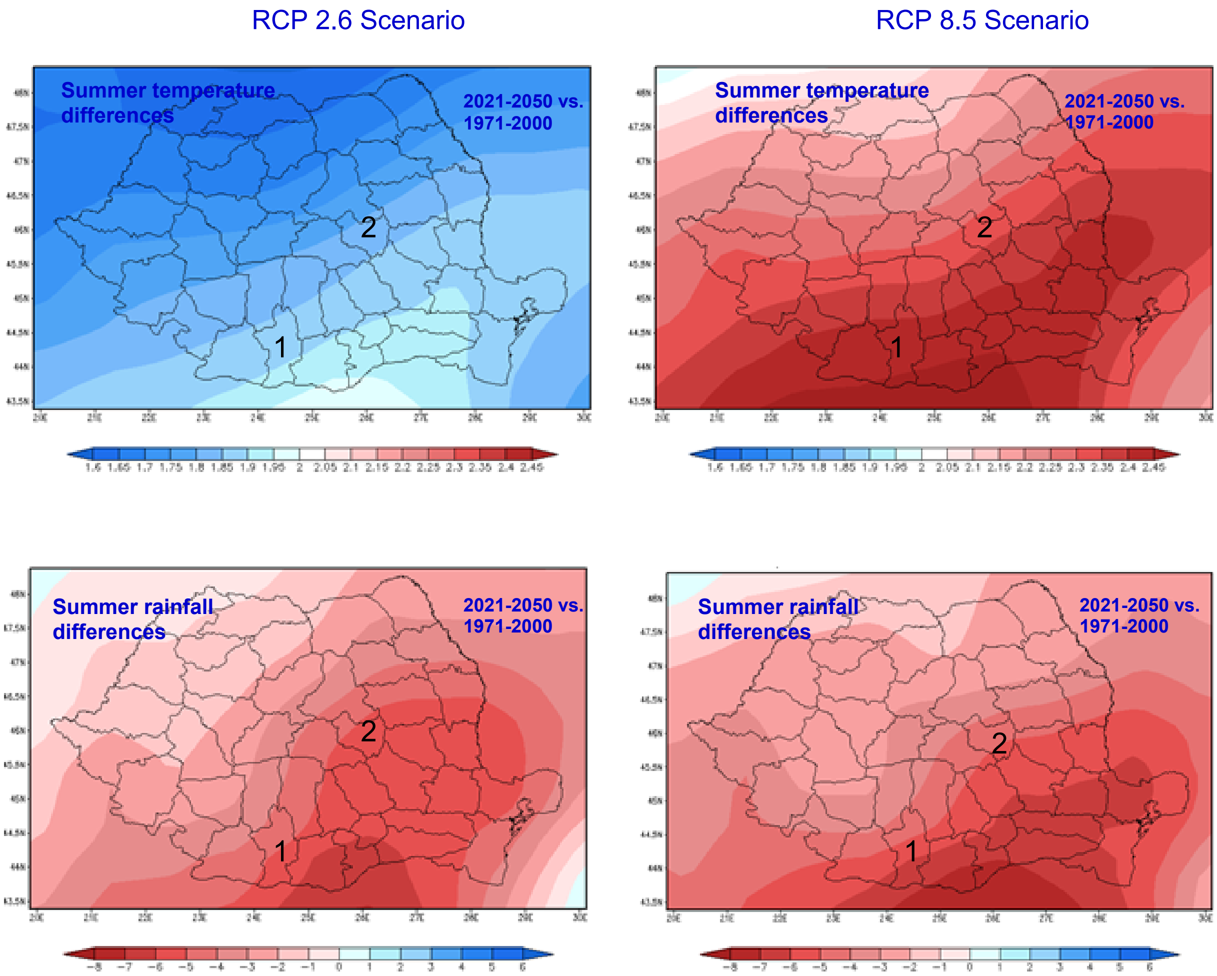


Figure 10. *The air temperature and rainfall projections in summer season from the CMIP5 experiments for 2021-2050 vs.1971-2000* (1- Caracal and 2- Covasna area)

The analysis compared to the period 1961-1990 has predicted an increase in mean annual air temperatures by around 1.8°C in Caracal area and 1.5°C in Tg. Secuiesc area respectively. The projections indicate a decrease of annual amount rainfall by 0.7% in Caracal and an increase by 6.1% in Tg. Secuiesc. In the summer season the monthly rainfall will decrease in comparison with the current period, an obvious decrease being possible especially in Caracal area (table 5).

Table 5. Projected changes of the monthly air temperature and rainfall for decade 2021-2050 in Pilot Study 2 agricultural area (*ensemble mean from CMIP5 experiments /RCP 2.6 scenario for 2021-2050 periods vs. 1961-1990 interpolated at station point)*

	CARACAL RCP 2.6 2021-2050 vs. 1961-1990		**TG. SECUIESC** RCP 2.6 2021-2050 vs. 1961-1990	
	Air Temperature (ºC)	Rainfall (%)	Air Temperature (ºC)	Rainfall (%)
January	1.6	1.5	1.5	7.4
February	2.1	3.7	2.1	12.2
March	2.4	1.1	2.4	12.3
April	2.3	5.5	2.1	13.5
May	2.4	0.3	1.9	4.8
June	2.5	-8.2	2.0	-5.1
July	2.3	-6.2	1.7	0.6
August	1.8	-2.7	1.1	5.2
September	1.2	5.7	0.7	11.7
October	1.0	-2.8	0.6	8.3
November	0.9	-0.9	0.7	6.3
December	1.2	-1.1	1.0	4.6
Annual	**+1.8°C**	**-0.7%**	**+1.5°C**	**+6.1%**

4.4.2. Drought indicators – climatic, agrometeorological and satellite derived indices

Crop productivity is affected by drought and the application of the different drought indexes for the identification and monitoring of phenomenon appears to be very useful for Romanian conditions particularly combining different time scales.

Drought indicators are the common measures for drought assessment being designed to provide a concise overall picture of phenomena derived from massive amounts of climatic and agrometeorological data, and are used for making decisions on water resources management for mitigating the negative impacts.

Drought intensity may be identified by different dedicated indexes prezented in table 6.

Table 6. *Drought indexes*

Drought Index	Description
Standardized Precipitation Index (SPI)	It is calculated from the long-term record of precipitation in each location (at least 30 years)
Palmer Drought Severity Index (PDSI)	Index based on evaluating soil moisture on the basis of an algorithm calibrated for homogeneous regions.
Standardized Precipitation Evapotranspiration Index (SPEI)	Is based on precipitation and temperature data, and it has the advantage of combining multiscalar character with the capacity to include the effects of temperature variability on drought assessment.
Soil Moisture (SM)	It is calculated based on soil water balance model. Requires in-situ measurements on the soil water moisture over various profiles/depths and at crop-specific calendar dates and provide information on areas affected by pedological drought phenomenon in terms of intensity, duration and spatial distribution.
Normalized Differences Vegetation Index (NDVI)	Used for accurate monitoring of vegetation dynamics as well as for the determination of the beginning, the end and the duration of the vegetation season.
Normalized Difference Water Index (NDWI)	Is a good indicator of water content of leaves and is used for detecting and monitoring the humidity of the vegetation cover.
Leaf Area Index (LAI)	Represents the amount of leaf material in an ecosystem and is geometrically defined as the total one-sided area of photosynthetic tissue per unit ground surface area. It is a good indicator of vegetation condition, relevant for installation, duration and intensity of drought.
Green Vegetation Index (GVI)	Is suitable to evaluate the effects of variations in soil water content.
Normalized Difference Infrared Index (NDII)	The index values increase with increasing water content (figure 29). Its applications include crop agricultural management, forest canopy monitoring, and vegetation stress detection.

4.4.2.1. The *Standardized Precipitation Index (SPI)* is an indicator to reflect drought situations, in comparison to historical records. This indicator can produce different time-related outputs, so meteorological drought evidence and evolution can be shown for the past month(s), season(s) and/or year(s), facilitating the establishment of links to other drought indicators.

The SPI developed in 1993, shows precipitation shortfall and excess over a variety of time scales (table 7).

Table 7.

SPI ≥ 2.0	Extremely wet
1.5 < SPI ≤ 2	Severely wet
1 < SPI ≤ 1.5	Moderately wet
-1 < SPI ≤ 1	Near normal
-1.5 < SPI ≤ -1	Moderately dry
-2 < SPI ≤ -1.5	Severely dry
SPI ≤ -2	Extremely dry

The three-month SPI provides a comparison of the precipitation over a specific 3-month period with the precipitation totals from the same 3-month period for all the years included in the historical record. A 3-month SPI reflects short- and medium-term moisture conditions and provides a seasonal estimation of precipitation. A 3-month SPI would capture precipitation trends during the important vegetation phases (reproductive and early grain-filling stages, the growing season etc).

A 3-month SPI was evaluated in terms of capturing precipitation trends during the important vegetation phases (reproductive and early grain-filling stages, the growing season etc) for the observed drought events. A 3-month SPI is supposed to reflect short- and medium-term moisture conditions and provides a seasonal estimation of precipitation.

Figure 11 presents the 3 – month SPI values show highlighting and expanding the rainfall deficit intensity in the most extreme droughty agricultural years in Romania in 2000-2012 period (2000, 2003, 2007 and 2012) especially during the months with high requirements for water crops (such as June-July-August which is the critical period for grain filling or November corresponding to the emergence period).

The results indicate that in extreme droughty events of rainfall deficit widened significantly affect the processes of growth and development of crops in the Pilot Study 2 such as 2000, 2003, 2007 and 2012 years.

Another climatic drought indicator refers to the *Palmer Drought Severity Index (PDSI),* built by Palmer in 1965. The PDSI has been computed based on the components of the local hydrological budget, taken into account not only the deficit in precipitation, but other variables as well, like air temperature, evapotranspiration and available water capacity (AWC) of the soil (Palmer, 1965; Alley, 1984). The Palmer index PDSI for drought severity (PDSI) is a diagnostic tool for multiannual or monthly behavior of aridity.

In figure 12 is shown the spatial distribution of the Palmer Drought Severity Index (PDSI) calculated for the warm season months (May-August) in Romania in the period 1961-2010. The negative values indicate the tendency of aridity and the positive ones show exceeding rainfalls. Hatched zones show statistically significant trends at a 90% confidence level (according with Mann Kendall test). Analysis of data indicates an increasing trend of aridity in the agricultural areas of Pilot Study 2 (Figure 12).

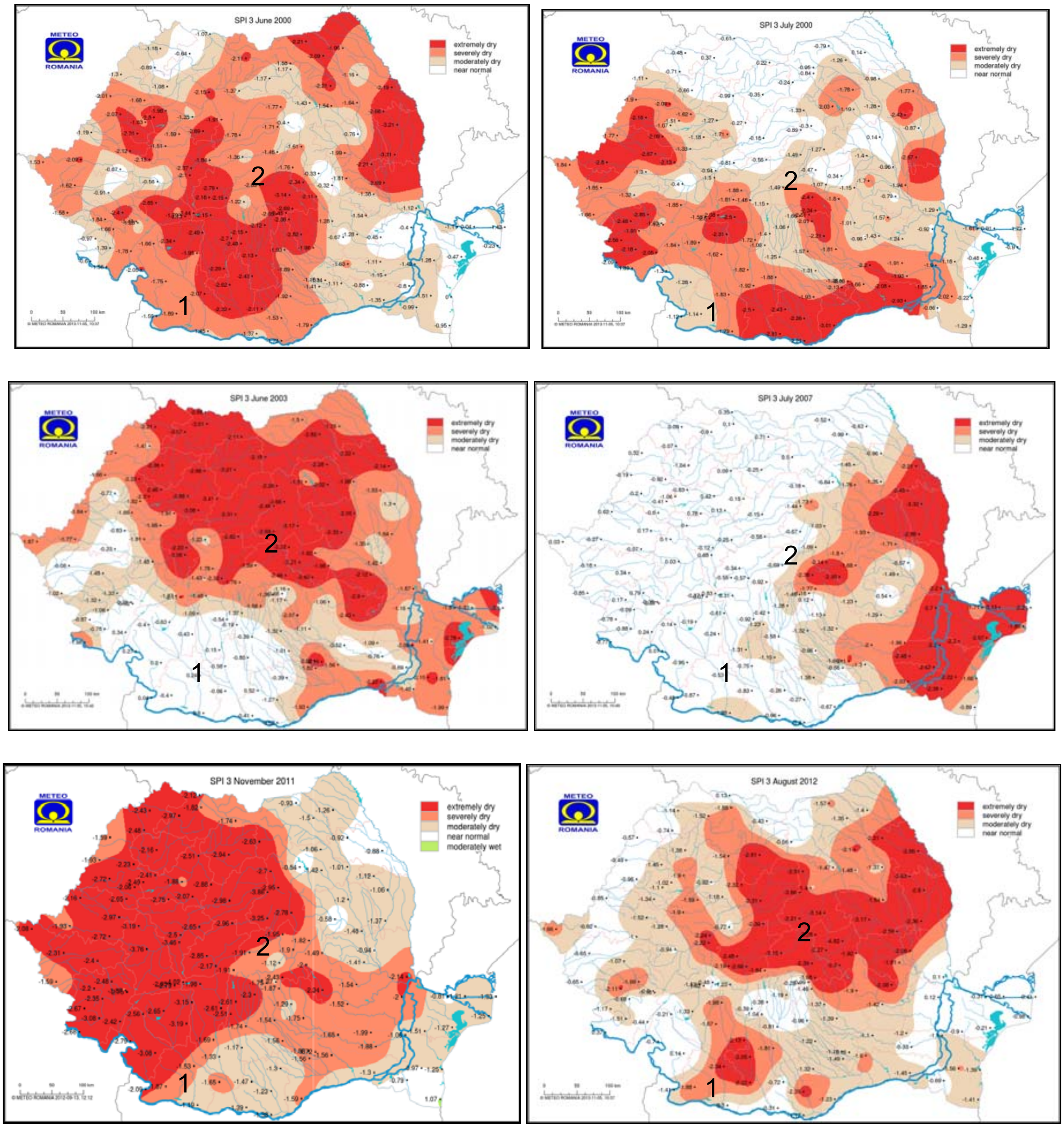


Figure 11. *The 3 – month SPI values in the most droughty years from 2000-2012 period (1 – Caracal and 2 – Covasna area)*

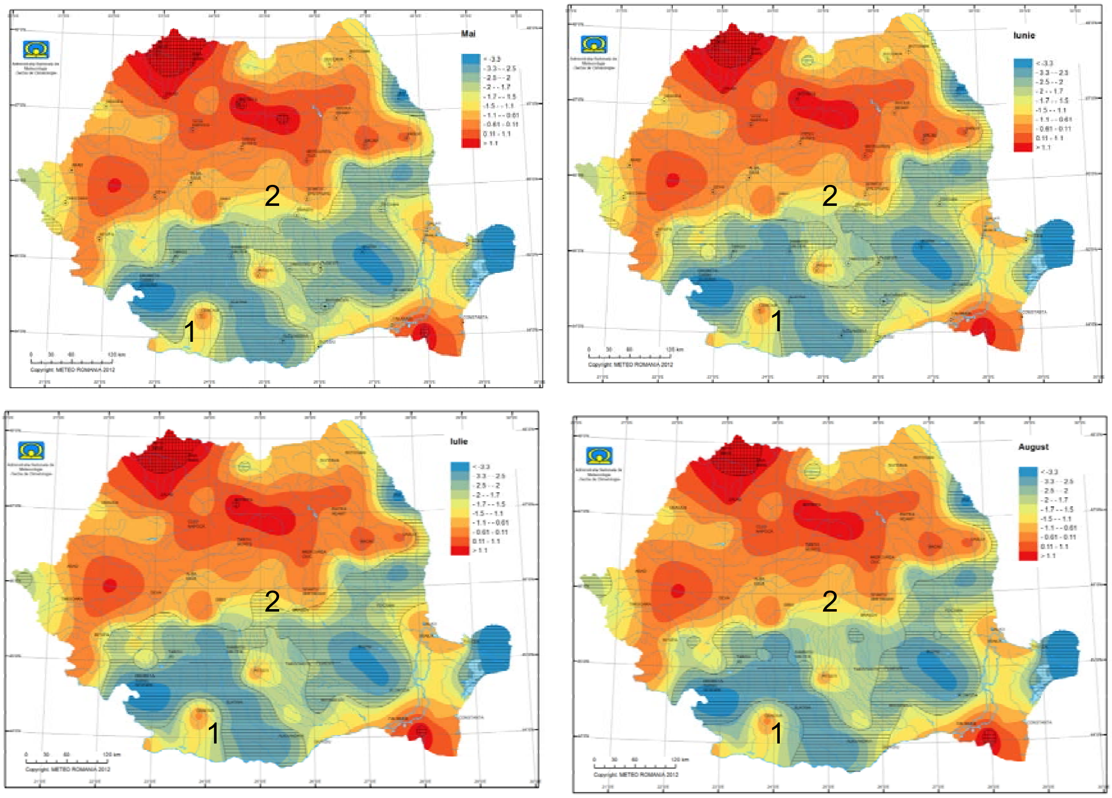


Figure 12. *Spatial distribution of the Palmer Drought Severity Index (PDSI) for the warm season months (May-August over the 1961-2010 period). The negative values indicate the tendency of aridity and the positive ones show exceeding rainfalls. Hatched zones shows statistically significant trends at a 90% confidence level (according with Mann Kendall test) (1 – Caracal and 2 – Covasna area)*

4.4.2.2. *The Soil Moisture Reserve* is one of the most important agrometeo-rological indicators expressing the water supply degree of the soil function of the water demand of the agricultural plants at specific calendar dates and various depths (0-20 cm, 0-50 cm and 0-100 cm). Classification of the humidity classes is presented in the table 8.

Table 8. *The humidity classes*

% of AWC	Humidity classes
0 – 20 %	Extreme pedological drought / ED
20 – 35%	Severe pedological drought / SD
35 – 50%	Moderate pedological drought / MD
50 – 70%	Satisfactory supply / SS
70 – 100%	Optimal supply / OS
>100%	Above normal moisture values / EX

Mapping of the soil moisture reserves (m3/ha) for the maize crops shows that the agricultural areas of the Pilot Study 2 are in generally affected by deficit especially in July and August (critical period for maize and sun-flower crops). The figure 13 presents maps of pedological drought phenomena during the observed extreme droughty events years in 2000-2012 period (2000, 2007 and 2012).

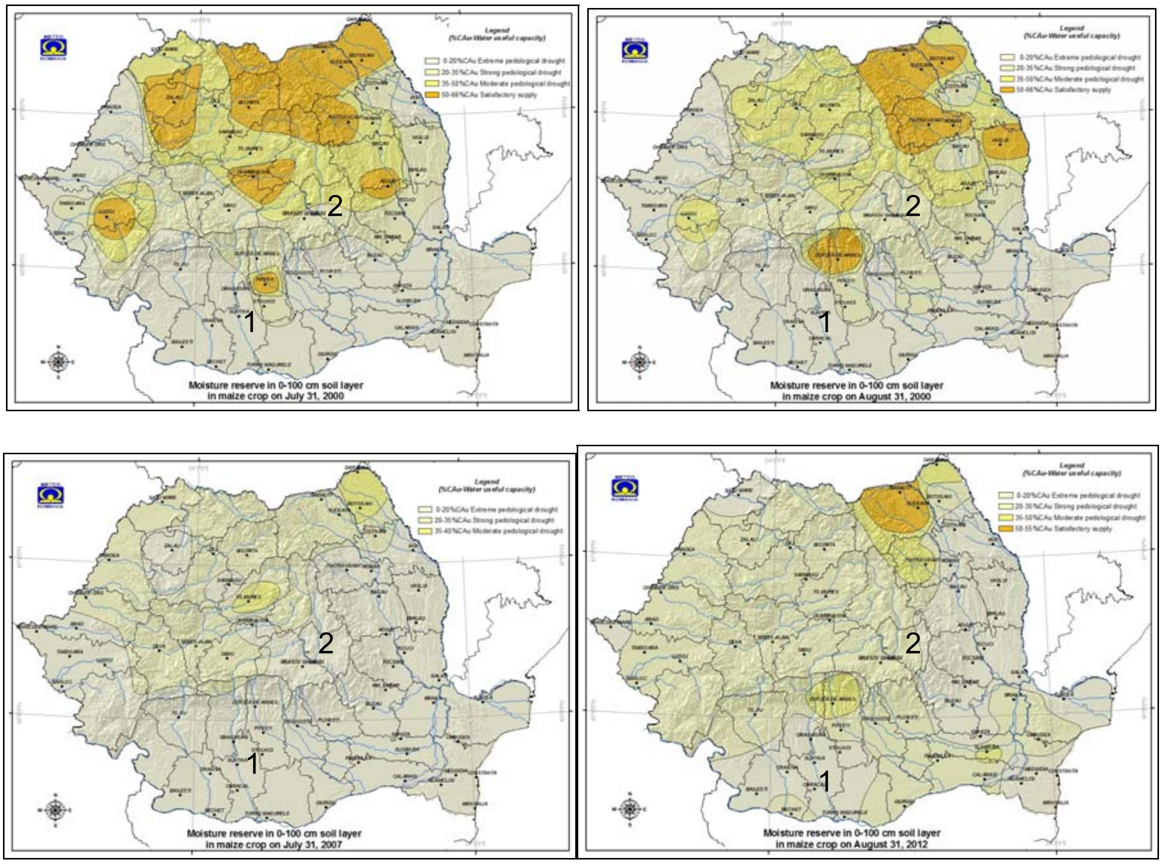


Figure 13. *Soil moisture reserve in the most extreme droughty years in the Pilot Study 2 area (1- Caracal and 2- Covasna area)*

A *heat wave* is a prolonged period of excessively hot weather. The definition recommended by the World Meteorological Organization is when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5ºC, the normal period being 1961–1990.

