Republic of Serbia
Republic Hydrometeorological Service of Serbia

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

Republic Hydrometeorological Service of Serbia (RHMSS)

- 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

Meteorological Observation System
- Meteorological Station Network -

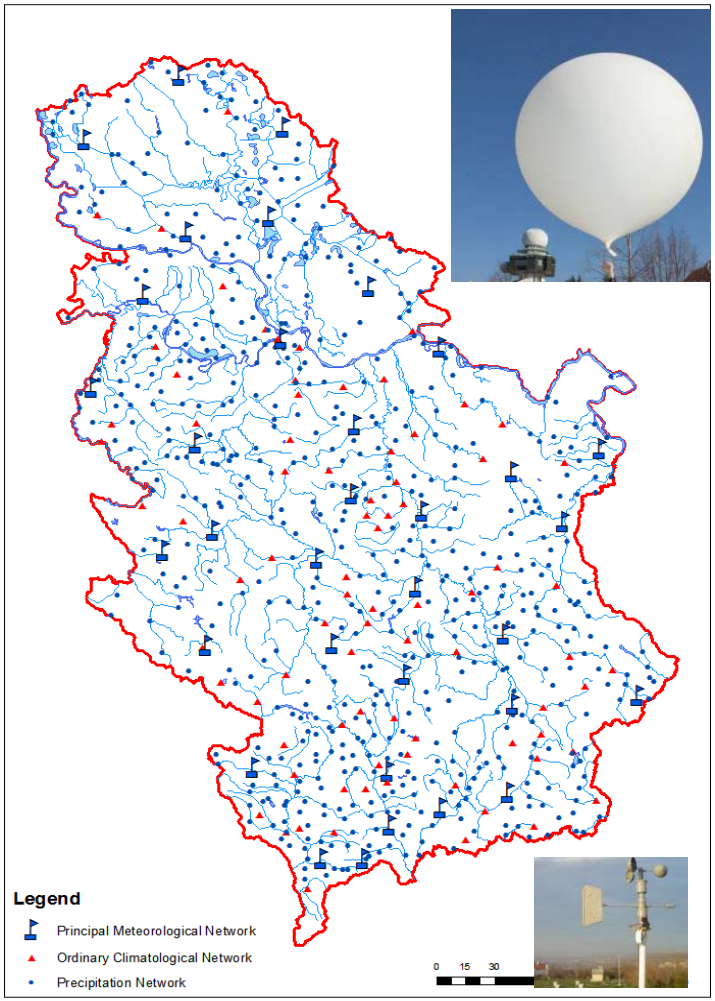
Programs of meteorological surface measurements and observations:

- 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 RHMSS

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;

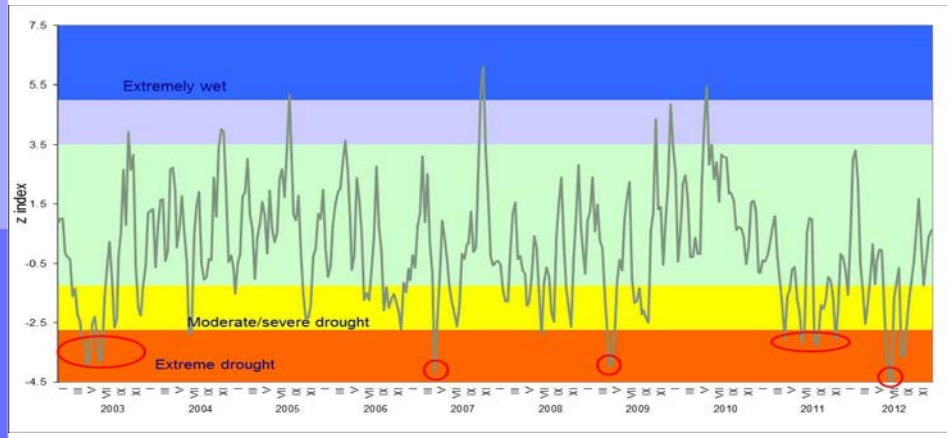
Analysis, monitoring and assessment of conditions for agricultural development, as well as the assessment of potential impacts of expected climate change on agriculture in Serbia

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
- The last decade was marked by 6 years with severe drought in Serbia (2000, 2003, 2007, 2011, 2012, 2015)



2012	•Extreme height of snow cover, cold wave •Heat wave, drought, forest fire
2013	•Spring mini tornado (Torda, Indjija) •Summer forest fires (Prijepolje)
2014	•Snowdrift •Extreme precipitation (floods) •Freezing rain
2015	•Heat wave •Forest fires

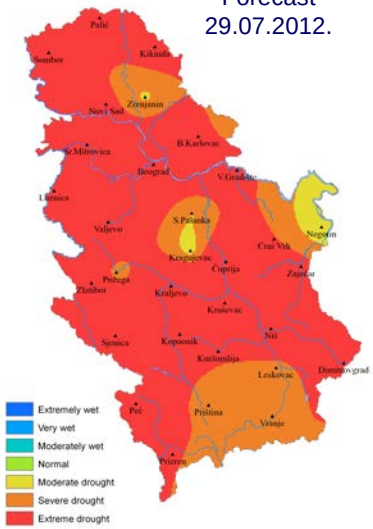
Example of Drought Monitoring and Early Warning
Heavy drought in 2012

Monitoring
29.07.2012.

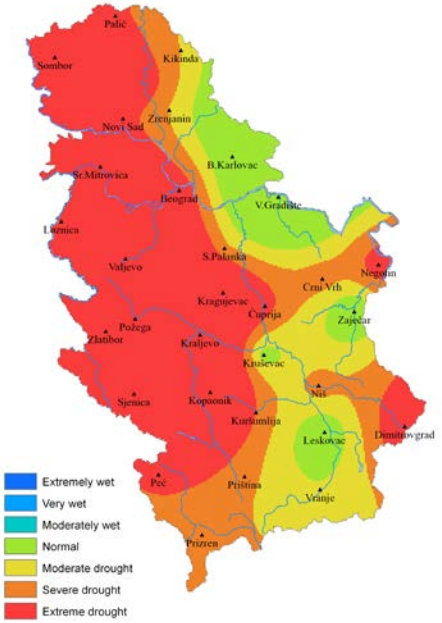
Moisture conditions in Serbia estimated on the basis of the Standardised Precipitation Index (SPI-2) determined for 60 days period

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

Forecast
29.07.2012.



