GWP Water and Climate Programme:

Integrated Drought Management in Central and Eastern Europe

Activity 5.5. Policy oriented study on remote sensing agricultural drought monitoring methods

Output 1 Report: Green and brown water resources on watersheds

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1. Introduction

The Activity 5.5. “Policy oriented study on remote sensing agricultural drought monitoring methods” case study focuses on identification of agricultural drought characteristics and elaborates a monitoring method (with application of remote sensing data), which could result in appropriate early warning of droughts before irreversible yield loss and/or quality degradation occur. The spatial decision supporting system to be developed will help the farmers in reducing drought risk of the different regions by plant specific calibrated drought indexes. This methodology will be extendable for other Central European countries when country specific data are available and entered into the system.

The case study has three important steps, milestones, which correspond and relate each other in hierarchical way. First, green and brown water resources should be analysed on the examined watersheds in order to gather information on water utilization of a site. These data are necessary for the calibration and validation of remote sensing data, which of validation and calibration is the second step. The third milestone is based on the results of the integrated data of step 1 and step 2 in order to develop drought indicators and integrate them to drought monitoring system.

The methods and databases to be explored include employment of remote sensing data on land use, as well as biomass production, soil characteristics for better integration and understanding of cropping patterns influenced by hydrology and soil types. Internationally available land use (CORINE database, topographic maps) remote sensing data, MODIS NDVI spectral indices, soil data (agro topographic map, soil water management properties, map of water management properties of soils), hydrology (soil water table), digital elevation models were processed and integrated to determine soil water holding capacities and water content and consumption of the concerned cultivated plants at different soil types.

The current Output 1 report is an analysis report on the role of soil and crop water content status in water balance within different agricultural, land use and water management practices at rain fed and irrigated systems for the most important crops and fruit (wheat, corn and apple).

The selection of the three mentioned crops from crop water requirement point of view is justified that the wheat has evolved as a C3 plant because it naturally occurs in temperate regions of the Central and Eastern Europe, where the temperature is mild and C3 plants are less energy efficient at high temperatures. Corn as a C4 plant is more energy efficient and more drought tolerant when high temperature occurs (Pethő, 2002). At the same time, C4 plant is more effected when drought develops by the end of summer than the wheat, which is already harvested in August. Mechanism of apple drought tolerance is also typical from special crop water evapotranspiration point of view (root zone, phytotechnology, year impact etc).

The purpose of this Output 1 report is to give information how agricultural practice, crop rotation, land use affect the brown and green water status, which can be the basis of converting remote sensing data to water management data system. Agricultural drought means critical decrease in water content of plants, therefore the identification of this critical water loss is essential. The amount of critical water loss is plant and soil dependent. Therefore we have chosen to analyse the three different plant species (wheat, corn and apple).

Based on the amount of green and brown water, water balance analysis of a watershed concerning different land use, agricultural practice for each crop (wheat, corn and apple) from agricultural drought severity point of view are as follow:

- Analysis of green water content at different soil terrain and climate (non irrigated circumstances and rain-fed) circumstances
- Analysis of brown water content at different soil terrain and climate (non irrigated circumstances and rain-fed) circumstances

Definition of brown water is complex. Brown water refers to water content of soil at different soil layers with different water holding capacities and with different water management properties based on different water storing capacity of soils at certain watersheds. As a result of Output 1 maximal, available water contents, field capacities and wilting points of different soil types at different soil layers were analysed and mapped.

Green water means the water content, demand and water consumption, evapotranspiration properties of the concerned cultivated plants. Within this output, the analysis of green water content was carried out based on cropping, yield data and remote sensing databases.

In the case study we utilize the available soil, yield and landuse database prepared for the Tisza River Basin. The land use in this basin is primarily agricultural type with dominant plough-land, which is characteristic to the so called corn-wheat belt of the Central and Eastern European countries and the region suffers from regular continental droughts.

2. Characteristics of case study sites

In the area at **Tisza river basin in Hungary**, young soils without distinct profile development are found (Cambisols). In lowland areas, one can find dark Chernozems, the most fertile soil of Hungary that supports the country’s agricultural production. Soils in river valleys that have developed on stratified sediments are called Fluvisols. Arenosoils, soils that have developed on windblown sands deposited after the end of the last ice age, are extensive in certain parts of the country. In certain situations, ground water containing soluble salts can be found close to the surface. If evaporation is higher than precipitation, then salt affected soils such as Solonchaks and Solonetzs can be found.

70% of Hungarian water management problems occur in Tisza valley (such as floods, surplus water and drought). Surplus water and drought often occur in the same year or even in the same vegetation period. For crop production, light or radiation, temperature and water relationships (soil moisture) are the three cardinal climatic factors affecting vegetative development and flowering of crop species. Hungary has a substantial global radiation. The average energy input by radiation onto the surface is 4,430 MJ/m^2/year, which is a vast resource for plant production. This relatively high radiation is due to the long photoperiod, which comprises 2,050 hours/year. In Hungary, the average annual daily temperature is 100 C, and for the growing season is 17.5 °C.

The most variable element of the Hungarian climate is precipitation. The average annual precipitation is around 600 mm, but differences between years and the seasonal distribution are extreme. For example, looking at figures from Debrecen, the minimum and maximum annual precipitations between years 1900 and 1950 were 342 mm and 874 mm, respectively. Thus the major limitation to agriculture in Hungary is precipitation. Climate change models predict that Hungary will experience extreme precipitation events in the future. The greatest challenge is to store the rainfall within the soil through effective soil management practices. Such techniques will control erosion, minimise the loss of topsoil and maintain or even enhance organic carbon and the bio-diversity levels of the soils.

It is seen that July rainfall may be close to zero or up to 150 mm. This provides an unpredictable water supply for the vegetation and makes crop and fruit production vulnerable. This vulnerability is also explained by the difference between annual precipitation and annual evapotranspiration. It is well known that in mid-season the potential evapotranspiration is high and the precipitation does not meet it, and so there is shortage of soil moisture for crops, furthermore the high clay content can be also a big problem concerning readily available water content of soils.