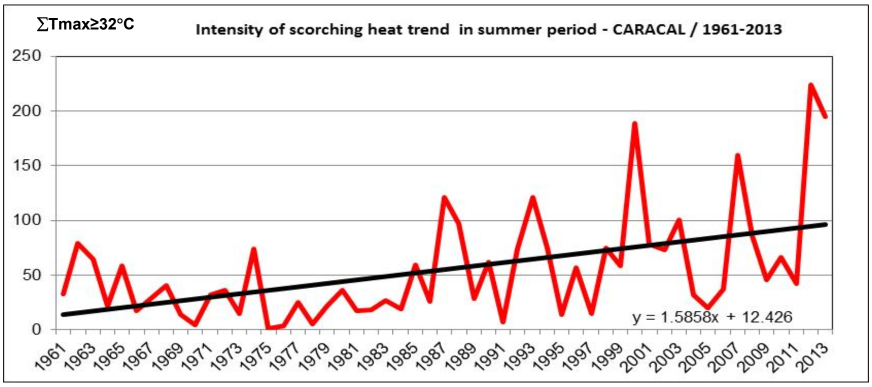
In Romania, a national heat wave is defined as a period of at least 3 consecutive days in which the maximum temperature reaches or exceeds 32°C. During the critical period for crops (June-August), the intensity of thermal stress evolution is made obvious by the scorching heat phenomenon, described by sums of daily air temperature highs equal to or above 32°C. This level (32°C) is a critical biological threshold representing the maximum air temperature that, on being topped, affects the optimum growth and development in cereal species particularly during the interval of great requests of heat, namely June-August. Air temperature highs above the critical biological threshold of 32°C (scorching heat) associated with high levels of humidity deficits in air (atmospheric drought) and soil (pedological drought) define a complex phenomenon – the agricultural drought – with severe effects upon plants.

Given the multi-annual means of scorching heat intensity, phenomenon quantified by sums of air temperature highs equal to or above 32°C recorded during the summer months, it has become apparent a significantly higher thermal stress over the critical interval for crops (June-August), an increase from 13 units of scorching heat between 1961 and 1990 to 28 units over 1981-2010 (table 9).

Table 9. *Intensity of scorching heat events in Romania, 1961-2010*

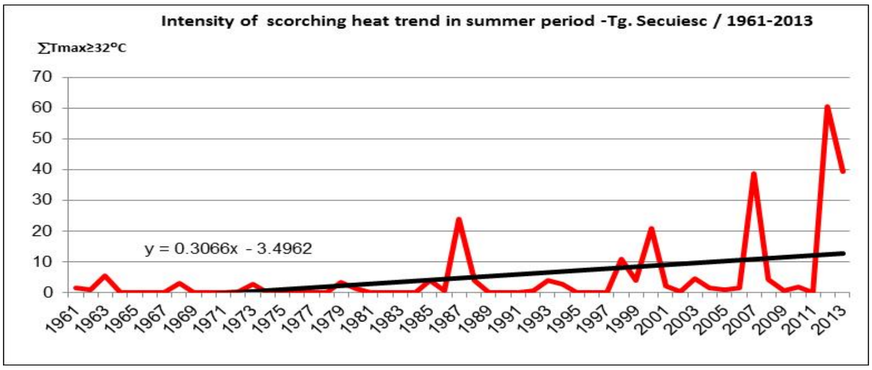
	Units of scorching heat (∑Tmax≥32°C, VI-VIII)
1961-1990	13
1971-2000	18
1981-2010	28
	2007 / 95 units **2012 / 123 units**

In the figure 14 are exemplified the intensity of scorching heat trend in summer period (June-August) in the Pilot Study 2 area the higher values registering especially through 1985 year.



CARACAL

1. 2012 / 224 Units
2. 2013 / 195 Units
3. 2000 / 189 Units
4. 2007 / 159 Units
5.1987,1993/121 Units



TG. SECUIESC / COVASNA

1. 2012 / 61 Units
2. 2013 / 40 Units
3. 2007 / 39 Units
4. 1987 / 24 Units
5. 2000 / 21 Units

1961-1990 / 2 Units
1981-2010 / 7 Units

Figure 14. *The evolution of scorching heat intensity in the Pilot Study 2 area /1961-2013*

Focusing on the warmest years, in five years they have reached the highest values compared to the normal (figure 14).

4.4.2.3. The satellite-derived vegetation indices data and biophysical parameters proved to be good indicators of vegetation condition and relevant for the installation, duration and intensity of the agricultural drought.

For the accomplishment of the project objectives it was used medium (TERRA/MODIS, SPOT/VEGETATION) and high resolution (Pléiades) satellite data.

Pléiades (1A & 1B), represent a new constellation of satellites, ensuring continuity of Earth observation up to 2023 [3]. The new high resolution Pléiades satellites, delivering as a standard, 50-cm ortho products. The first Pléiades (1A) was launched on 2011 and the second (1B) in 2012, both offering an ideal combination of coverage, resolution and speed.

The Pléiades satellites have a panchromatic band: Pan=0.47-0.83 µm and four multispectral bands: Blue = 0.43-0.55 µm, Green = 0.50-0.62 µm, Red = 0.59-0.71 µm, Near Infrared = 0.74-0.94 µm (NIR), with a product resolution by 0.5 m for panchromatic and 2 m for multispectral [3].

The revisit time is 1 day above 40^0 latitude within +/– 30^0 angle corridor (figure 15), 2 days between equator and 40^0 latitude and 1 day revisit with two satellites and an increased angle (45^0).

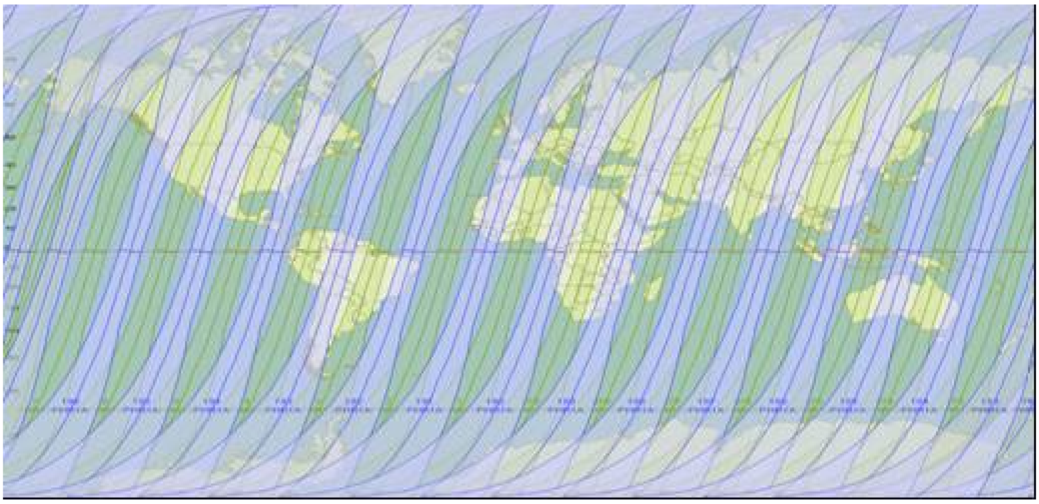


Figure 15. *Pleiades 1A & 1B combined corridor of visibility for the same day (+/– 300)*

Pléiades has an impressive acquisition capacity; the maximum theoretical acquisition capacity reaches 1 million square kilometres per day and per satellite (2 million for both). Pleiades coverage capacity is also due in part to its swath (20 km), the largest in this class of resolution, providing a larger native image footprint (from 30% to 73% better coverage compared to its peers in a single image).

A great feature of Pléiades is to offer a high resolution stereoscopic cover capability. The stereoscopic cover is achieved within the same pass of the area, which enables a homogeneous product to be created quickly. The system offers the possibility to achieve a “classical” stereoscopic imaging, composed of two images for which the angular difference (B/H) can be adjusted, but also stereoscopic imaging with an additional quasi vertical image (tristereoscopy), thus allowing the user to have an image and its stereoscopic environment.

Tri-stereo images can be used to create more accurate 3D models than can be done with basic Stereo, as the near nadir acquisition minimizes the risk of missing hidden items. This is ideal for dense urban and mountainous areas (Figure 16).

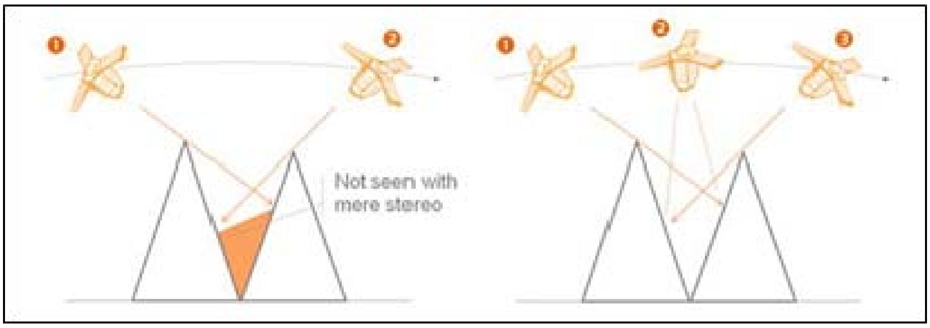


Figure 16. *Stereoscopic cover capabilities over mountainous areas*

The Pléiades products can be delivered in different raster formats like GeoTIFF or JPEG 2000, also a Rational Polynomial Coefficients are provided to easier orthorectification and geometric processing. A KMZ file format is included for easy and rapid display in Google Earth environment. Quality and cloud cover mask are included.

TERRA/MODIS

Moderate Resolution Imaging Spectre-radiometer (MODIS) is a key instrument aboard the Terra and Aqua earth observation system satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days.

MODIS has a viewing swath width of 2330 km and views the entire surface of the Earth every one to two days. MODIS is playing a vital role in the development of validated, global, interactive Earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment. In table 10, are presented the spectral bands of MODIS sensor.

Table 10. *MODIS bands and their corresponding wavelengths.*

MODIS Bands	Wavelengths (nm)
Band 1	620-670
Band 2	841-876
Band 3	459-479
Band 4	545-565
Band 5	1230-1250
Band 6	1628-1652
Band 7	2105-2155

The MODIS products in different spatial resolution can be downloaded from http://glovis.usgs.gov/ [9]. For this study were used vegetation index products (NDVI, NDWI) with spatial resolution by 500 m and eight days temporal resolution. The images were processed in specific remote sensing and GIS software.

SPOT/VEGETATION

The SPOT program is a series of Earth observing satellites launched by the French Centre National d'Etudes Spatiales (CNES), in cooperation with Belgium and Sweden [10].

The SPOT Vegetation sensor is carried aboard SPOT 4 and 5 which were launched in 1998 and 2002, respectively. The sensor is designed to monitor the Earth on regional and continental scales. It has the capability of imaging the entire Earth each day. It is particularly valuable for studying agriculture, deforestation, and other vegetation changes on a broad scale.

There are currently two Vegetation instruments on Spot satellites: Vegetation 1 (located in SPOT 4 Satellite) and Vegetation 2 (located in SPOT 5 satellite). SPOT Vegetation products are systematically acquired, archived, and available on-line. The VGT-S10 products (ten day synthesis) with 1 km resolution are compiled by merging segments acquired in a ten days. All the segments of this period are compared again pixel by pixel to pick out the 'best' ground reflectance values. These products provide data from all spectral bands, the NDVI and auxiliary data on image acquisition parameters.

The SPOT Vegetation product (NDVI) was acquired from VITO http://www.vgt.vito.be/.

Satellite data acquisition and processing

To have complex agro meteorological information it is necessary to improve the operational capabilities of monitoring using advanced remote sensing techniques and Geographic Information Systems (GIS).

Remote sensing techniques play an important role in crop identification, acreage and production estimation, disease and stress detection, soil and water resources characterization because they provide spatially explicit information and access to remote locations. These techniques allow examining the properties and processes of ecosystems and their inter-annual variability at multiple scales because remote sensing observations can be obtained over large areas of interest almost every day.

Data sets provided by satellite systems can be used in global, regional or local studies, to obtain input data used to produce various models of energy balance, water balance, etc.

From remote sensing data can be extracted biophysical and structural vegetation parameters: leaf area index, fraction of active photosynthetic active radiation, biomass, vegetation indices, etc.

For this task of the Orientgate project, three Pléiades images were acquired over the Caracal test site (figure 17).

Figure 17. *Caracal test site from Pleiades –10 May 2013 (resolution 2m)*

In order to highlight the land cover / use categories of the test area an unsupervised image classification for the Pleiadés image of 10 May 2013 was applied.

This method implies framing the pixels by certain classes without a prior need to construct samples in view to collect the spectral signatures; the unsupervised classification (initially by 30 classes) was performed with the support of the ERDAS-Image software. This type of classification is automatically performed, using an iterative method (in the sense that it ends the moment the best separation of the initially established classes is obtained).

Intervention may be performed in settling the number of classes, in defining certain statistical indicators taken into account and in establishing the distances among classes. In the case of the studied area, by regrouping the classes, a map with 6 main of land cover / use classes (water, winter crops, summer crops, pastures, barren soil, urban), was finally obtained (figure 18). A statistical approach underlines the large share of lands occupied by crops, usage categories specific to the plain area.

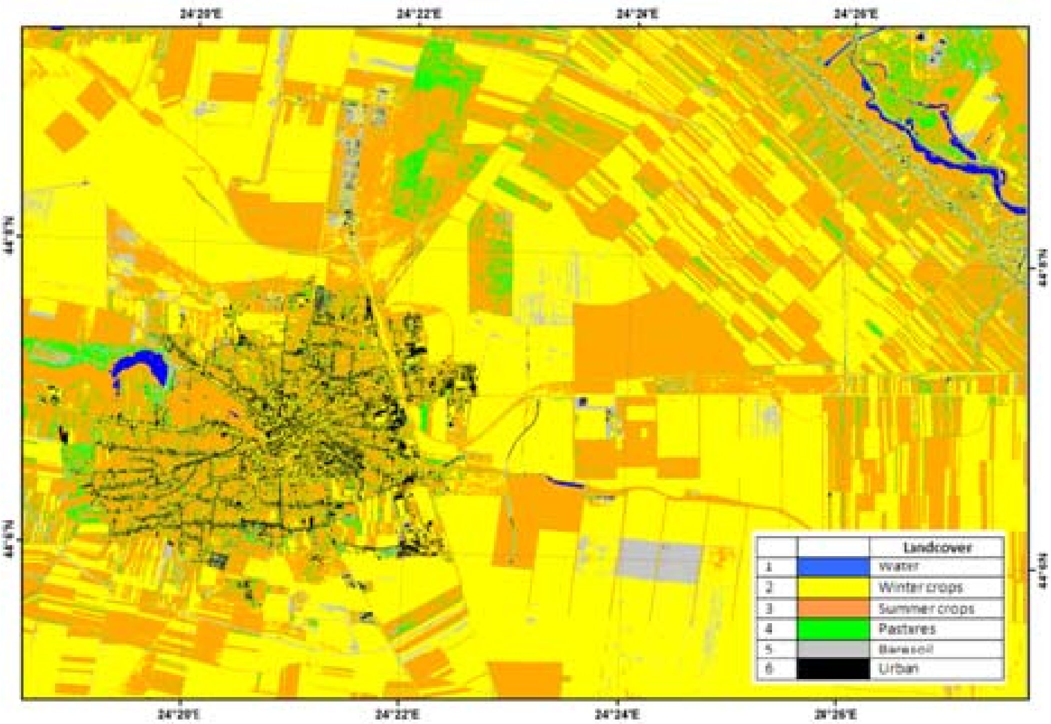


Figure 18. *Unsupervised classification of the test area from Pléiades, 10 May 2013*

Due to the satellite image capabilities in terms of spatial and spectral resolution, all the vegetation and crops type in the test area were correctly identified. For the agricultural crops classification, (especially for winter crops by summer crops discrimination), good results were obtained using the spectral bands 4 (NIR), 3 (blue) and 2 (green). For a better understanding and interpretation of vegetation classes and the computation of the vegetation indices, band combinations can be used to obtained color composite images.

By analyzing the images and knowing the crops phenology, land use and land cover have been determined for the test site, included the winter crops (wheat - Figure 19) and summer crops (corn and sun flower - Figure 20).

Figure 19. *Colour composite image (NIR, Blue and Green) for the test site – Pléiades, 10 May 2013*

Figure 20. Colour composite image (NIR, Blue and Green) for the test site – Pléiades, 03 July 2013

The Corine Land Cover (CLC) satellite-database was used to highlight the land cover / use categories of the Covasna study area (figure 21).

CLC uses a Minimum Mapping Unit (MMU) of 25 ha for areal phenomena and a minimum width of 100 m for linear phenomena. The time series are complemented by change layers, which highlight changes in land cover with an MMU of 5 ha.

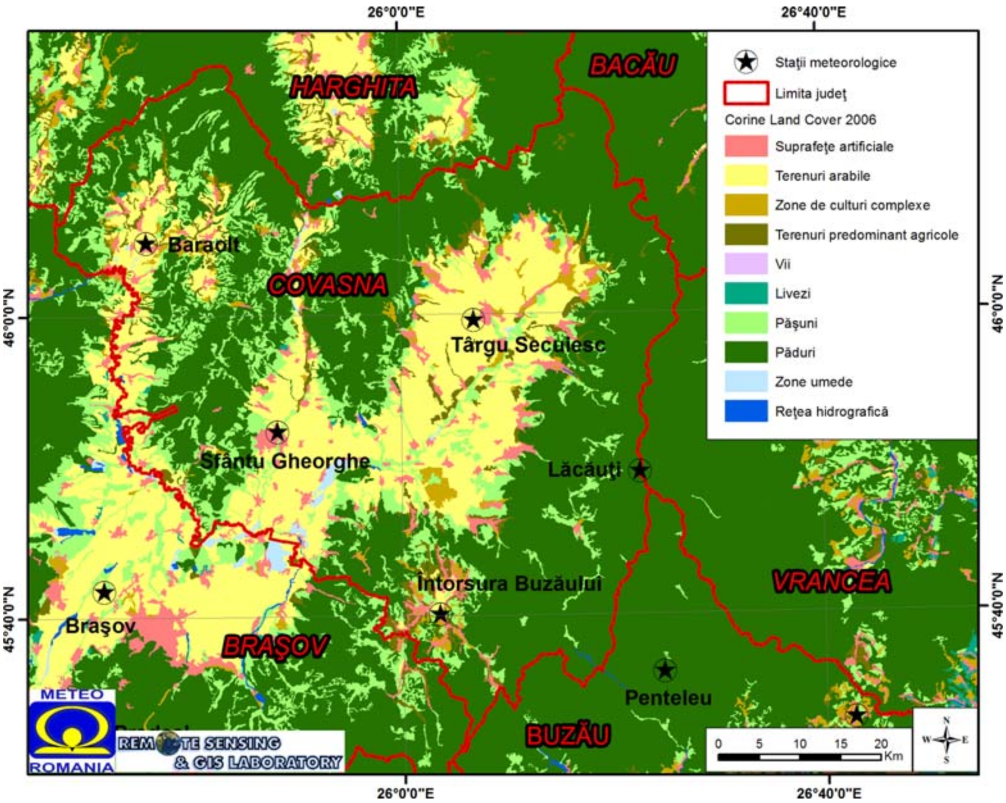


Figure 21. *Land cover/land use map over Covasna Study Area*

The map shows that the share of agricultural lands (represented in shades of orange, yellow and brown) is quite important in the Covasna county.

