

INTEGRATED SYSTEM OF EARLY WARNING, MONITORING AND DROUGHT RISK ANALYSIS FOR ROMANIA

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ABSTRACT:

Drought is one of the major natural calamities causing important damages to natural vegetation, agriculture and the society. The climate changes scenarios forecast the increase and intensification of extreme phenomena all over the globe. Romania is one of the most vulnerable countries, and has 7 million hectares located within areas affected by the risk of desertification.

An integrated system for early warning, monitoring and analysis of the drought risk on the Romanian territory, combining satellite information with field data and numerical models results, was created. The system is user-friendly, flexible, robust, extensible, with a user graphical interface and compatible with other databases. The instruments implemented within the system ensure user access, transformation and viewing of the main data, forecasts, warnings and satellite images.

The system includes a reliable configuration for the reception/pre-processing of satellite MSG images in real time at each 15 minutes. NOAA AVHRR, MODIS, MERIS, LANDSAT, MSG, SPOT, ENVISAT and TerraSAR images are acquired from international data bases (EOS NASA Gateway, KALIDEOS, European Space data base, JRC). The satellite image processing include GIS-integrated and combined with information regarding the FAO-LCCS land coverage/use, meteorological forecasts and warnings and agricultural culture data.

1. Introduction

Drought is one of the major natural calamities causing important damages to natural vegetation, agriculture and the society. In Europe the damages caused by drought during the past 30 years were estimated by the European Commission at minimum EUR 100 billion. The climate changes scenarios forecast the increase and intensification of extreme phenomena all over the globe. For South-Eastern Europe, the scenarios indicate a higher thermal regime and insufficient rainfalls. In the area of our country, it is estimated that, until 2050, the desertification process would intensify and extend over large areas in 11 counties.

Romania is one of the most vulnerable countries, and one of the most affected by drought in Europe. In Romania, in 2000, 2003 and 2007 drought caused a decline in agricultural production, water reserves and the population was affected by the heat. In 2003 the only nuclear reactor, from Cernavoda, was closed due to the low water level of the Danube River, and agricultural productions were the lowest ever measured and recorded. In 2007 14 people died in Bucharest due to the high temperatures, numerous wells dried up, the underground water level decreased, and autumn agricultural cultures were compromised on extensive areas. On June 22, 2007 the Government declared 34 counties under state of natural calamity and the Executive decided to unblock RON 500 million for agriculture compensations.

Within the past few years, the coverage/use of land, the thermal regime, the rainfall regime and the ecosystems response to climate conditions have changed significantly. The main drought characteristics are slow occurrence, variation in time and extension over large areas. When drought is detected by the classical method, it has already settled. Being an extremely rapid, objective and accurate source of assessing the geographical reality, satellite data represent the ideal basis for the system. During the past decade the extreme dryness phenomena extended due to the profound transformations of the agricultural and forest land property – deforestation, damaging of protection forest curtains, lack of irrigations, etc.

An integrated system for early warning, monitoring and analysis of the drought risk on the Romanian territory, combining satellite information with field data and numerical models results, was created. The system is user-friendly, flexible, robust, extensible, with a user graphical interface and compatible with other databases. The instruments implemented within the system ensure user access, transformation and viewing of the main data, forecasts, warnings and satellite images.

The satellite image processing include NOAA AVHRR, MODIS, MERIS, LANDSAT, MSG, SPOT, ENVISAT and TerraSAR images, GIS-integrated and combined with information regarding the FAO-LCCS land coverage/use, meteorological forecasts and warnings and agricultural culture data. The system includes a reliable configuration for the reception/pre-processing of satellite images.

2 The integrated system

The on-line interactive system, allowing easy and quick access to information, is based on a multi-disciplinary approach, including satellite techniques, climate numerical modeling, complex geodetic processing, IT, agronomy, social science and economics. The system allows the assessment of drought risk and early warning, the rapid, regular and very low cost assessment of the areas impacted by drought, the intensity, spatial dynamics and evolution in time. Immediate access to information of decision-making

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factors and of a high number of users represents a permanent benefit, due to the fact that the impact of drought varies throughout the year and will allow taking measures for rapid management actions and consequence mitigation.

The system implemented at the national level ensures integration with the European emergency quick response system (floods, earthquakes, land-slides, droughts) created within the GMES (Global Monitoring for Environment and Security) programme.