The **Crisurilor Plain in Romania** is a part of the Tisza Basin in the Carpathian Basin and it was known for its large areas. Also the rainfall is not in accordance with the optimum water requirement of the crops. In 1968 the researches regarding the irrigation crop started in Girisu de Cris and in 1976 the researches regarding the crops' water consumption were carried out in Agricultural Research and Development Station Oradea (Domuța C., 2003, 2005). The researches regarding the irrigation use in the Crisurilor Plain emphasized the irrigation opportunity in the sustainable agriculture system. The yield gains produced by irrigation were statistically significant every year. The maize, soybean and sugar beet yields showed improvements in their stability and quality, and the water use efficiency improved, as well. The correlations quantified in the soil-water-plant-atmosphere system (soil moisture-yield, soil moisture – yield gains, water consumption – yield, climate indexes – yield) and economical efficiency sustains the irrigation opportunity in this area. During the research period soil water content has been maintained between the easily available water content and the field capacity on irrigation depths (0-50 cm for wheat and bean; 0-75 cm for maize, soybean, sunflower, sugar beet, potato, alfalfa 1st year; 0-75 cm for alfalfa 2nd year). The water source for irrigation is ground water at a 15 m depth. The main chemical properties of the irrigation water are the natrium content (12.9%, which is low) and the salinization potential, which is also low (CSR=-17; SAR=0.52)

The soils of the **East Slovak Lowland** (Východoslovenská rovina) have regional feature and original character (Vilĉek, 2004). Gley soils constitute up to 65% of the agricultural land. Concerning grain size distribution 43% of the soils are formed by heavy or very heavy soils. Available water in the East Slovak Lowland is a limiting factor for crop production. Minimum groundwater level at 50% of the area is deeper than 0.5 m below the ground. Maximum groundwater level at 82% of the area is less than 2.0 m below the ground (Šútor et al., 2002). Reference field works took place on heavy Gleyic Fluvisoils in the area under the scope of Agroecology Research Institute Michalovce located in Milhostov, on the East Slovak Lowland (altitude 101 m above the sea level). The annual average precipitation is 559 mm, the precipitation during vegetation season is 348 mm. The annual average air temperature is 8.9 °C, average air temperature during vegetation season is 16.0 °C (Šútor et al., 1995). In this area Gleyic Fluvisoil can be found. Gleyic Fluvisoil was formed by a long-time contact between groundwater and surface water in heavy alluvial sediments with high water binding ability and low permeability in whole profile. On average, 47.75% of these heavy clay–loamy soils are formed by clay particles (<0.01 mm), following Novák scale (Zaujec et al., 2009). Detailed analysis of soil grain size shows that these soils contain 26.53% of clay, 21.22% of fine and medium dust, 29.96% of coarse dust, 20.50% of fine sand and 1.79% of medium sand (Matia et al., 2011). Saturated hydraulic conductivity of these soils is ∼10−6 ms^{-1}. The structure of the field crops grown since 1998 has been as follows: field pea, spring and winter wheat, sugar beet, spring barley, 1st crop year clover-grass mixture, 2nd crop year clover-grass mixture, winter wheat, broad bean, winter wheat, sunflower, spring barley and soybean.

At the East Slovak Lowland lies in the transitional zone between the oceanic and continental climate, which accounts for specific climatic conditions of the area as same as neighbourhood Hungarian and Romanian plans (Sútor et al., 1995).

3. Analysis of brown water status

The drought causes significant damage for the producers, but the heat waves relating to the climate change increases it further. The extent of the damage can be increased or decreased the amount of brown water, which is available for vegetation. The amount of these water resources is not known exactly. Várallyay (1989) estimated the water storing capacity of the Hungarian agricultural soils at 30-25 km^3 per year. This means base water resources for the vegetation, since for the production every water resources originate from the soil without interception water of 1-5% catching on the foliage. The vegetation transpiration and soil surface evaporation decrease these water resources continuously. The surplus water infiltrates into the deeper soil layers or flows further on the surface. The soil root zone is not a simple water container. The formation of soils is influenced by the geological, climatic, topographical, biological and human factors, as well as the age of soils. In our case study site, the Great Plain, due to the basin character, these effects are mixed especially strongly and this resulted high uncertainty to estimate the quantity of brown water sources. The basic factors affecting soil formation, and the ever-changing soil processes in the Carpathian Basin resulted more complex spatial and temporal heterogeneity to the European average in the formation of the similar soil formations, which resulted three-dimensional mosaic soil variability in the topsoils. The disadvantage of used traditional soil conditions related tabular data sources are that they are unable to give back accurately the spatial 3D properties of soil units and their water processes in time.

For this reason it is very important to determine the exact amount of these brown water resources. The digital soil maps of agricultural lands in the Tisza River catchment were used to determine it.

There are no common soil mapping methods and maps for the area of GWP CEE. The national and international taxonomy nomenclature evaluates the soil types, the soil formations in different ways on the basis of the intensity and direction of the phenomena (FAO; 2006). In our approach this is not important, because the final aim is to determine the moisture supply, which is available for the vegetation. The soil taxonomic maps do not contain direct data for this, but it can be produced by the taxonomical hierarchical data layers with the pedotransfer methods or data conversion. So we can characterize the taxonomical and information data, too. We introduce the data sources used in the calculating of the brown water amount as follows.

In Hungary the used digital soil mapping was methodologically well developed based on JRC SOTER database (SOil and TERrain Digital Database) (Dobos et al, 2005, e-SOTER 2012). Early development of this system was performed by Várallyay et al. (1994) creating the HUNSOTER. Hungary currently has two digital soil databases, which cover the entire country. The Digital Agro-topographic Map (AGROTOPO) was made in 1:100 000 scale in a variety of different formats (DXF, MapInfo, ArcMAP). This map was based on the HUNSOTER methodology developed in the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences. Brown water estimation method developed was based on Hungarian reference site. In the system Hungarian soils were classified into nine main categories (Table 1.). In the case of soils which were classified into categories 1-5 the following parameters were given with their limit values: (a.) field capacity

(FC); (b.) wilting percentage (WP); (c.) available moisture range (AMR); (d.) infiltration rate (IR); (e.) saturated hydraulic conductivity (HC). In the case of these categories the hydrophysical characteristics depend primarily on texture, therefore beside the previous parameters the saturation percentage (SP) and hygroscopic moisture content (hy) limit values were also specified (Makó et al.. 2004). FC, WP and AMR values are not given for the soils classified into categories 6 and 7, because their poor water management and their extreme moisture regime are resulted mainly by their low infiltration rate and hydraulic conductivity. The organic soils were attached to category 8, the soils with shallow depth to category 9 (Várallyay et al., 1989).

