Kartografické listy / Cartographic letters, 2014, 22 (2), 63-71

DETECTION OF WOODY INCREMENT WITH ANALYSIS OF LANDSAT IMAGES IN ORDER TO DETECT THE INVASIVE TREE SPECIES

Gábor BAKÓ[1,2], Györk FÜLÖP[1,3], Boglárka SZABÓ[1,4]

Detection of woody increment with analysis of landsat images in order to detect the invasive tree species

Abstract: In continental climate regions of the EU, one of the largest environmental and conversational problems is caused by the spread of invasive plant species, especially in agriculturally abandoned regions. Several invasive species spread rapidly, and push the native vegetation out of its ecological niche. Moreover, some of these adventive species cause risk also for human health – e.g. resulting allergic reactions, they change the physical structure and chemical composition of the soils, affect the microclimate, thereby contributing to climate change processes. The common feature of the belonging species is that they spread rapidly and develop a significant amount of biomass in a short time. In the course of our research we worked out a remote sensing and GIS method, which localize efficiently the infected areas, exploiting the high biomass intensity change attributes of the targeted sites.

Keywords: remote sensing, biomass monitoring, Earth Observation, T-BEA

Introduction

Curbing the spread of invasive plant species has a significant economic interest. The eliminating of invasive plant species, which endanger the biodiversity, the agricultural productivity and the health, is another important European interest. Since 1992, the EU within the framework of 180 projects have spent more than 38 million Euros to stop the spread of invasive species in natural and agricultural areas (EUROPEAN COMMISSION, 2008), while the USA, based on their estimates, marked out 80 billion Euros annual for the combat against the biological intruders (Asner and Vitousek, 2005).

However, the energy supplies endeavour to application of renewable and alternative energy sources (EUROPEAN COMMISSION, 2009). Thus, the interests of the energy sector can be set aside to the environmental protection, so an efficient environmental resolution can be planned, thus solving productivity with environmental planning (Joshua, 2009). Bioenergy stands for traditional biomass energy and for sustainable energy source (Wiseman et al., 2013). The biomass, which is necessary for the operation of the bio-energy power-plants, is getting harder to be accessible, since the cultivated energy plantations destroy the topsoil. For the previously built power plants, it is useful to operate them with biomass-stock of invasive vegetation, which is causing environmental damage.

[1] Developing geoinformatician, GeoData Services Ltd., - Hungary, Szentkirályi Street 8, Budapest, e-mail: geoadat@geoadat.hu,

[2] Gábor BAKÓ, MSc, Institute of Botany and Ecophysiology, Faculty of Agricultural and Environmental Sciences, Szent István University, Páter Károly Street 1, Gödöllő, e-mail: GBako@geoadat.hu,

[3] Györk FÜLÖP, PhD candidate, assistant of professor, Faculty of Horticultural Sciences, Department of Biometry and Agricultural Informatics, Corvinus University of Budapest, Villányi street 29-43, G. building, Budapest, e-mail: GyFulop@geoadat.hu,

[4] Boglárka SZABÓ, MSc, Institute of Environmental and Landscape Management, Faculty of Agricultural and Environmental Sciences, Szent István University, Páter Károly Street 1, Gödöllő, e-mail: BSzabo@geoadat.hu

Primarily, the woody, quickly renewable species came into the focus of interest, e.g. Tree of Heaven (*Ailanthus altissima*), Russian Olive (*Elaeagnus angustifolia*), Black Pine (*Pinus nigra*), Common Hackberry (*Celtis occidentalis*). Although, the non-indigenous herbs can cause serious environmental problems in the European landscapes (Bakó, 2013). In our study we worked out the methodology of detection the woody increment. Our aim was that in compliance the control of the appropriate renewable energy directive, to promote the excavation of such renewable energy directive control (EUROPEAN PARLIAMENT & COUNCIL, 2009), which has not a conservation or forestry value, but they threat the native vegetation and the ecosystem.

In order to achieve these objectives it was necessary to examine the cost-effective Earth Observation (satellite remote sensing) techniques, which are able to monitor the renewable production of biomass stocks. The ongoing EUREKA labelled (EUREKA, 1985) T-BEA project (T-BEA, 2013) (Tool for Biomass Accessibility with Earth Observation) is aiming to detect efficiently with Earth Observation tools the biomass stocks, which are sustainable to be utilized for bio-energetic use, and which mean significant danger for the natural and agricultural environment.