The research activity is focusing on the satellite techniques, climate numerical modelling, agro-meteorology, plants physiology and ecology. Early warning is prepared combining the information obtained from the analysis of satellite product with the information obtained following the analysis of the regional climate model and measured data. The regional climate model provides estimating of the rainfall and thermal regimes, one season, one month and 3 days in advance.

The activities were:

1. Elaboration of the integrated system for early warning and monitoring, combining the information obtained from the regional climate model with the information obtained from satellite image processing,
2. Implementation of the drought forecast and warning system;

Four stages to implement the interactive system are necessary:

- system definition, development strategy and technical coordination; System definition consists of definition of the methods, procedures and development strategy of the system (preparation of service procedures, training plans, product specifications and standards).

- algorithm elaboration, processing method and statistical analysis of satellite images;

- developing the regional climate model;

- system application, implementation and verification.

3. System validation will be made with real field data, rainfall and temperature anomalies, vegetation density and agricultural production. The forecasts will be validated by meteorological diagnoses.

At the end of the research stage: Satellite image processing, a report will be prepared, including: the algorithms, satellite image processing methods and

2.2 System definition

The system consists in five modules: geo-spatial and satellite databases, spatial technique, climate numerical modeling and accessing, preparing warnings and products, viewing information and products.

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The system allows the assessment of drought risk and early warning, the rapid, regular and very low cost assessment of the areas impacted by drought, the intensity, spatial dynamics and evolution in time. Immediate access to information of decision-making factors and of a high number of users represents a permanent benefit, due to the fact that the impact of drought varies throughout the year and will allow taking measures for rapid management actions and consequence mitigation.

The first activity of the system is designed for early warning on the likelihood of occurrence of meteorological drought, followed by pedological and agricultural drought. The second implies the system extension, on a medium and long term, in order to be able to obtain a quick and efficient response in case of drought, response materialized especially in the form of mapping products derived from satellite data. The performance criteria for this objective will regard the capacity to offer value added products, allowing the authorities to take efficient measures and accurately assess damages.

2.3 System architecture

The system consists of:

- gateway access: it is a system providing several services and allowing users to know and choose the available service/product, select an alternative and, finally, obtain a desired product;
- a final-user community;
- delivery of thematic maps along with interpretation reports;
- quality service control: system management and maintenance: this component deals with the component/network distribution and monitoring system.

The operational service is characterized by:

1. Output: real time access to in-situ data and information archives, access to data and information from another European service.

Two product types were identified: reference maps and damage evaluation maps. The reference maps are obtained either from preexistent data or from simulations and they can be detailed in: geographic maps including cartographic, topographic and thematic information, and historic maps. Reference maps will be provided to support routine activities, mainly the long- and medium-range monitoring. Damage evaluation maps are derived directly from in-situ data and images obtained during droughts or indirectly from numerical modelling and comparisons between archived information and crisis situations. They give information related to a certain event, such as its time, place, danger level and damages. As the service relies on the availability of already acquired satellite images, the archive will play an important part in the service infrastructure.

2. Dissemination: this activity should be organized by cataloguing and maintaining stores, providing the possibility to access, upload, search and find, visualize and download products, by support and training. Products should be accessed on a specialized web portal. Also, they should be disseminated so as the user may easily integrate them in other data sets and catalogued for an effortless use. This is the object of correctly defining data formats and preserving metadata for future uses. The components of this infrastructure will include: metadata for data and services, 3-D data themes and services; network of services and technologies; exchange, access and use agreements; coordination and monitoring mechanism, processes and procedures.

3. System-related research and development: the connection between service/product provider and users should be preserved in the context of its future evolution and development.

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The user's interface showed in Fig. 1 is acquired through WMS (Web Map Service) system comprising client and server application components integrating in-situ and satellite data with numerical modelling for thematic map products able to produce complex mapping, either for basic or for assessment user procedures. This system would allow using the existing databases which respect to the INSPIRE European Directive.

The system designing and implementation involve a distributed architecture using the newest Web technologies so that the information flows between the various types of data (maps, analysis, charts and synthesis). The front end graphical interface is determined by the interaction between users and their requests (De Bernardinis, 2007).