Table 1. Applied hydrophysical soil properties and relation with soil parameters

Hydrophysical soil properties	**Soil parameters used for estimation**										
Soil subtype (SST)	-	(soil taxonomy: SOTER)									
Soil layering	*SST*	1	2	3	4	5	6	7			
Texture	*SP* (saturation percentage)	coarse sand	sand	sandy loam	loam	clayey loam	clay	heavy clay	organic soils	stony soils	salty soils
Field capacity (FC) [vol%]	*SP; HC* (humus content %)	< 10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50 <
Wilting percentage (VVP) [vol%]	*SP; HC; LC* (lime content CaC03%)	<2	2-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40 <
Available moisture range (AMR) [voI%]	*SP; HC; LC*	< 10	10-15	15-20	20 <						
Average depth of the groundwater (ADG) [m]	-	<0,5	0,5-1	1-2	2-3	3 <					
Capillary water transport rate [mm/year]	*ADG; SST; SP*	<0	0-50	50-100	100-150	150-200	200<				

Gombos et al. (2009) define soil drought beginning at the level of the threshold point, showed at the retention curve as pF = 3.3. The required soil hydrophysical parameters of category system completed with average layer depth was applied to estimate brow water capacity of root zone (Table 1).

Soil Taxonomic recently used in Romania describing that part of soil classification whereby arrangements of various soil groups and categories are mainly based on natural relationships between various soils (Ianoş, 1995). In order to create a common understanding of soil resources in different countries, a new soil classification system, named WRB-SR has been adopted from the International Union of Soil Science. The SRTS 2012 is organized into 10 chapters and the general principles are: the classification of soils is based on diagnostic horizons, properties and characteristics and the selection of diagnostic horizons, properties and characteristics takes into account their relationship with soil farming processes. The SRTS 2012 is a two-level system of soil taxonomy, where high level consists of 12 classes, 29 soil Genetic Types and 67 Soil Subtypes; while low level, with Soil Variety, Soil Species, Soil Family and Soil Variant. The Romanian Soil Taxonomy System has a good correlation with WRB (World Reference Base for Soil Resources) and also with the USDA Soil Taxonomy (Florea and Munteanu, 2003).

Soil taxonomy data and data relating to physically properties were completed with other values for reference depths. In these layers the values of Field capacity (FC) (vol%), Maximum water capacity (Wmax) (vol%), Available moisture range (AMR) (vol%), Wilting percentage (WP) (vol%) and Hydraulic conductivity (HC) (mm/d) are different. These parameters are important factors to total available soil water content, which is essential for growing crops. The attribute table was filled up with these data for the examined sites. Based on these data and the following equitations of water resource of a certain soil layer were calculated.

$$\Sigma(\text{Area}_i \text{ x Layer\_Depth}_i \text{x Wmax}_i) = \Sigma\text{WaterWmax}$$

$$\Sigma(\text{Area}_i \text{ x Layer\_Depth}_i \text{x Fc}_i) = \Sigma\text{WaterFc}$$

$$\Sigma(\text{Area}_i \text{ x Layer\_Depth}_i \text{x AMR}_i) = \Sigma\text{WaterAMR}$$

where,

Area_i: area of soil polygon on day i (m^2)
Layer_Depth_i: Layer thickness of soil polygon i (m)
Wmax_i: Value of Wmax water resource on the layer i (%)
Fc_i: Value of Fc water resource on the layer i (%)
AMR_i: Total value of AMR water resource on the layer i (%)
ΣWaterWmax: Total value of maximal water resource of each polygon on the layer i (m^3)
ΣWaterFc: Total Fc water resource of each polygon on the layer i (m^3)
ΣWaterAWC: Total available water content value of each polygon on the layer i (m^3)

In case of soil polygons, 4 layers were defined on each soil type. Thus the combined water resource was calculated and presented on a map. From the values of calculated water resource, many query operations could be carried out. Different water resources could be determined, e.g. on watershed areas or on different land use categories. This method is ideal to identify the vertical distribution of total available water content on the soil.

4. Analysis of green water content

4.1. Spectral time series data sources of green water

The development of remote sensing techniques and the new generation of satellite and airborne sensors could give advanced tools for analysing the biomass productivity in different space and time. Products of new generation of satellite and airborne sensors could give advanced tool for end users to produce new drought related products. The NASA and the U.S. Department of Agriculture Foreign Agricultural Service (USDA FAS) jointly funded a new project to assimilate NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) data and in monitoring crop conditions for a specific region, remotely sensed vegetation index data can be use to track the evolution of the growing season compared to reference long-term mean conditions (Tucker, 1985). A global normalized difference vegetation index (NDVI) is produced from MODIS data, and is referred to as the "continuity index". MODIS NDVI data from the Terra and Aqua platforms represent improvements in the ability to monitor land photosynthetic capacity. Croplands vary from year to year due to events such as drought and they vastly differ across the globe in accordance with characteristics such as cropping intensity and field size. To describe this temporally heterogeneity a global NDVI time-series database, with a spatial resolution of 250 meters has been assembled using USGS archive mapserver data 16 days compositing period, allowing for interannual comparisons of growing season dynamic. Basic data source is made after dual average by MODIS Terra remote sensing data from the whole Carpathian basin. In this way from 2000 to 2012 several image were downloaded from the site (Figure 1.).

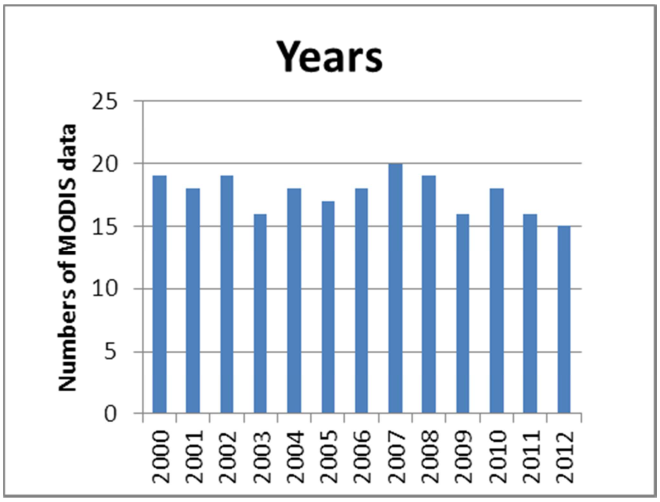

Figure 1. Numbers of MODIS data on Carpathian basin

This MODIS NDVI dataset is reprojected from Sinus projection into common UTM 34 projection and mosaicked to suit the Tisza river plan areas with 250 meter ground resolution. For the calculation of NDVI values the reflected solar radiation in the red (RED=620-670 nm) and near-infrared (NIR=841-876) wave-length bands were used from the MODIS 36 hyperspectral channels: NDVI = (NIR-RED)/(NIR+RED). NDVI values vary with absorption of red light by plant chlorophyll. NDVI is a nonlinear function which varies between -1 and +1 but it is undefined when the reflectance or sum of RED and NIR are zero. The progress of biomass process is a climate dependent periodicity in time so it is manifest to analyse the observation of time series by time steps methods. Basic data source consists of dual averaging NDVI values counted by MODIS Terra remote sensing data. These data are monthly frequency covering 16 day periods which had respected for in 13 years duration. Discrete time steps in time describe phenomenon of biomass growth. The components of time series applied theoretical model were described by Tamás et al. (2009).