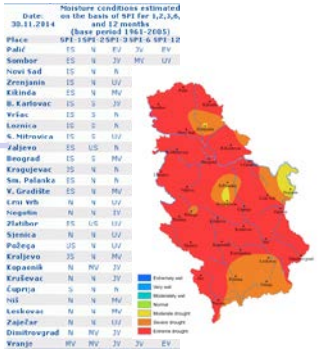
Moisture conditions in Serbia estimated on the basis of the Standardised Precipitation Index (SPI-2) forecast for next 30 days, based on precipitation forecast (ECMWF/RHMSS)



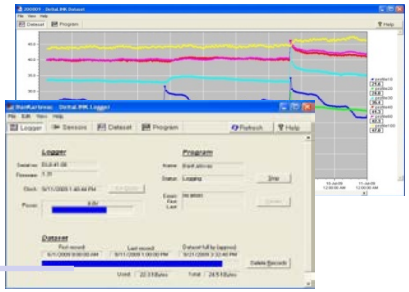
Moisture conditions in Serbia estimated on the basis of the Standardised Precipitation Index (SPI-3) determined for 90 days period
(July, August, September)

The Program of Operative Tasks

*Operational production and analysis of a number of humidity/drought indices and parameters in the framework of **drought monitoring**:*

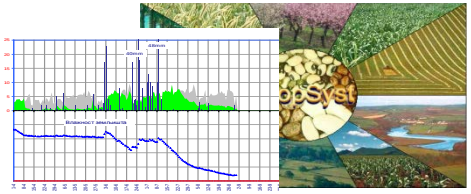


- **Standardized Precipitation Index** (SPI)
- **Standardized Precipitation Evapotranspiration Index** (SPEI)
- **Palmer Drought Stress Index** (PDSI) and **Palmer Z Index**;
- **Evapotranspiration**
- Value of the **soil moisture** obtained by measurement;



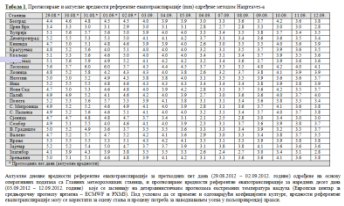
Operational use of products from agrometeorological models:

- **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** 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)

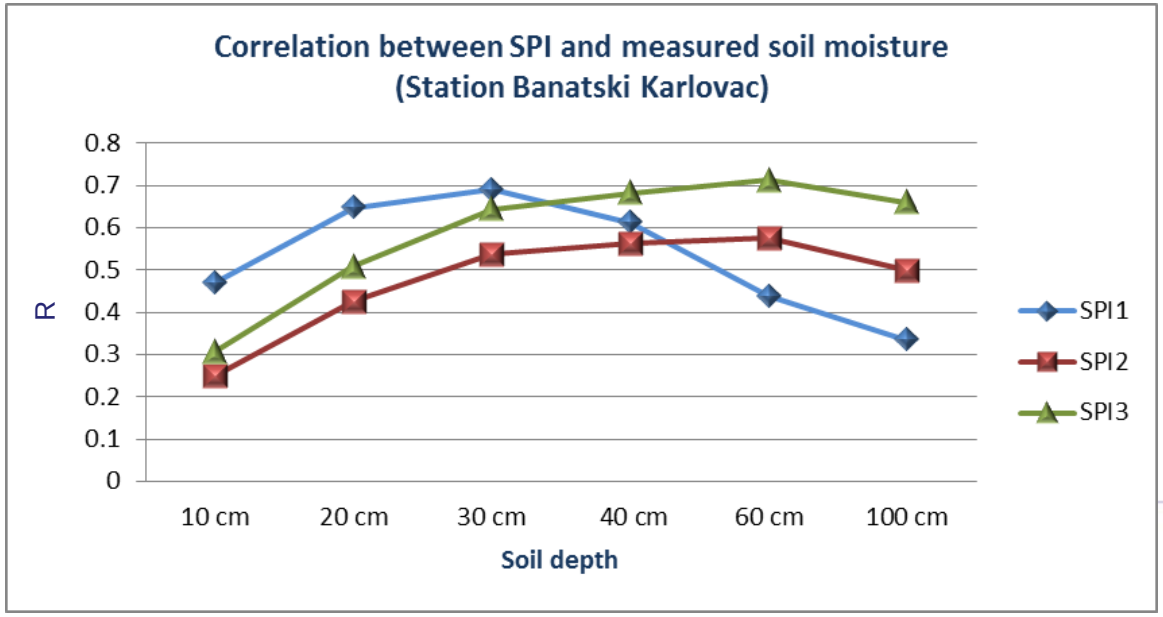
Standardized Precipitation Index - SPI

- 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

Value	Moisture conditions	Symbol
SPI ≤ -2.326	Exceptional drought	IS
-2.326 < SPI ≤ -1.645	Extreme drought	ES
-1.645 < SPI ≤ -1.282	Severe drought	JS
-1.282 < SPI ≤ -0.935	Moderate drought	US
-0.935 < SPI ≤ -0.524	Minor drought	S
-0.524 < SPI < +0.524	Near normal	N
+0.524 ≤ SPI < +0.935	Slightly increased moisture	MV
+0.935 ≤ SPI < +1.282	Moderately increased moisture	UV
+1.282 ≤ SPI < +1.645	Considerably increased moisture	JV
+1.645 ≤ SPI < +2.326	Extremely wet	EV
SPI ≥ +2.326	Exceptionally wet	IV

