Drought Monitoring in RHMSS: Drought Indices and Application of Remote Sensing in Agricultural Meteorology (FVC index)

Division for Applied climatology and agrometeorology
www.hidmet.gov.rs
specialized organization within the public administration system

expert activities in the field of meteorology, hydrology and climate change

only public administration body in charge of issuing alerts and warnings from the field of meteorology and hydrology

fulfils its international obligations from the field of meteorology and hydrology, meteorological air and river traffic security, transboundary air and water pollution monitoring, climate and climate change monitoring and research

fulfils obligations assumed by the ratification, related to the early warning of natural disasters and dangerous concentrations of substances resulting from nuclear disasters and industrial accidents
Programs of meteorological surface measurements and observations:

- Synoptical program - 32
- Climatological program - 97
- Precipitation program - 558
- Soil moisture program - 4
- Phenological program - 52

Observatories - 3 (Belgrade, Novi Sad and Nis)

Upper air observations - 1 (Belgrade)

Automatic meteorological stations - 30
Scope in the field of Agrometeorology in RHMS

Monitoring of the implementation of the observation program and participation in special agrometeorological observations (lysimeter measurements, measurement of the soil moisture).

Processing and analysis of agrometeorological data and publishing of agrometeorological yearbooks: phenological, soil temperature, transpiration and evapotranspiration.

Analysis, monitoring and assessment of conditions for agricultural development, as well as the assessment of potential impacts of expected climate change on agriculture in Serbia.

Monitoring, analysis and assessment of weather and climate condition impact are based on values of agrometeorological indices, application of agrometeorological models and results of climate models.

In the area of applied researches - studying of climate extremes and meteorological phenomena causing major damages in agriculture and their consequences (drought, extremely high and low air temperatures).
Extreme weather conditions in Serbia

- The analysis of the years characterized by drought trend in Serbia indicates the increasing frequency of very dry years in the last decades, covering most of the territory of Serbia.

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
</table>
| 2012 | - Extreme height of snow cover, cold wave  
- Heat wave, drought, forest fire |
| 2013 | - Spring mini tornado (Torda, Indijja)  
- Summer forest fires (Prijepolje) |
| 2014 | - Snowdrift  
- Extreme precipitation (floods)  
- Freezing rain |
| 2015 | - Heat wave  
- Forest fires |
Example of Drought Monitoring and Early Warning

Heavy drought in 2012

Heavy drought in 2012 – record long registered wave of extremely high air temperatures, material damage around 2 billion USD in the agricultural sector

Moisture conditions in Serbia estimated on the basis of the Standardised Precipitation Index (SPI-2) determined for 60 days period


Forecast 29.07.2012.

Moisture conditions in Serbia estimated on the basis of the Standardised Precipitation Index (SPI-2) determined for 90 days period (July, August, September)

Moisture conditions in Serbia estimated on the basis of the Standardised Precipitation Index (SPI-3) determined for 90 days period


Forecast 29.07.2012.

Moisture conditions in Serbia estimated on the basis of precipitation forecast (ECMWF/RHMSS)
Operational production and analysis of a number of humidity/drought indices and parameters in the framework of drought monitoring:

- **Standardized Precipitation Index (SPI)**
- **Standardized Precipitation Evapotranspiration Index (SPEI)**
- **Palmer Drought Stress Index (PDSI) and Palmer Z Index**;
- **Evapotranspiration**
- **Value of the soil moisture** obtained by measurement;

Operational use of products from agrometeorological models:

- **CROPSYST** (Cropping Systems Simulation Model) used for the simulation of growth, development and forecast of maize

Application of remote sensing observations in agrometeorology

- The Fractional Vegetation Cover (FVC) index
**Standardized Precipitation Index - SPI**

- SPI is the most applicable index - only data on precipitation amount are used for SPI calculation.

- SPI - precipitation amount recorded during some period of time which is represented through the values of random variable that has standardized normal probability distribution.

- Values of statistical parameters are obtained by the procession of long-term series of precipitation data (1961 – 2005).
Standardized Precipitation Index - SPI

- Quality assessment of the moisture conditions as per criteria defined for operative use

- Criteria are defined only on the basis of SPI probability distribution

- Not defined by cause/effect analysis

- Quite a frequent there is a significant correlation between the magnitude and duration of precipitation regime anomaly and consequences in agriculture, water management

