Application development for the utilisation of ENVISAT data in remote sensing based regional flood/waterlog and drought monitoring

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Keywords: regional flood/waterlog and drought monitoring, low and medium resolution satellite data, ESA ENVISAT

ABSTRACT: Natural disasters connected to climatic extremities (floods, waterlog and drought) tend to occur more frequently in Hungary in the past decade. Serious waterlog affecting more than 100 000 hectares of arable land, flood peak records during spring and serious drought in summer causing losses to agriculture and to the whole economy happened yearly between 1998-2002. After the development and application of monitoring methods, FÖMI RSC have started to develop a cost-effective satellite based model to monitor these natural disaster at regional level. The ESA-FÖMI Prodex-ENVISAT R&D project titled “Application development for the utilisation of ENVISAT data in remote sensing based regional flood/waterlog and drought monitoring (2000-2003)” aimed at the rapid and large scale monitoring of these disasters utilising available low- and medium resolution operational satellite data (NOAA AVHRR, SPOT VEGETATION, IRS-1C/1D WiFS and ERS SAR) involving the new ESA ENVISAT data. This paper describes the present status of the project and shows several examples about the achievements.

1 INTRODUCTION

After a series of severe floods, waterlog and drought for years in Hungary, FÖMI RSC started to develop a cost-effective satellite based model to monitor all these natural disaster at regional level. Making use of the ESA Scientific Experiment Development Programme (Prodex), the FÖMI-ESA Prodex-ENVISAT R&D project have been started in 2000. The main objectives of the project were to extend the already developed methodologies to the rapid, regional monitoring of flood/waterlog and drought affected areas using currently available, low- and medium resolution operational satellite data with the possible involvement the new ESA ENVISAT data. (MARD) by a strict calendar across the season based on remote sensing, measuring the areas and expected yields of the 8 main crops. Other related monitoring programs (waterlog and impact monitoring 1998-1999, experimental flood and drought monitoring 2000) were also carried out on CROPMON basis (Lelkes et al. 2001). Further extension of the already developed methodologies was proposed by increasing the availability and the quality (temporal, spatial or spectral) of satellite data. It was based on the processing and the comparative analysis of low- and medium resolution operational satellite data (NOAA AVHRR, SPOT VEGETATION, IRS-1C/1D WiFS) using large data set (1998-2003) and a regional test area. Experimental utilization of integrated radar/optical data set and the new ENVISAT satellite (launched in 1st March, 2002) data was also planned.

2 BACKGROUND

More than 300 man years R&D investment during the Hungarian Agricultural Remote Sensing Project (HARSP 1980) led to the operational satellite based National Crop Monitoring and Production Forecast Program (CROPMON 1997-) at FÖMI RSC (Csornai 1999). The operational CROPMON provides county and country level crop production forecast to Ministry of Agriculture and Rural Development (MARD) by a strict calendar across the season based on remote sensing, measuring the areas and expected yields of the 8 main crops. Other related monitoring programs (waterlog and impact monitoring 1998-1999, experimental flood and drought monitoring 2000) were also carried out on CROPMON basis (Lelkes et al. 2001). Further extension of the already developed methodologies was proposed by increasing the availability and the quality (temporal, spatial or spectral) of satellite data. It was based on the processing and the comparative analysis of low- and medium resolution operational satellite data (NOAA AVHRR, SPOT VEGETATION, IRS-1C/1D WiFS) using large data set (1998-2003) and a regional test area. Experimental utilization of integrated radar/optical data set and the new ENVISAT satellite (launched in 1st March, 2002) data was also planned.

3 REGIONAL FLOOD/WATERLOG AND DROUGHT MONITORING

Meteorological satellite data (NOAA AVHRR) are commonly utilised for crop development assessment, yield forecast or drought monitoring. These methods can be further extended using other available similar data sets (SPOT VEGETATION or IRS-
1C/1D WiFS) as well for large scale disaster monitoring. The most valuable features of these data are their low price, large area coverage, frequent availability and quick processing which can compensate for their low or medium spatial (120 ha and 3.6 ha) and spectral (2-5 wide spectral bands) resolution. The efficiency of flood/waterlog monitoring can also be increased by the integrated utilization of radar and optical satellite data set. These data can also be used to test the imaging capabilities of the sensors on board the ESA ENVISAT satellite to establish the methodologies for the experimental utilization of ENVISAT (MERIS, ASAR) data in regional disaster monitoring.