4.2. Data integration and processing

After reprojection of the MODIS NDVI data sets, a complex model was established in order to select and delineate arable lands and orchards from the whole Charpathian basin. The reason for selecting the concerned sites was to eliminate the disturbing effect of other landuse categories on NDVI values. The selected areas will be the bases of the signalling and intervention levels for the next output and it will be calibrated by yield data. Certainly, the identification of exact site for wheat and maize crops were made based on the time series, and NDVI pattern changes of the sites. ArcGIS 10.2 software was used to create models for the data processing of NDVI images. First those Boolean mask images were produced with which the MODIS data set can be extracted. Masking was based on several datasources of landuse and terrain models. USGS SRTM models were used to select plain areas (below 200 m altitude). The SRTM digital elevation data, produced by NASA originally, is a major breakthrough in digital mapping of the world, and provides a major advance in the accessibility of high quality elevation data. The SRTM 90 m DEM's have a resolution of 90m at the equator, and are provided in 5 deg x 5 deg tiles. Thereafter CORINE Landcover datasets (CLC 2006) were used to select arable lands and orchards. The European Environmental Agency (EEA) provides the CORINE (COoRdinate INformation on the Environment) land data base, a pan-European land cover/ land use map for non-commercial use. After all the plain areas and arable lands and orchards site were selected, the layer of plain and arable land was merged together to select overlapping sites. Following these steps the polygons of counties were selected from reference sites and the arable lands and orchards were extracted from counties. Eventually the produced county-arable land-plain and county–orchard-plain masks were used to extract the certain sites form MODIS images (Figure 2).

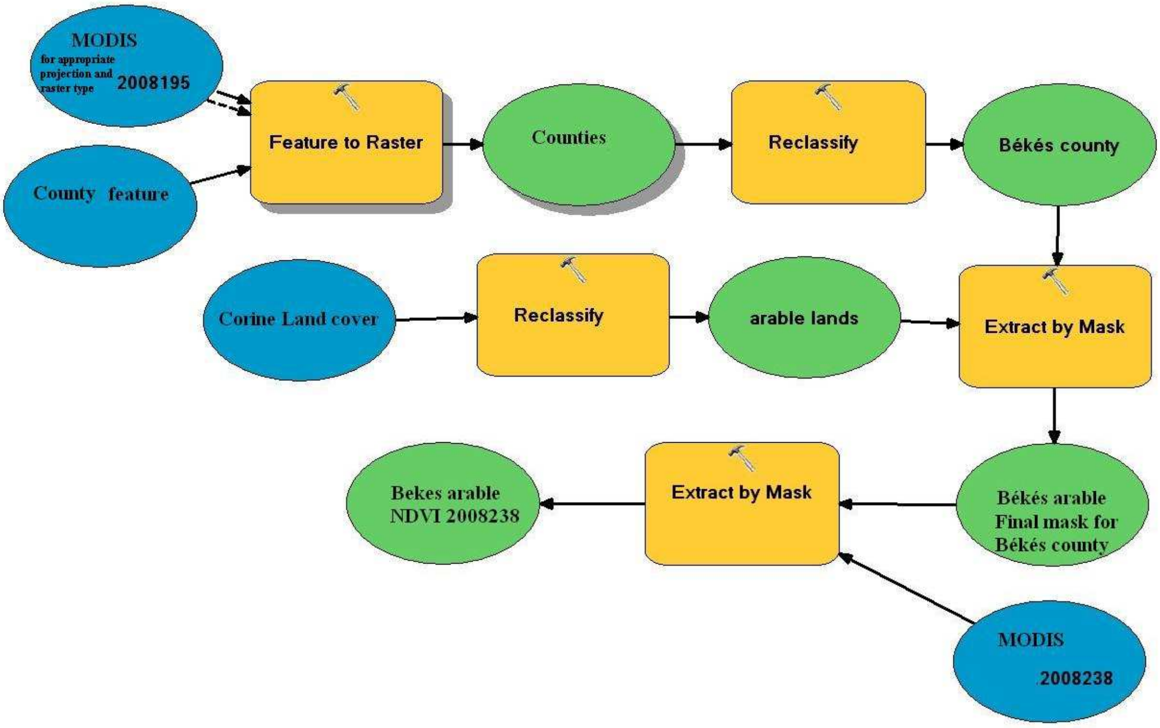

Figure 2. ArcGIS model for creating mask and extraction of arable land of Békés out of a MODIS image

Critical issue was to create such mask images for the examined counties and medium watersheds, which had the same projection type, raster structure and cell size in order to provide the exact masking from the MODIS images. As 7 counties in Hungary, 2 counties in Slovakia and 1 county in Romania were extracted from MODIS NDVI images, new models had to be established for faster extractions. These models were built for group extraction of Carpathian basin MODIS NDVI images by final county masks. Three models were established, one model is for drought affected years (Figure 3), one is for wet years and one is for the average years. Models were run for each MODIS NDVI image with each county.

After extraction, drought affected years (2003; 2007; 2011; and 2012) and wet or average years (2005-2010) were chosen for analysing the changes of the NDVI pattern during the years, and to identify differences between dry and average or wet years. Since NDVI has a strong correlation between chlorophyll content LAI (Leaf Area Index) and chlorophyll content, LAI is sensitive to stress symptoms caused by the inappropriate water supply, thus NDVI is a good tool for monitoring the effect of droughts.