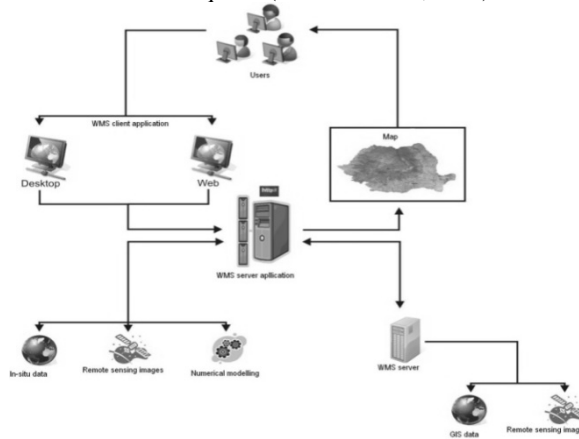


Fig.1. WMS data access

The system architecture is presented in fig. 2.

The functional decomposition of the system foresees:

- access gateway, which allow the users to know and chose available services, to select possible alternative and to obtain the service;
- end users (decision- making factors);
- the basic component, maps, delivered to users together with an interpretation report, prepared by experts;
- quality control service component.

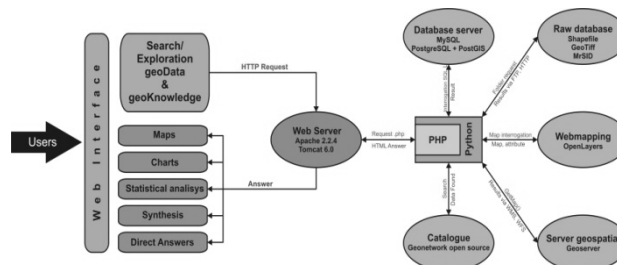


Fig. 2. - System Architecture

3. Data

The system allows forecasting meteorological drought one year/season in advance, based on regional climate simulations, and agricultural drought 3-6 weeks in advance, based on satellite images directly received or available in the international satellite image bases. Warnings, maps of drought intensity and extension and of space and time evolution are created. Meteorological data, satellite images and in situ measured data a integrated in system. The data flow is presented in figure 3.

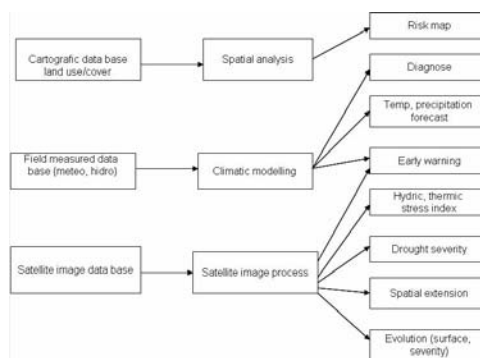


Fig.3. - System data flow

3.1 Meteorological database

The meteorological data base was created in ORACLE and contains received primary data, metadata and processed data. All data are validated using filters and correlations. The data base structure is presented in fig. 4.

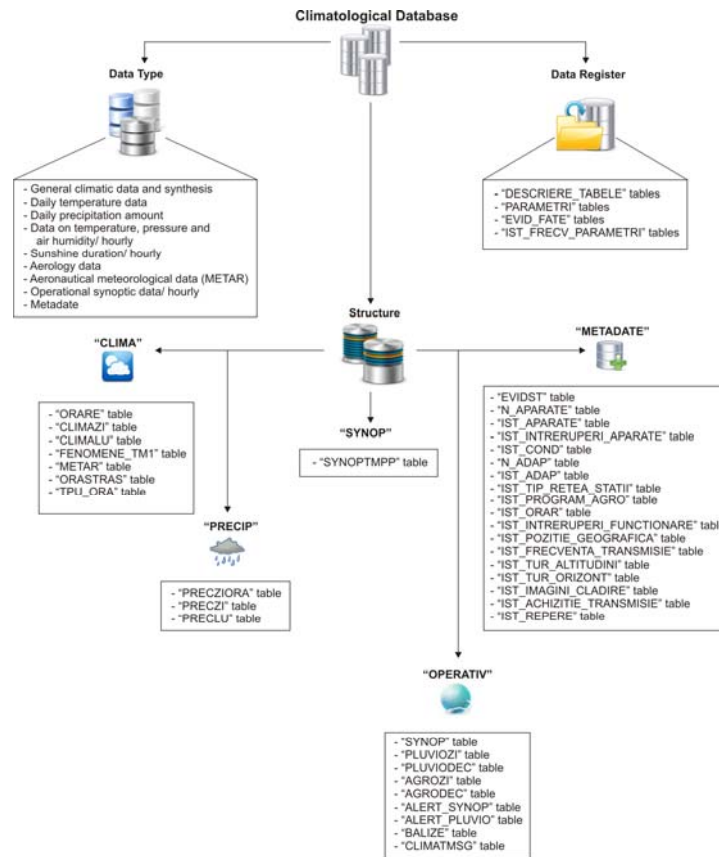


Fig. 4 Meteorological data base

3.2 Remote sensing data base

The geo-spatial database is used to prepare the risk map, to feed numerical models and validate satellite products. The satellite image process contains:

1. **Receiving satellite images** in near-real time and downloading images from databases;
2. **Calibration and pre-processing of satellite images** acquired in near-real time and of archive images;
3. **Preparation of algorithms** for processing satellite images with medium, high (HR) and very high (VHR) spatial resolution to obtain drought indexes
4. **Validation of algorithms** used for image processing. Validation will be made with field data for representative areas and dry years
5. **Implementation of the method** used for image processing, including image acquisition, calibration and pre-processing, elaboration and application of algorithms;
6. **Elaboration of products** from satellite images (drought index maps, delimiting impacted areas, estimation of intensity, space and time dynamics).

At this time, operating system receiving and processing data from meteorological satellites receive data streams transmitted in real time the following satellites:

- MSG-2 (operational): 12 spectral channels, 15 minute repeat cycle
- MSG-1 (Mission quick scan): 12 spectral channels, 10 minute cycle repetition
- NOAA 16 / 17 NOAA / NOAA 18: AVHRR (6 channels) + ATOVS, 4 passages/ day
- METOP-2: AVHRR (6 channels), ATOVS, IASI, 4 passages/ day
- GOES-E and GOES-W: 4 images / day
- Meteosat-7: IODC (Indian Ocean) / 30 minute repeat cycle.

Also, longer receives products derived from satellite data and the EUMETSAT SAF Consortium (LANDSAF, OSISAF, CMSAF)

The amount of data received and processed within 24 hours amounts to 20 GB. Four independent systems are in operation receiving and processing satellite data, as follows:

- Operating system (2 systems)
- Pre-operational system (1 system)
- Development system (1 system)

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It is actually a system of two identical lines of reception and processing operating under a "hot spare". It is the most modern and most secure system and was installed in 2007. This system is the main operational system and provide meteorological satellite products 24h/24h to all Regional Meteorological Centers.

The system presented in fig. 5 consists of a parabolic antenna with a diameter of 3m in band C, 2 and 2 receptor systems and processing systems operating in parallel identical. Thus, if a malfunction in one module, the program supervisor reconfigured the system so that it will use backup module. The main products obtained are:

- MSG RGB: 20 items
- NWC SAF MSG: 18 items
- MSG LAND SAF: 8 items
- MSG OSI SAF: 10 items
- MSG CM SAF: 8 items

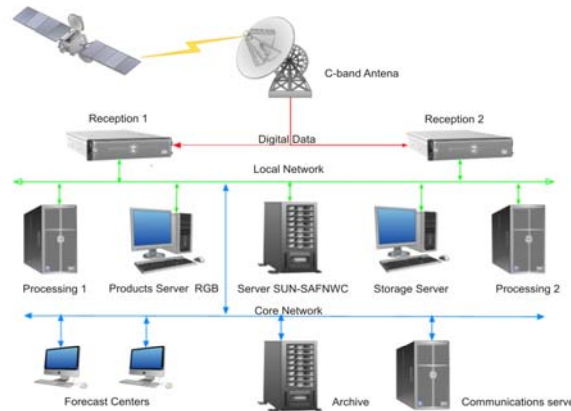


Fig. 5 Remote sensing data receiving system

The main requirements for based-space observation are range resolution (from medium to VHR) and spectral resolution (visible and IR). Satellite data (NOAA AVHRR, MODIS, MERIS, LANDSAT, MSG, SPOT, ENVISAT and TerraSAR), received in near-real time or downloaded from international databases (EOS NASA Gateway, KALIDEOS, European Space data base) are geometrically and radiometrically corrected, integrated in a GIS environment and processed together with land use/land cover information and with climate numerical models results.