Vegetation indices

Spectral vegetation indices (VI) are among the most commonly used satellite data products for the evaluation, monitoring, and measurement of vegetation cover, condition, biophysical processes, and change. They have been used for over last decades in a broad variety of applications, including monitoring the effects of drought over regional, national, and even multinational areas.

Vegetation structure is characterized by the position, orientation, size and shape of the vegetation elements. The distribution of optical properties can be considered as part of the structure of the vegetation cover. The architecture of vegetation cover varies in time, from fractions of seconds and minutes (wind, water stress, etc.) to seasonal (phenological evolution, environmental constraints) and years (ecosystem dynamics). Vegetation indices are a subset of spectral indices and are based on spectral responses of the objects that interact with the incident solar radiation. The most useful spectral areas for vegetation monitoring by remote sensing are located between 600-700 nm and 750-1350 nm. Vegetation indices calculated using radiance or reflectance values of the two channels have applications in monitoring vegetation dynamics, determination of photosynthetic active radiation absorbed, vegetation conductance and photosynthetic capacity. Vegetation indices are useful parameters to estimate the effects of vegetation over seasonal variations of atmospheric carbon dioxide and to quantify the effect of CO2 and temperature variations on vegetation. Vegetation indices are an important tool for drought monitoring and evaluation because of the accurate discrimination of vegetation, and correlations with biophysical parameters that determine the vegetation state.

Several vegetation indices (VI) obtained from satellite data were used in order to detect and monitor the crop vegetation state.

The *Normalized Difference Vegetation Index (NDVI)* was computed using the red and near-infrared (NIR) bands of an image and is calculated with the expression:

$$NDVI = \frac{\rho NIR - \rho R}{\rho NIR + \rho R}$$

where: ρR is spectral reflectance from red band and ρNIR is spectral reflectance from near infrared (NIR) band [2, 5, 7, 8].

Usualy, NDVI values range from -1.0 to 1.0, with negative values indicating clouds and water, positive values near zero indicating bare soil, and higher positive values of NDVI ranging from sparse vegetation (0.1 - 0.5) to dense green vegetation (0.6 and above).

In the NDVI color composite map of 10 May 2013, derived from Pléiades (figure 22) the green color is specific for parcels covered with vegetation; winter crops, like wheat, are well highlighted, while the bare soil seeded with corn or sun flower are represented in shades of brown. After harvesting the winter crops, (image of 03 July 2013) the colors of these parcels are changing in brown (because there is no more vegetation on the ground) while the areas cultivated with corn and sun flower become green (figure 23). In the image of 26 August 2013 the only green colors are associated with corn parcels (few days before harvesting) as well as with the grass and weeds, which grow up on the bare fields after the crops are harvested (figure 24).

Figure 22. *Normalized Difference Vegetation Index (NDVI) from Pleiades – 10.05.2013*

Figure 23. *NDVI from Pleiades – 03.07.2013*

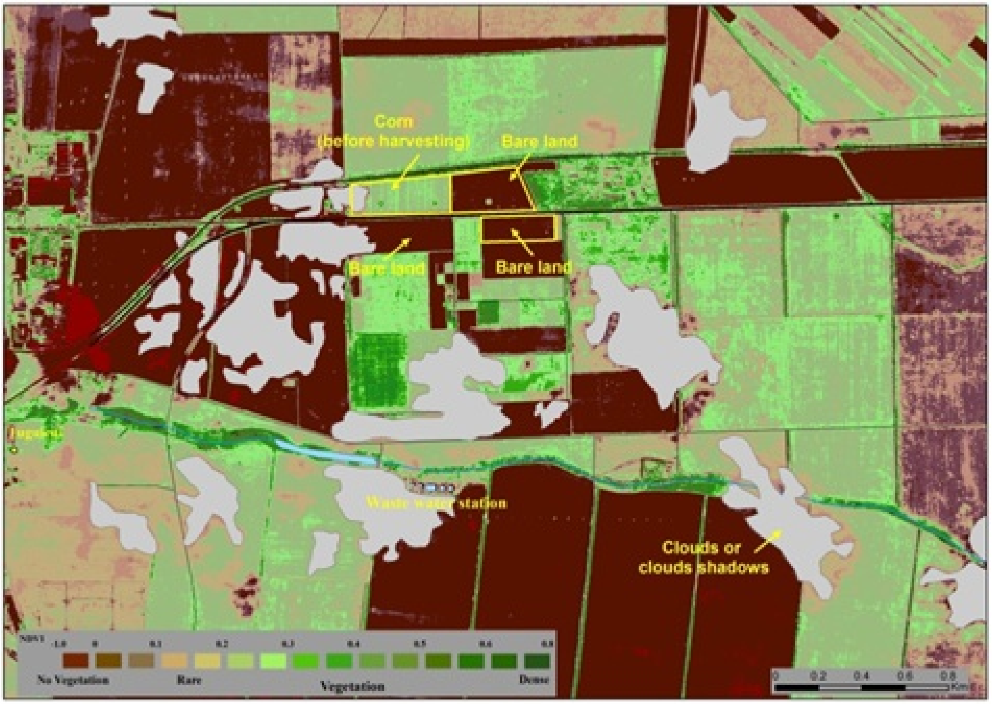


Figure 24. *NDVI from Pleiades – 26.08.2013*

Comparing current NDVI images with older ones it can monitor the positive and negative deviations that occur during the growing season of vegetation and evaluate the state's relative vegetation throughout the growing season (figure 25). Figure 25 presents an example of the NDVI spatial distribution obtained from MODIS Surface Reflectance product (MOD09 product for the 21.07-13.08.2013 time interval.

NDVI is an indicator of presence, density and health of vegetation compared to a pixel (500 m); the positive values are colored in shades of green to dark green and negative values are colored in shades from yellow to brown, indicating a lack of vegetation or bad health.

Table 11 shows the soil mosture and soil water supply capacity values recorded at agrometeorological station Sfantu Gheorghe.

Comparing with land use/land cover map and taking into account the values from Table 11, it can be observed that the most affected by moderate or strong pedological drought are the arable land.

The complex analysis of the evolution of vegetation indices and the main agro-meteorological parameters (precipitation, soil moisture) highlight their usefulness in monitoring the evolution of crop vegetation status, as well as droughts (figure 26).

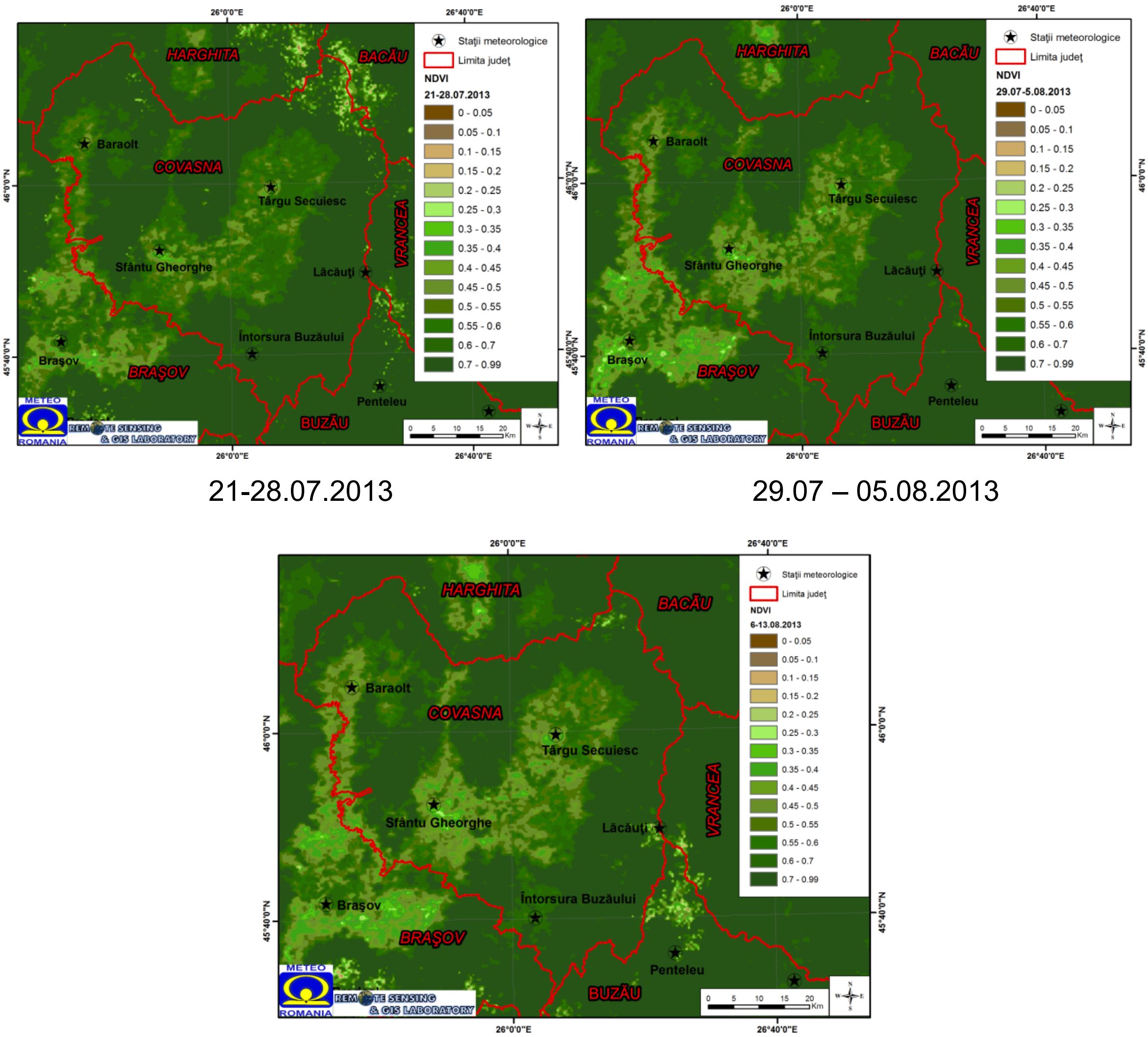
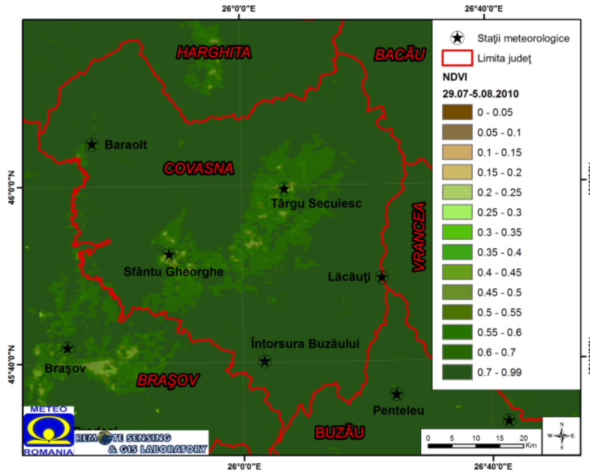


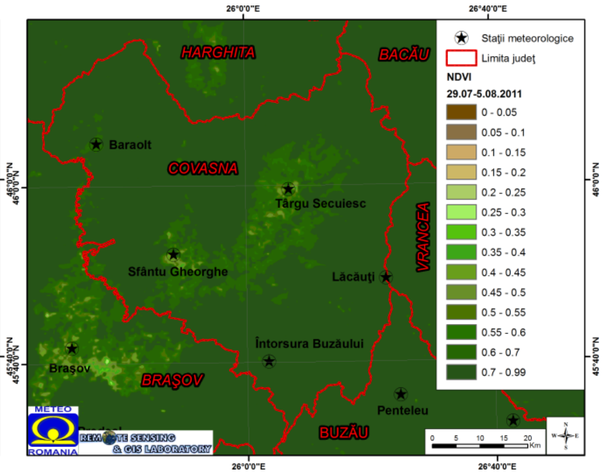
Figure 25. *The NDVI spatial distribution (21.07-13.08.2013)*

Table 11. *Soil moisture and Soil water supply capacity to agrometeorological station Sfantu Gheorghe (10-20.08.2013)*

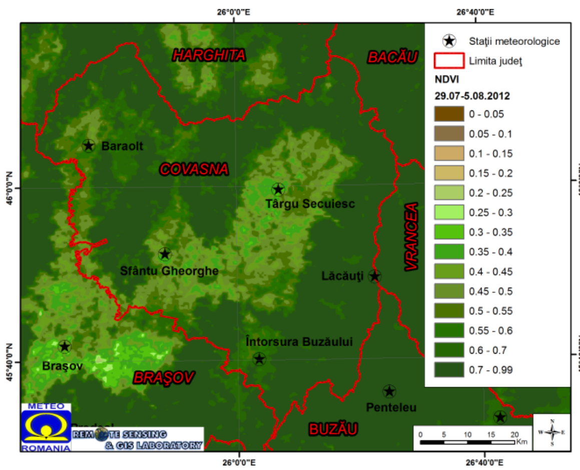
Date	Soil moisture (mc/ha)	% CAu (Soil water supply capacity)	Classes
10.07.2013	1216	76 %CAu	Close to the optimal supply
20.07.2013	883	55 %CAu	Satisfactory supply
31.07.2013	695	43 %CAu	Moderate pedological drought
10.08.2013	548	34 %CAu	Strong pedological drought
20.08.2013	667	42 %CAu	Moderate pedological drought



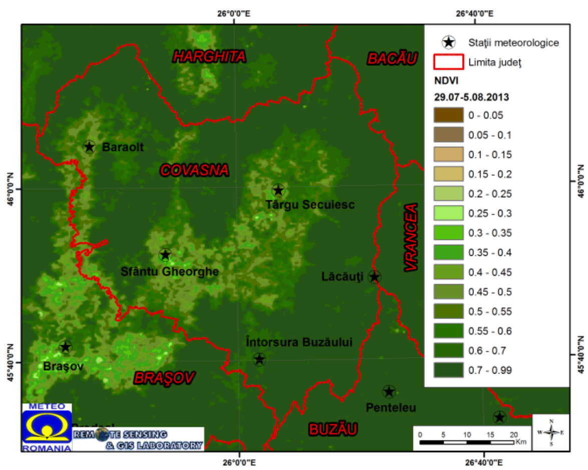
29.07 – 5.08.2010
Close to the optimal supply



29.07 – 5.08.2011
Satisfactory supply



29.07 – 5.08.2012
Moderate pedological drought



29.07 – 5.08.2013
Moderate pedological drought

Figure 26. *NDVI evolution obtained from MODIS data (MOD09A1) for the interval 29.07-05.08, and the years 2010, 2011, 2012 and 2013*

Comparing with land use/land cover map the moset affected by moderate pedological drought are agricultural areas.

The *Green Vegetation Index (GVI)* was determined by the formula:

$$GVI = \frac{\rho NIR - \rho G}{\rho NIR + \rho G}$$

where: ρG is spectral reflectance from green band and ρNIR is spectral reflectance from near infrared (NIR) band [6].

There are direct relationships between the GVI and the grazed pasture green-up with the evolution of the vegetative season (Lecain et al., 2000). The GVI and NDVI are also suitable to evaluate the effects of variations in soil water content (Todd and Hoffer, 1998).

The negative weights of the GVI on the visible bands tend to minimize the effects of the background soil, while its positive weights on the near infrared bands emphasize the green vegetation signal (figure 27).

Figure 27. *Green Vegetation Index (GVI) – 10.05.2013*

The *Soil-adjusted Vegetation Index (SAVI)* index tends to minimize the soil brightness. SAVI is a compromise between NDVI and PVI (Perpendicular Vegetation Indices) [1] and is defined as:

$$SAVI = \left[\frac{(\rho NIR - \rho R)}{(\rho NIR + \rho R + L)}\right] x \ (1 + L)$$

where: L is a correction factor and its value is dependent on the vegetation cover.

The correction factor, in the SAVI equation, accounts for the first order soil-vegetation optical interactions. Huete (1988) defined the optimal adjustment L factor: L = 0.25 for higher plants canopy density, L = 0.5 for intermediate plants canopy density and L = 1 for the low plants canopy density. For this research project the calibration factor L = 0.5 was successfully used to minimized the effect of bare soil variations on the spectral response of the green vegetation, compared to NDVI and GVI.

Table 12 presents the vegetation indices computed for wheat, corn and sun flower crops in the study area, for three dates associated with the satellite images acquisition.

Table 12. *Computed vegetation indices for the study area*

Satellite data	Crop	NDVI	GVI	SAVI
10-May-2013	Wheat	0.824	0.692	1.227
	Corn	0.235	0.197	0.358
	Sun Flower	0.246	0.196	0.368
3-Jul-2013	Wheat	0.166	0.106	0.235
	Corn	0.687	0.54	1.024
	Sun Flower	0.704	0.594	1.045
26-Aug-2013	Wheat	0.124	0.07	0.182
	Corn	0.23	0.292	0.357
	Sun Flower	0.156	0.114	0.242

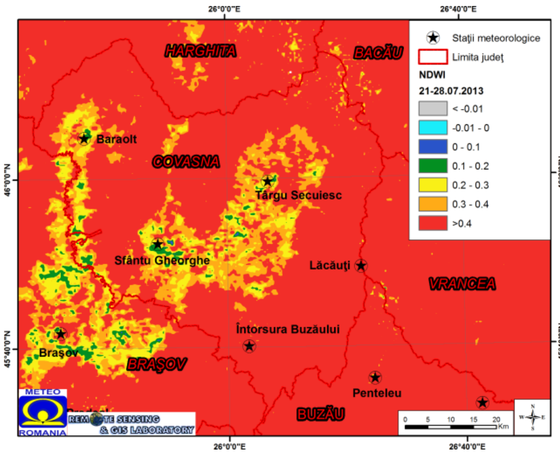
As it can be observed from table 11 the VIs values for wheat correspond to the starting process of maturity and for corn and sunflower the VIs values correspond to the first stage of leaf development (10.05.2013). At the beginning of July wheat is on harvesting phase, VIs values being at minimum level. Corn and sunflower are in the flowering and fertilization phases (NDVI~0.7, GVI~0.55 and SAVI~1). In August, corn and sunflower are in the grain filling and maturity stages. VIs values are lower due to lack of precipitation from middle of July.

The *Normalized Difference Water Index (NDWI)* is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) reflectance channels [5, 7]:

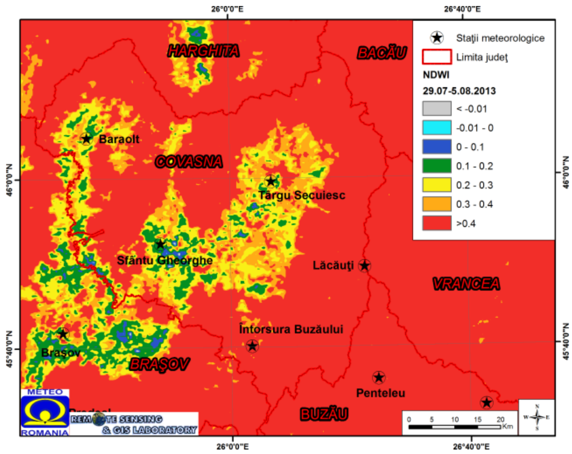
$$NDWI = \frac{\rho NIR - \rho SWIR}{\rho NIR + \rho SWIR}$$

where ρSWIR and ρNIR are spectral reflectance from short wave infrared band and near-infrared regions, respectively.