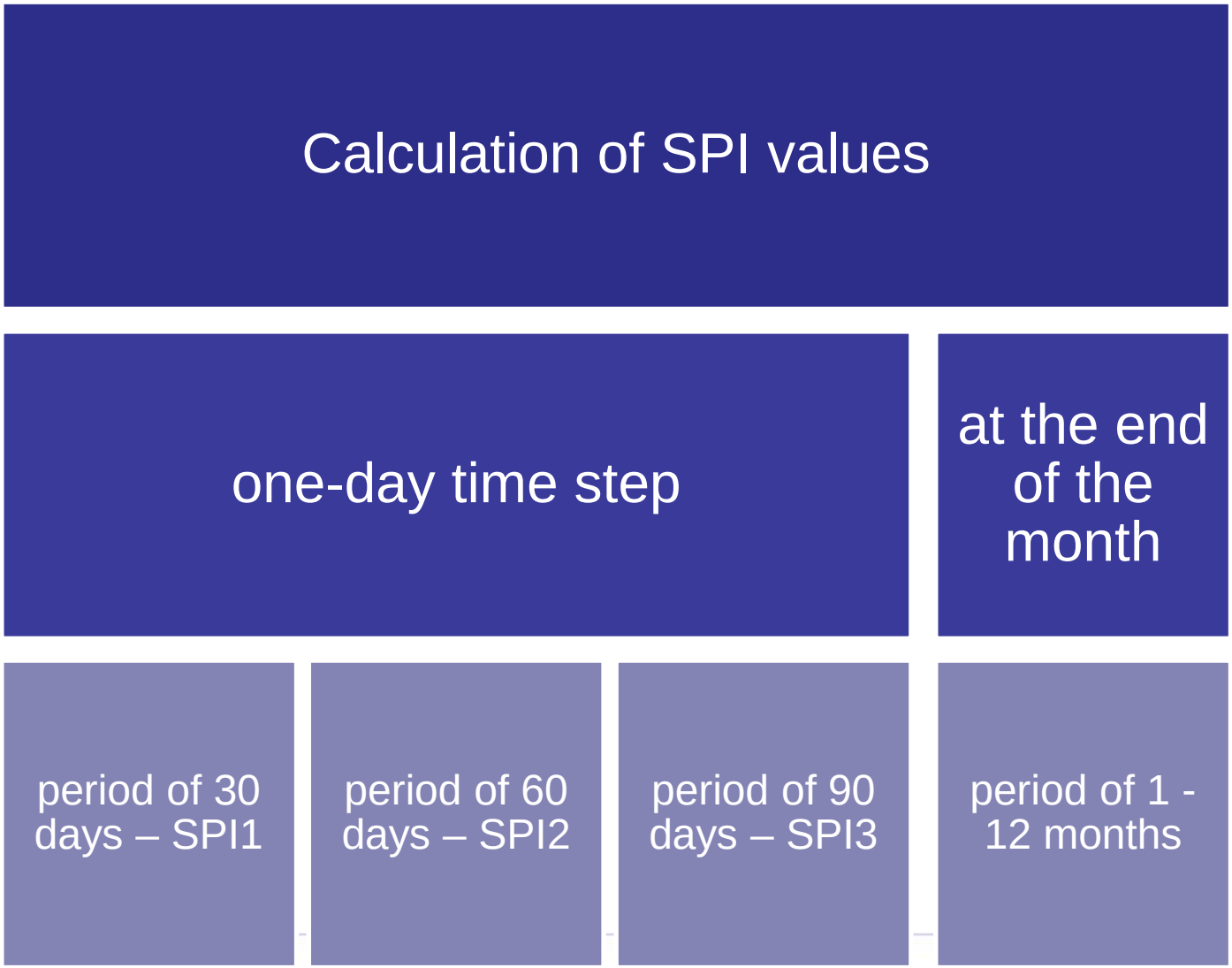
Standardized Precipitation Index - SPI

- 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…



- *<u>Example</u>: good correlation between SPI1,2,3 and measurements of soil moisture up to 1 m depth*

SPI Operative Use



SPI Operative Use

Agricultural meteorology

Agricultural meteorology
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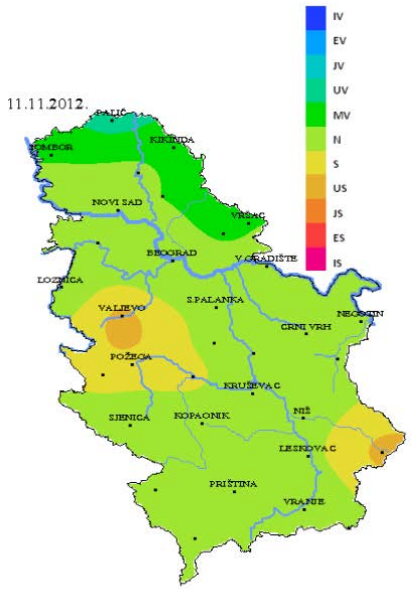
Republic of Serbia

MOISTURE CONDITIONS-DROUGHT MONITORING
on the basis of Standard Precipitation Index (SPI)



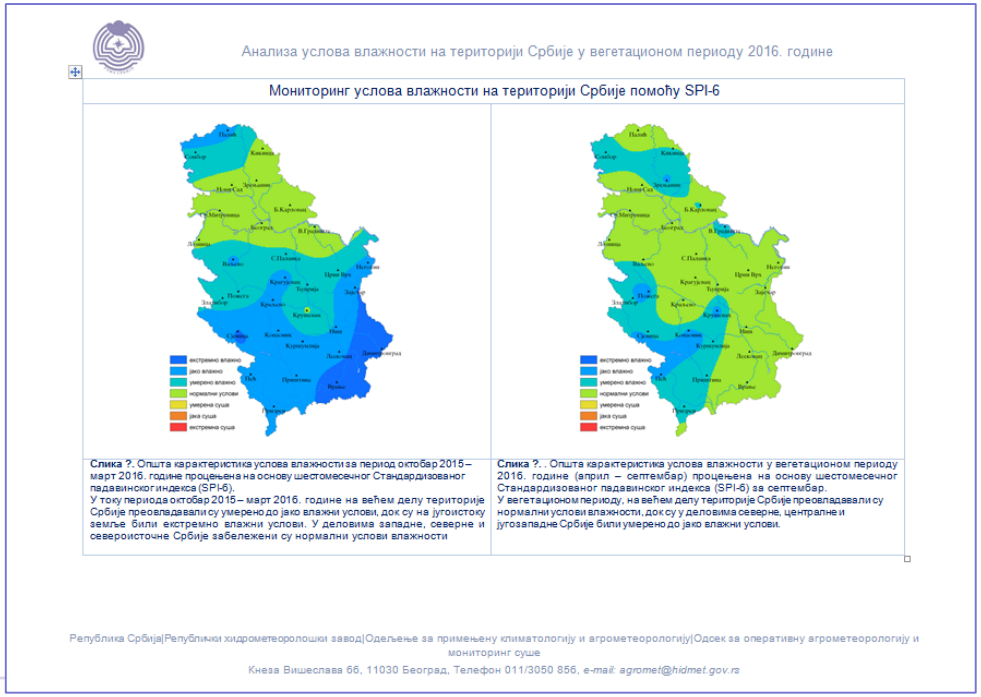
Date: 31.10.2012	Moisture conditions estimated on the basis of SPI for 1,2,3,6, and 12 months (base period 1961-2005)				
Place	SPI-1	SPI-2	SPI-3	SPI-6	SPI-12
Palić	N	ES	ES	JS	ES
Sombor	N	ES	ES	ES	IS
Novi Sad	US	IS	ES	US	JS
Zrenjanin	N	ES	US	US	US
Kikinda	S	ES	US	JS	ES
B. Karlovac	N	US	N	S	S
Vršac	N	N	MV	N	N
Loznica	JS	IS	IS	US	ES
S. Mitrovica	JS	IS	IS	US	ES
Valjevo	S	IS	IS	ES	ES
Beograd	S	ES	ES	US	JS
Kragujevac	JS	IS	IS	US	US
Sm. Palanka	US	IS	JS	N	S
V. Gradište	N	ES	MV	MV	N
Crni Vrh	JS	ES	JS	N	S
Negotin	JS	IS	ES	US	ES
Zlatibor	JS	IS	ES	ES	ES
Sjenica	S	ES	ES	IS	ES
Požega	ES	IS	IS	ES	IS
Kraljevo	ES	IS	IS	IS	ES
Kopaonik	JS	IS	IS	ES	JS
Kruševac	US	N	S	N	N
Ćuprija	S	ES	ES	S	US
Niš	US	ES	JS	N	N
Leskovac	US	IS	S	N	N
Zaječar	US	IS	N	N	S
Dimitrovgrad	US	ES	ES	S	US
Vranje	N	S	US	N	S