NOAA images are used for computing the Normalized Difference Vegetation Index (NDVI), the Water Supplying Vegetation Index (WSVI) and the brightness temperature (BT) which is converted to the Vegetation Condition Index (VCI) and the Temperature Condition Index (TCI). The differences in TCI values and their spatial distribution give information where and when the drought is started and how intensive it is (Jain et al., 2009 and Wan et al., 2004). The research also demonstrated that backscattering coefficient extracted from ERS2 / RADARSAT1 data characterises surface soil moisture condition and can be used for drought detection and mapping (Prevot et al., 2003).

Based on the satellite image processing maps containing :

vegetation indexes, (Normalized Difference Vegetation Index, Modified Soil Adjusted Vegetation Index, Vegetation Condition Index, Enhanced Vegetation Index) bio-physical parameters Leaf Area Index, Fraction of Photosynthetic Radiation) and drought indexes are created.

3.3 In-Situ Data

To support image processing, in-situ data should include:

- a collection of very accurate ground-level points user in ortorectifying images;
- instantly acquired information to help in image analysis (for instance, photographs);
- information derived from primary sources, such as mapping products (drought risk maps);
- socio-economic information related to approaches to drought.

In-situ data can play a crucial role in the emergency situations allowing a global collection of high precision ground control points and ad hoc collected information to support the analysis of imagery.

Thus, the early warning is acquired from satellite data processing and analysis, regional climate modeling and in-situ data. The regional climate model provides estimates of the rainfall and thermal regimes, one season, one month and 3 days in advance.

4. Climate modelling

The specific objective of regional climate model development was accomplished by the following activities:

1. **Adaptation of regional climate models** to high resolution (10 km) and model calibration for a domain covering Romania;
2. **Regional climate model implementation and validation** on a domain covering Romania;
3. **Climate estimates** and forecasts, one year, season, month, decade in advance

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The high resolution regional model will be calibrated and validated for a domain covering Romania, using the data measured at the meteorological stations as input. The model calibration will be made such as

- to simulate, as accurately as possible, dry years in Romania
- to simulate climate changes due to the greenhouse effects

to simulate the occurrence of extreme events, by sub-domains, and estimate changes in the occurrence of extreme events.

During the high resolution **climate model** development stage, simulations will be carried out, one year, season, month, 10 days in advance and, if necessary, the drought warning will be prepared. For the purpose of updating the information, the model will be run with variable time steps, depending on the users' requirements. The model outputs will be presented in the form of graphs and maps:

- Rainfalls (daily total)
- Maximum day temperature
- Minimum day temperature
- Relative humidity (daily average)
- Surface pressure
- Wind speed (10m, 1000hpa)
- Geo-potential (700, 500, 200 hPa)
- Sunny hours (daily total)
- Soil humidity (100 cm depth)
- Potential evapo-transpiration (daily total)
- Humidity at 5 cm depth
- Soil surface temperature (min., max.)
- Leaf temperature (min., max.)
- Leakage (% of total rainfalls)

4. Conclusions

The research was focused on operational system achieving which integrates early warning, monitoring and drought risk analysis in the Romania's regions by access to real time and archive in-situ data and information, access to data and information produced by other European services and value added products. For the added products have been identified reference maps and drought damage assessment maps.

Reference maps are maps derived from pre-existent data or obtained by pre-event simulations containing cartographic information as well information about climate change, agricultural practices, surface soil moisture, main infrastructure and networks, completed with DEM information and combined in a GIS environment by moving from the 1:100.000 to the 1:25.000 scale.

Assessment maps are maps directly derived from in-situ data and satellite images acquired during the crisis or indirectly obtained through numerical modelling and comparing between post crisis and drought archive information, provide information about location, level of hazard and damage in a scaling moving from detailed scales (1:10.000–1:25.000) and overview scales (1:50.000–1:25.000).

Main mapping products are;

- specific drought indexes, thermal stress, hydric stress, drought intensity, impacted areas' extension
- variation in time and space of the areas impacted by drought
- emissivity,
- surface temperature,
- area covered by vegetation
- changes in the area covered by vegetation

The system allows forecasting meteorological drought with one year/season, based on regional climate simulations and agricultural drought with 3-6 weeks in advance and on the statistical analysis of the multi-temporal series of satellite images.

Also, the system allows the assessment of drought risk and early warning, the rapid, regular and very low cost assessment of the areas impacted by drought, the intensity, spatial dynamics and evolution in time. Immediate access to information of decision-making factors and of a high number of users represents a permanent benefit, due to the fact that the impact of drought varies throughout the year and will allow taking measures for rapid management actions and consequence mitigation.

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