In the first phase of the investigation, we looked for the answer, how we can approach to the technical challenge by using exclusively freely available Earth Observation datasets. First, we tested the sufficiency of the quoted vegetation indices and the correction calculations with the freely available Landsat 4, Landsat 5 and Landsat 8 satellite images. Here we present the first results, which may draw up the frame for the future developments.

1. Method

The set up methodology aimed to frame the servicing GIS infrastructure, which shall be used operatively in the near future to detect accessible, unused and sometimes even harmful biomass stocks with Earth Observation technology. The introduced solutions stands for only the first phase of the development chain, however, with the utilization of these results the information production could be optimized on an objective basis.

1.1 The applied satellite images

The procurement of images came true across the website of USGS Earth Explorer. The Landsat 4 operated between July 16, 1982 – December 14, 1993, while the Landsat 5 between March 1, 1984 – January 2013. Thematic Mapper functioning of the board (TM) sensor made the images on seven spectral bands (Tab. 1). The uncompressed images are georeferenced, and have mapping projection, they take on each channel average 60 MB storage space, and they are more than 8000 x 7000 pixels in size.

Tab. 1 Bands of the Thematic Mapper (platform: Landsat 4-5 (USGS, 2014a))

Band	Spectral range	Spatial resolution	
1	0.45 - 0.52 µm	30 m	Blue
2	0.52 - 0.60 µm	30 m	Green
3	0.63 - 0.69 µm	30 m	Red
4	0.76 - 0.90 µm	30 m	Near-Infrared
5	1.55 - 1.75 µm	30 m	Near-Infrared
6	10.40 - 12.50 µm	120 m	Thermal
7	2.08 - 2.35 µm	30 m	Mid-Infrared

A Landsat 8 satellite entered service on 30 May 2013. The located on bands of Operational Land Imager (OLI) sensor differ from the bands of TM sensor, therefore have to be used different calculations in case of two types spectral response images. The OLI sensor data are contained in Tab. 2.

The uncompressed images are georeferenced, and have mapping projection, they take on each channel average 120 MB storage space, and they are more than 8000 x 8000 pixels. Since the satellite images are available in georeferenced form, after the uncompressing, sorting and methodizing we can immediately start the adjustment of evaluation processes.

Tab. 2 Bands of the Operational Land Imager (OLI) (platform: Landsat 8 (USGS, 2014b))

Band	Spectral range	Spatial resolution	
1	0.433 - 0.453 µm	30 m	Coastal / Aerosol
2	0.450 - 0.515 µm	30 m	Blue
3	0.525 - 0.600 µm	30 m	Green
4	0.630 - 0.680 µm	30 m	Red
5	0.845 - 0.885 µm	30 m	Near Infrared
6	1.560 - 1.660 µm	30 m	Short Wavelength Infrared
7	2.100 - 2.300 µm	30 m	Short Wavelength Infrared
8	0.500 - 0.680 µm	15 m	Panchromatic
9	1.360 - 1.390 µm	30 m	Cirrus

1.2 The applied vegetation indexes and the suggested softwares

The NDVI (Normalized Difference Vegetation Index) is a dimensionless value, which express the vegetative activity of a given area. The value of NDVI is supplied by the quotient of difference and the amount between the vegetation reflectance intensities of near infrared (NIR, usually 845 to 885 nm) and visible red (RED, usually 630-680 nm) range (ROUSE et al., 1978).

Described the formula:

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})} , \quad (1)$$

where NIR – Reflectance value of the near infrared band (Landsat 4,5: band 4; Landsat 8: band 5)

RED – Reflectance value of the red band (Landsat 4,5: band 3; Landsat 8: band 4)

If the measurement performing sensor is on an airplane, or on a space-borne device, it must take into account the disruptive effects of the atmosphere at the measurement of solar radiation on given wavelength. The radiation passing through the atmosphere is subjected to the scattering and absorption, which can be induced by both molecular gas and aerosol particles. To reduce the radiation modifying effects of atmosphere, atmospheric correction, while in order to reduce the dependence of the measured reflectance direction (normalize) a bidirectional reflectance distribution function model (BRDF) should be adapted (Kern, 2011).

For the atmospheric correction mainly the following variables are necessary to identify:
– Aerosol optical depth at 550 nm,
– Vertically integrated water vapour,
– Quantity of vertically integrated ozone,
– Surface pressure.

The latter can be determined from MODIS data, which can be an alternative way of field data collection and purchase of archive meteorological data. The MODIS is an ideal choice, because the data can be obtained from less than 150 crossing annual.