MOISTURE CONDITIONS ON THE BASIS OF STANDARD PRETICIPATION INDEX FOR THE PREVIOUS 60 DAYS.
Index value calculated for the mentioned period can be used for the estimation of soil moisture conditions in the surface ground layer, as well as agricultural drought indicator. **More about SPI calculation and use...**
The analyses of moisture conditions on the territory of Republic of Serbia for the vegetation period, season...

EXPLANTION OF THE MOISTURE CONDITIONS CATEGORIES

Symbol	Moisture conditions	Value	
IS	Exceptional drought	SPI ≤ -2.326	
ES	Extreme drought	-2.326 < SPI ≤ -1.645	
JS	Severe drought	-1.645 < SPI ≤ -1.282	
US	Moderate drought	-1.282 < SPI ≤ -0.935	
S	Minor drought	-0.935 < SPI ≤ -0.524	
N	Near normal	-0.524 < SPI < +0.524	Usual moisture conditions
MV	Slightly increased moisture	+0.524 ≤ SPI < +0.935	
UV	Moderately increased moisture	+0.935 ≤ SPI < +1.282	
JV	Considerably increased moisture	+1.282 ≤ SPI < +1.645	
EV	Extremely wet	+1.645 ≤SPI < +2.326	
IV	Exceptionally wet	SPI ≥ +2.326	

Obtained SPI analysis - accessible and regularly updated on the web page of RHMSS presentation ”Moisture conditions” and in various bulletins



Анализа услова влажности на територији Србије у вегетационом периоду 2016. године

Мониторинг услова влажности на територији Србије помоћу SPI-6

Слика ?. Општа карактеристика услова влажности за период октобар 2015 – март 2016. године процењена на основу шестомесечног Стандардизованог падавинског индекса (SPI-6).
У току периода октобар 2015 – март 2016. године на већем делу територије Србије преовладавали су умерено до јако влажни услови, док су на југоистоку земље били екстремно влажни услови. У деловима западне, северне и североисточне Србије забележени су нормални услови влажности

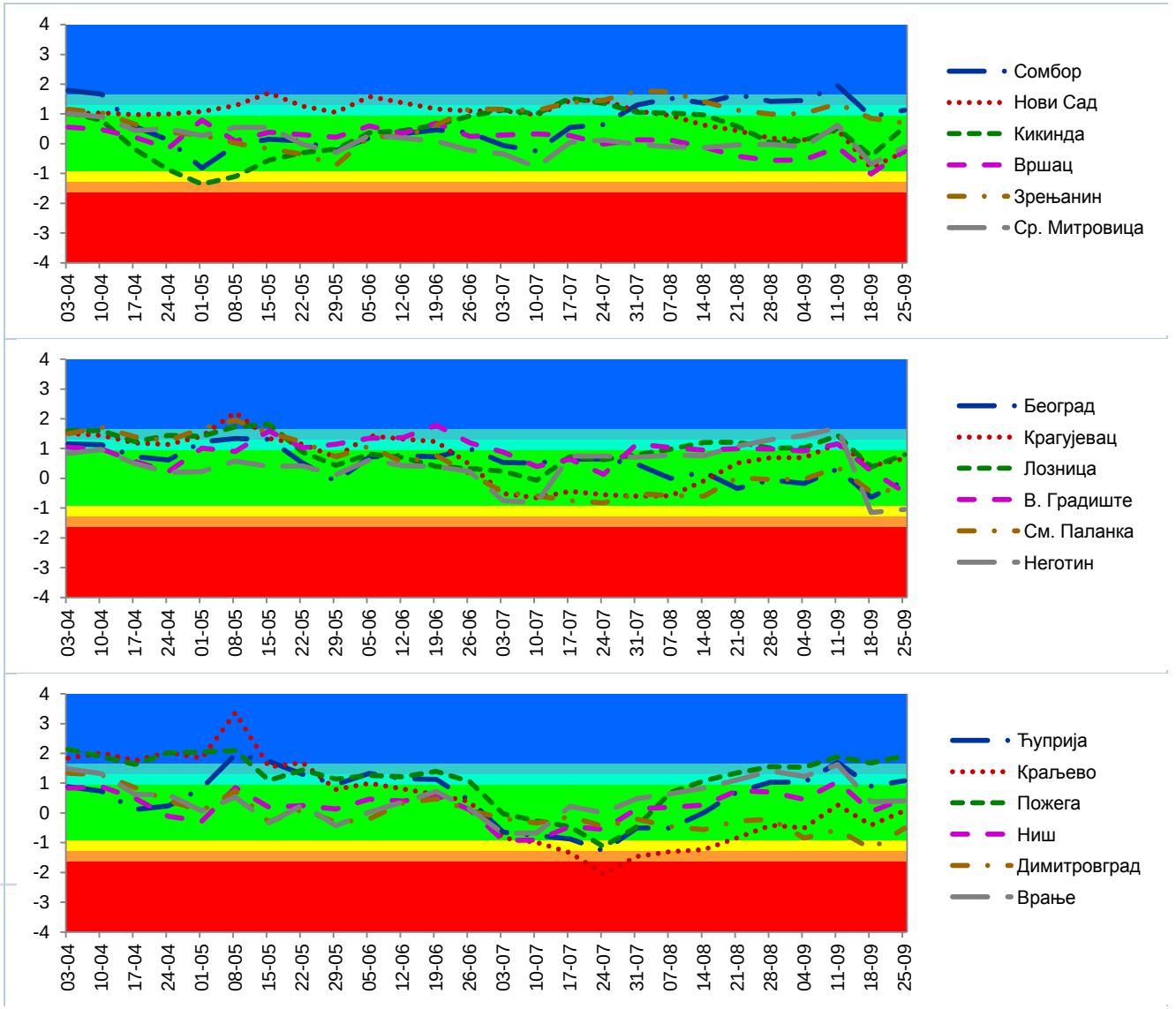
Слика ?. Општа карактеристика услова влажности у вегетационом периоду 2016. године (април – септембар) процењена на основу шестомесечног Стандардизованог падавинског индекса (SPI-6) за септембар.
У вегетационом периоду, на већем делу територије Србије преовладавали су нормални услови влажности, док су у деловима северне, централне и југозападне Србије били умерено до јако влажни услови.