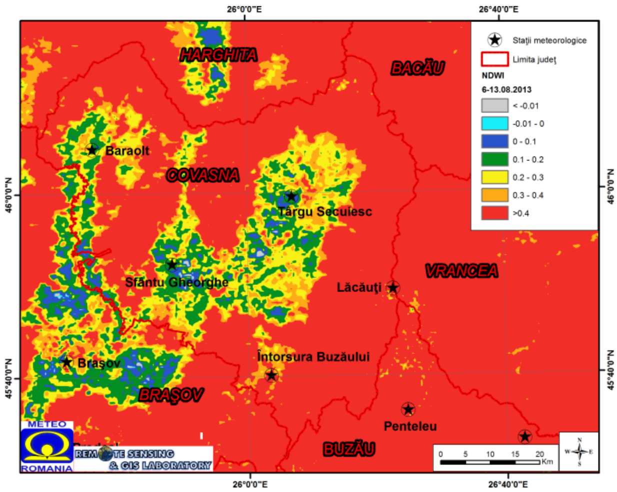
NDWI values range from -1.0 to 1.0. The common range for green vegetation is -0.1 to 0.4. This index increases with vegetation water content or from dry soil to free water. NDWI index is a good indicator of water content of leaves and is used for detecting and monitoring the humidity of the vegetation cover (figure 28). It is well known that during dry periods, the vegetation is affected by water stress, which influence plant development and can cause damage to crops. NDWI holds considerable potential for drought monitoring because the two spectral bands used for its calculation are responsive to changes in the water content (SWIR band).



21-28.07.2013



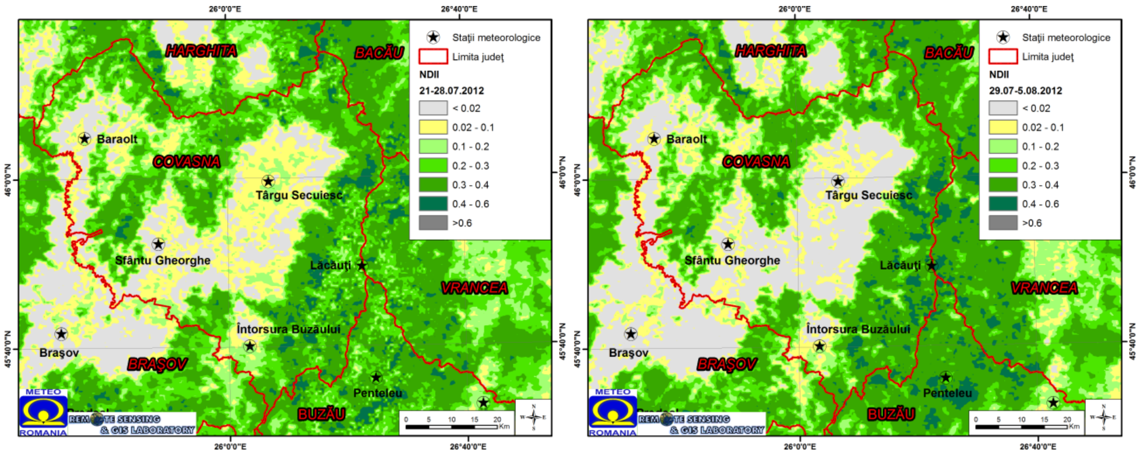
29.07 – 05.08.2013



06 – 13.08.2013

Figure 28. *The NDWI obtained from MODIS data (MOD09A1) spatial distribution (21.07-13.08.2013)*

The *Normalized Difference Infrared Index (NDII)* is a reflectance measurement that is sensitive to changes in water content of plant canopies, a combination of SWIR and NIR bands [8, 11]. The NDII uses a normalized difference formulation instead of a simple ratio, and the index values increase with increasing water content (figure 29). Its applications include crop agricultural management, forest canopy monitoring, and vegetation stress detection. The value of this index ranges from –1 to 1. The common range for green vegetation is 0.02 to 0.6.



21.07 – 28.07.2012 Satisfactory supply	29.07 – 5.08.2012 Moderate pedological drought

Figure 29. *NDII evolution obtained from MODIS data (MOD09A1), 21.07-05.08.2012*

The *Normalized Difference Drought Index (NDDI)* is a new index for drought monitoring which is calculated from normalized difference vegetation index (NDVI) and normalized difference water index (NDWI) [5,7], according to the following formula:

$$NDDI = \frac{NDVI - NDWI}{NDVI + NDWI}$$

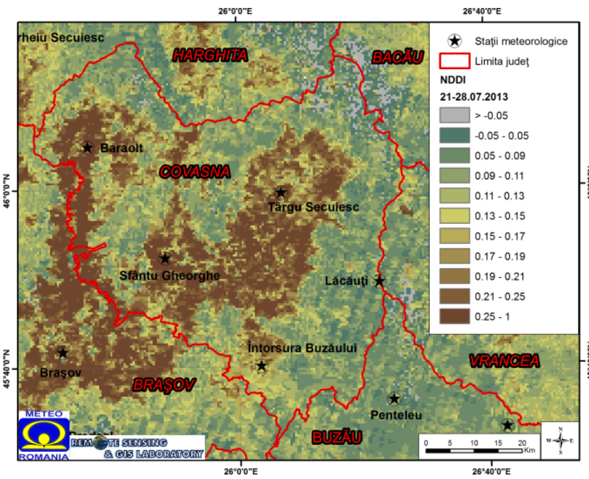
It combines information from visible, NIR, and SWIR channel. NDDI can offer an appropriate measure of the dryness of a particular area, because it combines information on both vegetation and water. NDDI had a stronger response to summer drought conditions than a simple difference between NDVI and NDWI, and is therefore a more sensitive indicator of drought (figure 30).

NDDI index can be an optimal complement to in-situ based indicators or for other indicators based on remote sensing data.

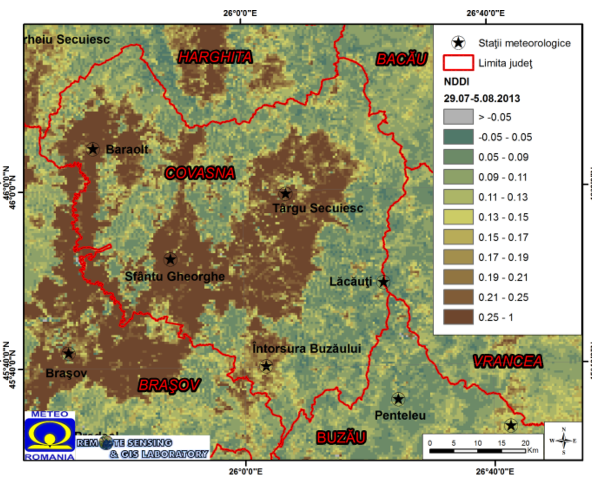
Through processing the data obtained from SPOT Vegetation (1 km spatial resolution) and comparing them with the agrometeorological data recorded at Caracal weather station it can be noticed that, although in the April-May period the precipitation amounts were small, the NDVI values increased, due to the existed in-soil water reserve, accumulated from the precipitation fallen in March through 10 April, 2013 (figure 31).

However, due to the scarce amount of precipitation (in the periods 11 April – 10 June 2013 and 11.07 – 20 August 2013) the vegetation state of the crops was affected by drought, situation highlighted by the NDVI decrease trend. Owed to the spatial resolution of the SPOT Vegetation image products (1 km) and to the small size of the parcels, no clear delimitation can be made between the various crop types.

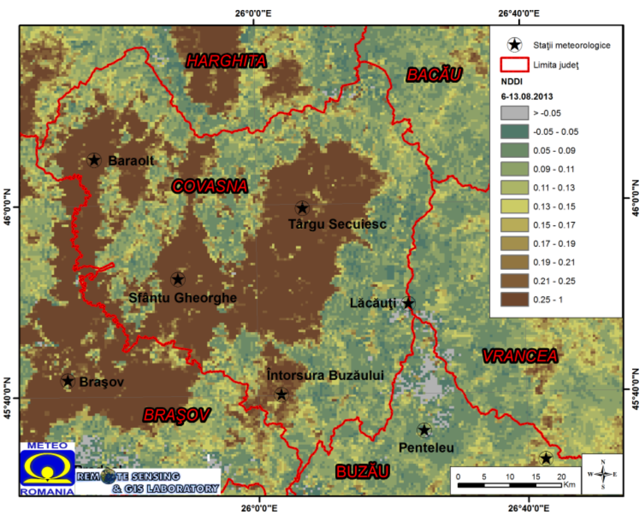
Through processing the MODIS (MOD09A1) data with 500 m resolution, more precise results can be obtained regarding the evolution of the various vegetation indices assigned to different crops. NDWI has a good reaction to the crops withering and dehydration and because of that is considered a better indicator of agricultural drought then NDVI.



21-28.07.2013



29.07 – 05.08.2013



06 – 13.08.2013

Figure 30. *The NDDI obtained from MODIS data (MOD09A1) spatial distribution (21.07-13.08.2013)*

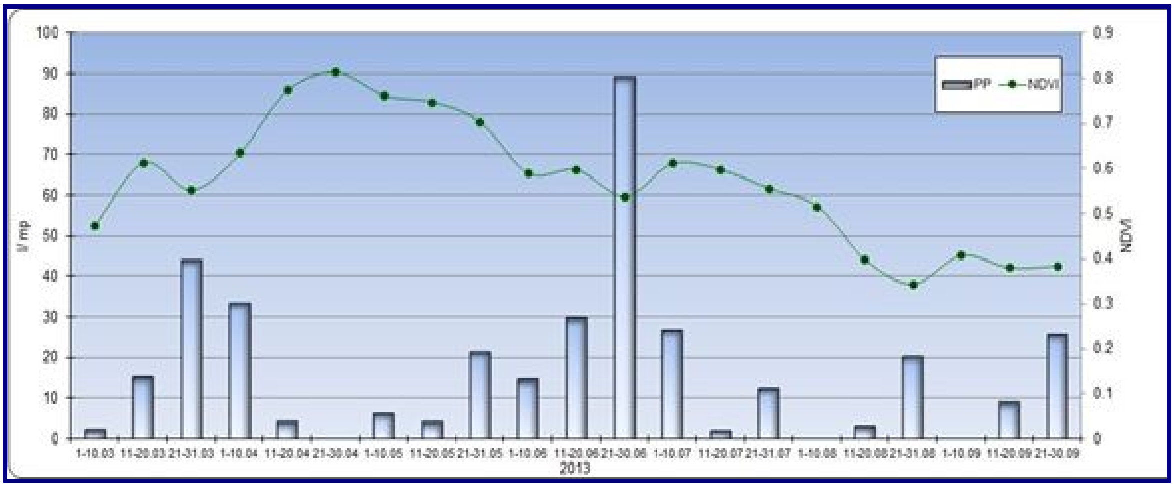


Figure 31. *NDVI evolutiuon from SPOT VGT and amount of precipitation from Caracal weather station*

The figure 32 renders the evolution of NDVI and NDWI derived from MODIS data, for the wheat crop, from May to September 2013. Through comparing it with the precipitation recorded at Caracal weather station, a minimum NDVI value was noticed at the beginning of May, due to the lack of precipitation. Further, due to the precipitation recorded in May and June, the NDVI values returned to normal (> 0.6). A NDVI decrease trend can be noticed over the interval when wheat was harvested (July). The same trend can be seen in the course of NDWI. NDWI correlates well with the moisture measured at the stations and in the test area. According to the figure 32, the mmaximum values of NDWI (~0.4) correspond to medium vegetation water content and to medium vegetation fraction cover.

Figure 32. *NDVI and NDWI evolution from MODIS and the amount of precipitation registered at Caracal weather station (wheat)*

For the spring crops (corn and sun flower), the evolution of NDVI and NDWI was similar. The recorded differences are dues to crop type and to specific phenological phase. The decrease of both NDVI and NDWI for the sun flower crop in August through September 2013 is explained by the decline of the in-soil water reserve. The interval coincided with the maturity phenological phase (figure 33 and figure 34).

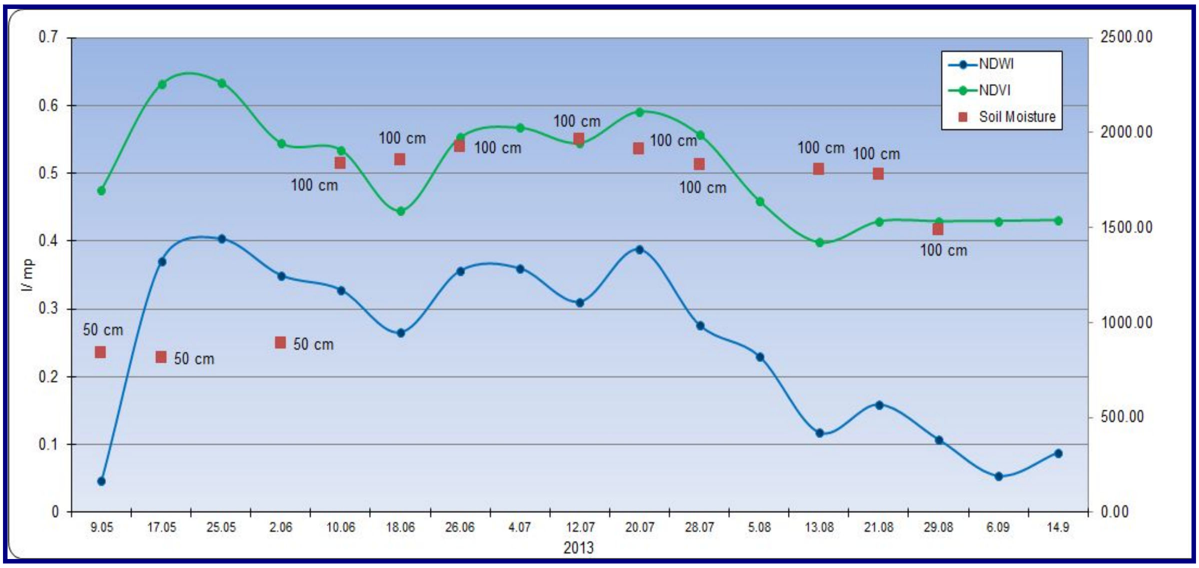


Figura 33. *NDVI and NDWI evolution from MODIS and the soil moisture measured at Caracal weather station (sun flower)*

Figure 34. *NDVI and NDWI evolution from MODIS and the amount of precipitation registered at Caracal weather station (sun flower)*

The decrease of NDVI and NDWI for the corn crop in the August – September 2013 period was also due to the dwindling of the in-soil moisture reserve. The interval coincided with the maturity and harvesting phenological phases (Figure 35).

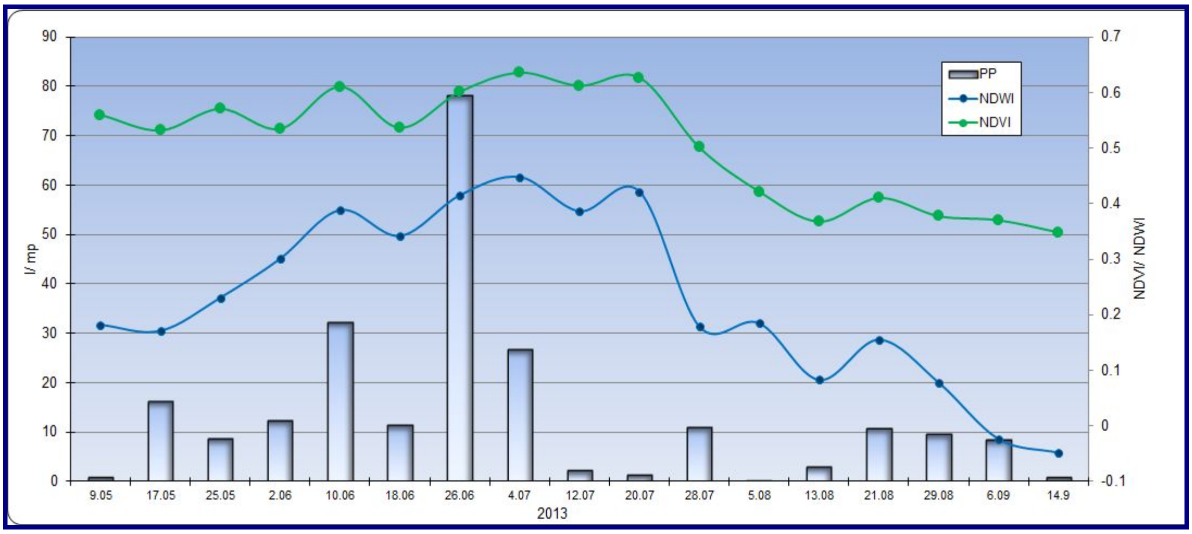


Figure 35. *NDVI and NDWI evolution from MODIS and the amount of precipitation registered at Caracal weather station (corn)*

Taking into account the values from table 10 and comparing vegetation indices estimated for Covasna study area (NDVI, NDWI, NDII) and NDDI evolution with land use/land cover map and, for the period 21.07-13.08.2013 it can be observed the existence of moderate pedological drought during 29.07-13.08.2013. The most affected areas are the arable land.

The same conclusion is highlight by analyzing the evolution of vegetation indices and precipitation recorded to Sfantu Gheorghe agrometeorological station (figure 36). The minimum values of NDVI (NDVI ∈(02-0.35)), NDWI (NDWI ∈ (0.1-0.3)) and NDII (NDII < 0.1) are recorded between 20.07-15.08.2013, due to the lack of precipitation. For this period NDDI has maximum values between 02.-0.4.

The areas with low NDVI, NDWI or NDII values doesn't necessary mean that drought occurred there: the index's value can be also associated with bare soil or with the lack of vegetation due to various regions. A good example for such a situation are the values corresponding to the end of the year. Therefore, vegetation indices are very useful for vegetation monitoring, depending on the evolution of the main agrometeorological parameters and phenological phase.

For the agrometeorological information to be as complex and accurate as possible, it is mandatory to improve the operational monitoring capabilities through the use of advanced remote sensing techniques.

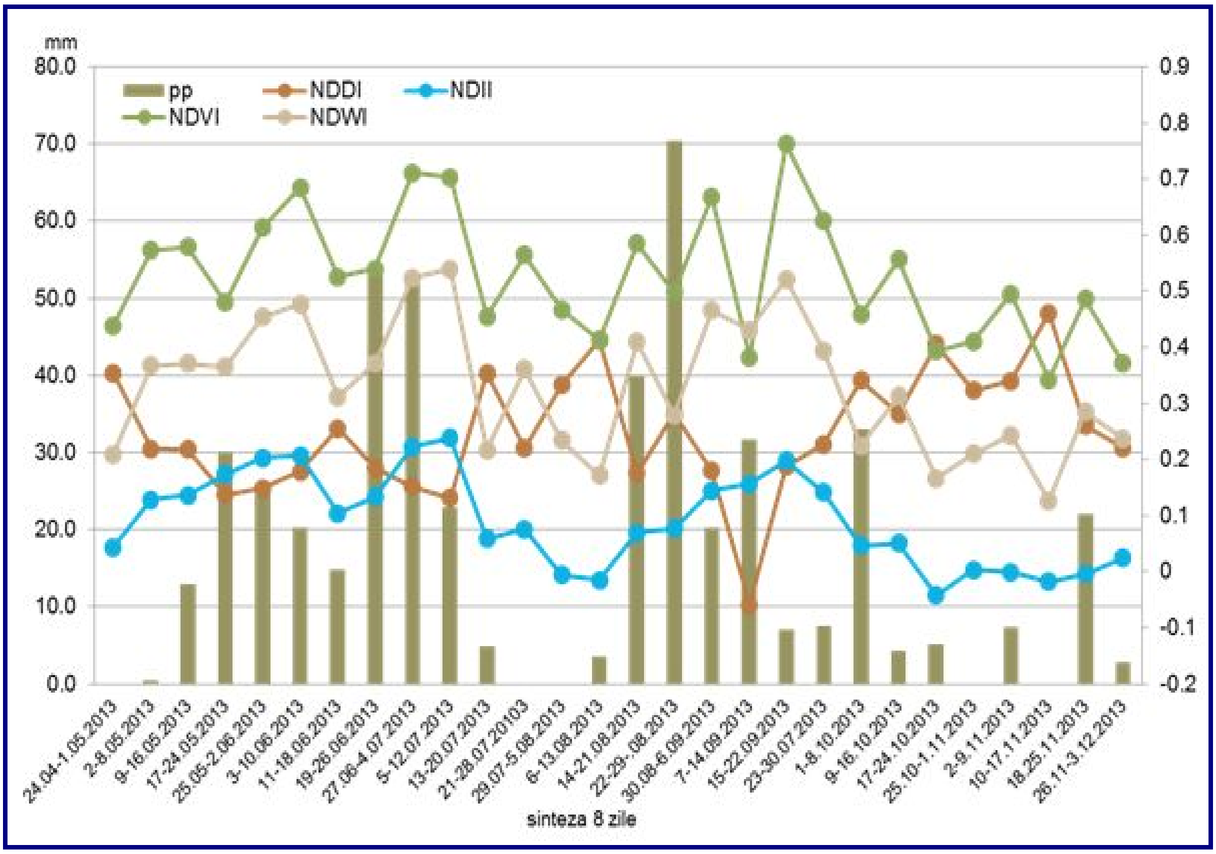


Figure 36. *Analysis of vegetation state evolution with satellite-based indices in Sfantu Gheorghe area on 24.04 – 03.12.2013*

GIS technologies offer the possibility of crossed-analysis between various data sources such as vegetation indexes and CORINE land-cover classes. Such analysis revealed the fact that the most affected by drought land-cover classes are the arable land and pastures.