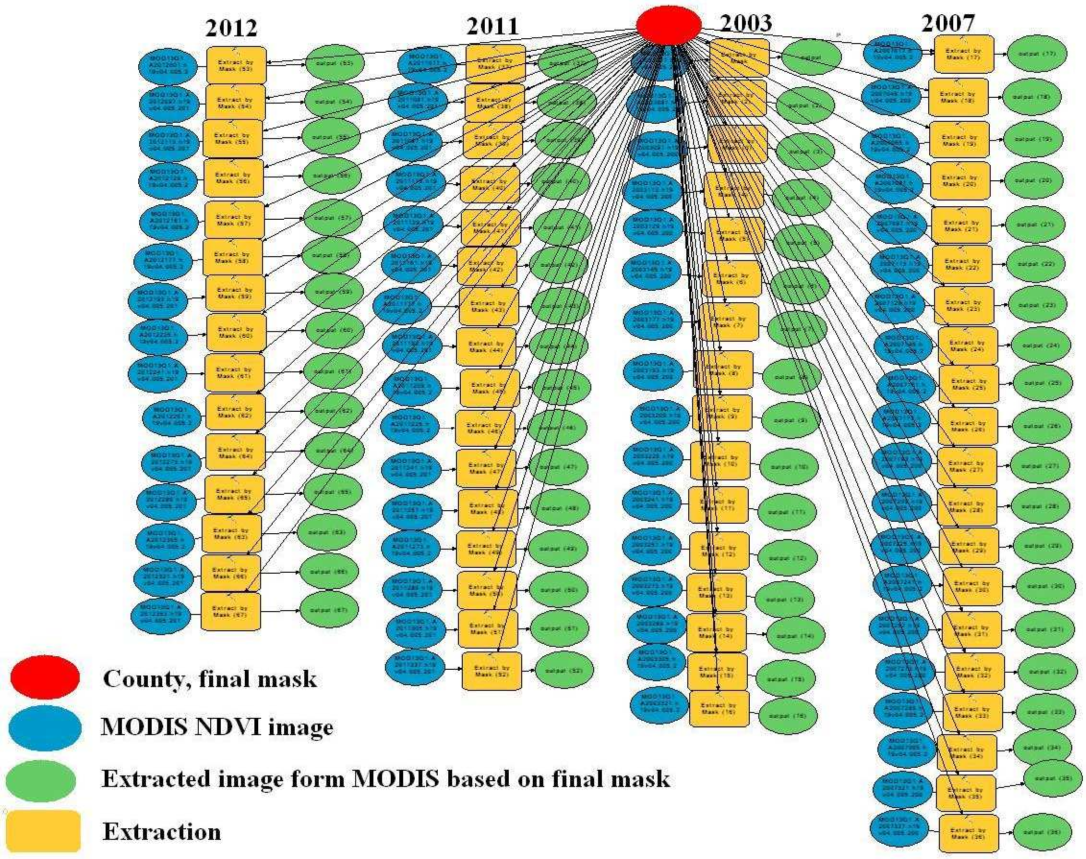

Figure 3. ArcGIS model for extraction process of a final county mask from MODIS NDVI images

Regarding to climate change effects the higher yearly mean temperature and less precipitation cause an earlier vegetation cycle. For this reason we can expect lower yearly average NDVI values in Hungary. The large NDVI values wet conditions tend to occur, while low NDVI values imply warm-dry climate conditions mainly observable this phenomena regarding to the NDVI values in August: i.e. average year, excess water and/or drought hazarded extreme year.

Analysing of the drought affected years, in the case of arable lands and orchard drought can appear at the middle of June in the Southern part of the counties, but in the case of East Slovak Lowland the drought appears in the middle of July. On the other hand in wet years the higher NDVI values were detected representing good water supply circumstances (Annex 1). In July NDVI values were about 0.5-0.6 in 2003, meanwhile 0.6-0.8 in 2010, and in August the average difference NDVI was 0.3- 0.4. The same drought effects can be observed on NDVI values in the case of apple orchards as well in the case of 2010 and 2012 years (Annex 2).

4.3. Water content and consumption of the concerned cultivated plants

In order to calibrate the NDVI images, the water content of the vegetation had to be assessed. Water content was calculated directly from yield data of the maize, wheat and apple. The calculation was made for the total yield amount / county and for T/ha, as well. According to the results the maize and wheat yield water content was found significantly lower in the case of drought affected years, than in years with average or wet precipitation circumstances. (Figure 4).

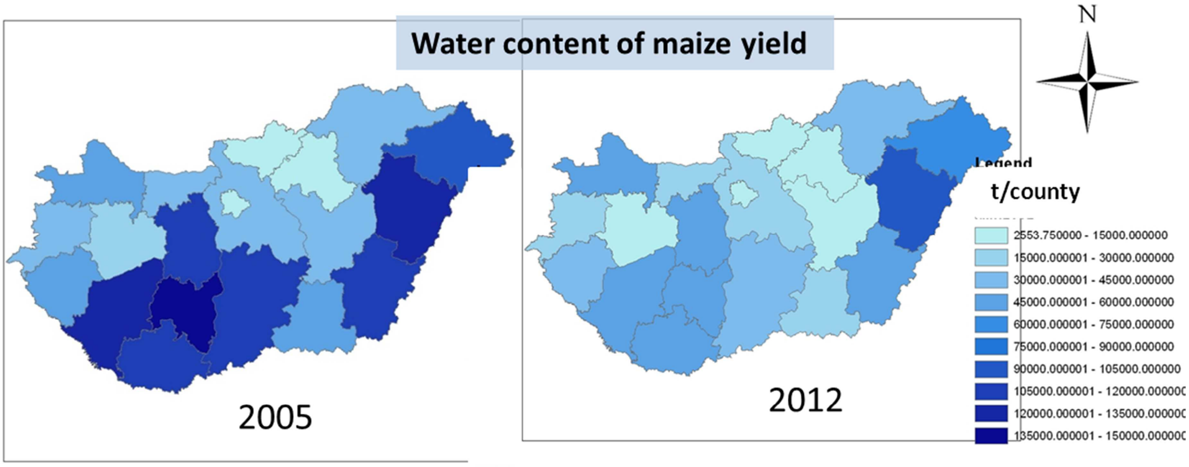

Figure 4. Water content of maize in dry (2012) and wet (2010) years

In the case of apple the effect of drought cannot be clearly observable based on only yield data. The reason for this is that several other factors can significantly influence the yield. These factors are mostly climatic. In some of the examined years there were severe freeze damages in early spring, which caused decrease in yield. Another typical problem in summer is the hail damages. There was special circumstance in 2010, when the amount of precipitation was nearly twice as much as the long term average annual precipitation, thus the effect of excess water and pathogen agents had also negative effect. Although the water demand of the apple trees were fulfilled in this year, but other factors (e.g. temperature, humidity and inappropriate soil conditions) were under the ecological demand of apple orchards (Figure5).