Република Србија|Републички хидрометеоролошки завод|Одељење за примењену климатологију и агрометеорологију|Одсек за оперативну агрометеорологију и мониторинг суше
Кнеза Вишеслава 66, 11030 Београд, Телефон 011/3050 856, *e-mail: agromet@hidmet.gov.rs*

Standardized Precipitation Evapotranspiration Index - SPEI

- **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



CROPSYST – Cropping Systems Simulation Model

Mr. Stockle, Mr. Nelson, Biological Systems Engineering Dept. Washington State University

CROPSYST - crop growth model; simulate biomass and crops yield, water and nitrogen reserves in the soil and crop phenology.

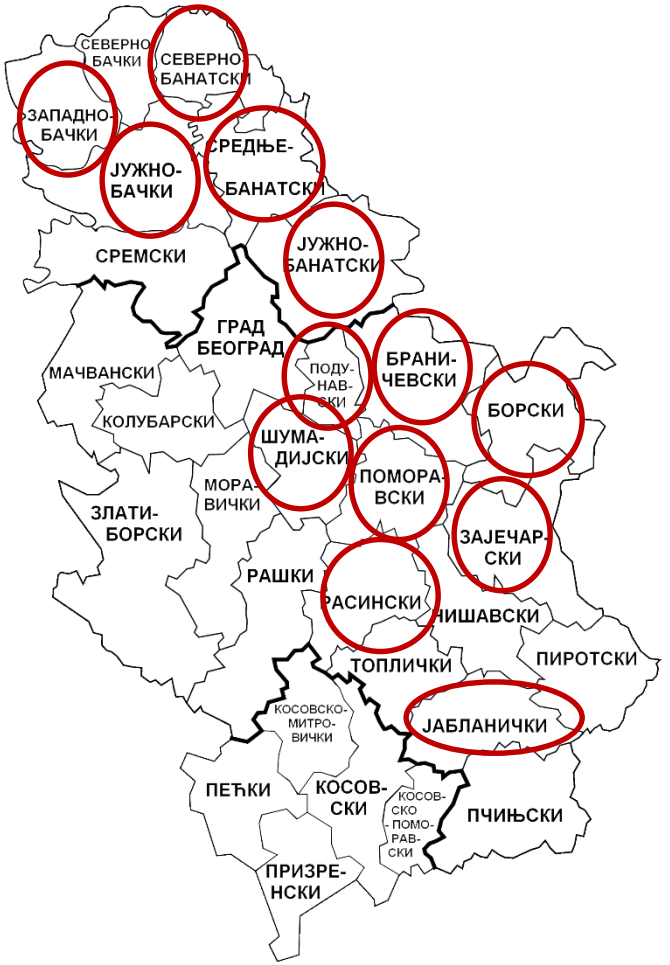
Data	***Input***	***Output***
Climatic	Daily maximum and minimum air temperature, rainfall, air relative humidity (%), solar radiation and mean wind speed	Products of statistical analysis of climatic parameters: mean validity, standard deviation, maximum and minimum value
Crop	Planting date, thermal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

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



Ten-day CropSyst Bulletin

- 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

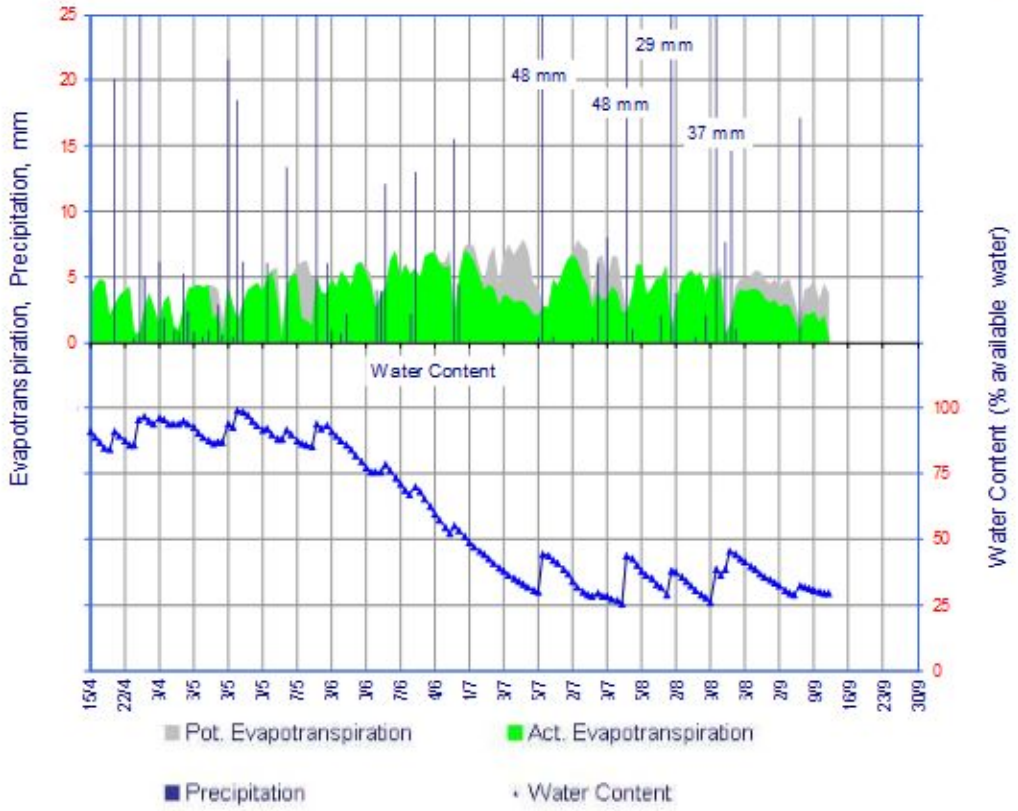
- Prognostic part of simulation presented in tabular form: cumulative values of potential and actual evapotranspiration and precipitation since the beginning of the vegetative period till the forecasted end of the growing season, the dates of corn phenophases, forecasted yield for the three weather scenarios