The satellite remote sensing techniques play an important role in crop identification; disease and water stress detection, because they provide spatially explicit information and access to remote locations. The use of multispectral satellite data may ensure an improvement of the classical methods destined to determine the agrometeorological parameters of interest.

The vegetation indices are among the most commonly used satellite data products for the evaluation, monitoring, and measurement of vegetation cover, condition, biophysical processes, and change. The main advantages consist in the possibility to obtain spatial information with a resolution varying from kilometers to meters and to update those data at time intervals that may vary from hours to seasons.

4.5. Adaptation options in agriculture

The complex effects of climate upon the agriculture justify the decision-making measures regarding the reduction of risks in order to protect the production process. The use of resistant genotypes (species/hybrids), as well as the application of specific technologies (fertilization, weed and pest control, irrigation, etc.) increase the efficiency within environmental conditions corresponding to the optimum physiological function of plants and lower it within limitative climate and edaphic conditions.

Under current climate conditions, the mean length of the vegetation season (from seeding time to ripeness) for winter wheat is 270 days, and considering future climate scenarios is expected to reduce the vegetation period by 13-19 days. For maize crop, the simulations show that reducing the duration of the vegetation is higher (15-25 days) due to increased of the air temperature, especially in summer months (figure 37).

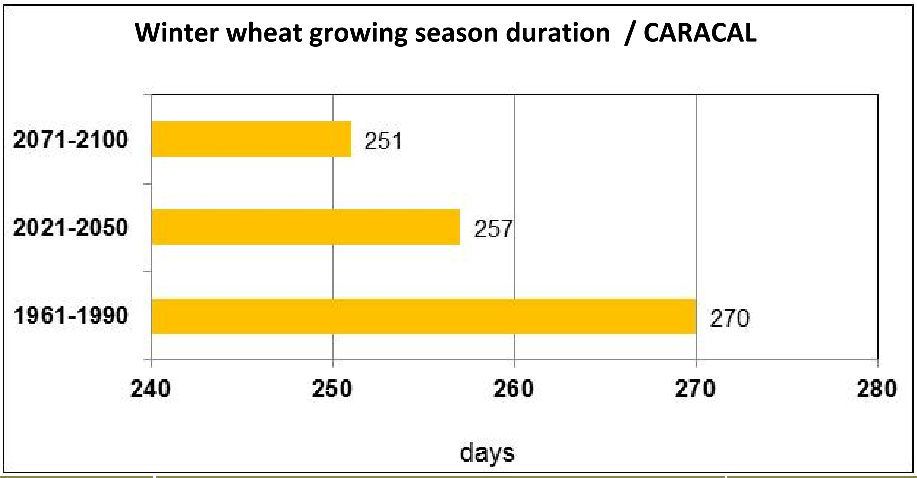
A 30-year mean of winter wheat yields simulated under current climate conditions is 4452 kg/ha at Caracal. Given the probable climate conditions according to the RegCM3/SRES A1B scenarios-predicted future evolution, the mean wheat yield is higher by 6.3% considering scenario 2021-2050 and 15.6% for 2071-2100 scenario than the 1961-1990 one (figure 38).

In current climatic conditions the average maize yield is 5094 kg/ha at Caracal. Analyzing the simulated results highlighted that for maize, which is more sensitive than wheat to local climate and future climate severity, average grain yields tend to decrease by 14.4%in 2021-2050 period, and more abruptly, by 36.5% in 2071-2100 period (figure 38).

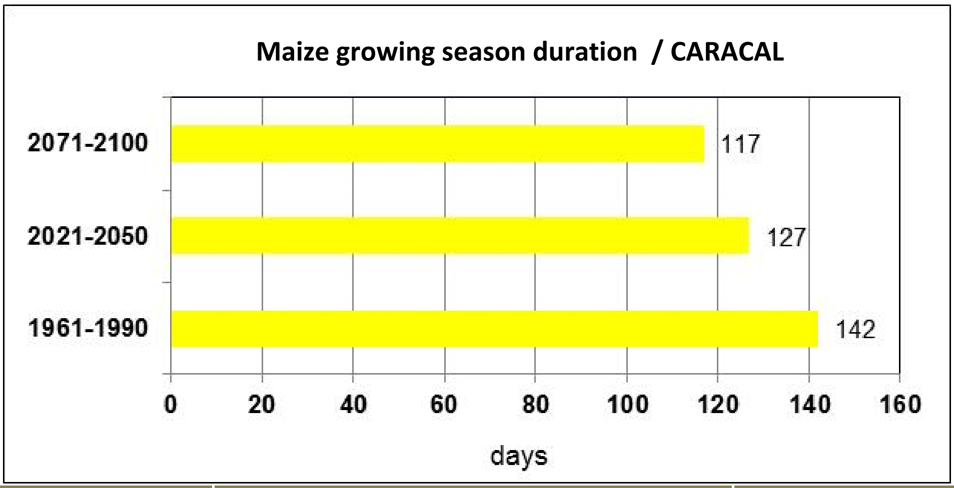
Given the regional climate predictions, water is used more efficiently by the winter wheat crop with the later sowing date (October 20 and November 1) in comparison with earlier dates of September and first decade of October (figure 39). In the case of maize crops the water use efficiency increases with an earlier sowing date (April 1 and 11) in comparison with later date (April 20), figure 39.

Maize yields get lower due to a shortening of the vegetation season, following an increase in temperature, as well as due to water stress during grain filling, caused by diminished scenario-forecasted precipitation amounts. Being also a C4 plant, maize benefits less from the effect of increased CO_2 concentrations upon photosynthesis.

At Caracal under future climate condition for the winter wheat crop the most suitable genotype are varieties with high or moderate vernalization (P1V=6.0…P1V4.0) and with moderate photoperiod requirement (P1D=3.5), respectively version 2 of the total of five simulated (figure 40).

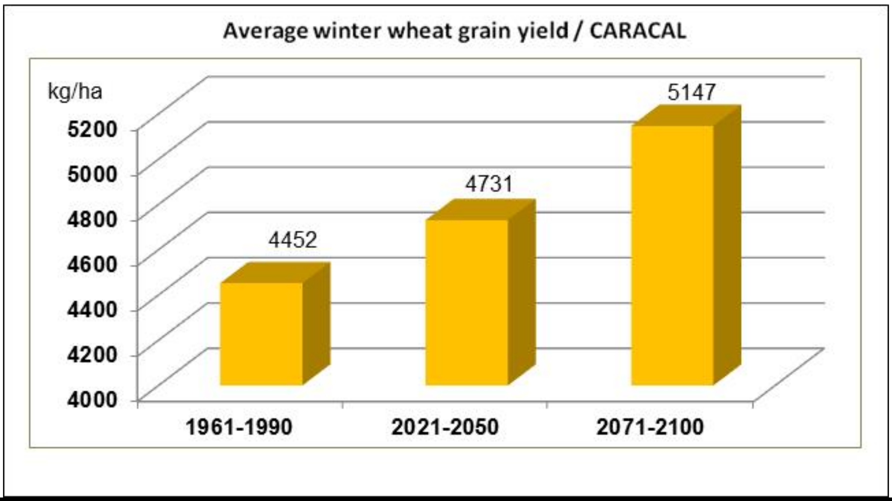


	No. days of SD / Winter wheat	Diff
1961-1990	270	
2021-2050	**257**	**-13**
2071-2100	**251**	**-19**

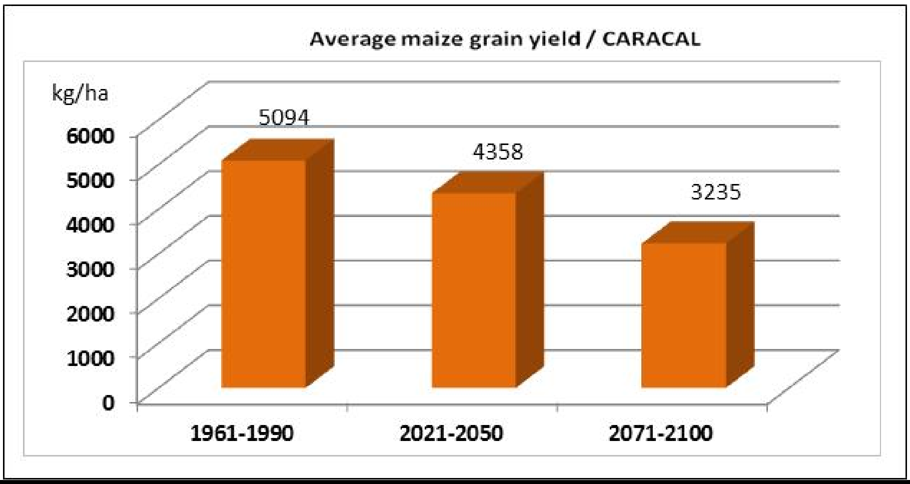


	No. days of SD / Maize	Diff.
1961-1990	142	
2021-2050	**127**	**-15**
2071-2100	**117**	**-25**

Figure 37. *The results simulated under current conditions and predictions (RegCMs/2021-2050 and 2071-2100/SRES A1B scenario) referring to the growing season duration of winter wheat and maize crops in the Pilot Study 2 area.*

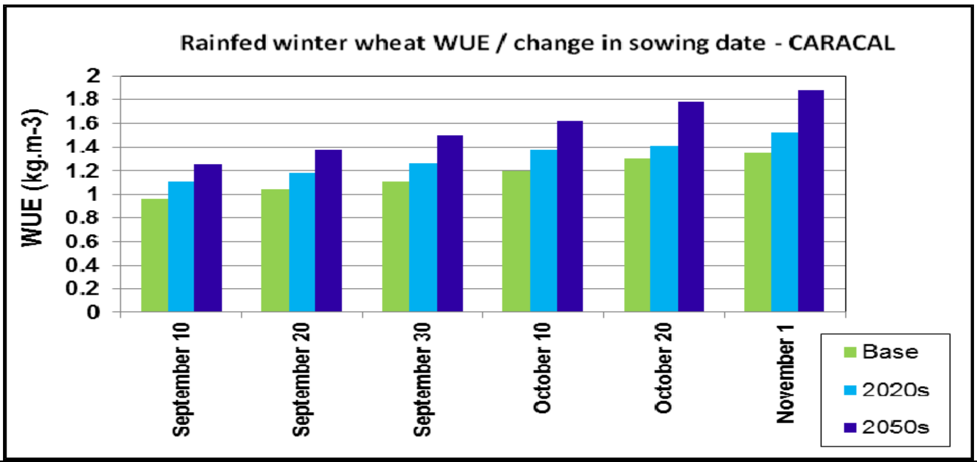


	Grain yield / Rel. Diff (%)
Current climate / 1961-1990	4452 kg/ha
Scenario / 2021-2050	4731 kg/ha / 6.3%
Scenario / 2071-2100	5147 kg/ha / 15.6%

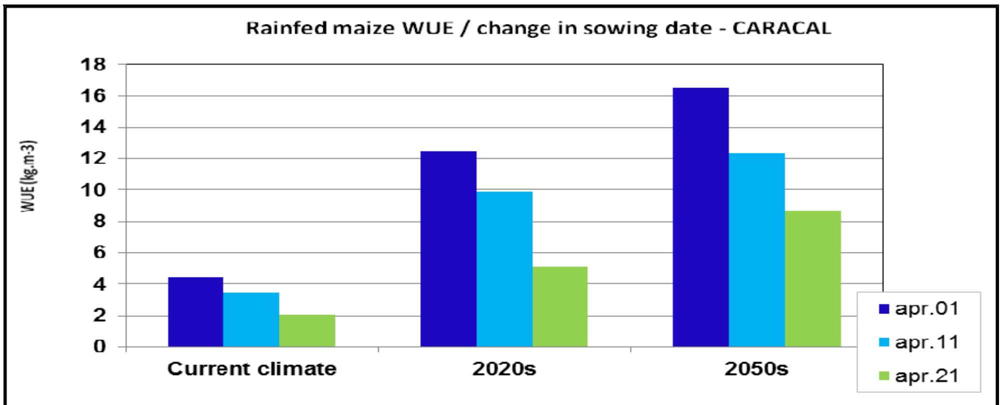


	Grain yield/ Rel. Diff (%)
Current climate / 1961-1990	5094 kg/ha
Scenario / 2021-2050	4358 kg/ha / -14.4%
Scenario / 2071-2100	3235 kg/ha / -36.5%

Figure 38. *The results simulated under current conditions and predictions (RegCMs/2021-2050 and 2071-2100/SRES A1B scenario) referring to the winter wheat and maize grain yield in the Pilot Study 2 area.*

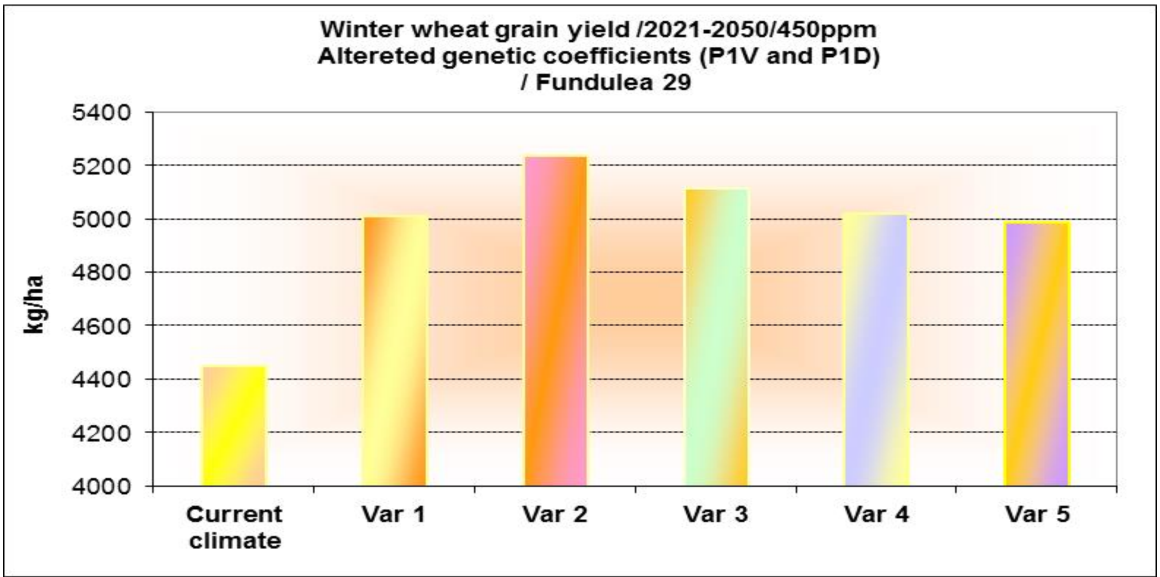


Sowing date	WUE (kg.m-3) Base	WUE (kg.m-3) 2020s	WUE (kg.m-3) 2050s
November 1	1.35	1.52	1.88
October 20	1.30	1.41	1.78
October 10	1.20	1.38	1.62
September 30	1.10	1.26	1.50
September 20	1.09	1.18	1.38
September 10	0.96	1.10	1.25



Sowing date	WUE (kg.m-3) Base	WUE (kg.m-3) 2020s	WUE (kg.m-3) 2050s
April 1	4.45	12.5	16.5
April 11	3.5	9.9	12.3
April 20	2.05	5.1	8.7

Figure 39. *The effective use of water by crops (WUE) by changes of the sowing date*

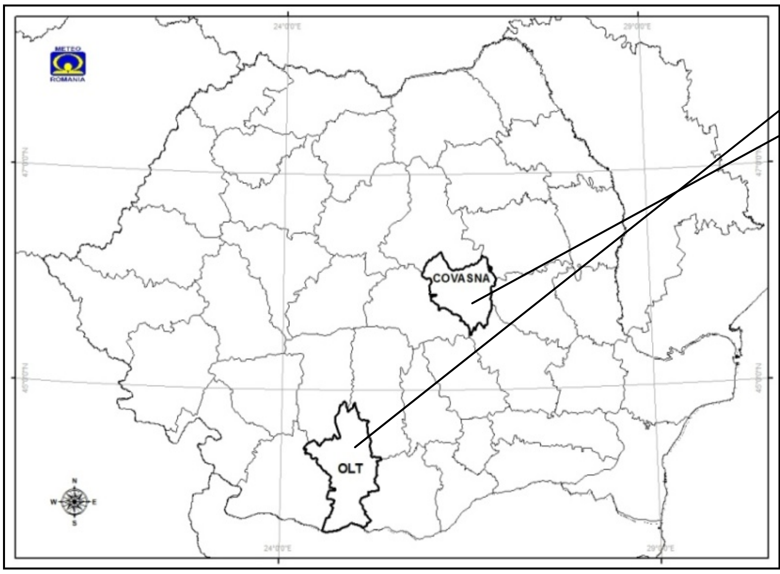


	Current climate P1V=6.0	Scenario VAR 1 P1V=3.0/ P1D=3.0	2020-2050 VAR 2 P1V=4.0/ P1D=3.5	/ 450 ppm VAR 3 P1V=6.0/ P1D=2.5	VAR 4 P1V=4.0/ P1D=2.0	VAR 5 P1V=6.0/ P1D=1.0
GY (kg/ha)	4452	5014	**5238**	5118	5022	4989
SD (days)	270	258	255	252	243	241

Figure 40. *Winter wheat genotypes recommended in future climate change conditions*

In the Pilot Study 2 the water is used more efficiently by the winter wheat crop with the later sowing date (October 20 and November 1 in Caracal area; September 10 and October 5 in Tg. Secuiesc) compared with earlier dates of end of September and beginning of October month. For the maize crop water is used more efficientlywith an earlier sowing date (April 1 and 11 in Caracal area; March 20 and April 1 in Tg. Secuiesc) in comparison with later date (April 20 or 10), figure 41.

Analyzing the results simulated of climate change estimations for 2021-2050 and 2071-2100 periods shows that the future climate evolutions may have important effects upon crops and they are conditioned by an interaction between the following factors: current climate changes on a local scale, severity of climate scenario-forecasted parameters, how the increased CO_2 concentrations influence photosynthesis, and the genetic nature of plant types. Winter wheat can benefit from the interaction between increased CO_2 concentrations and higher air temperatures, while maize is vulnerable to climate change, mainly in the case of a scenario predicting hot and droughty conditions



Study Pilot 2:
Olt County / Caracal area
Covasna County / Tg. Secuiesc area

2021-2050 period:
Winter wheat:
later sowing date
Caracal area:
October 20 and November 1
Tg. Secuiesc area:
September 10 and October 5

Maize: earlier sowing date
Caracal area: April 1 and 11
Tg. Secuies area: March 20 and April 1

Figure 41. *Adaptation measures: changing the sowing date in the Pilot Study 2*

For both analyzed crops, the vegetation season gets shorter and there are fewer days available to reaching full ripeness. This shortening of the vegetation season is more marked in maize crops than in winter wheat. Such a forcing is mainly due to a probable increase in air temperature, estimated by the regional model.

As to the possible effects of climate change upon yields, they depend on the genetic type (C_3 or C_4), direct effects of increased CO_2 concentrations on photosynthesis, local conditions and the severity of changes in climate evolution according to the two scenarios. So, maize yields decrease in comparison with the current clime case, due to higher temperatures leading to shorter vegetation seasons associated with water stress, mainly during the phenological stage of grain formation and filling. In winter wheat, grain yields are higher than in current clime conditions due to a positive effect of increased CO_2 concentrations in the atmosphere (from 330 ppm to 450 ppm) upon photosynthesis and water use, which counterbalances the negative effect of a shorter vegetation period.

The results shown in this Pilot study can contribute to developing the management adaptation options to climate change-related negative effects affecting crop systems. These options could include: changing the sowing date, cultivation of winter wheat genotypes that require a high or moderate vernalization and moderate photoperiods as well as certain maize hybrids with a better resistance to hot summer and drought.

