OPERATIONAL REMOTE SENSING PROGRAMS IN HUNGARY: FROM CROP MONITORING TO DISASTER MANAGEMENT

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Abstract

Remote sensing provides an efficient basis for several agricultural applications. In Hungary, the foundation of systems based on remote sensing goes back to 1980, when the Remote Sensing Centre (RSC) of the Institute of Geodesy, Cartography and Remote Sensing (FÖMI) was established and started the research and development and later the operational applications continuously adapting to the actual needs. The Hungarian Agricultural Remote Sensing Program (HARSP: from 1980 to date) supported by the Ministry of Agriculture and Rural Development (MARD) led to a concise methodology for further operational applications.
The National Crop Monitoring and Production Forecast Program (CROPMON, 1997-2003) has been provided a nation-wide and regional crop production forecast, including the crop areas and the expected yields to MARD. CROPMON used remote sensing to assess crop areas and also for the estimation of the yields of the main crops in Hungary.
Several operational applications have evolved from the CROPMON's technology basis such as: the remote sensing control of area-based agricultural subsidies (CwRS, 1999-), the remote sensing supported national ragweed exemption program (2004-) together with satellite based disaster management including waterlog/flood (1998-) and drought monitoring and impact assessment (2000-).
From 2004, a special operational endeavour reinforced the application of medium and high resolution images: the ragweed monitoring and control. By Hungarian experts estimation some 500 000 – 700 000 hectares are covered by ragweed. The technique developed for ragweed monitoring and control (2004-) came from the methods that had been used in CROPMON. However, the remote sensing identification of ragweed stands is much more difficult than the crop identification. The majority of all the infected area can theoretically be pinpointed by HR remote sensing on the arable land. The recognition of ragweed spots is accomplished by remote sensing. The temporal development assessment of ragweed has fundamental importance. FÖMI RSC produces a countrywide ragweed risk map focusing on the most heavily infected croplands. The major factor in the efficiency of the system is the high reconnaissance performance and accuracy (better than 90%) of the spots independently from the terrain, location and

environment. The follow on ground measurement and record are done by GPS plus integrated GIS tools.
A series of severe flood, waterlog and drought events has hit Hungary recently, thus the provision of quick, objective and homogenous information about the development and impact of these disasters is very imperative at a sub-regional scale. Remote sensing is an excellent tool for treatment, monitoring and documentation of disasters, because it assures to gain information on a rapid, reliable and objective way. Operational remote sensing based rapid regional disaster monitoring model could be developed and applied effectively for waterlog/flood (1998-) and drought monitoring plus impact assessment (2000-), with the integration of available high, medium and low resolution satellite data. Through the derived remote sensing based waterlog/flood or drought maps, the monitoring and quantitative analysis of the spatial extension and temporal changes of the disasters–obtained from different individual or integrated input satellite data were carried out yearly (2004-2007) at different level (countrywide, regional, local). Due to the climate change, the occurrence of drought is expected to get more frequent. The usage of remote sensing is very important in the assessment of possibilities of cropping technologies so that protection and loss compensation can be effectively carried out.

1. INTRODUCTION

Up to 1990 the crop production was based on some 1400 co-operative or state farms in Hungary. The crop information and production forecast system used their reports that were obligatory by law. This information system worked fairly well. Because of the dramatic changes in the Hungarian economy and also in the agriculture, the former crop information system became inadequate. The land privatization brought dramatic changes in the holdings and parcel sizes, the number of farm owners or operators, the agricultural technology and also in the investment structure. In this very quick transition, the need for an efficient information system became even more imperative.
The priority Hungarian Agricultural Remote Sensing Program (HARSP) was launched in 1980 and has been implemented by FÖMI Remote Sensing Centre (FÖMI RSC). The final objective of the program was to introduce remote sensing to the operational agro information system in Hungary. In the beginning of HARSP (Csornai et al, 1983, 1988, 1990), the satellite image analysis methods development and validation were the most important (1980-85). In 1984 the reviews of the yield models showed that the research for a direct relationship between the crop development, the expected yield and the crop canopy - that can be observed by satellite data – could be a good alternative. Despite of the first results in canopy development assessment by satellite data we studied the capabilities of agromet models (WOFOST-MERA, Csornai et al., 1996). FÖMI put a real emphasis to the remote sensing based model.
The operational system was expected to be capable to monitor crops in the entire country, providing accurate, timely and reliable information on the area of the major crops, their development quantitatively. This should be accompanied by problems areas delineation focusing to drought assessment plus the provision of reliable yield forecast and final yield estimates. These data are to be available at the country as well as the

counties (19) levels. The main user of the information included, primarily the Ministry of Agriculture and Rural Development (MARD) and has been indirectly gradually the grain processing and trading companies and associations, the farmers and their different organizations, associations. After a seven year of continuous operations (1997-2003) and having a lot of experience to meet the strict accuracy and deadline requirements there has been a continuous improvement in the technology applied.