The determinations of vegetation index in case of images, which have been normalized and underwent the atmospheric corrections are facilitated by number of software. Calculation of NDVI from Landsat images is realized in the following way:

We can produce the NDVI maps by using ESRI ArcMap application, by definition of appropriate bands from Landsat with the image analysis module (Image Analysis): Select the Processing Toolbox NDVI “maple leaf”. For a new layer will perform the calculation.

Using the ENVI software package we can prepare our maps NDVI map also. In the toolbar (Toolbox), select the Spectral / Vegetation / NDVI option. Consequently in the appearing NDVI window we can select the images that will be analysed and narrow the calculation to the area of the image. We can select the type of image, if the sensor is in the list (TM, MSS, AVHRR, etc.), or give the appropriate red and near-infrared bands of opened image (in case of known sensor the software selects the appropriate bands). However, we need to decide that do we export the result into the computer's memory, or we specify the file format.

The NDVI module can be activated in the ERDAS 2011 software package by clicking the Raster / Multispectral / Unsupervised tab, for the type of NDVI classification. Setting of this is similar to the ENVI NDVI panel. Of course, in this case, we gave values between -1 and 1 for each pixel and the positive integer means the healthy green vegetation.

NDVI calculation is also supported by the SPRING GIS. First, here we open the image, then click to the İmage tab and select the option of Arithmetic Operations. At the Operations button we select the "C = Gain * ((AB) / (A + B)) + Offset", option, then we give the A channel as the near infrared, while B channel is the red channel. By clicking the button of ColorPallet we can give hues for the outcome. The user should choose colours from the often used in the international literature. For example, the White - Yellow - Green tone NDVI colour scale, which provides a good basis for comparison the graphic material of different publications.

The free MultiSpec software is able to perform the NDVI calculation. The images must be open, and then after selecting the Reformat option from the Processor menu, click the Change Image File Format. In the appearing dialog we can select the output format (you should use *.geoTIF), then we can load the Transform data box, which calls for a new dialog box. Here select the New Channel from General Algebraic Transformation opportunity. After we have accepted it, a new window appears, into which we can write the wanted formula, in this case:

$$\mathrm{NDVI} = 0 + \frac{1.0C3-1.0C2}{1.0C3+1.0C2} * 1 \quad , \tag{2}$$

where C1 and C2 mark the R and NIR bands.

To perform the calculations we can use free and opensource GRASS GIS by writing the "r.mapcalc" command. In the GRASS GIS Raster Map Calculator window, firstly we give the name of the layer, what we want to create and then we compile the formula. To do this, add the appropriate bands with the Insert existing raster map button. With click to the Run button we can prepare the new NDVI layer.

With QGIS open source GIS software we can also calculate NDVI after installing the Measuring Vegetation or the Raster Calculator plugin. With at the GRASS software reviewed method gives the formula.

The load time of the NDVI layer depends on the size of the used image. On the gray-scale layer, the dark parts of the areas are the less vegetation covered areas.

We made own algorithm for vegetation index calculation and for the subsequent operations for partially automate the process.

1.3 The processing of Normalized Difference Vegetation Index maps

During the optimization of the process, if we would like to retrieve a map from the vegetation coverage, we must give an identification threshold, for selection of the vegetation and bar pixels by the software. So, we can determine the vegetation covered areas with a relatively simple classifications process. Ultimately, we get two categories: vegetation and bare surfaces.

The extraction of vegetation indexes can be achieved with mathematical operations applied on the raster file bands, result a new raster band, the coverage map (Fig. 1). Since the selection of the woody growth is our aim, we need to compare the coverage maps of different months, for that we can filter out the harvested plots covered with herbs and spring herbaceous weeds. In this way we get a woody cover overlay for every year and create a digital vector map, which can be compared with the forestry and conservational digital databases. Thus we can quickly and automatically mark the areas covered by woody weed increment with the taking the vegetation cover of the precious years into consideration.