By identifying practical adaptation measures the farmers can establish options to improve climate resilience of the crop systems by new agricultural technologies based on water use efficiency in irrigated or non-irrigated regime. In this project adaptation measures are presented at local and regional level. It is important, however, to extend the research to other areas with similar or different conditions in order to establish actions in accordance with regional/national policy planning.

4.6. Conclusions and lesson learnt

The climate is already changing and the agricultural areas of Romania are vulnerable to these changes. The temperatures become higher, precipitation variable in time and space and extreme weather events more frequent and severe. In this context, agriculture sector, which play a major role in ensuring of food security will be strongly affected by CC because of its dependence on the weather. In this context, ensuring stable agricultural production in a changing climate is one of the main challenges of the coming decades. Facing this challenge requires developing a dedicated pilot study as best practices in order to identify adaptation measures that can be taken to reduce the climate change impacts.

In the agricultural area of Pilot Study 2, the winter wheat yield will slowly increase in comparison with the current conditions as a consequence of increased CO_2 concentrations in the atmosphere (affecting photosynthesis) and of using water supplies to counter-balance the negative effect of shorter vegetation periods. The maize yields will decrease due to higher temperatures that shorten the vegetation season, coupled with a water stress, mainly during the phenological phases of grain formation and filling.

The management and sustainable development decisions should aim to increase the agricultural production by growing in each region the appropriate crops that have the largest benefit from the natural potential for agriculture, which is evaluated through analysis of local agropedoclimatic conditions.

Within the field crop production, the selection of the cultivated species includes mainly the correlation of the local environment conditions with the degree of genotypes resistance (varieties / hybrids) according to the limitative vegetation conditions (drought, humidity excess, high temperatures, cold / frost period, etc.).

The presented results of climate change impact studies on agricultural crop production in Romania highlighted following key points:

1. Climate change will cause significant shift in the environmental conditions, adaptation of the farmers being crucial;
2. Drought frequency and severity is expected to increase;
3. Yields of winter wheat crops are expected to increase and for maize to decrease mainly in the case of a scenario predicting hot summer and droughty conditions;
4. The agriculture will face more climate-related risks, the adaptation options being requiring continuing research on the effect from irrigation and sustainability of yields under various water saving methods and irrigation technologies;
5. Modeling of the potential impacts of climate change on farming systems with identification of adaptation responses and need to develop the capacity of

stakeholders to implement these measures in practice are goals that requires long-term responses.
6. Numerical experiments to determine the optimal dates and water quantity for irrigation crops for various climate scenarios are necessary to be carried out and the calculations are applied by taken in regard to biophysical and economic analysis of the final yield associated with the economic models.
7. Better dissemination of meteorological information to farmers and raise awareness on water saving techniques in order to prevent drought and water scarcity.

Concerning current policies regarding drought monitoring and management in the past few decades it has become evident that in all countries affected by drought and water scarcity is a clear need to improve national and regional policies with the goal of improving preparedness measures and reducing negative impacts. Better coordination of the management policies is also needed due to the transboundary or regional/local character of drought events.

4.7. Complementary analyses

Analysis of the relationship between changes of climate, irrigation requirement and yield for Romania was made by the experts from CMCC (Italy) as project coordinators.

High resolution climate simulations performed at 14 km of horizontal resolution over the SEE domain with COSMO CLM have been used to characterize indicators indicating impact of climate on agriculture in Romania. In particular were used simulations characterizing 1) present climate (1980-2011) forced by the ERA-INTERIM meteorological reanalysis and CMCC-CM GCM, and 2) future climate projections forced by the CMCC-CM GCM under RCP4.5 IPCC scenario covering 30 years periods (2006-2036, 2037-2066). From these climate datasets, the following climate variables were extracted and used to characterize climate impact: daily precipitation, net solar radiation, daily minimum temperature and maximum temperature.

The Decision Support System for Agrotechnology Transfer (DSSAT) is a crop modelling software that simulate growth, development and yield for several crop types as a function of dynamics between plant, soil and climate. DSSAT supports and exploits data base management for several types of soil, weather, and crop management and experimental data. The DSSAT program has been utilized within a R-based spatial platform routine to implement spatially distributed projection of crop modeling in combination with large scales GIS databases (e.g. netcdf) of climate, soil and management practices. The COSMO CLM projections made available four daily climate variables at 14 km (precipitation, solar radiation, min and max temperature), which were used in combination with the ISRIC-WISE (http://www.isric.org/data/isric-wise-international-soil-profile-dataset) derived soil properties on a 5 by 5 arc-minutes and country-based estimates of agronomic practices (e.g. planting dates, irrigation, fertilization, etc.) to derive crop predictions (e.g. yield and irrigation requirements) for maize and wheat for the whole Euro-Mediterranean area covering 30 years periods (present 1980-2011; future 2006-2036 and 2037-2066).

Besides other environmental factors (e.g. soil), crop yield is largely fostered by positive climate conditions, like availability of water needed for leaf gas exchanges and photosynthetic processes and temperature influencing crop development rate from emergence to maturity. Climate change would definitively lead to increases in temperatures, which will in turn increase vegetation water consumption (EvapoTranspiration) and intensify growth stages. Growing Degree Days (GDD) measures the number of temperature degrees above a threshold base temperature, and is used to assess suitability for specific crops, estimate growth-stages and heat stress for crops. According to climate projections described above, GDD will increase in Romania with higher rates towards the mid of the century (2050) and in the southern part of Romania (figure 42).

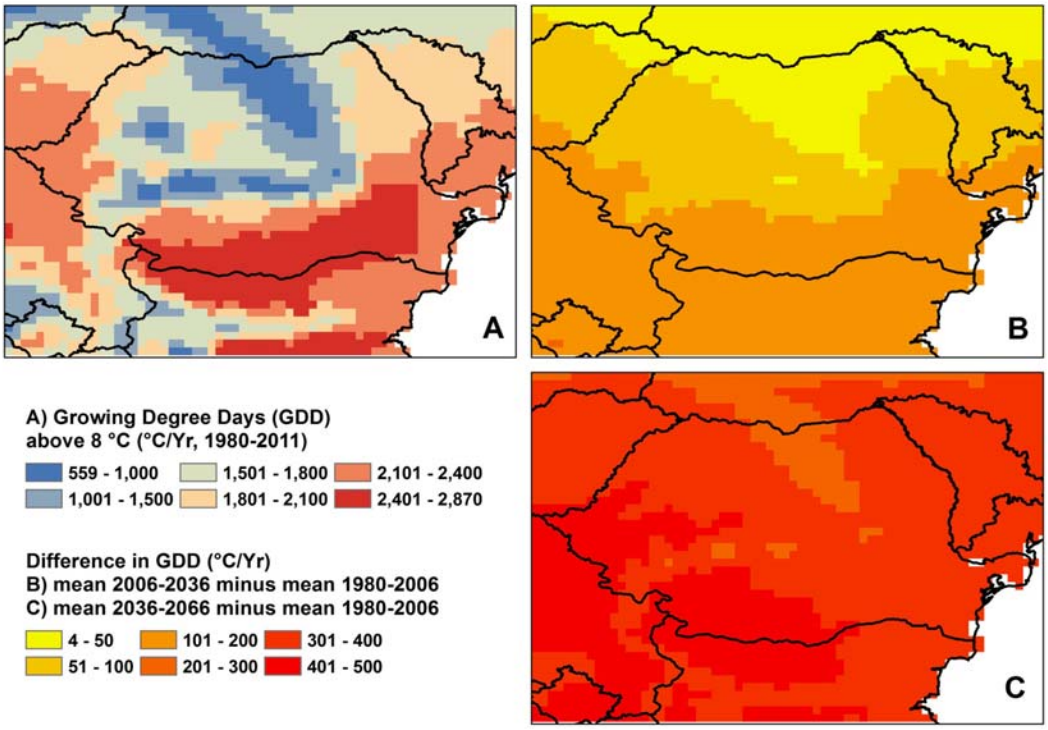


Figure 42. *A) Average Growing Degree Days (GDD; base 8 °C) simulated with COSMO-CLM RCM (forced with ERA-INTERIM reanalysis) over the 1980-2011 period. Difference in GDD between projected conditions (COSMO-CLM RCM forced with CMCC-CM GCM, RCP45) for 2006-2036 (B) or 2036-2066 (C) and actual conditions.*

Based on the climate scenario, precipitations are projected to increase in the center-North part of the country (figure 43), although it is widely recognized that precipitation projections are tied to strong uncertainties. Maize suitability requires 800 to 1400 GDD to reach crop maturity.

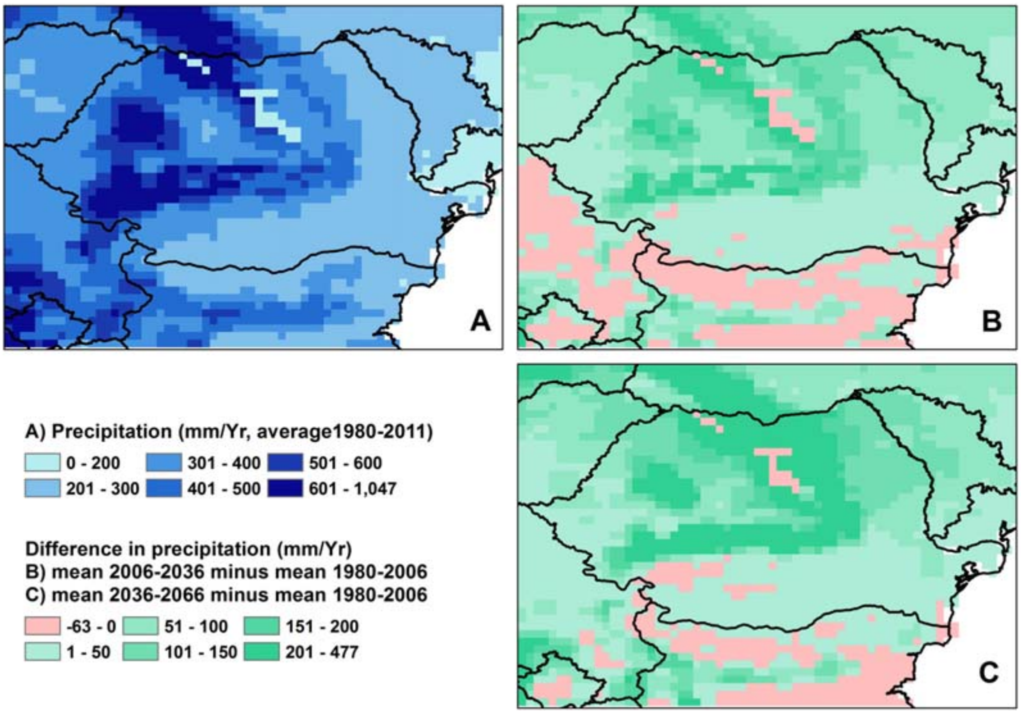


Figure 43. *A) Average precipitation simulated with COSMO-CLM RCM (forced with ERA-INTERIM reanalysis) over the 1980-2011 period. Difference in precipitation between projected conditions (COSMO-CLM RCM forced with CMCC-CM GCM, RCP45) for 2006-2036 (B) or 2036-2066 (C) and actual conditions.*

Thus areas with already high GDD may have shorter growing season in the future for Maize and associated lower irrigation requirements (IrrReq), while areas with lower GDD may see in the future expansion of areas suitable for Maize in North Romania (Figure 44). Rainfed agriculture (e.g. wheat) will increase productivity (CropYld) mostly in the central and northern part of Romania, mostly due to projected increases in precipitation (figure 45).

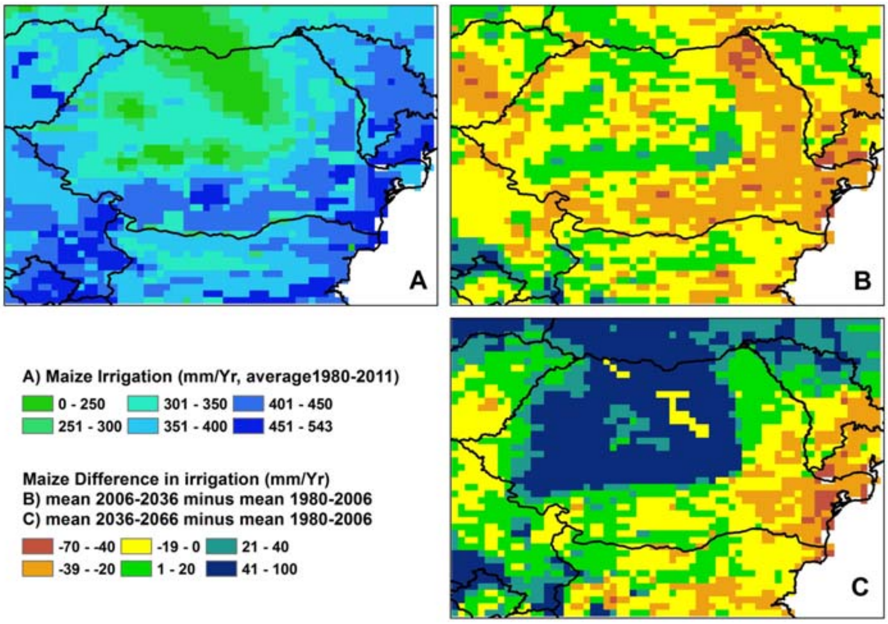


Figure 44. *Average Maize irrigation requirements (mm/year) simulated with DSSAT crop model based on COSMO-CLM RCM climate data (forced with ERA-INTERIM reanalysis) over the 1980-2011 period. Difference in Maize irrigation requirements between projected conditions (DSSAT based on climate COSMO-CLM RCM forced with CMCC-CM GCM, RCP45) for 2006-2036 (B) or 2036-2066 (C) and actual conditions.*

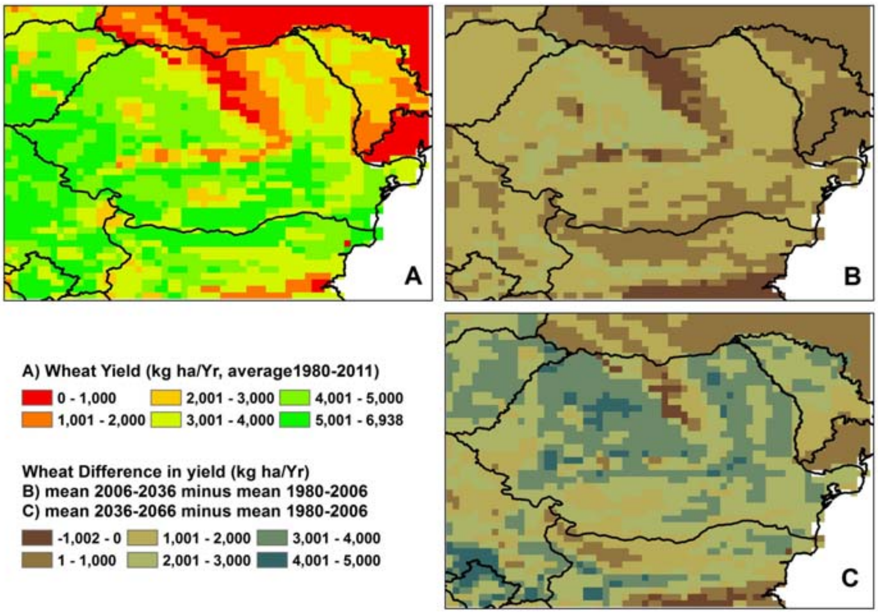


Figure 45. *Average wheat yield (kg ha/year) simulated with DSSAT crop model based on COSMO-CLM RCM climate data (forced with ERA-INTERIM reanalysis) over the 1980-2011 period. Difference in wheat yield between projected conditions (DSSAT based on climate COSMO-CLM RCM forced with CMCC-CM GCM, RCP45) for 2006-2036 (B) or 2036-2066 (C) and actual conditions.*

5. Climate adaptation strategy in Romania

5.1. State of the art in term of policies and strategies

In Romania, the central competencies within the field of climate change adaptation are assigned to the Ministry of Environment and Climate Change through the Directorate for Climate Change.

The Government policy on climate change is assisted by the National Commission on Climate Change set up as an advisory body in 1996 in order to provide equal and consistent implementation of the UNFCCC and the Kyoto Protocol throughout the country. The National Commission on Climate Change comprises representatives from line ministries and one NGO with competencies in climate change. Some of its tasks are to:

- periodically review the progress of Romania's Climate Change Strategy,
- consider the opportunity for new or updated policies and measures under the National Action Plan on Climate Change,
- identify financial resources for actions and targets on climate change, and
- recommend project developments under the Kyoto Protocol.

In 1992 Romania signed the United Nations Framework Convention on Climate Change (UNFCCC), ratified by Law no. 24/1994, pledging to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent anthropogenic interference with the climate system. Romania also signed the Kyoto Protocol in 1999 being the first Part located on Annex I of the UNFCCC which ratified it by the Law no. 3/2001. Commitment value for mitigation of greenhouse gases emissions assumed by Romania for the period 2008-2012 was 8%, considering the level of emissions in 1989 as a benchmark.

Since 2002, Romania submit annually to UNFCCC Secretariat, the national inventory of emissions of greenhouse gases, elaborated according to IPCC methodology, using common reporting format for all countries (CRF Reporter).

In the framework of the flexible and voluntary mechanisms implemented in the Kyoto Protocol for international cooperation (Joint Implementation (JI), Clean Development mechanism (CDM) and Marketing), Romania has been involved in investment projects of "Joint Implementation". In particular, Romania is working with states to achieve technology transfer, increased energy efficiency of objectives where the investments have been made and improve of environment. Thus, Romania signed Memorandums of Understanding with Switzerland, Netherlands, Norway, Denmark, Austria, Sweden and France, Italy, Finland, World Bank, in the frame of Prototype Carbon Fund, the legal basis for these projects.

In Romania, the Directive 2003/87/EC establishing a scheme for greenhouse gases emissions trading, has been implemented since 2007 (EU accession). This is a tool created to support member states to promote reducing emissions of greenhouse gases in an economically efficient way in order to fulfill the commitments under the Kyoto Protocol. Operation scheme is based on limiting - trading the greenhouse gases emissions certificates allocated to operators holding a plant in which the activities are covered by the Directive, to the extent that they comply with the limits for CO2 emissions set out in the National Allocation Plan (NAP).

In 2007 following the European approach on adaptation, a Working Group on adaptation to climate change was formally established, gathering representatives from all key sectors: ministries, research institutes, NGOs (Ministerial Order No. 82/2007 on establishing the nominal composition of the WG). In 2010-2011 (during the preparation of the component on adaptation to climate change from future National Strategy on Climate Change 2013-2020), this working group was expanded by recruiting new institutions and professionals with responsibilities in this area in order to effectively contribute to national efforts on climate change policy.

The first National Climate Change Strategy, drawn up in 2005 and approved by the Governmental Decision (no 645/2005) was related to the 2005-2007 period. In this Strategy, climate change adaptation issues were highlighted separately in the chapter "Impact, Vulnerability and Climate Change Adaptation", which briefly detailed the effects of climate change adaptation on the following sectors: agriculture, forestry, water management, and human settlements.

Moreover, in 2008, in response to the EU Green Paper "Adapting to climate change in Europe - options for EU action", the Ministry of Environment and Forests developed the Guide on the adaptation to the climate change effects approved by Ministerial Order (no 1170/2008). This guide provides recommendations to reduce the risk of adverse effects of climate change in 12 key sectors as follows: Agriculture, Biodiversity, Water resources, Forests, Infrastructure, Construction and Urban Planning, Transport, Tourism, Energy, Industry, Health, Recreational Activities, Insurance.

From 2010 onwards the Annual Reports drawn up by the National Environmental Protection Agency include separate chapters for climate change and its impact on human and natural systems and adaptation related issues.

Currently, Romania finalized the National Climate Change Strategy with time horizon on medium and long term (2013-2020) in which adaptation will be an important part of the document. The strategy addresses two main components: the reduction in the concentration of greenhouse gases (Mitigation) and the adaptation to climate change (Adaptation). At national level, once the Adaptation component was launched, the interministerial working group developed a large consultative process with central and local stakeholders in order to draw up an efficient adaptation component and to reduce the adverse inevitable effects of climate change and to meet the EU objective on adaptation. On the Adaptation component were identified 13 sectors vulnerable to climate change: Food, Agriculture and Fisheries, Tourism, Public Health, Construction and Infrastructure, Transportation, Water Resources, Forestry, Energy, Biodiversity, Insurance, Recreation, Education. In this context, the integration of the adaptation in the sectorial strategies will help to have a comprehensive approach and select appropriate measures for the direct and indirect effects of climate change. In order to develop a realistic adaptation strategy we have to adjust the existing sectorial strategies on climate change basis.