The unique methodology of the operational Crop Monitoring and Production Forecast Programme (CROPMON, 1997 - 2003) provided an excellent basis for further applications development (Csornai et. al., 1997, 1998). One of the operationally proven programme components could support the ragweed control in Hungary (Csornai et. al., 2006, 2007, 2008) and the other one supporting the operational disaster (flood/waterlog/drought) monitoring (Lelkes et al., 2001, Csornai et. al., 2004, 2007, Suba et al., 2008).

2. Operational remote sensing programs in Hungary

1. CROPMON (1997-2003)

The substantial R&D and validation provided a compact basis to move forward to an operational program (CROPMON 1997-2003). The crop data-reporting schedule was set by the customer, the Ministry of Agriculture and Rural Development. The data-reporting consisted of five dates from July 5 to October 1 in harmony with the existing traditional production forecast system of MARD.

The area covered directly, have been a characteristic subsample (6-9) of all the counties (19). This 40-57 % of the total cropland in Hungary was directly monitored, by remote sensing, while appropriate area and yield estimates for the non-covered counties were computed by a historical spatial correlation of these values. This relationship was found quite strong suggesting an R^2~0,9 or better fit. Confidence values were also reported. From 2002 the whole country was covered by direct remote sensing measurements. The eight main crops monitored are winter wheat, winter and spring barley, maize, sugar beet, sunflower, alfalfa and maize to ensilage. These crops all together represent the 78-82 % of the entire Hungarian cropland.

The cropland assessment is based on the quantitative analysis of multitemporal high resolution images (Landsat TM and IRS-1C/1D LISS III.) from early April (or earlier sometimes) through August, to compensate for the cloudiness. The comparison of the remote sensing results with CSOH data was an indication. The differences cannot be interpreted, by any means, as errors of the remote sensing technology. On the contrary, the area estimation bases, the crop maps were always thoroughly checked at some pixels in details.

The difference of crop area estimation of FÖMI RSC and the Central Statistical Office, Hungary (CSOH) is in the range of 0.8-3.7 % for the entire cropland in Hungary. The county crop area differences occurred in the interval of 1.5-21 % depending on the crop and county. The total area average difference was 4.08 %. This partly can be explained by the main differences in definitions, that is the ownership based sampling of CSOH and the administrative boundary based total coverage of cropland by the satellite images

(FÖMI RSC). The actual standard crop maps derived from remote sensing data were also provided to MARD.
The crop yield forecast was accomplished by the application of FÖMI RSC developed model which combines high-resolution satellite (Landsat TM and IRS-1C/1D LISS III. or SPOT) data and NOAA AVHRR time series. The reporting dates corresponded to those of the operative Production Forecast System of the Ministry of Agriculture and Rural Development. Both appeared prior to the harvest. The earliest official production data estimates were available after the harvest: by the end of August for wheat and barley and in December (January) for the rest. Until 2002 FÖMI RSC provided yield estimates for the counties (6-9) and expanded these measurements to Hungary using a regional-historical correlation scheme. From 2002 all the 19 counties were covered directly, so there was no need for extrapolation any more. The country average yield data were compared with CSOH preliminary values that appear six weeks later. The differences were less than 1 % for wheat and 4.5 % for maize average yields in Hungary. The differences at county level averages were somewhat bigger. Yield spatial distribution maps could also be reported for the major crops.
Around 180 data pairs (CROPMON – CSOH) were available either for area or yield to compare in the 1987-2003 period. The differences and R^2 –s were carefully be interpreted. The inherent advantages and limitations of the traditional and remote sensing methodology suggest the handling of these data.
Although the CROPMON has been suspended to operate from 2004 because of the national resources are directed to EU member states' obligations, in more recent cases, definite demand appeared for its revitalization.

2.2. Ragweed monitoring and control program

The ragweed pollen induced allergy has gradually become an important issue in Hungary. The number of people suffering from pollen allergy had been increasing so that there was an imperative need for a National Ragweed Control Program. To the efficiency of this priority program, the government amended the plant protection law in 2005. This allowed to the Central Agricultural Office of Plant Protection and Soil Conservation Directorate (CAO PPSCD) to cut the infected areas almost immediately after their detection. This can be done before the pollen scattering. The ground recording can be done very efficiently by the Land Office Network (LON). The authorities can retrieve the cost of exemption from the land user later. In Hungary, some 500.000 – 700.000 hectares was estimated to be strongly infected by ragweed. About 80% of this area can be pinpointed by remote sensing on the arable land.
The ragweed recognition is much more difficult than the crop identification. FÖMI produces a countrywide ragweed risk map focusing on the most heavily infected croplands. These ragweed risk maps are derived from time series of medium and high-resolution satellite images. Based on the characteristics of weeds and the high resolution (HR) images, the delineation focuses to the spots larger than 0.8 hectares. The most significant pollen production comes from these infected spots.
In 2005 ragweed risk maps were produced several times. The first risk map was the result of a retrospective analysis of year 2004. Based on ground data from PPSCD and