The first stage of the project was focused on the setup, extension and testing of the model (data from 1998-2000) utilising archive data for retrospective monitoring of disasters using new data sources (SPOT VEGETATION, IRS-1C/1D WiFS and IRS-MOS, ERS-2 SAR). The second stage was the semi-operational phase of the model which included further testing with year 2001 data. The third operative stage of the project includes real-time monitoring of natural disasters and the experimental utilisation of integrated radar/optical satellite data and ENVISAT data, since 2002.

3.1 The regional extension of the monitoring model
A wide test area has been selected for the development and testing of the model which included 3-4 counties of the Great Hungarian Plain, where land is mainly used for intensive agricultural cultivation. The area is mainly along river Tisza and its affluents, affected by spring waterlog and summer drought yearly, as well as some floods in the northern part (Figure 1).

Waterlog monitoring established in CROPMON at three levels - producing low (120 hectares), medium (3.6 hectares) and high (0.1 hectares) resolution waterlog maps from NOAA AVHRR, IRS WiFS and Landsat TM/IRS LISS images - was improved. Waterlog maps have been produced for three counties from IRS WiFS, SPOT VEGETATION and Landsat TM images by developing a new physical category system to compare the results on a pixel-by-pixel basis at regional level. The comparative analysis has shown that the matching and similar categories are around 90% for both the Landsat TM - SPOT VEGETATION and the IRS WiFS - SPOT VEGETATION comparison (see Figure 2). The degrees of wet soils and wet vegetation could be identified and differentiated more effectively at regional level using the lower spatial but higher spectral resolution SPOT VEGETATION images. These data have also been used for retrospective flood monitoring for year 2000, with good results. Vegetation index maps have been derived from NOAA AVHRR, IRS-WIFS and SPOT VEGETATION images for drought monitoring at regional level. The results have shown that SPOT VEGETATION data are efficient tool also for drought monitoring. The areas affected by drought can be clearly identified on the eastern part of the country in June 2000 from the derived NDVI difference map (see Figure 4).

3.2 Semi-operational and operational stage of the model
The developed model was tested in the semi-operational phase in 2001 and entered in the operational phase in 2002. The first real-time application was the monitoring of the flood of the Tisza river in March 2001.

All of flood, waterlog and drought occurred on the test area in 2001 with different intensity and spatial extension. The fast melting of snow in the Carpathians followed by severe rains in the plain resulted a serious flood situation on by 5th March 2001. For the first time after 53 years, the dike along river Tisza was breached by the water at midday on 6th March. The water flooded the neighboring areas through a 120 m wide gap threatening tens of villages and thousands of people.

Figure 1. The regional test area of the model on IRS-WIFS satellite image
The elements of real-time monitoring with the evaluation of available satellite data were carried out both in the framework of Prodex (low and medium res.) and CROPMON (high res.) project. The extent of flooded areas was evaluated both on the Ukrainian and the Hungarian side and low-, medium- and high resolution flood maps derived from NOAA AVHRR, IRS WiFS and Landsat TM data were forwarded to the central and local management authorities through electronic transmission (Figure 3). Weather independent ERS-2 SAR data was also processed which was very important because of the presence of clouds.

Drought and waterlog maps have been produced for the whole test area from IRS WIFS and SPOT VEGETATION satellite images confirming the good results achieved previously for the year 2000. The derivation of WiFS-SPOT VEGETATION combined waterlog map allowed better to exploit the spatial and spectral resolution of the data set for the mapping the wet/waterlogged areas more effectively.
Figure 3. (top)
Real-time flood monitoring in March 2001 in Hungary with NOAA AVHRR time series (top) and high/medium resolution IRS LISS/WIFS (bottom left, middle) and Landsat TM images (bottom right)

Figure 4. (bottom)
NDVI difference (June, 2000-1998) map derived from SPOT VEGETATION images. The areas affected by drought can be clearly identified on the Great Hungarian Plain.

\[ \Delta \text{NDVI} \]
(2000-1998)
- seriously affected by drought
- moderately affected by drought
- weakly affected by drought
- not significantly affected by drought
- not affected by drought
3.3 Utilisation of ENVISAT and radar data in flood/waterlog monitoring

The preparation for integration of ENVISAT data into the model included several steps from the experimental use of radar data for flood/waterlog monitoring through the use of the IRS-MOS data.

