# FOREST CONDITION ASSESSMENT THROUGH ANALYZING RELATIONS BETWEEN METEOROLOGICAL PARAMETERS DESCRIBING CLIMATE CHANGES AND VEGETATION INDICES DERIVED FROM LOW-RESOLUTION SATELLITE DATA

**Zbigniew Bochenek[1], Dariusz Ziolkowski[1], Maciej Bartold[2,1]**

**[1]Institute of Geodesy and Cartography, Modzelewskiego 27, 02-679 Warsaw, Poland**

**[2]Department of Geoinformatics, Cartography and Remote Sensing, Faculty of Geography and Regional Studies, University of Warsaw**

zbigniew.bochenek@igik.edu.pl; dariusz.ziolkowski@igik.edu.pl; maciej.bartold@igik.edu.pl

## ABSTRACT

NOAA AVHRR satellite data were applied for studying relationships between vegetation indices derived from these images and meteorological parameters describing climate changes, in order to assess forest condition. Five forests areas located in various parts of Poland located in various climatic zones, characterized by different tree species were used for this purpose. 15-years database of NOAA AVHRR images and meteorological data was utilized in this work. The conducted study revealed, that there is distinct relation between meteorological situation, described by temperature and precipitation and NDVI index derived from low resolution satellite data. This conclusion is supported with results of ground measurements and high-resolution satellite data analyzed for selected forest areas.

Keywords: NOAA satellite data, climate change, forest condition

## INTRODUCTION

The presented work is part of the joint Polish-Norwegian project aimed at assessment of impact of climate change on forest and tundra ecosystems with the use of remotely sensed data. Monitoring of impact of climate change on ecosystems by remote sensing was reported in recent publications [1], [2], [3]. In order to achieve the project's goal the detailed spatial and temporal analysis of meteorological parameters has been carried out in combination with spatial and temporal variability of vegetation indices derived from various satellite and aerial images. The results of plant condition derived from remote sensing data (expressed through vegetation indices) are validated using archival and current hyperspectral ground measurements in five study areas (located in various parts of Poland).

## MATERIALS AND METHODS

1-km NOAA AVHRR images have been used at first part of the research work. The images collected by receiving station installed at the Institute of Geodesy and Cartography, Warsaw, Poland were pre-processed geometrically and radiometrically, including atmospheric correction algorithm; next cloud screening procedure was done applying split-window technique and individual images were composited to produce 10-day cloud-free composites. Next values of Normalized Difference Vegetation Index (NDVI) were extracted from the regions of interest – five forest areas located in southern and northeastern Poland. The values were collected both for the whole forest areas and for 1-km test sites representing homogeneous tree stands.

At the next stage of the work NDVI time series were generated for each study area, covering vegetation period (March – October) for the dataset comprising NDVI images from 1997 till 2014. Preliminary analysis of these series revealed a problem of quite high fluctuation of NDVI values within vegetation period, which had to be analyzed and accounted for prior to the next stage of the work – comparison of changes of remote sensing based indices with changes of meteorological parameters for the study areas. Therefore, two approaches of smoothing NDVI time series were applied in order to remove noise existing in original values due to non-precise cloud removal and changeable atmospheric conditions – a method of noise reduction based on Savitzky-Golay filter [4] and a method applying spline technique. Moreover, in order to reduce fluctuations of NDVI values the study was done with use of parameters describing short-term changes of atmosphere (temperature and humidity). First results of the study revealed, that there is a relation between major changes in atmosphere and abrupt NDVI decline. As a result of that study it was found that smoothing method based on Savitzky-Golay filter renders more precisely NDVI run within vegetation period, preserving subtle changes and removing abnormal ones.

The research was also done to determine if NDVI values derived from low-resolution satellite images for the large forest areas, which include mixed forest information (e.g. deforestation patches, boundary mixed pixels, etc.) can be representative for dominant tree stands. The study included comparison of vegetation index derived for forest mask including whole forest area, for 1-km homogeneous test sites and a mean value from all 1-km test sites existing within particular forest masks. The results of this study proved that NDVI values derived for forest masks are compatible with means from 1-km test sites, whereas individual test sites can slightly deviate from that pattern.

In parallel, information on radiation temperature was derived from NOAA AVHRR thermal channels for the same study areas, test sites and time periods. At the next stage meteorological data were compiled from meteo stations adjoining study areas – air temperature and precipitation (including information on snow appearance). These data were analyzed in order to find anomaly weather periods, which could affect condition of tree stands within study areas. As a result of the analysis three years which differ much in meteorological conditions were selected for comparative analysis – 2006, 2013 and 2014. Year 2014 was characterized by mild winter, with temperatures above 0 from mid-February, reaching maximum temperature at the beginning of August and gradual decrease till the end of October. There were three precipitation peaks within vegetation period – in decades 14, 19-20 and 23. On the contrary, in 2006 and 2013 winters were quite long – with air temperature below 0 till beginning of April and snow coverage, followed by rapid temperature increase to to the end of July / beginning of August. In 2013 there were three precipitation peaks within vegetation period – in decades 15- 16, 20 and 26, while two in 2006 - in decades 15 and 23. Exemplary graph demonstrating air temperature changes in 2013 and 2014 for northeastern forests is presented at figure 1.

At the next stage of the works NDVI indices derived from NOAA AVHRR data collected in 2013 and 2014 were computed for three forest areas located in northeastern Poland – Bialowieska Forest, Knyszynska Forest, Augustowska Forest and for two study areas located in southern Poland – Beskid Zywiecki and

Karkonosze. NDVI changes for northeastern forests are presented at figure 2.