In the period 2013-2015, the Ministry of Environment and Climate Change (MECC) will work together with the experts from World Bank to achieve the National Objectives and EU Requirements in the Field of Climate Change. The list of top six priority sectors refers to agriculture, water resources, forests, biodiversity, energy, transport and the main objectives of the funding application for the Climate Change RAS (Reimbursable Advisory Service) will include the most important climate change effects necessary to be managed by each sector.

As such, the members of the working group approved by the MECC will provide the most important response measures, including crosscutting measures, for each of these priority sectors.

In the frame of The Clearinghouse Mechanism (CLIMATE-ADAPT: European Climate Adaptation Platform), each Member State has an individual section. Romanian page can be found at the following link: http://climate-adapt.eea.europa.eu/countries/romania.

At local level: According to the provision of the National Strategy on Climate Change- Adaptation Component, the strategy has to be assumed and continuously improved at the local government level, through relevant, specific measures for the economical context and local public needs. At the same time, local authorities will develop action plans on climate change.

The municipality of Sfantu Gheorghe, the capital City of Covasna County in collaboration with the Environmental Protection Agency of Covasna initiated the elaboration of the "Adaptation to climate change strategy for Sfantu Gheorghe City" in the frame of the EU Cities Adapt project. The project is carried out for DG CLIMATE Action. More information about the project can be found on the webpage: http://eucities-adapt.eu/cms/.

The Romanian Municipalities Association initiated a consultative process through "The Romanian Municipalities Association Commitment for Climate Change Effects Prevention", which has so far been signed by 35 out of 109 municipalities. One aspect of this commitment is related to the assessment of climate change risk and implications for public services and local communities and their capacity to adapt to climate change.

On 30th July 2009, the Romanian Municipalities Association signed an agreement in order to become a partner organization in implementing the Covenant of Mayors in Romania.

Currently 30 of the municipalities-part of the Romanian Municipalities Association have so far signed this Convention, together with another 1200 local authorities.

5.2. Cross-sectoral links

Main Climate Change Mitigation (CCM) and Climate Change Adaptation (CCA) actions in the principal thematic areas in Romania are presented in the following table.

Table 13.

SECTORS/AREAS	CCM/CCA actions
Transport	**Strategy for a sustainable transport for the periods 2007-2013 and 2020, 2030** • development and modernization of the transport network, especially the ones with European and National interests • increase safety conditions and the quality of services • compatibility with the surrounding environment **General Master Plan for Transport** • increase the efficiency of the transport system
Air quality	**Emission inventory of green house gases - Romanian NIR 1989-2008. National Inventory Report, submission 2010** **Emission inventory of green house gases - CRF Tables 2010. Common Reporting Format, submission 2010** **National Transition Plan (NTP) for combustion installations within the provisions of Chapter III of the 2010/75/UE Directive, concerning industrial emissions** • ensuring the conformation of installations foreseen by the NTP, as of 1st of July 2020, by implementing the necessary measures in period 1st of January 2016 – 30th June 2020 • ensuring a steady linear decrease of national emissions between 2016-2020 for SO_2,NO_x, residual dust resulting from burning installations • ensuring a mechanism to monitor the state of fulfilled objectives and the proposed measures as well as for reporting Governmental Order 64/ 2011 regarding geological carbon capture and storage according to the EU Directives. **Program for renewal of the national car park, financed by the National Fond for the Environment 2012** **Program for reduction of the impact on the atmosphere, financed by the National Fond for the Environment 2012**
Energy	**Romania's Energy Strategy for the period 2007-2020, updated for 2011-2020** • increase energy efficiency; • promotion of renewable energy sources • promotion of CHP plants, with special interest on those with high efficiency • support for the activities of researcher's in this field as well as dissemination of their results • reduce the negative impact of the energy sector on the environment • rational and efficient use of primary energy resources

SECTORS/AREAS	CCM/CCA actions
	PNAEE II. National Action Plan in the field of Energy Efficiency for the period 2011-2020 • continue the adoption, by law, of high energy efficiency standards when installing new capacities (having as an effect the reduction of energy consumption to 9,5 million toe)[toe=tons equivalent petrol] • initiation, development and implementation of an organizational program and institutional measures to increase energy efficiency (having the goal of reducing the current energy consumption from 15.9 million toe) **National Action Plan for Renewable Energy Sources (PNAER 2010)** • the share of renewable energy in the gross final energy 2005 (S2005) - 17,8 % • the objective of the renewable energy share in the gross final energy 2020 (S2020) - 24,00% • adjusted total energy consumption expected for 2020 - 30278 (ktep) • the expected consumption of renewable energy according to the objective for 2020 - 7267 (ktep) **The Strategy of CENTRU Region on the use of reusable energy resources, elaborated by Regional Development Agency CENTRU** **Priority axis 1**- Efficient energy management through well based local policies and through the modernization of the local and regional administration structure **Priority axis 2** - Capitalization of the natural potential of CENTRU region in order to produce energy from renewable sources **Priority axis 3** - Stimulation of alternative energy use of local entrepreneurs **Priority axis 4** - Increase the capitalization of the researchers results and develop innovation potential in the field of renewable energy **Priority axis 5** - Improve the qualification of human resources and develop a managerial atitude of people implicated in renewable energy **Government Decision - 935/2011** regarding the promotion of utilization of bio-fuels and bio-liquids **Law - 220/2008 r**egarding establishment of promotion system for energy production from renewable energy sources **Government Order - 22/2008** regarding energy efficiency and promotion of renewable energy sources for the final consumers **Government Decision - 443/2004** regarding the promotion of electrical energy from renewable energy -sources **Government Decision - 1892/2004** regarding establishment of promotion system for energy production from renewable energy sources **Government Decision - 750/2008** regarding the approval of the help aid scheme of the regional state on capitalization of renewable energy resources **Green House Programme** for individuals and legal persons, financed by the National Environment Fund – regarding the installation of heating systems using renewable energy

SECTORS/AREAS	CCM/CCA actions
Forest	**National Forest Administration Strategy on medium term 2011-2016** • scientific identification and formalization of ecological data bases of sustainable forest management • natural risk identification and quantification of their impact on the ecosystems of the forests • implementation and perfection of the Forest Monitoring System at the level of EU • ensuring sustainable fishing and hunting management • ensuring sustainable protected area management (natural preserves, Natura 2000 sites **National Forest management Plan for 10 years including:** • description of the administered surface • forest management master plan • registering methods and evidence of the work that has been done on the forest fund **Annual plan for protection against forest fires**, elaborated at the level of forest districts **Protection plan for the forest fund and for the control of wood traffic,** elaborated at the level of forest districts **Program for improvement of the environments quality by afforestation of degraded agricultural lands, ecological reconstruction and sustainable forest management,** financed by the National Environment Fund
Waste management	**National Waste Management Strategy 2014 - 2020** • development of such measures that encourage the prevention of waste generation and reutilization, promoting a sustainable resources utilization • increase the rate of recycling and improvement of the recycled materials quality in close collaboration with the financial sector and with the entrepreneurships that capitalize waste • promotion of capitalization of waste from packages • reduce the produced impact of the generated carbon • encourage the production of energy from those types of waste that can't be recycled **National Waste Management Plan:** provides the basic principles of the Romanian environmental policy, established according with the European and international provisions, assuring the protection and the preservation of nature, the biodiversity and the sustainable use of its components. **Regional Waste Management Plans and County level Waste Management Plans,** elaborated in respect of the National Waste Management Strategy **Project „ Integrated Waste Management System for Covasna County"** financed by Environmental Operational Programme (Cohesion Fund), unrolled in the period 2010 -2015
Spatial Planning	**National Infrastructure Development Program** • 10.000 km of county roads with local interests • modernization of the Romanians villages

SECTORS/AREAS	CCM/CCA actions
	• sewerage and sewage water treatment • water supply infrastructure • multiannual programmes for the environment and water management • water management infrastructure, hydro-technical work for protection against floods, increase grade the safety of dams and rehabilitation and protection of coastal areas **Law - 350/2001** regarding spatial planning and Governmental Decision 525/1995 for approval of the general urbanism regulations **Program for realization of bicycle roads financed by the National Environment Fund**
Agriculture	**Research-Development and Innovation Strategy in Agriculture and Rural Development for 2014 –2020:** • development of biotechnologies in the animal, vegetal, nutrition field and unconventional energies obtained from agricultural resources; • rural development research and promotion for ecologic and sustainable agricultural system; • research to prevent and control desertification and against the impact of regional and global climatic changes; • research on preservation and sustainable administration of biodiversity; • research on systems of the sustainable exploitation of agricultural and zootechnical resources considering the global climatic modifications; • research on fuels generation and utilization and unconventional power resources in agriculture and the sustainable development of the rural environment; **The Code of Action for Reducing the Impact of Climate Change in Agriculture** **National Strategy for Rural Development 2007-2013** **Axis 2:** Improving the environment and the countryside in order to promote a sustainable management of agricultural lands and forests **Priority 1:** Biodiversity conservation **Priority 2:** Protection and sustainable management of natural resources **Priority 3:** Mitigation of green house gas emissions and combating climate changes **Measures:** Agro – environment payments; Natura 2000 payments for agricultural land; Afforestation of agricultural lands; Afforestation of non-agricultural lands; Natura 2000 payments for forest; development and increased use of renewable energy sources, including biofuels from agriculture and production of biomass from forestry as well as increasing the level of conformity with EU standards for zootechnical farms (mitigation of ammonia emissions)
Sustainable development	**Romanian National Strategy for a Sustainable Development Orison 2013-2020-2030** • **Orison 2013**: incorporation of the practices and principles on sustainable development into the Romanian programs and policies • **Orison 2020:** reaching the average EU indicators on sustainable development • **Orison 2030:** significantly closing in on the actual years EU average indicators on sustainable development

SECTORS/AREAS	CCM/CCA actions
	CENTRU Region Development Strategy for the period 2014-2020 **Priority axis 1** - urban development, the development of regional technical and social infrastructure **Priority axis 2** - increase the economic competitivness, stimulating innovation **Priority axis 3** - protection of environment, increase the efficiency of energy consumption, stimulation of alternative energy sources **Priority axis 4** – development of rural areas, supporting agriculture and forestry **Priority axis 5** - development of tourism **Priority axis 6** - development of human resources, increase social inclusion **Environmental Action Plan for Covasna County** • Improving water quality • Reducing soil and groundwater pollution • Waste management improvement • Improving water resources management • Management of urban areas • Tourism and recreation • Nature protection and conservation of biodiversity • Ecological education • Mitigation of atmospheric pollution • Managing threats caused by major accidents or by natural or anthropogenic • Health of the population • Strengthening local authorities capacity to manage climate change
Industry	**Sectorial Operational Programme "Increase the economic competitivness",** **Axis IV,** financed from Structural Funds**:** • increase the energetic efficiency and the security of energy supply in the context of fighting against climate change • support the investment of installations and equipment of the industry, in order to make economic savings on energy to improve the efficiency • linking the national electric energy and natural gas transport networks with the European networks
Tourism	**Master Plan for National Tourism Development 2007 – 2026**
Water resources	**1. River Basin Management Plans for 2009 - 2015 which include Plan for the Watershed (Quantitative component of Water Management) and Water Management Plan (Qualitative component of Water Management).** In-depth assessment topics are: - Governance (administrative arrangements, public participation, international cooperation) - Characterization of the river basin district - Monitoring of surface waters and groundwater - Assessment of groundwater status - Environmental objectives and exemptions - Programme of measures - Strategy to deal with water scarcity and droughts - Adaptation to climate change in RBMP

SECTORS/AREAS	CCM/CCA actions
	2. Regulations approved by Ministerial Orders (M.J.O.nr. 638/420/ 31.05.2005) - Procedures for Management of Emergency Situations due to hydrological drought. It includes obligation to elaborate an Operational Report about: - Hydrological situation - Area of restriction - Measures for supplements of flow rates of the rivers - Program of restrictions in drinking water consumption. **3. Regulation regarding emergency situations management generated by floods, dangerous meteorological phenomena, accidents at hydro-technical constructions, accidental running water pollution and sea pollution, approved by Order 192/1422/ 2012** **4. At the level of each basin there are elaborated Water Restriction Plans during deficit periods of water. The main aspects from Water Restriction Plans are:** The informational and decision-making system and alarm system for population and for social – economic entities; The list of water users, necessary flow rates and minimum flow rates; The control sections along the rivers and characteristics for special situations (Normal Stage, Attention-Alarm Stage, Restriction Stage). **5. Environmental Operational Programme, Priority Axis 5, Sector protection against floods and reduction of coastal erosion** **6. Program financed from National Environment Fund: "Works for prevention, mitigation and combating the effects of dangerous meteorological phenomena at public waterworks"**
Biodiversity	**National Strategy and Action Plan for Biodiversity Conservation 2010 – 2020** **Action 1:** Stopping the declining biological diversity represented by the genetic resources, species, eco-systems, landscape and restoration of degraded systems till 2020 **Action2:** biodiversity conservation related policy integration into sectorial policies till 2020 **Action 3:** Knowledge, practice, innovating method, pure technologies promotion as measures for supporting biodiversity conservation as part of sustainable development, till 2020. **Action 4:** Improvement of communication and education in the field of biodiversity, till 2020 **Management Plans for Romanian** Natura 2000 sites **Management Plan** of Natura 2000 site - Ciomad-Balvanyos **Management Plan** of Natura 2000 site - Herculian
Education	**Program with the aim of education of the public and raising public awareness on the topic of environment protection** - financed by the National Environment Fund
Insurances	**Law - 260/2008 regarding mandatory house insurance for earthquakes, landslides and floods** **Law no. 381/2002 on the provision of compensation in case of natural disasters in agriculture**

SECTORS/AREAS	CCM/CCA actions
Water management	**National Strategy for the Management of Flood Risks: Prevention, Protection and Mitigation of the Flood Effects, for the period 2010-2035,** approved through Government Decision 846/2010 • it's according to the European Framework Directive regarding the Water; • avoid the alterations and anthropical influences in the geomorphology of hydrographical basins; • prevent the pollution of running waters and of underwater after floods, and the effects on the ecological quality of running waters; • protection and improving of the quality of crop lands, and where is possible, the encouragement to change the agricultural techniques in order to prevent or mitigate the floods and their effects because of intensive agricultural works; • protection and conservation of historical assets, of the monuments, of protected areas and ecosystems; • protection and improvement of the environment; • prevention and mitigation of the impact of climatic changes over the floods phenomena
Costal and marine systems	Master Plan regarding the Protection and Rehabilitation of Romanian Costal Area The Strategy for Danube Delta, for the period 2011-2015
Human health	The National Strategy to Prevent Emergency Situations, approved by Government Decision 762/2008 Protection Plans against floods, dangerous meteorological phenomena, accidents at hydro-technical constructions and accidental running water pollutions, elaborated by the County Committee for Emergency Situations - at the level of each County, providing: - short description of the county - synoptic of hydro-meteorological and managing information system of the county - tables with the technical protection elements of the local committees, the human forces at county level, the protection materials stocks - the drawings with the flood bands for the running waters, with a limit of 1% and for the maximum historical level - profiles of the hydro-technical constructions - the prevention and action plan for accidental pollutions - water restriction plans during deficit periods of water Joint Order of the Minister of Interior and Administrative Reform, Minister of Public Health, Minister of Labour, Family and Equal Opportunities and Minister of Environment and Sustainable Development on the approval of the Plan of measures to achieve cooperation actions between the prefects and mayors, in their capacity of presidents of the county committees for emergency situations, respectively of the local committees for emergency situations, and the authorities of public health, for the attenuation of the high temperatures effects on the population.

Exploatation of the project outomes by EPA Covasna referes to the review of the Local Action Plan for Environmental Protection of Covasna County by:

- entering weather-climate in local planning;
- creating a bridge between the organization generates meteo-climatic data and local decision makers;
- including relevant results of pilot studies carried out in the project OrientGate;
- including the provisions of National Strategy on Climate Change of Romania 2013 – 2020;
- initiating actions to disseminate the results obtained by specialized research projects conducted in order to identify adaptation measures to climate change, to local authorities and farmers in the area;
- initiating projects on adaptation to climate change, with the involvement of other public institutions and NGOs in the county;
- cooperating with local governments to carry out plans to adapt to climate changes.

Given the fact that at the end of 2014 a new process of revising of the Environmental Action Plan for Covasna County will start, the EPA Covasna will find solutions to include the results of the Pilot Study 2 into actions at regional level (table 14). A similar goal will have also the Municipality of Caracal. This approach will serve as a bridge between scientific community and stakeholders such as local/regional authorities and farmers.

Table 14. *Local Action Plan for the Environment/ Covasna County*

General Objective	*Specific Objective*	*Target*	*Actions*	*Responsible for implementation*
1.1. Increasing capacity of authorities to handling issues related to the phenomenon of climate change	1.1. Identifying and accessing funding sources projects for human resource development and international exchange	1.1.1.1. Increase the training of personnel involved in managing the climate change issues	105. Identification and implementation of projects on the topic of climate change, including research projects	- County Council - institutions - municipalities
			106. Developing international cooperation and exchange of experience in the field	- County Council - institutions - municipalities
			107. Cooperation of institutions / authorities to integrate climate change issues in the development of policy sector and the promotion of environmental efficiency;	- County Council - institutions - municipalities

6. Policy recommendations for agriculture adaptation to climate changes

The climate in Romania is expected to undergo **significant changes** over the coming decades. In the next decades, the most pressing consequences are those related to thermal changes (e.g. hotter summers with more frequent and persistent heat waves) over entire country and to reduction in mean precipitation especially in Southern, South-eastern and Eastern parts of Romania (Mateescu at all, 2009, 2020, 2012).

In order to **study the regional aspects and variability of climate change impacts in agriculture** field four critical areas must be addressed:

1. The effect of climate change on the future climatic conditions at regional and local level;
2. The effect of climate change (including the effect of CO_2 concentration) on crop growth and productivity of cultivated key crops;
3. Developing recommendations for adaptation options based on the dedicated case study results.
4. Much more vulnerability assessments have to be coupled with the information about physical basis of climate change to obtain updated and improved knowledge for adaptation in agriculture field.

Adapting to climate change through a better crop system management will benefit mainly from the knowledge given by our responses to severe climate events, when plans to adapt to and mitigate predictable climate change risks are implemented. A number of agronomic can be recommended to avoid or reduce negative climate change effects and exploit possible beneficial options. Hereby short-term adjustments and long-term adaptation can be differentiated. The first ones imply changes in planting dates as well as cultivars, changes in external input like irrigation, and techniques to conserve soil water. Long-term adaptations include major structural changes to overcome disadvantages caused by climate change. Land use, breeding and biotechnology applications, crop substitution as well as changes in farming systems are some examples for long-term adaptations (Sandu I. at all, 2010, 2014).

Given the fact that at the end of 2014 a new process of revising of the Environmental Action Plan for Covasna County will start, the EPA Covasna will find solutions to include the results of the Pilot Study 2 into actions at regional level. A similar goal will have also the Municipality of Caracal. This approach will serve as a bridge between scientific community and stakeholders such as local/regional authorities and farmers.

The need for policy coordination at regional, national and local level as an urgent issue is important to develop and implement specific adaptation measures, especially in the case of areas vulnerable to climate change and drought. The development and implementation of **regional training, education and public awareness programs** focused on adaptation to climate change and drought impact on agricultural crops, having as focus groups the regional and local authorities, relevant stakeholders and scientific communities, quantifying the effects at regional and local levels by encouraging contributions and personal action in addressing climate change will conduct to appropriate technologies, climate-friendly attitudes and behavioral changes.

The Romanian National Strategy for Climate Change (2013-2020) adds extra guidance on the approaches and institutional cooperation needed to cope with climate change in an integrative and multi-sectoral approach. As for the sectoral recommendations, a sound base for assessing costs related to climate change for different sectors is the evaluation of the state of the art in the knowledge of adaptation to climate change. Defining specific objectives on different time horizons and the tools to monitor the way to reach these are also important for sectoral approach of adaptation*.* In this context, the integration of the adaptation measures in the sectoral strategies will help to have a comprehensive approach and select appropriate measures for the direct and indirect effects of climate change. To develop a realistic adaptation strategy the existing sectoral strategies on climate change basis have to be adjusted.