Example of CropSyst Bulletin

REPUBLIC HYDROMETEOROLOGICAL SERVICE OF SERBIA
Department for Apply climatology and agrometeorology
E mail:agromet@hidmet.gov.rs

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

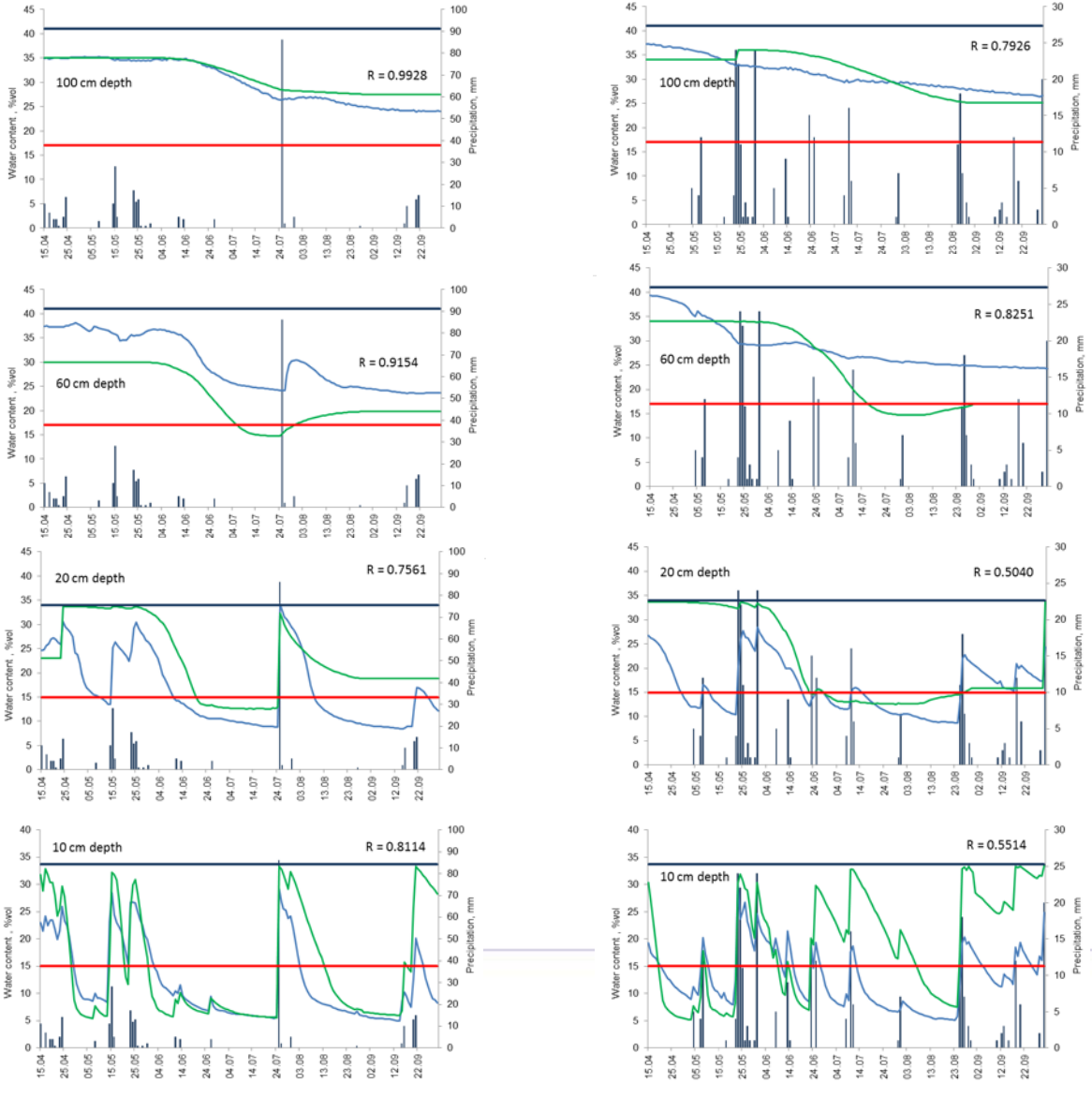
Location: Banatski Karlovac



Estimated agrometeorological parameters of corn growth during vegetation period 2016

Actual condition	Date:	
	Planting	15.04.
	Grain filling	30.07.
	Maturity	27.08.
	Harvest	12.09.
	The final yield estimates of the model, kg/ha:	7791
	Accumulated values in vegetation period :	
	Pot.Et, mm	703.1
	Act. Et, mm	583.1
	Precipitation, mm	485.4

Analysis of soil moisture (CropSyst and measurements)



- Station Banatski Karlovac
- Year 2012 and 2013

Drought Frequency

"Climate characteristics and analysis of meteorological hazards for the Republic of Serbia"

- The **role of the RHMSS** 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, RHMSS is authorised for assessing the risk of large precipitation amounts, heat and cold waves (based on the new methodology, adopted in March 2017)