satellite images from the previous year, a substantial model validation was carried out. It was found that about 10 times larger infected area (approximately 100 000 ha) could be detected using year 2004 images than the cases recorded by PPSCD in the field, restricting the comparison to ragweed stands reaching 0.8 ha. The operational ragweed monitoring started to examine the current (2005) status. The target of remote sensing detection was non-cultivated arable spots and the stubble-fields of cereals. Some 20 000 spots of 60 000 hectares were identified altogether in Hungary.

In 2006 a very limited ragweed monitoring program was performed. The emphasis was put on the development of Central Ragweed Server (CRS). The remote sensing control brought up about 3 500 spots (18 601 hectares) of ragweed spots in the reduced target area, these findings were published in the form of ragweed risk maps. They were one of the input data for the LON's on-the-spot checks, which are supported by dedicated integrated hand-held GIS-GPS equipment. The Server synchronized 400-500 people's field work in the most critical July-September period.

Certainly, the redesigned Ragweed Control Program primarily builds on the co-operation of the land users. To persuade the activity of inhabitants, spatial statistics of ragweed infection are available for people in the form of electronic maps, via the web sites of FÖMI and MARD. After developing the server and providing multi-day trainings for users, the Central Ragweed Server ensured a more efficient service in 2006. Since then, the server has undergone further major improvements, which were driven by the needs arising at different institutions participating in the programme.

In 2007, the target of ragweed detection was extended again. We identified high risk ragweed spots in several time periods on highly infected areas in the whole Hungarian territory. The number of spots was more than 4 000, covering about 10 000 hectares. Some new functions and modules for CRS were developed to speed up the administration and documentation of the Ragweed Control Program.

In 2008, the focus was on the remote sensing based production of risk maps. The aim was to derive maps for the most infected areas 3-5 times from mid-July. The thematic focus was put on cereal stubbles, which are usually strongly covered by ragweed after harvest. IRS P6 LISS and AWiFS and SPOT XS/Xi satellite images were used during the remote sensing assessment. The difference in size of elementary mapping unit of the field measurements and recording (1-5 m) and that of the remote sensing one (20-60 m) sometimes caused conflicts, together with the improper application and interpretation of the "risk map" notion.

In 2008, the real accuracy and the potential of ragweed risk maps were cooperatively assessed on two test areas. The assessment was managed by the experts of MARD, FÖMI and LON. Collective on-the-spot checks were carried out in 10 days after the ragweed risk map production. The accuracy of remote sensing survey was 90%. Based on the risk maps, the Land Office experts recorded some 300 hectares of areas that were actually infected with ragweed, in two days! These collective checks have proven that the risk maps are so efficient that the total area of ragweed spots that can be recorded and documented in situ is 50-100 times larger if remote sensing based risk maps are applied properly.

The Ragweed Control Program has been operational since 2005 to date, with similar overall technological and administrative background. The implementation of components and the extent of survey have been changed throughout the past years to satisfy the needs arose. Based on the results we can conclude that the immense problems of ragweed and pollen allergy in Hungary could not be efficiently controlled without space technologies. The introduction of four high tech components (RS+GPS+GIS+web) was inevitable to basically improve the traditional ground-based ragweed control system in Hungary. The remote sensing assessment covers the whole arable land and helps in the optimization of in situ measurements and their documentation. The time requirement of ground based components was dramatically decreased by a productive geo-informational provision (remote sensing), surrounded by GPS and GIS techniques, the data exchange and the new legal provisions of the Plant Protection Law. The administrative tasks were also made much more effective.

2.3 Drought monitoring and yield loss assessment (2000-)

The basic idea behind drought monitoring is the comparison of actual year's vegetation index maps (NDVI, MGVI) with the maps representing a mean of the vegetation index maps derived from the maximum value composites (MVC) of a reference period. This is the approach, that is most studies or systems practise. FÖMI also explored and applied this approach, but having a strong yield prediction model, developed that performed well it was straightforward to use it for drought assessment and alarm. Beyond the widely used methods that apply NDVI or similar indices or their maximum values in a period to indicate the categories of drought or yield losses FÖMI utilized the yield model for this purpose. The quantitative yield model was used to the characterization the strength and spatial distribution of drought. This is quantitative and provides the expected yield for that particular area. The compared period – usually 1-3 weeks – and the whole growing season are compared by the model output in different years.