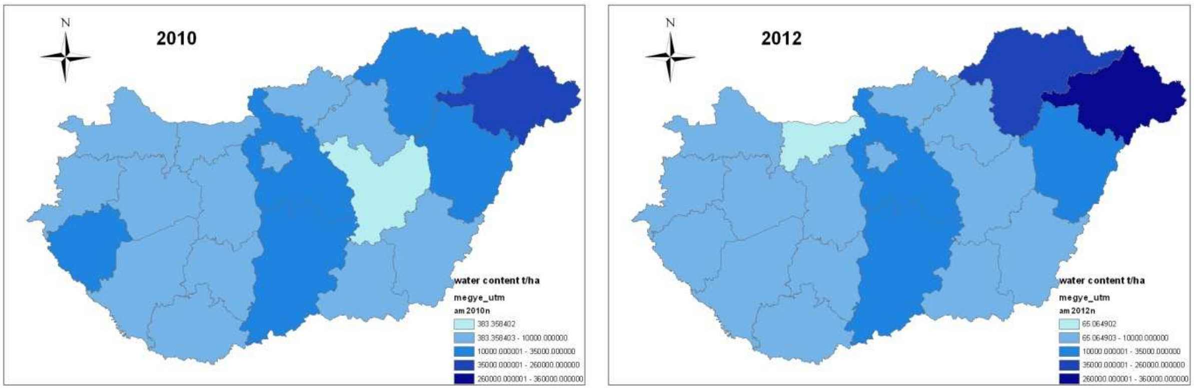

Figure 5. Water content of apple in dry (2012) and wet (2010) years (tons/county)

Many factors affect the water demand of crops and fruits:

a) climatic conditions: linear effect to a certain extent (physical and energetic conditions of evaporation)
b) canopy growth of crops and fruit trees (growing is exponential at the beginning than it converges to a maximum.
c) length of vegetation period of species concerning the specific periods when water demand reaches its maximum;
d) within the effect of vegetation density and nutrient supply on transpiration surface.

The water demand of the vegetation, thus the crops and fruits as well changes markedly during the vegetation period. Depending on crop species after reaching the LAI (Leaf Area Index) 3-4 times value, further canopy growth, thus growth of vegetation and yield weight do not affect evapotranspiration and water demand significantly. One example for maize is that increasing crop density from 30,000 to 60,000 results 60 mm increase in water consumption. Therefore, in the case of soils with good water management properties small density is not recommended, though the annual oscillation of yields can be minimized, but the average annual yield would be less, than on those sites, where the average density of crops are higher. On the other hand soils with low water capacity and water management properties safe crop and fruit production can only be carried out successfully with low density (Szalóki, 1989).

The length of vegetation period determines the dynamic and quantity of water demand. Maize species with short vegetation period have less water demand then species with long vegetation period. It is true that the amount the precipitation is greater in the case of longer vegetation period but this precipitation amount does not fulfil the water demand of the crops. In the case of wheat 2 weeks difference in vegetation period results 50-70 mm water demand increase. This increase cannot be always fulfilled even in the case of good water capacity soils, thus greater yield amount cannot be realised. If irrigation is available, species with longer vegetation period can be applied, because in this way greater yield capacities can be utilized.

Larger nutrient supply increases water consumption but the crease the partial water demand utilized for the production of one ton yield thus it enhances water utilization. This suggest the fact that it is no use to give nutrient if there is not enough water supply since appropriate water supply makes nutrient doses utilizable. On the other hand nutrient and supply even in the case of good water supply can enhance yield and water demand till on optimum level but in decreasing extend. The irrigation can be the most effective if other parameters are optimized (Szalóki, 1989).

The water demands of crops and fruit orchards are changing within phonological stages. The daily water demand of wheat reaches its maximum (4-5 mm/day) at the end of May and at the first part of June. Total water demand of wheat is 270-350 mm. Vegetation period of wheat ends before the hottest and most drought effected period of the year, thus wheat can generally utilize this small amount of water. The vegetation period of maize starts from the end of April and lasts till the end of September. Total water demand of maize is 420-550 mm (Figure 6). Crucial period of phonological face lasts from blooming period to milk ripening and its daily water demand reaches 4-6 mm.

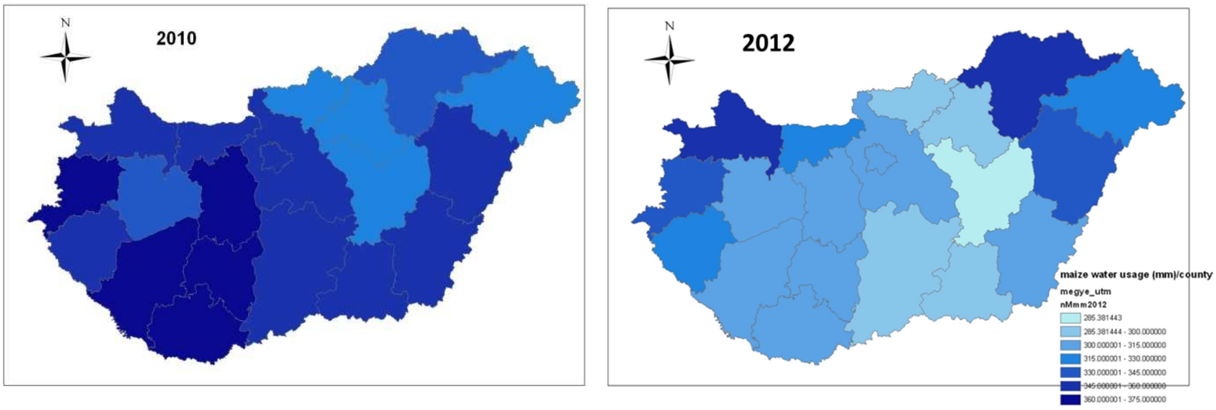

Figure 6. Water usage of corn mm/year in dry (2012) and wet (2010) years

Water utilization is good at the rate of 20-25 kg seed/ha/mm. Within the growing yield amount, the partial water utilization for production of 1 tonne of yield is decreasing. Based on this statement and a hyperbolic algorithm, the partial water usage of maize, wheat and apple was calculated. Based on these calculations, in drought affected years, the water usage for 1 tonne was greater than in wet years (Figure7.).