<table>
<thead>
<tr>
<th>Value</th>
<th>Moisture conditions</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI ≤ -2.326</td>
<td>Exceptional drought</td>
<td>IS</td>
</tr>
<tr>
<td>-2.326 &lt; SPI ≤ -1.645</td>
<td>Extreme drought</td>
<td>ES</td>
</tr>
<tr>
<td>-1.645 &lt; SPI ≤ -1.282</td>
<td>Severe drought</td>
<td>JS</td>
</tr>
<tr>
<td>-1.282 &lt; SPI ≤ -0.935</td>
<td>Severe drought</td>
<td>JS</td>
</tr>
<tr>
<td>-0.935 &lt; SPI ≤ -0.524</td>
<td>Moderate drought</td>
<td>US</td>
</tr>
<tr>
<td>-0.524 &lt; SPI &lt; +0.524</td>
<td>Minor drought</td>
<td>S</td>
</tr>
<tr>
<td>+0.524 ≤ SPI &lt; +0.935</td>
<td>Slightly increased moisture</td>
<td>MV</td>
</tr>
<tr>
<td>+0.935 ≤ SPI &lt; +1.282</td>
<td>Moderately increased moisture</td>
<td>UV</td>
</tr>
<tr>
<td>+1.282 ≤ SPI &lt; +1.645</td>
<td>Considerably increased moisture</td>
<td>JV</td>
</tr>
<tr>
<td>+1.645 ≤ SPI &lt; +2.326</td>
<td>Extremely wet</td>
<td>EV</td>
</tr>
<tr>
<td>SPI ≥ +2.326</td>
<td>Exceptionally wet</td>
<td>IV</td>
</tr>
</tbody>
</table>
Standardized Precipitation Index - SPI

- SPI values defined for the periods of one to three months - relatively well correlated with storage of productive moisture in surface soil layers (assessment of moisture conditions for the growth and development of agricultural crops)

- SPI values defined for longer time periods indicate to prevailing characteristics of moisture conditions during vegetation period, calendar year...

- Example: good correlation between SPI1,2,3 and measurements of soil moisture up to 1 m depth
Calculation of SPI values

one-day time step

period of 30 days – SPI1

period of 60 days – SPI2

period of 90 days – SPI3

period of 1 - 12 months

at the end of the month
SPI Operative Use

Obtained SPI analysis - accessible and regularly updated on the web page of RHMSS presentation "Moisture conditions" and in various bulletins.
SPEI - the difference between rainfall and potential evapotranspiration (PET) represented by the corresponding statistical distributions that takes into account both negative values

- PET - calculated according to the Hargreaves's equation
- SPEI - easily identifies the role of evapotranspiration and temperature variability in drought analysis
- Operatively SPEI is calculated for the periods of 30, 60 and 90 days for 18 selected main meteorological stations on the territory of Serbia
- Same categorization as for values of SPI
Standardized Precipitation Evapotranspiration Index - SPEI

- Сомбор
- Нови Сад
- Кикинда
- Вршац
- Зрењанин
- Ср. Митровица

- Београд
- Крагујевац
- Лозница
- В. Градиште
- См. Папанка
- Неготин

- Ћуприја
- Краљево
- Пожega
- Ниш
- Димитровград
- Врање
CROPSYST - crop growth model; simulate biomass and crops yield, water and nitrogen reserves in the soil and crop phenology.

<table>
<thead>
<tr>
<th>Data</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climatic</td>
<td>Daily maximum and minimum air temperature, rainfall, air relative humidity (%), solar radiation and mean wind speed</td>
<td>Products of statistical analysis of climatic parameters: mean validity, standard deviation, maximum and minimum value</td>
</tr>
<tr>
<td>Crop</td>
<td>Planting date, thermal crop requests for specific growth level progress, morphological attributes crops (maximum index leaf area, depth root)</td>
<td>Date of growing stage, length of growing season, estimation yield depending on variability of climatic components, depth root</td>
</tr>
<tr>
<td>Soil</td>
<td>Hidropedological parameters of soil, soil texture</td>
<td>Potential and actual evapotranspiration, soil moisture deficit</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Irrigation scheduling criteria</td>
<td>Estimated yield depending on the application of agrotechnical practice</td>
</tr>
</tbody>
</table>
Operative use of CropSyst model

- Model has been applied on 15 selected locations on the territory of Serbia for maize crop since 2007

- The agrometeorological conditions analyzed and monitored during the period April-October

- Ten-day Bulletin with selected products obtained by using CROPSYST model
The values of actual and potential evapotranspiration, daily precipitation sum and water content in soil up to 1 m depth, as well as cumulative values of actual and potential evapotranspiration and daily precipitation sum since the date of planting until date of simulation presented in the bulletin in a graphic form.

Prognostic part of simulation presented in tabular form: cumulative values of potential and actual evapotranspiration and precipitation since the beginning of the vegetative period till the forecasted end of the growing season, the dates of corn phenophases, forecasted yield for the three weather scenarios.
Example of CropSyst Bulletin

AGRICULTURAL METEOROLOGY BULLETIN WITH MAIN COMPONENTS OF WATER BALANCE AND ASSESSMENT OF THE INFLUENCE OF WEATHER CONDITIONS ON GROWING STAGE AND CROP YIELD

Location: Banatski Karlovac

Estimated agrometeorological parameters of corn growth during vegetation period 2016

<table>
<thead>
<tr>
<th>Date</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting</td>
<td>15.04</td>
</tr>
<tr>
<td>Grain filling</td>
<td>30.07</td>
</tr>
<tr>
<td>Maturity</td>
<td>27.08</td>
</tr>
<tr>
<td>Harvest</td>
<td>12.09</td>
</tr>
</tbody>
</table>

Actual condition

- The final yield estimates of the model, kg/ha: 7791
- Accumulated values in vegetation period:
  - Pot. Et, mm: 703.1
  - Act. Et, mm: 563.1
  - Precipitation, mm: 465.4
Analysis of soil moisture
(CropSyst and measurements)

- Station Banatski Karlovac
- Year 2012 and 2013
The role of the RHMS in the field of risk assessment and risk map production for hail, windstorms, drought, snow drifts, blizzards and icing – is defined within the framework of the Serbian legislation, the Law on Meteorological and Hydrological Activity (“Official Gazette of RS” No. 88/2010), and the Guidelines on the methodology for the production of vulnerability assessments and plans for protection and rescue in emergency situations (“Official Gazette of RS” No. 096/2012).