The autonomous **adaptation capacity** has to be assessed and the direct and indirect effects of climate change and the intersectoral links between the most important sectors of the economy have to be evaluated and the **risk assessment approach** taking into account the frequency and magnitude of the future effects of climate change on different economic, social and environmental systems has to be amended.

Finally, mainstreaming climate change adaptation considerations into **key EU policies** must be the most important elements of the work in the area of adaptation. Building on this existing work, the **EU Adaptation Strategy** aims to enhancing the preparedness and capacity to respond to the impacts of climate change in the EU, its Member States and regions, down to the local level.

Also, **the Horizon 2020 (12) Programme** referring to the call named “Climate action, environment, resource efficiency and raw materials (2014-2010)” aims to improve understanding of the impacts of climate change on the water cycle in order to better inform decision makers and ensure sustainable water management and agricultural productivity improvements in the EU.

The impact of the climatic extremes varies function of the crop type and the local characteristics of the climatic and agro-meteorological conditions. In other words, **the climate change has a significant impact on agriculture** through that is diminished the crops in both quantity and quality, it shortens the vegetation period and it modifies the water balance elements, especially in the agricultural areas highly prone to drought and having low adaptation potential.

Drought is one of the most damaging natural hazards through its effects on agricultural, hydrological, ecological and socio-economic systems. In this context, a distinction can be made between meteorological drought (low rainfall), hydrological drought (low river flow and abnormal low groundwater levels), and agricultural drought (low soil moisture content). The primary cause of the occurrence of drought in a region is determined by the failure or absence of rainfall. High air temperatures and evapotranspiration rates may increase the intensity and duration of droughts.

Therefore, **drought hazard mapping** is instrumental towards enhancing Romania's ability to address the major priorities for the programming period 2014-2020 consequently focusing on the implementation of projects for rehabilitation and development of the land reclamation infrastructure and ensuring the access to water for the irrigation in areas with chronic shortage of water resources wherein drought has been increasing sharply for the last years.

Furthermore, additional gains are expected, such as substantially raising the living standards of the local population, as a result of increased agricultural production, improving the conditions of conservation of soil and constant supply of food. The development and implementation of **regional training, education and public awareness** programs focused on adaptation to climate change and drought impact on agricultural crops, having as focus groups the regional and local authorities, relevant stakeholders and scientific communities, quantifying the effects at regional and local levels by encouraging contributions and personal action in addressing climate change will conduct to appropriate technologies, climate-friendly attitudes and behavioral changes

Finnaly, concerning **current policies** regarding drought monitoring and management in the past few decades it has become evident that in all countries affected by drought and water scarcity is a clear need to improve national and regional policies with the goal of improving preparedness measures and reducing negative impacts. **Better coordination of the management policies** is also needed due to the transboundary or regional/local character of drought events. Also, the need for policy coordination at regional, national and local level as an urgent issue is important to develop and implement specific adaptation measures, especially in the case of areas vulnerable to climate change and drought.

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7. List of Indicators

Short Name	Long Name	Short description
CDD	Consecutive dry days	It represents a maximum length of dry spell. It counts the largest number of consecutive days in a chosen period where RR < 1 mm.
PRCPTOT	Total precipitation in wet days	Precipitation amount on days with RR ≥ 1 mm in a chosen period (e.g. year)
SPI03	Standardized Precipitation Index - 3 months	Computation of the SPI involves fitting a Gamma probability density function to a given frequency distribution of precipitation totals for a station. It is calculated from the long-term record of precipitation in each location (at least 30 years) It represents a meteorological drought indicator, convenient for both monitoring and prediction of drought events. Its nature allows an analyst to determine the rarity of a drought event at a particular time scale (seasonal in this case) for any location in the world that has a precipitation record.
AI	Aridity Index	It is a numerical indicator of the degree of dryness of the climate at a given location Let P be accumulated precipitation and PET Thornthwaites' potential evapotranspiration in the chosen period, the aridity index for the period is given by P/PET.
SM	Soil Moisture	It is calculated based on soil water balance model. ● it allows analysing the in-soil water reserve over various profiles / depths and at crop-specific calendar dates; ● it identifies areas potentially affected by pedological drought phenomenon dynamics (intensity, duration and spatial distribution).
HS	Heat stress	It occurs when the maximum temperature reaches 32°C during the summer season (June-July)
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation Index	It is the solar radiation reaching the canopy in the 0.4–0.7 μm wavelength region. fAPAR parameter is considered a good indicator for detecting and assessing the impact of drought on plant coatings (crops, natural vegetation). fAPAR is one of the 50 Essential Climate Variables recognized by the UN Global Climate Observing System (GCOS) as

Short Name	Long Name	Short description
		necessary to characterize the climate of the Earth. Is a satellite derived product being obtained from SPOT Vegetation data (1 km spatial resolution).
NDVI	Normalized Difference Vegetation Index	It is a satellite-derived index from the visible (VIS and Near-Infrared (NIR) and Short Wave Infrared channels. The index can be used to provide information for agriculture and vegetation health situation. This information is useful in determining water stress levels in vegetation and estimation of crop yield and is useful in drought assessment.
NDWI	Normalized Difference Water Index	NDWI is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels. Is a good indicator of water content of leaves and is used for detecting and monitoring the humidity of the vegetation cover. It is known that vegetation during dry periods is affected by water stress, which influence plant development and can cause damage to crops in agricultural areas. NWDI holds considerable potential for drought monitoring because the two spectral bands used for its calculation are responsive to changes in the water content (SWIR band).
NDDI	Normalized Difference Drought Index	It is a new index for drought monitoring which is calculated from normalized difference vegetation index (NDVI) and normalized difference water index (NDWI). It combines information from visible, NIR, and SWIR channel. NDDI can offer an appropriate measure of the dryness of a particular area, because it combines information on both vegetation and water. NDDI had a stronger response to summer drought conditions than a simple difference between NDVI and NDWI, and is therefore a more sensitive indicator of drought.
IrrReq	Irrigation Requirements	Fraction of crop water requirement to be supplied via irrigation
GDD	Growing Degree Days	It represents the number of temperature degrees above a threshold base temperature (8°C in this case) in a chosen period.
CropYld	Crop Yield	It represents the measure of the yield of a crop per unit area of land cultivation.

8. Glossary of terms

The chapter contains the definitions of a number of terms connected to the topics approached through this book. Other information and definitions connected to agriculture and the environment can also be found in the glossary hosted by the website of the European Environmental Agency
http://glossary.eea.europa.eu/EEAGlossary/.

Agriculture system: the way of practicing a technological system of the agricultural production characterized in the main by the intensive or extensive specific of the agriculture, through the land use mode and through the way production branches are combined, through the method applied to maintain and augment the soil fertility, the way the labour force is used and through production relations.

Agricultural drought: the drought is defined through meteorological parameters with an impact on the yield and stability of the crops. These parameters are the in-soil water reserve, potential evapotranspiration – real evapotranspiration (PET-RET), in-soil water deficit, the decrease of the phreatic water level NAF), etc. The water requirements of the plants depend on environment conditions, especially on the meteorological parameters (Max. temp., Min. temp. air moisture, precipitation), the phenophase and the agricultural species.

Available water [AW] {%, mm/mm, mm/m}: the share of the water within a soil that can be easily absorbed by the plants' roots. It is the water amount ranging from the in-situ field capacity and the point of permanent withering.

Climate: the multiannual regime of the meteorological processes, characteristic to a given region or the mean state of the atmosphere. In other words, the climate summarizes the average, domain and variability of the elements pertaining to the weather state, for instance, the rain, wind, temperature, fog, thunder strikes and sunshine, observed during a big number of years (usually a 30-year period), in a certain location or a whole region. The climate of one region determines the type of cultivated and spontaneous plants, as well as the specific fauna.

Climate adaptation: The adjustment of ecological, social and economic systems in response to the current or expected impacts of climate change and in order to moderate or offset possible damage and exploit beneficial opportunities.

Climate change: changes directly or indirectly attributed to the anthropic activity that alters the composition of the global atmosphere and that are, together with the natural climatic variability, observed over comparable time periods.

Climatic variability: in the most general sense, the term *climatic variability* refers to the inherent characteristics of the climate acting in the climatic changes occurred throughout time. The variability degree may be described through the differences between the long-term statistics of the meteorological elements, as computed for various periods. The term *climatic variability* is often used to express the deviations of the climate statistics over a given time interval (a certain month, season or year) from the long-term climate statistics connected to the corresponding calendar period. In this sense, the climatic variability is measured through those deviations that are usually called "anomalies".

Climate vulnerability: Thesensitivity of a system to climate changes; the ability to sustain damage caused by climate change; lack of resilience to the impacts of climate change.

Crop coefficient [Kc]: a coefficient used to modify the reference evapotranspiration, so as to reflect the use of water by a certain plant or group of plants, with special reference to plant species.

Crop evapotranspiration [Etc]: the amount of ET in a cultivated area of a field, which is associated to growing one crop.

Crop rotation: the practice of cultivating a series of crops of different types on one and the same space in successive seasons. Choosing the crops and their succession depend on the soil nature, on climate and precipitation, which together determine the type of plants that may be cultivated. Other important aspects, like the marketing and the economic variables must also be taken into account when choosing the crop rotation. Only certain plants prevail here, especially the cereals and the technical plants, the most widespread being the monocultures (grain maize) and the two-year rotation (maize, winter wheat), which implies large mineral fertilizer amounts and pesticides.

The technique of dividing a cultivable terrain in more plots (function of the number of plants to be cultivated) and of distributing each plant on a certain plot by turns.

Deep percolation [DP] [mm]: downward motion of the water through the soil, beyond the area of the roots, becoming unusable by plants.

Desertification: the process through which terrains within the arid, semiarid and sub-humid regions are degraded, as a result of various causes, including climatic ones and human activities (Convention to Combat Desertification – CCD).

Effective precipitation [Ep] {mm): the share of the total precipitation that can be used for the plant growth.

Evaporation [E] {mm/day, mm/week, mm/month}: water motion from a moist soil or from the plants' surface without passing through the plants.

Evapotranspiration [ET] {mm/day, mm//week, mm/month}: a mix of the water transpired by the vegetation and the water evaporated by the soil and the plants' surfaces.

Field capacity [FC] {%, mm/mm, mm/m}: water amount left in the soil when the gravity-owed downwards motion of the water becomes negligible.

Fraction of Absorbed Photosyntetically Active Radiation [fAPAR]: fraction of the radiation absorbed by the vegetal cover in the 400-700 nm spectral interval.

Gross irrigation requirement [IRgross,] {mm}: total irrigation requirement that comprises the net requirement of the crop plus the losses resulted from distribution and application and from operating the system.

Irrigation system: equipment necessary for bringing the water in the designed area.

Leaf Area Index [LAI]: half of the surface of the green leaves (or of coniferous needles) projected over the soil surface unit.

Leakage/runoff: a term used for the water resulted from rain, snow melting or irrigation that flows on the soil surface without being absorbed and which goes in rivers or other surface waters or in depression areas.

Limiting factor: any condition that limits the functions and/or use of a soil.

Maximum allowable depletion [MADp] {-}: depletion allowed through management (deficit) [MAD] {%, -}. Planned soil moisture deficit at the moment of irrigating.

Meteorological drought: from the meteorological standpoint, the drought is defined as a period with an important deficit (or even absence) of precipitation. The meteorological drought settles after 10 consecutive days without precipitation. The intensity of the meteorological drought is assessed function of the number of days without precipitation and by the number of days with below normal precipitation or below the multiannual mean of the analysed period.

Net irrigation requirement [IRnet,] {mm}: the water depth (without considering the effective precipitation, soil moisture or ground water), which is necessary to compensate for crop evapotranspiration, to yield the production and for other utilities, such as the water necessary for leaching, protecting against frost and cooling.

Normalized Difference Vegetation Index [NDVI]: a nonlinear transformation of the visible bands (red) and near infrared (nir), being defined as the difference between these two bands, divided by their sums.

Normalized Difference Water Index [NDWI]: index derived from satellite data, defined as the ratio of the difference between reflectance in near infrared and the reflectance in infrared and their sum.

Permanent (irreversible) withering point [PWP, WP] {%, mm/mm, mm/m}: the moisture content in water lacking conditions at which plants can no longer obtain sufficient moisture from the soil, so as to meet their requirements. Plants will not fully recover when the water reaches the root area if this point has been reached. Classically, the 15- atmosphere (bar) tension of the soil moisture is used to estimate PWP.

Plant available water [PAW] (mm): the water available in the root area.

Porosity {%,-}: the volume of the pores within a soil sample related to the total volume sample.

Precipitation [P] {mm}: total amount of atmospheric water reaching the soil surface: rain, snow, hail, dew etc.

Readily available water [RAW] {mm/m}: The share of the available water which is more easily available to the plants. It varies with the plant type.

Reference evapotranspiration [ETo]: the evapotranspiration rate in the cold season, from a wide surface, uniformly covered by 12-cm high green grass undergoing active growth and not lacking water.

Remote sensing: ensemble of methods (research, monitoring and covering) used to remotely process data regarding different objects or phenomena with the aim to obtain information impossible to collect through classical methods.

Resilience: The ability of a system to recover from the impacts of a disaster by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.

Root area, Root zone (RZ) {mm, m}: the depth of the soil easily crossed by roots, where the roots develop their prevailing activity.

Soil: the upper part of the terrestrial crust made up of mineral particles, organic matter, water, air and organisms.

Soil degradation (deterioration): Alteration of soil properties with negative effects on one or more of its functions on the environment. The general expression defining any process that leads to the soil fertility decrease. Soil degradation is determined by irrational exploitation of the terrain, often leading to its partial or total elimination from the agricultural circuit.

Soil fertility: usual state of a soil as regards its capacity to sustain growth and developments of the plants. A complex property or attribute of the soil through which nutrients are made available to the plants, the water and air the plants need for their growth and development in the broader perspective of satisfying the other vegetation factors also; valuating human labour in view to obtain high yields.

Soil Moisture Deficit [SMD], Water deficit {mm}: water amount necessary to fill the root area up to the field capacity.

Soil productivity: capacity o a certain soil to yield crops in usual conditions. The property of a terrain (of the soil-plant-atmosphere system) to yield crops.

Surface waters: interior, marine waters, standing and flowing, whose surfaces are in a direct contact with the atmosphere.

Transpiration [T] {mm/day, mm/week, mm/month}: water circuit from the soil to the plant root, through the stem and finally through the root, as vapours.

Water resources: surface waters consisting in the water flows with their deltas, the lakes, the ponds, the interior maritime waters and the territorial sea, as well as the whole of the ground waters.

Water use efficiency [WUE]: the ratio between the yield from a surface unit and the consumption of irrigated water on the surface unit.

Vulnerability assessment: The identification of who and what is exposed and sensitive to climate changes, taking into consideration factors that make human beings or the environment susceptible to harm.

DSSAT - Decision Support System for Agrotechnology Transfer

CERES – Crop simulation models for Wheat and Maize crops

NMA Bucharest – National Meteorological Administration, Bucharest

EPA Covasna – Environmental Protection Agency, Covsana

GCM: General Circulation Model

IPCC: Intergovernmental Panel on Climate Change

RCP: Representative Concentration Pathway

SEE: South-Eastern Europe

SRES: Special Report on Emission Scenario

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National research projects

- Evaluation of climate change impact on Romanian agriculture potential http://www.meteoromania.ro/anm/?page_id=1266
- Methodologies for reducing the impact of climate change on Southern part of Romania http://www.meteoromania.ro/anm/?page_id=1275
- Analysis system for assessment of vulnerability and adaptation capacity to climate change in touristic sector
- Changes in climate extremes and associated impact in hydrological events in Romania (CLIMHYDEX) http://climhydex.meteoromania.ro/

European Projects

- FP 7 The European Reanalysis and Observations for Monitoring project http://www.euro4m.eu/
- FP 7 CryoLand - Copernicus Service Snow and Land Ice
- http://www.cryoland.eu/
- FP 7European Provision Of Regional Impacts Assessments on Seasonal and Decadal Timescales (EUPORIAS) http://www.euporias.eu/
- SEE Joint Disaster Management risk assessment and preparedness in the Danube macro-region http://www.meteoromania.ro/anm/?page_id=1431
- SEE OrientGate - A network for the integration of climate knowledge into policy and planning http://www.orientgateproject.org/
- Mitigating Vulnerability of Water Resources under Climate Change http://www.meteoromania.ro/anm/?page_id=2485
- Drought – coordinated actions in Europe http://www.meteoromania.ro/anm/?page_id=1288
- Mitigation Drought in Vulnerable Area of the Mures Basin http://www.meteoromania.ro/anm/?page_id=1482

European networks

CIRCLE-2 http://www.circle-era.eu/np4/home.html

The OrientGate partnership comprises 19 financing partners, nine associates and three observers, covering 13 countries.

Partners

Euro-Mediterranean Centre on Climate Change (IT)
Forest Department, BMLFUW (AT)
Ministry of Regional Development and Public Works (BG)
National Institute of Meteorology and Hydrology (BG)
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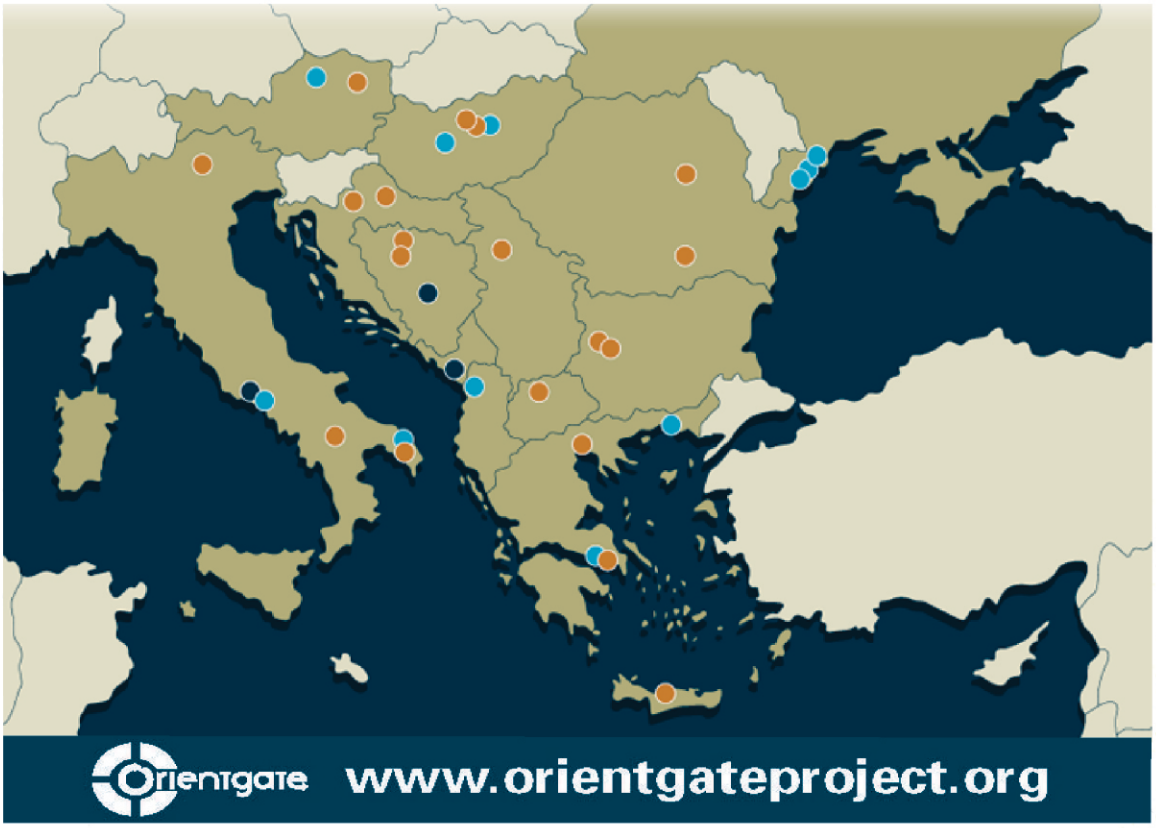
Ministry of the Environment, Land and Sea (IT)
Region of Puglia, Mediterranean Department (IT)
GFEAEI, Odessa Regional State Administration (UA)
Odessa State Environmental University (UA)
Vilkovo City Council (UA)

Observing Partners

Federal Hydrometeorological Institute (BiH)
Union of Italian Provinces (IT)
Ministry of Sustainable Development and Tourism (ME

More information about OrientGate project:
http://www.orientgateproject.org/
http://www.southeast-europe.net/



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