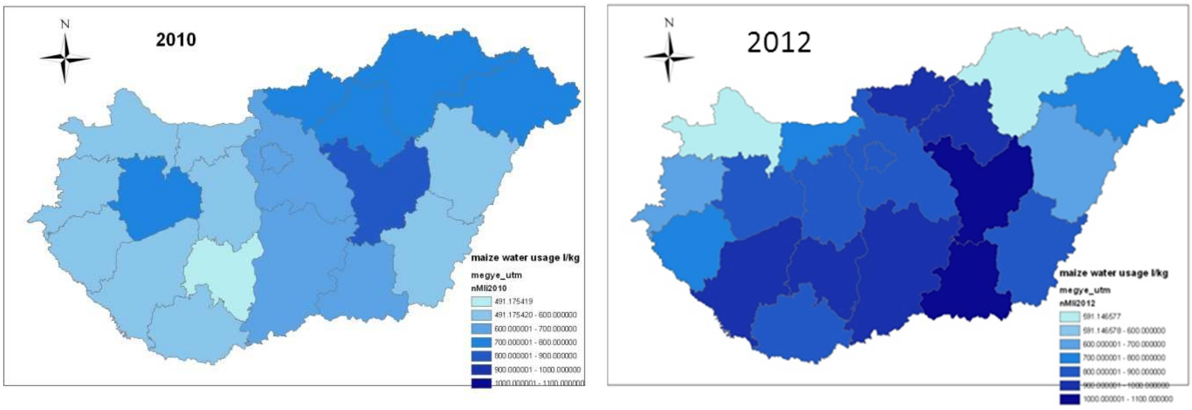

Figure 7. Water usage of corn l/tonne in dry (2012) and wet (2010) years

In the case of apple production the water and nutrient uptake, water transport, canopy size can be influenced by the changing type of rootstocks that cause significant differences in the transpiration and water use efficiency. Young and dwarf apple trees are sensitive to drought and the high crop load also affect on their water use. Considering the growing technology and economical aspects, the very dwarf type and type of rootstocks were rather used in the intensive high density orchards. Use of M 9 and MM 26 rootstocks, with restricted root volumes, result a decrease in nutrient uptake under drought that cause a decrease in fruit size and expected crop the next season. The degree of drought tolerance of apple trees depends on the interaction between rootstocks and scion. MM 111 rootstocks are considered to have high drought tolerance. Apple generally suffers from drought. The precipitation of July and August months have the most crucial effect on the fruit crops. During these periods the water use efficiency of apple trees is affected by their water demands. This depends on the age, growing periods, and climatic factors, such as temperature radiation, precipitation, wind and available water content of soil, respectively. The excessive absence or presence of these factors regulates the water transport inside the trees. In July water use of apple trees is the highest because by then the canopy reached the 80–90 percent of the full shape and the fruit begins to develop very intensively. The daily water use per tree showed peak values around 35–40 l/day/tree from middle of June to middle of July, then gradually declining after mid-July (Nemeskéri, 2007).

Vegetation with greater weight canopy and developed roots transpires more, but uses soil moisture capacity more intensively enhancing the standards of the plant protection and reducing weed coverage. More water is available for crops and apple orchards as the rate of productive transpiration increases.

Optimal nutrient supply and plant protection enhance the water demand of calculating plants but also increase the productivity as well. Due to these facts the yield amount become more significant and water demand increase, but in smaller extent than the increase of yield growth. The productivity of the utilized water amount, originated from precipitation increases, thus eventually the yield increases as well. Although, the sensitivity for water stress is enhancing.

There are no controversies between the abovementioned statements. In order to maximally utilize the yield potential of a species, nowadays every factor and parameter can be provided, except for water supply, thus in the case of years with optimal precipitation circumstances large yields can be achieved. On the other hand in the case of drought affected years the effect of water shortage cannot be compensated by any other factors. This suggests that the effect of yield capacity increasing factors can be more effective if water supply is adequate for the given species. Therefore appropriate or inadequate water supply has greater differentiating effect on yields in the case of high agrotechnical level, then in the case of crop production at extensive or lower agrotechnical level. The annual fluctuation of yield and yield loss will not show decreasing tendency in the future, furthermore it will become more and more severe especially in the case of soils with poor total available water capacity.

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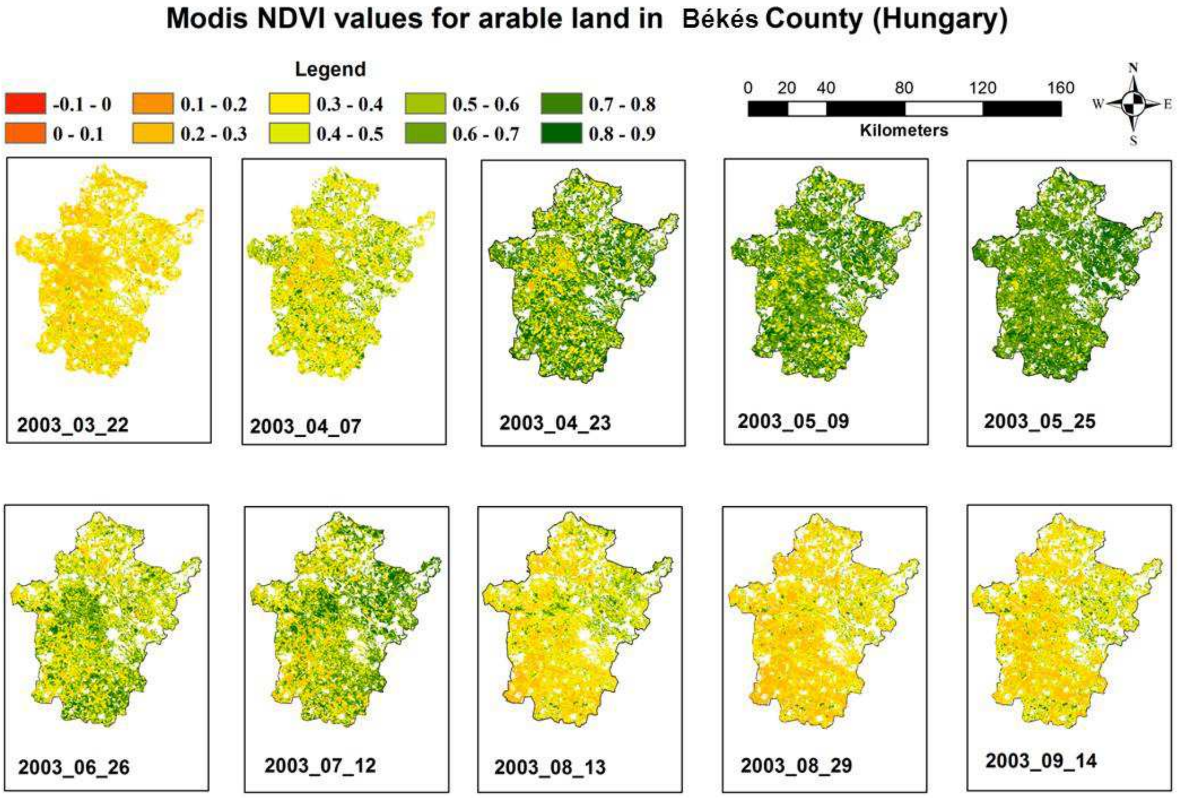
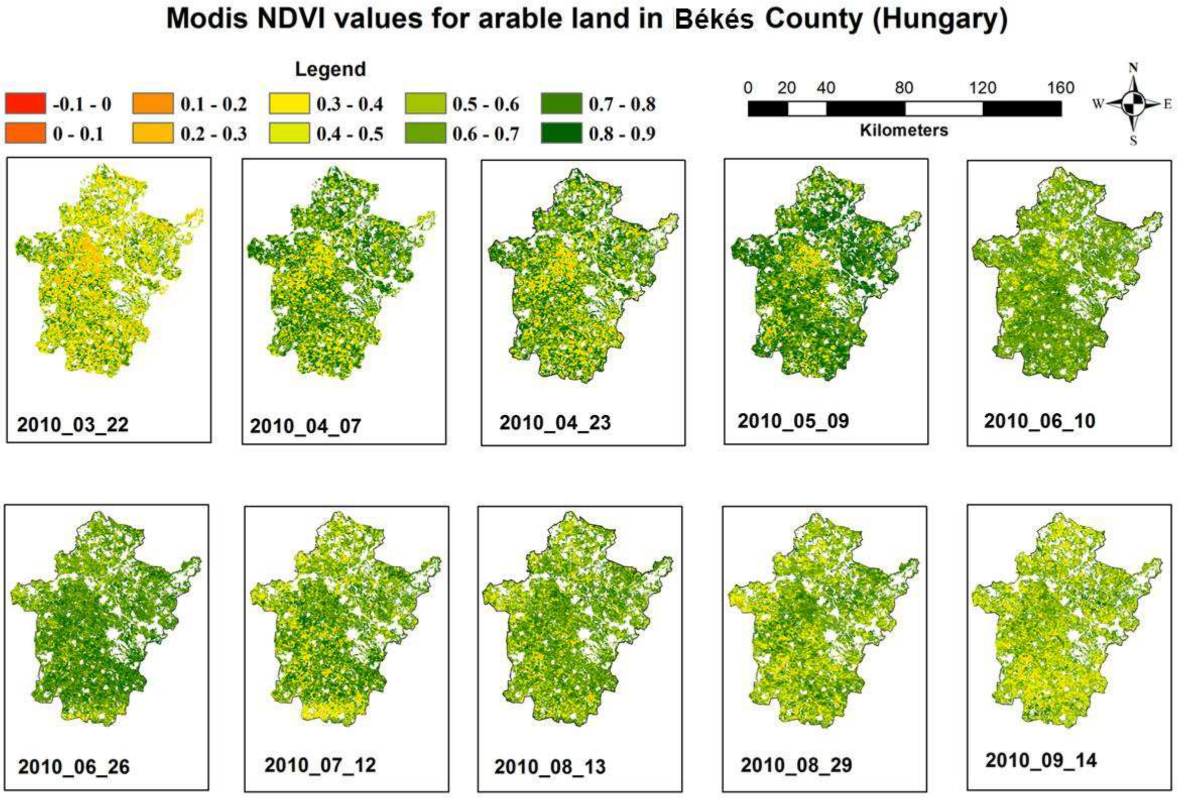
Annexes