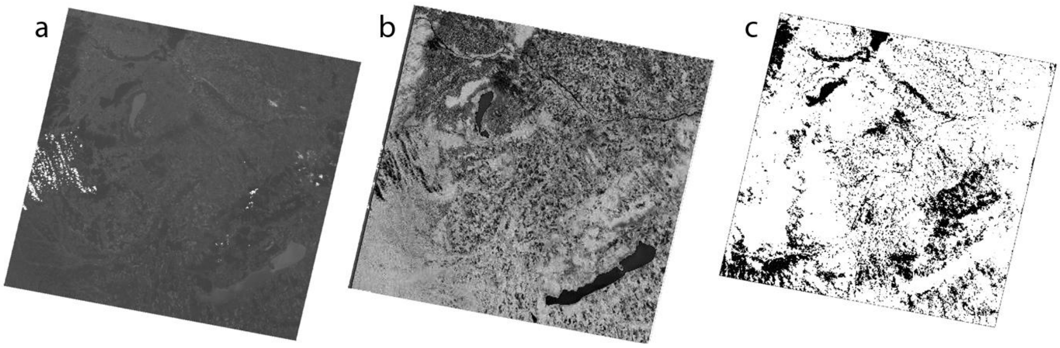

Fig. 1 The original image’s band 2 (a), the NDVI map (b) and the coverage map (c)

First, we give a threshold, where the higher NDVI values belong to the areas, which are of interest for us and which are covered by vegetation in the whole vegetation period. If at the NDVI calculation we did not apply atmospheric correction and normalization calculations, than this value will be empirically determined (Tab. 3). The difference between satellite datasets are arising from the spectral difference of the acquisitioned sensor bands, while between the seasons the atmosphere may cause the main difference.

Tab. 3 The applied NDVI thresholds in case of our working area

Satellite	Images of the summer months	Images of early spring and autumn
Landsat 8	**NDVI 0.44**	**NDVI 0.35**
Landsat4 and 5	**NDVI 0.53**	**NDVI 0.44**

Then, we give the cover of biomass areas in a given year from the cutaway of the given acquisition dates of the characteristic plant biomass cover maps (Fig. 2). Where a rapid growth of biomass can be observed in the consecutive years, there appear likely invasive, but at least R-strategist species. We can detect the largest plant infections efficiently with this monitoring system.

1.4 Checking the method with using HR ortho images and field validation

During the checking we found that the created monitoring system digest the fast-growing photosynthetic biological production with 60 meters resolution. The areas infected by *Ailanthus altissima* can be detected very well (Fig. 3).

The smallest detected increment areas are 3600 m^2 (Fig. 4). Due to the limitation of Landsat images resolution, these results may not be accurate, but by the checking the areas in the field, necessary interventions can be performed. The method is useful for the design of local and national protection, because it shows large increment areas.

Conclusions

Although the 30-m spatial-resolution HS and MS images do not allow the racial and association-level vegetation mapping in diverse environment, they are suited for building a rapid and cost-effective biomass monitoring system. We have achieved 60 m detail for woody plants biomass monitoring with Landsat imagery, that is available free of charge. So the created IT system indicates that somewhere R strategist species appear suddenly and in great crowd. The control of such areas the plant infections can be localized, at the most infected areas can perform the output of invasive species. With the utilization of the set up methodology the optimization of the processing chain can be started in an iterative manner, providing a strong basis for developing an operatively adequate technology in order to serve the energy-efficiency and the nature protection aims in a synergetic way.

Fig. 2 Woody biomass cover map of the year 2011 controlled with GeoEye space images (illustration background source: Google Earth)

Fig. 3 The area is infected by Ailanthus altissima presented in the Google street view service. The red line is the boundary of polygon from our monitoring system

Fig. 4 Increment areas are in the Google Earth service. The red line is the boundary of polygon from our monitoring system

*The preparation of this publication was helped by the EUREKA labelled T-BEA project (EUREKA Secretariat E!7651) coordinated by the National Innovation Office (**EUREKA_HU_121-2012-0042 PROJECT**), lead by GeoData Services Ltd. – Hungary.*

References

ASNER, G. P., VITOUSEK P. M. (2005). Remote analysis of biological invasion and biogeochemical change. *PNAS*, vol. 102, no. 12, March 22, pp. 4383–4386.

BAKÓ, G. (2013). Növényi invázió a Balatonnál. *Élet és Tudomány*, LXVIII. 2013/35, pp. 1104-1106, [Plant invasion at Lake Balaton. *Life and Science*, LXVIII. 2013/35.]

EUREKA (1985). *EUREKA Programme* [online]. [cit. 2014-04-29]. Available at: <http://www.eurekanetwork.org/>

EUROPEAN COMMISSION (2008). *Commission presents policy options for EU strategy on invasive species*, Brussels: 5 December 2008. 20 pp. European Commission - IP/08/1890.