The IRS-MOS imaging spectrometer data have been used for waterlog monitoring as the sensor spectral bands (17 narrow spectral channels) are similar to the ENVISAT MERIS bands. The comparison of the results with IRS WIFS and SPOT VEGETATION based waterlog maps has shown that the degrees of wet soils and wet vegetation could be identified and differentiated more effectively with IRS-MOS than IRS-WIFS data. Based on these results the ENVISAT MERIS sensor is a promising tool for waterlog monitoring.

The weather independent radar data have been used previously for flood and waterlog monitoring as a supplementary data source of optical/infrared data during the waterlog period in 1999 (CROP-MON) and for the spring flood of 2001. The experimental use of ERS-2 SAR data for flood monitoring started with retrospective monitoring of the spring flood of 2001 on the Tisza river. The monitoring of flood could be carried out with solely radar images and the comparison of flood mapping results has shown 90 percent matching between the flood maps derived from ERS-2 SAR and IRS-LISS, where the differences mainly came from the inundated floodplain forests' mapping problems. The multitemporal analysis of flood with radar images (including difference image between flooded and dry dates) resulted higher mapping accuracy than the monotemporal approach.

The use of integrated optical-radar data gave good results in flood monitoring. The integration of radar and optical/infrared data from different dates of the flood, results multitemporal-multisensor data-set, which is an excellent tool for extent flood monitoring and to follow the movement of floods.

The use of radar data in waterlog monitoring is much more complicated task, as in this case we have to differentiate not only between open water and dry surfaces, but also between classes of wet soil and wet vegetation. With monostatic single-polarization radar data it is not possible to differentiate nor between wet and dry soils, neither between wet and dry vegetation with the accuracy of high resolution optical/infrared data. However, with the integration of radar and optical data mapping of open waterlog is accurate and the mapping of vegetation standing in water is more accurate than on high resolution optical/infrared data.

The integration of low and medium resolution optical/infrared images with high resolution radar data has given better results. With the integration of SPOT VEGETATION/IRS WIFS and ERS-2 SAR images the open waterlog of smaller extent could be mapped more accurately than on the different data-sets separately (Figure 5 and 6).

Figure 5. Waterlogged areas on ERS-2 SAR (top, ©ESA, 2000), SPOT VEGETATION (middle) images and on integrated ERS-2 SAR - SPOT VEGETATION data (bottom) in April 2000.
Waterlog maps derived from SPOT VEGETATION (top) and integrated ERS-2 SAR - SPOT VEGETATION data (bottom, ©ESA, 2000). (blue-open waterlog, magenta-soil affected by waterlog, red-vegetation affected by waterlog, beige-not affected by waterlog)

The implementation of the third stage of the project will continue in 2003 including the further analysis of available satellite data and the experimental processing and testing of ESA ENVISAT data (ASAR, MERIS) emphasising the utilization of MERIS data for regional drought monitoring.

4 CONCLUSIONS

When large scale natural disasters happen regularly, there is a need for a complex model for monitoring them at regional level providing quick, objective and homogenous information to the various end users. The spatial extent, intensity and temporal development of these disastrous events can be rapidly and objectively assessed by remote sensing techniques. The effectiveness of the remote sensing based monitoring model can be improved using available medium- and low resolution optical satellite data (NOAA AVHRR, SPOT VEGETATION, IRS-1C/1D WiFS) of different sensors. The integration of high resolution radar and low/medium resolution optical/infrared data is also promising tool to enhance the quality of the monitoring. Such models need to be developed and tested on several years’ data from various data sources in order to assess their effectiveness in operational disaster monitoring. The extension of the model also leads to the establishment of the methodologies building on new sensors of similar imaging capabilities.

The presented examples shows that this approach and the possible involvement of the new generation sensors (MERIS, ASAR) on board the ENVISAT satellite will increase the data availability and the effectiveness of remote sensing based rapid, regional flood/waterlog and drought/crop monitoring model.

ACKNOWLEDGEMENTS

The ESA-FÖMI Prodex-ENVISAT R&D project is carried out from ESA Prodex (Scientific Experiment Development Programme) fund and FÖMI’s own resources through the use of CROPMON program supported by MARD. The ERS-2 SAR datasets have been provided by ESA.

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