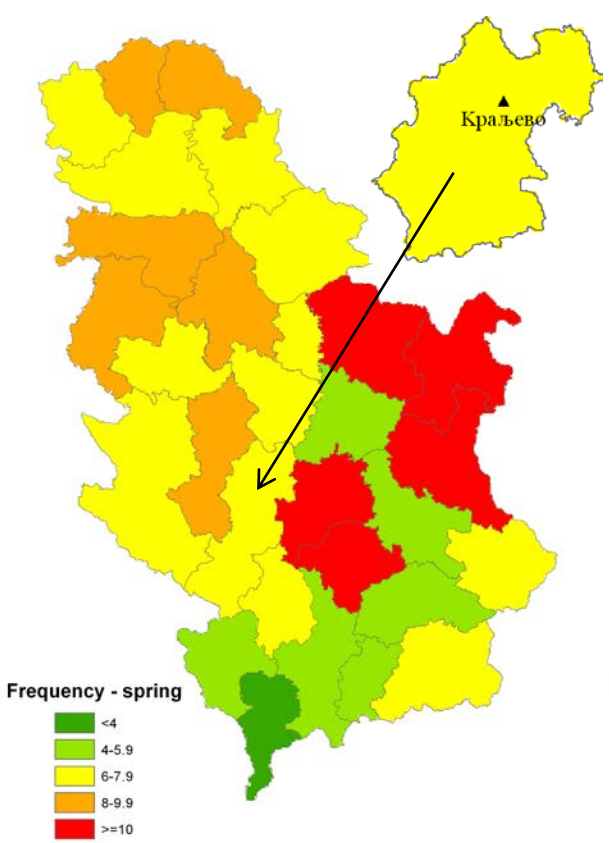
Drought Frequency

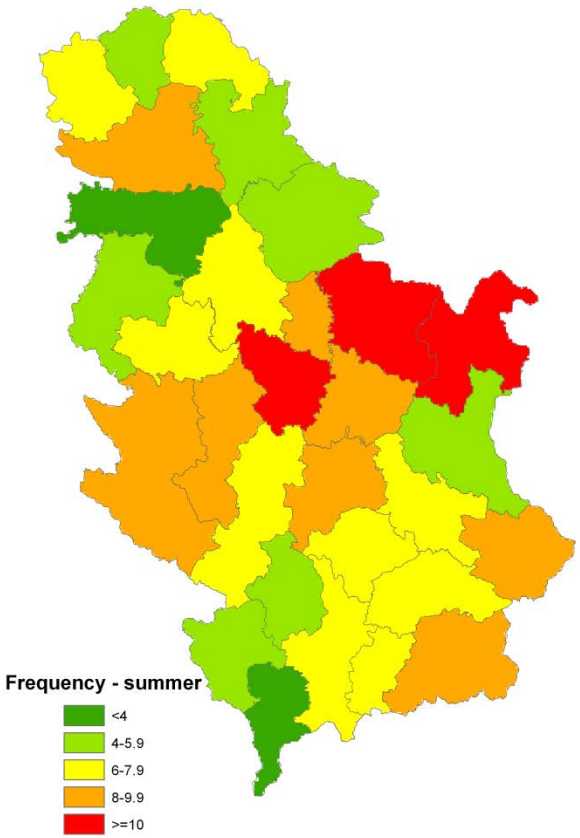
"Climate characteristics and analysis of meteorological hazards for the Republic of Serbia"

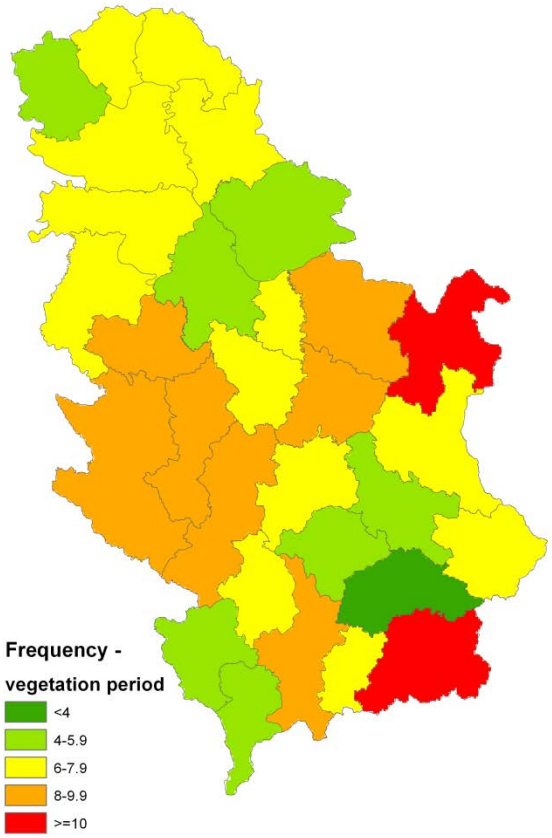
- "**Climatic characteristics and analysis of meteorological hazards for the Republic of Serbia"** was made in 2014 (applying "Methodology for the Development of Risk Assessment and Plans for Protection and Rescue in Emergency Situations")
- Analysis of risk assessment for four hazards (drought, wind 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***
- 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

Application of Remote Sensing Products in Agricultural Meteorology (Fractional Vegetation Cover - FVC)

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 Southeasttern Europe - DMCSEE

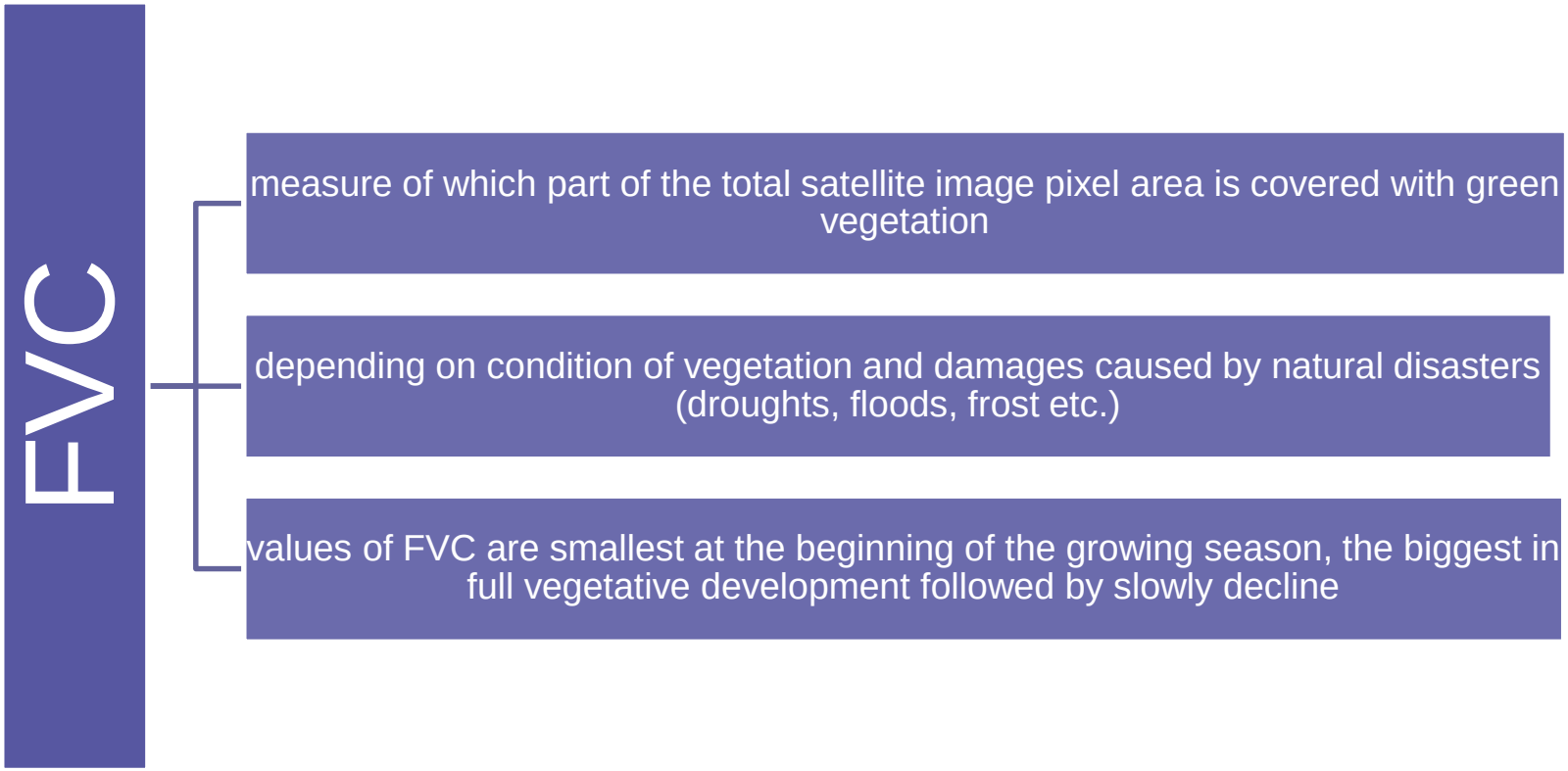
Application of Remote Sensing Products in Agricultural Meteorology (Fractional Vegetation Cover - FVC)