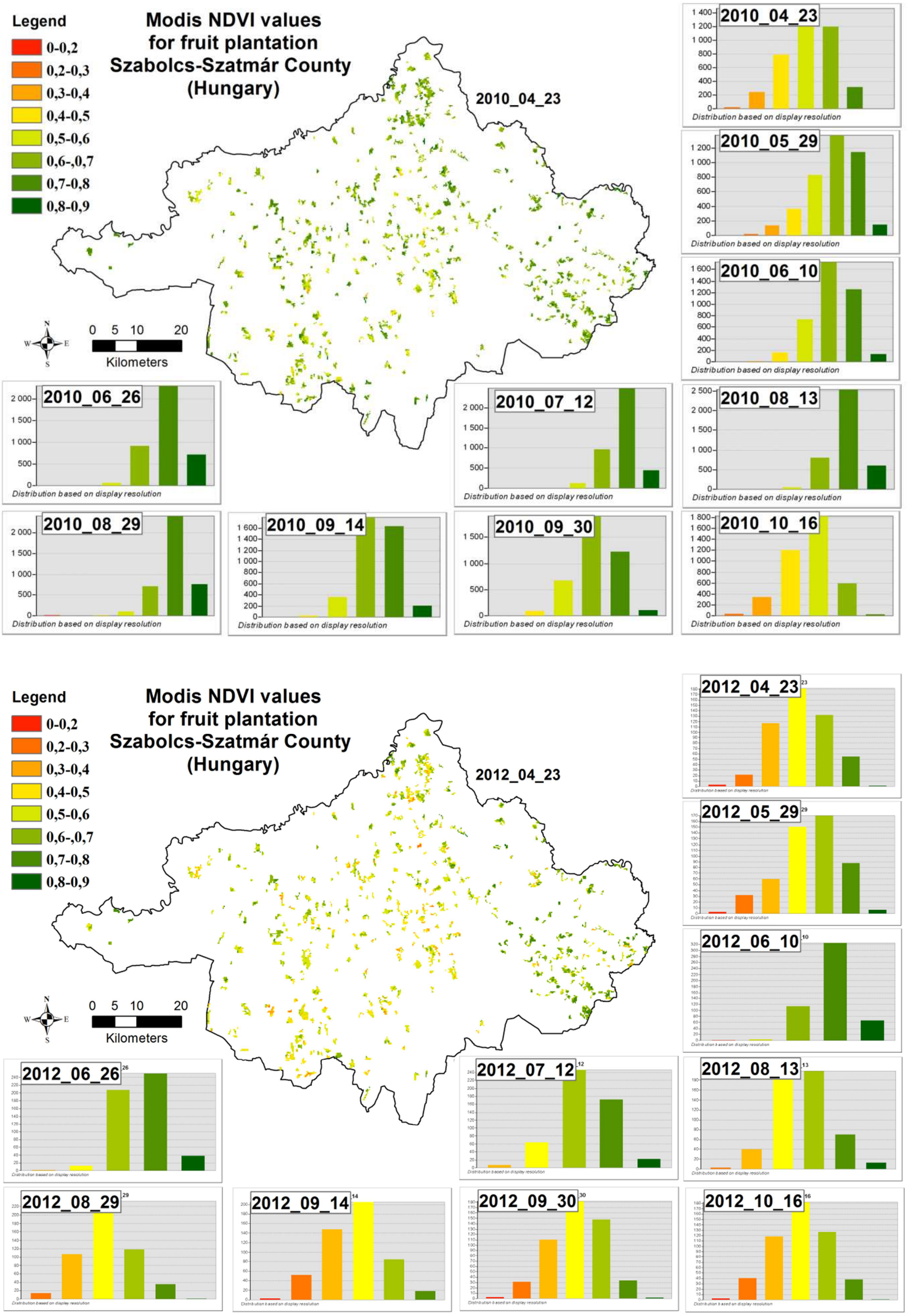


Modis NDVI values for arable land in Békés County (Hungary)



Modis NDVI values for arable land in Békés County (Hungary)

Annex 1 MODIS NDVI values for arable lands in Békés county for dry (2003) and wet (2010) years



Annex 2. NDVI histograms for fruit plantations in Szabolcs Szatmár county in dry (2012) and wet (2010) years