In addition to the above hazards, RHMS is authorised for assessing the risk of large precipitation amounts, heat and cold waves (based on the new methodology, adopted in March 2017).
Drought Frequency

“Climate characteristics and analysis of meteorological hazards for the Republic of Serbia”

- “Climatic characteristics and analysis of meteorological hazards for the Republic of Serbia” was made in 2014 (applying "Methodology for the Development of Risk Assessment and Plans for Protection and Rescue in Emergency Situations").

- Analysis of risk assessment for four hazards (drought, wind storm, snowstorm and hale) and maps of their frequencies was made - for the territory of the Republic of Serbia and for districts and municipalities individually.

- Estimation of drought frequency and intensity influence on agriculture:
  
  • three-month SPI index for May and August (critical months in the development of agricultural crops)

  • six-month SPI index for September (moisture conditions during growing season)
Drought Frequency

“Climate characteristics and analysis of meteorological hazards for the Republic of Serbia”
Remote Sensing Products – LSA SAF

- **Satellite data** provides data for larger areas and measurements are taken once or several times a day - daily monitoring of soil, better insight into the state of vegetation

- **SAF** (Satellite Application Facilities) – a service for the processing of satellite data, created by experts from the National Services of the EUMETSAT Member States.

- **LSA** (Land Surface Analysis) **SAF** - products related to the analysis of the soil surface

- Daily in RHMSS arriving satellite data, LSA SAF among others, which are sent by EUMETSAT and DWDSAT-a (2009 Serbia signed an agreement on cooperation with EUMETSAT)

- LSA SAF **archived data** available on web page [http://landsaf.ipma.pt](http://landsaf.ipma.pt)

- Experts from RHMSS attended:
  - Training course “Application of remote sensing data for drought monitoring; introduction to EUMETSAT LANDSAF products”, 2013, Slovenia
  - Secondment of experts to the Drought Management Center for Southeastern Europe, 2014, Slovenia
On secondment of experts a remote-sensing index is calibrated with drought indicator

- analyzed four areas planted with grapevines, three areas with maize in Serbia
- chosen representative meteorological station for each area
- Daily precipitation data collected from 6 meteorological stations is used for calculation of SPI1 (30 days accumulated precipitation), SPI2 (60 days accumulated precipitation) and SPI3 (90 days accumulated precipitation).
- Values of FVC index for same areas was calibrated with calculated SPI1, SPI2, SPI3

Two locations in Serbia with dominant grapevine production (Veliko Srediste in vineyards Vrsac and Malo Orasje in vineyards Smederevo) were chosen for Drought Monitoring Bulleting of Drought Management Center for Southeastern Europe - DMCSEE
### Correlation coefficient (R) between FVC and SPI 1, 2 and 3

<table>
<thead>
<tr>
<th>Location</th>
<th>Grapevine</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPI1</td>
<td>SPI2</td>
</tr>
<tr>
<td>Sremski Karlovci</td>
<td>0.7956</td>
<td>0.8192</td>
</tr>
<tr>
<td>Alibunar</td>
<td>0.7382</td>
<td>0.8249</td>
</tr>
<tr>
<td>Veliko Srediste</td>
<td>0.7906</td>
<td>0.9109</td>
</tr>
<tr>
<td>Malo Orasje</td>
<td>0.8887</td>
<td>0.9502</td>
</tr>
<tr>
<td>Kanjiza</td>
<td>0.6823</td>
<td>0.8217</td>
</tr>
</tbody>
</table>
Within the RHMSD drought monitoring:

- downloaded available **historical LSA SAF products** (FVC) for the period 2007 - 2016 in .hdf5 format from: [http://landsaf.ipma.pt/](http://landsaf.ipma.pt/)

- performed **selection of location** with homogeneous agricultural crops (areas covered with vineyards)

- files from original .hdf5 format were converted to .txt format and **numerical values** of FVC index for selected locations on the territory of Serbia and time period were extracted, using programming language for the statistical analysis of data R

- Currently only **FVC** index is in operational use
Application of Remote Sensing Products in Agricultural Meteorology
(Fractional Vegetation Cover - FVC)

- **FVC**
  - measure of which part of the total satellite image pixel area is covered with green vegetation
  - depending on condition of vegetation and damages caused by natural disasters (droughts, floods, frost etc.)
  - values of FVC are smallest at the beginning of the growing season, the biggest in full vegetative development followed by slowly decline
FVC index during the growing season

6 locations in Serbia mostly covered with vineyards
THANK YOU FOR YOUR ATTENTION

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