Correlation coefficient (R) between FVC and SPI 1, 2 and 3			
Grapevine			
Location	**SPI1**	**SPI2**	**SPI3**
Sremski Karlovci	0.7956	0.8192	0.8405
Alibunar	0.7382	0.8249	0.8776
Veliko Srediste	0.7906	0.9109	0.9604
Malo Orasje	0.8887	0.9502	0.9114
Maize			
Rimski Sancevi	0.7858	0.7707	0.8926
Stara Pazova	0.7129	0.5485	0.5731
Kanjiza	0.6823	0.8217	0.5515

Application of Remote Sensing Products in Agricultural Meteorology (Fractional Vegetation Cover - FVC)

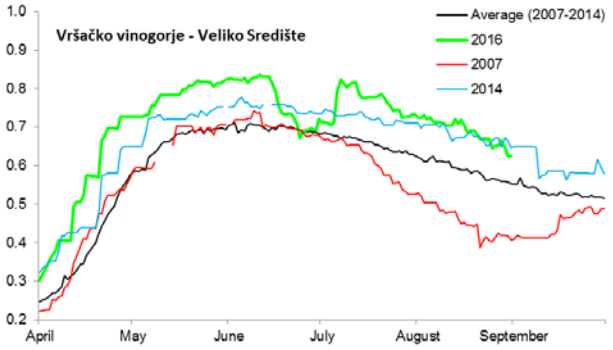
- Within the RHMSS drought monitoring:
  - downloaded available **historical LSA SAF products** (FVC) for the period 2007 - 2016 in .hdf5 format from: http://landsaf.ipma.pt/
  - performed **selection of location** with homogeneous agricultural crops (areas covered with vineyards)
  - files from original .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

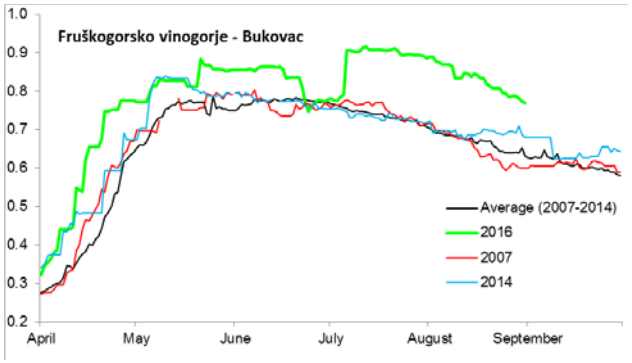
Application of Remote Sensing Products in Agricultural Meteorology (Fractional Vegetation Cover - FVC)

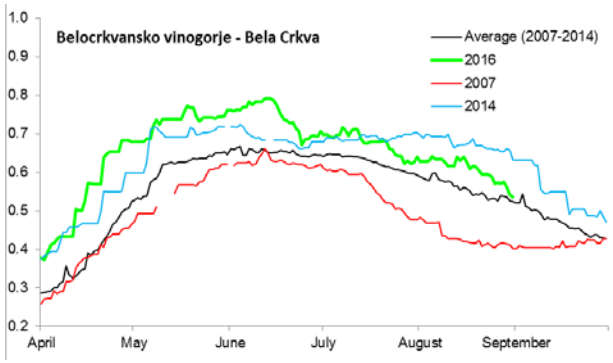


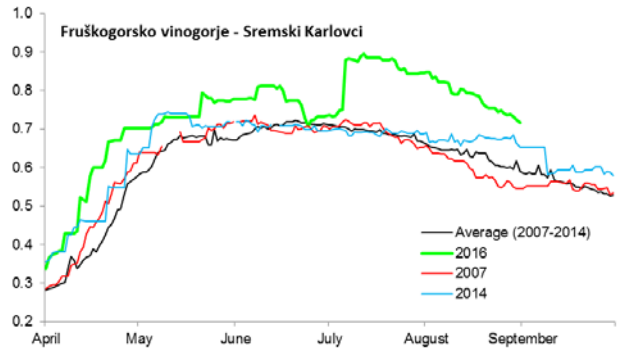
FVC index during the growing season

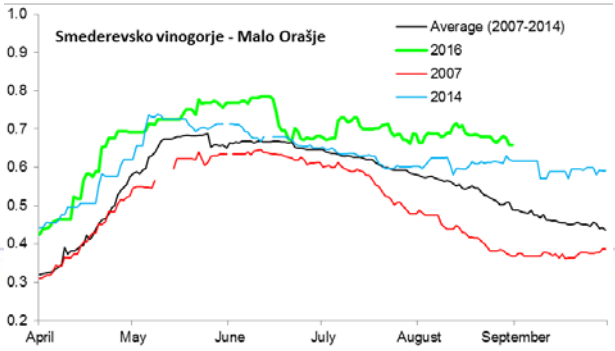
6 locations in Serbia mostly covered with vineyards

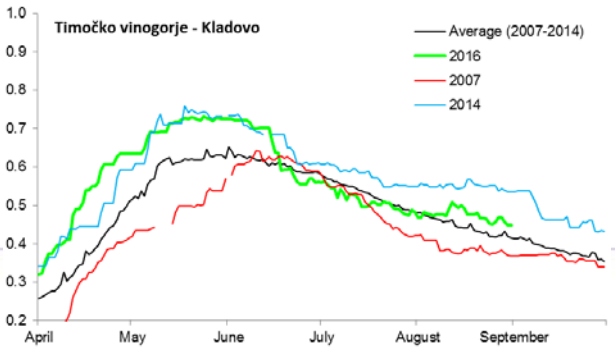












THANK YOU FOR

YOUR ATTENTION

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