EUROPEAN COMMISSION (2009). *Renewables Directive – Brussels: 2009/28/EC*, 23 April 2009.

EUROPEAN PARLIAMENT & COUNCIL (2009). *Renewables Directive 2009/28/EC, L140*, 5 June 2009, pp. 16-62.

JOSHUA, G. (2009). The Elusive Green Economy. *The Atlantic, July/August 2009* [online]. [cit. 2014-04-29]. Available at: <http://www.theatlantic.com>

KERN, A. (2011). *Production of remotely sensed vegetation index data from MODIS and AVHRR*. (Dissertation Eötvös Loránd University, Budapest).

ROUSE, J. W., HAAS, R. H., SCHELL, J. A., DEERING, D. W. (1978). Monitoring the vernal advancement and retrogradation (green wave effect) of natural vegetation. *Prog. Rep. RSC 1978-1*, Remote Sensing Centre, Texas A&M Univ., College Station, 93 p. (NTIS No. E73-106393)

T-BEA (2013). *Tool for Biomass Accessibility with Earth Observation* [online]. [cit. 2014-04-29]. Available at: <http://www.eurekanetwork.org/project/-/id/7651>

USGS (2014a). *Landsat 5 History* [online]. [cit. 2014-03-10]. Available at: <http://landsat.usgs.gov/about_landsat5.php>

USGS (2014b). *Landsat Missions* [online]. [cit. 2014-03-10]. Available at: <http://landsat.usgs.gov/band_designations_landsat_satellites.php>

WISEMAN, J., EDWARDS, T., LUCKINS, K. (2013). *Post carbon pathways*. CPD Discussion Paper: April 2013, Melbourne (Centre for Policy Development). [online]. [cit. 2014-04-29]. Available at: <http://cpd.org.au/2013/04/post-carbon-pathways>

R e s u m é

Detekcia drevného prírastku pomocou analýzy snímok družice Landsat za účelom identifikácie invazívnych stromových druhov

V tejto štúdii sme predstavili riešenie integrujúce detekciu invazívnych druhov, monitoring opustených poľnohospodárskych plôch a poskytovanie informácií pre výrobu energie z biomasy. Riešenie je založené na fakte, že invazívne druhy sa stávajú invazívnejšie v kontinentálnych klimatických regiónoch Európy, pretože ich produkcia biomasy je výrazne väčšia než u pôvodných drevinných druhov. Ak považujeme drevný prírastok na zarastajúcich opustených poľnohospodárskych plochá potenciálny pre výrobu energie z biomasy, potom šírenie invazívnych druhov je ideálnym ukazovateľom tohto potenciálu. V článku sme predstavili „dolovanie" informácií z obrazových zdrojov, ktoré v súčasnosti využívame v rámci projektu EUREKA (T-BEA) s cieľom odhaliť dostupnú biomasu pre energetické využitie na báze technológií diaľkového prieskumu Zeme. Prezentovali sme prahové hodnoty indexu NDVI, ktoré sme identifikovali ako optimálne pre kategorizáciu snímok Landsat 4-5 a 8. V ďalšom výskume chceme smerovať k odhadu objemu a dynamickému modelovaniu drevného prírastku na opustených poľnohospodárskych plochách, ktorý je udržateľný bioenergetickým zdroj opustených poľnohospodárskych oblastí v strednej a východnej Európe.

Obr. 1 Zobrazenie 2. pásma pôvodnej snímky (a), mapa vegetačného indexu NDVI (b) a mapa pokrytia

Obr. 2 Mapa drevnej biomasy v roku 2011 na báze snímok družice GeoEye (zdroj obrázka v pozadí: Google Earth)

Obr. 3 Oblasť postihnutá druhom Ailanthus altissima prezentovaná pomocou služby Google Street View. Červená čiara je hranicou polygónu z nášho monitorovacieho systému
Obr. 4 Oblasť prírastku zobrazená pomocou služby Google Earth. Červená čiara je hranicou polygónu z nášho monitorovacieho systému
Tab. 1 Pásma snímača Thematic Mapper (nosič: Landsat 4-5 (USGS, 2014a))
Tab. 2 Pásma snímača Operational Land Imager (OLI) (nosič: Landsat 8 (USGS, 2014b))
Tab. 3 Použité prahové hodnoty indexu NDVI v prípade nášho pracovného územia

Preklad: Mgr. Michal GALLAY, PhD.

Prijaté do redakcie: 28. august 2014
Zaradené do tlače: december 2014