In the frame of FÖMI-ESA co-operational programs (Prodex[*]: 2000-2004, PECS[**]: 2004-2007, Csornai et. al 2004, 2007) the CROPMON based drought monitoring, crop development and yield loss assessment (2000-2003) activities based on NOAA AVHRR data received at FÖMI satellite station were also continued and developed further (2003-). Other available satellite data (SPOT VEGETATION, IRS WiFS, AWiFS and ENVISAT MERIS) were integrated into the regional drought monitoring model to detect the extension and intensity of the drought at regional or country level (2003-2007). High and medium resolution images (AWiFS and MERIS) provide fast, objective and accurate information to the monitoring of spatial and temporal progress of drought. They can serve as a basis to drought loss compensation measures and to the consideration of such claims. In the final phase of PECS project the ENVISAT MERIS based drought model was extended to the whole country in 2007. The model utilized solely ENVISAT MERIS and also calibrated ENVISAT MERIS-IRS AWiFS time series data (2003-

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[*] Prodex= Scientific Experiment Development Programme

[**] PECS= Plan for European Co-operating States

2007) for covering more drought monitoring periods (May, June, July, August 2007) in crop development. The derived drought maps reflected well the differences in crop developments – the central part of Great Plain was affected the most seriously in July and August - as the drought progressed. The latter was justified by the deviation (yield loss) and strong spatial differences of the observed yields[1] of the main crops (wheat and maize) at the level of the counties. Further validation of the model was accomplished using IRS-P6 AWiFS based drought maps which were derived for May, July and August of 2007 applying an improved and strong intercalibration procedure of MERIS and AWiFS data over a three years period (2005-2007). The results of ENVISAT MERIS based drought and crop development monitoring, carried out in the framework of this project, provide a reliable basis to the drought impact assessment at regional and country level.

2.4. Waterlog/Flood and impact monitoring

As a component of CROPMON, further additional extension of remote sensing based operational applications were launched to extract information about those most significant factors, extreme natural disasters which occur on large areas and produce negative effects on crop development and crop production. Thus, satellite based waterlog/flood and impact monitoring (1998-), and recently ragweed monitoring and control program (2004-) were all growing out from the CROPMON methodology and technology basis.

Waterlog and impact monitoring program was initially launched for MARD, that covered the most affected 4 (in 1998) and 7 (in 1999) counties of about 4 million hectares. Reliable waterlog/flood maps and derived area measures reflected the static status assessment of the areas under water or having saturated soil. Beyond this, temporal evaluation of waterlog/flood affected areas, impact analysis on the crops and the dynamism of changes could also be monitored quantitatively. During the combats against flood, when serious flood events occurred on Hungary's largest rivers, the Körös and Tisza, in April 2000 and March 2001, FÖMI RSC provided real time satellite data and flood maps for the disaster areas. The extent of flooded areas was evaluated and high-, low- and medium resolution flood maps were forwarded to the central and local management authorities through electronic transmission (Lelkes et. al, 2001). These effectively helped the local water management authorities in planning the necessary steps and managing the fight against the flood. Further improvements of the models to map and monitor waterlog and flood affected areas were also carried out in the frame of FÖMI-ESA co-operational R+D programs. Yearly monitoring tasks were performed at regional level in 2005-2006 for waterlog and flood assessment using also integrated radar (ERS, Radarsat, ENVISAT ASAR) and optical (IRS WiFS, AWiFS, ENVISAT MERIS Landsat/IRS LISS) satellite data sets. The previously applied waterlog/flood monitoring methodology had been significantly improved with new methodological elements in the preprocessing (radiometric calibration, speckle suppression, incorporating DEM data into the preprocessing chain and ortorectification), integration

[1] derived from CSOH data.

and classification steps of ENVISAT ASAR radar and through the utilization of multitemporal and integrated ENVISAT (ASAR+MERIS) radar and optical data set.

3. CONCLUSION

Both the validation of the developed remote sensing based crop area assessment and yield forecast methods plus the first Operational Crop Monitoring and Production Forecast Program (CROPMON 1997-2003) in Hungary clearly demonstrated that these methods can be efficiently applied for the entire cropland. Substantial background and investment were certainly needed.

Remote sensing could be very efficiently used for precise crop area estimation and provision of crop maps. The results suggest that the necessary classification performance can be obtained in most of the cases therefore the analysis could be cost effective. The investment to achieve this seems to be worthwhile.

The new primary quantitative crop development assessment and yield prediction model works on the basis of a combined AVHRR and high resolution images based crop monitoring. The quantitative yield prediction model performed properly and efficiently in a more counties' area application and also for the entire country. This model produces spatial distribution map for the predicted yields.

CROPMON was extended into different directions. CROPMON provided a tool for going far beyond the qualitative comparisons of vegetation periods through non crop specific NDVI-values and provided potential yield estimates to characterize the extent of drought. Parallel to these, many other applications could efficiently be added similarly to the ragweed monitoring and flood/waterlog/drought assessment.

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