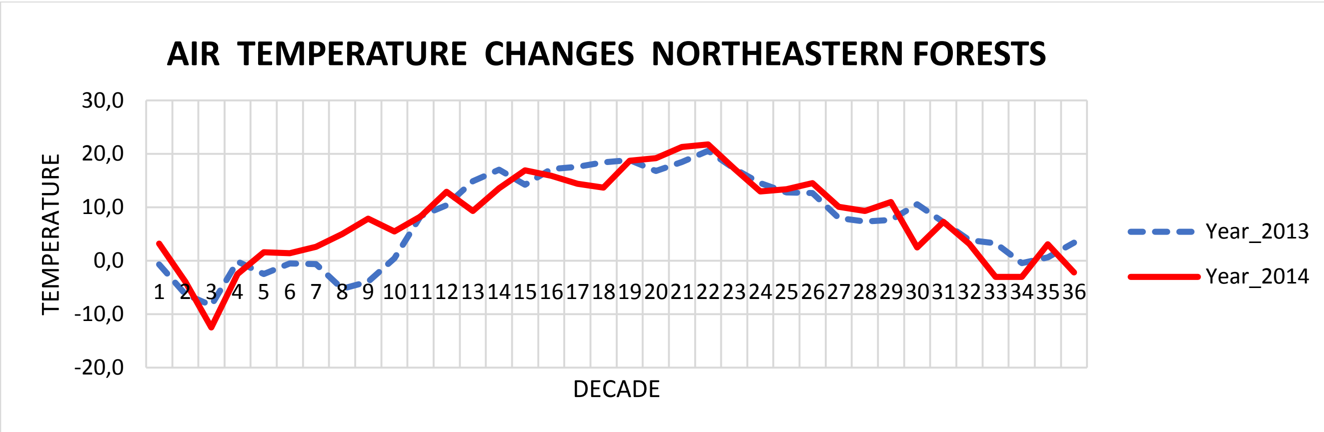


Fig. 1. Air temperature changes for northeastern forests 2013 – 2014

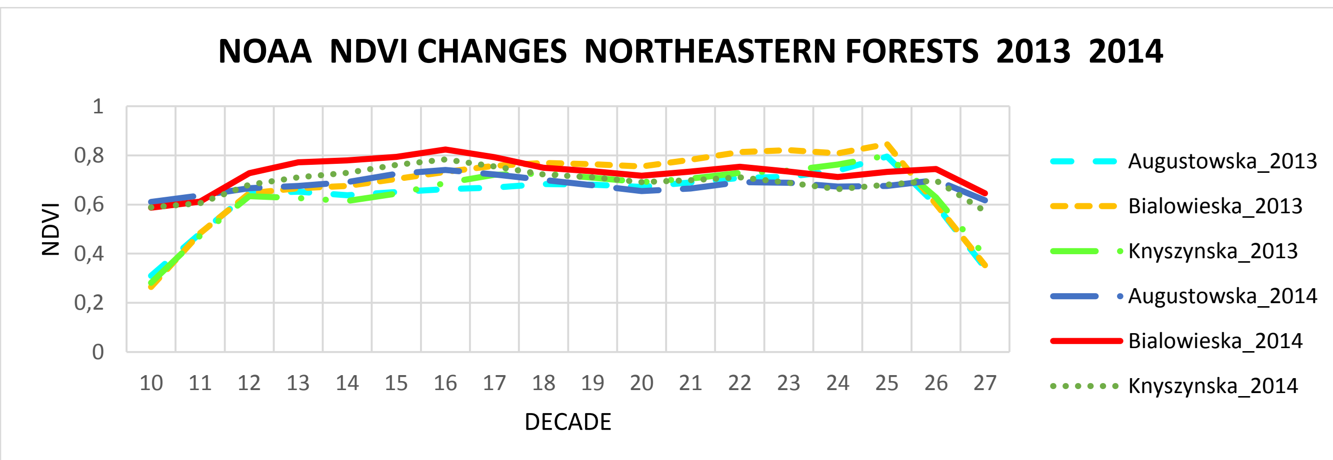


Fig. 2. Changes of NOAA NDVI for northeastern forests in 2013 and 2014

## RESULTS AND CONCLUSIONS

Comparative analysis of NDVI runs in 2013 and 2014 for northeastern forests enabled to draw the following conclusions:

- Start of vegetation season in 2013 was expressed by much lower NDVI values comparing to 2014 (0.3 mean value for 3 forests in decade 10, 2013 versus 0.6 in 2014)
- Till mid-June (decade 17) NDVI values for 3 forests were higher in 2014 than in 2013.
- From the end of June (decade 18) to the beginning of August (decade 22) NDVI values in 2013 and 2014 are similar (except of Bialowieska Forest)
- From mid-August (decade 23) to early September (decade 25) NDVI values in 2013 are higher comparing to 2014 for all three forest areas

- In two last decades in September (26 and 27) NDVI values are again higher in 2014.

The results of NDVI analysis are highly supported with analysis of meteorological data. Much lower air temperatures at the start of vegetation season stopped development of vegetation, which was expressed by much lower NDVI index. Higher temperatures in 2013 from decade 13 till 18, accompanied by high precipitation rates in decades 15 and 16, caused that at decade 18 NDVI values in 2013 and 2014 were similar. The similarity is kept until mid-September, when in 2013 strong decrease of NDVI index is observed, caused most probably by high precipitation rates, which increased moisture amount in leaves/needles, thus decreasing NDVI levels.

Relations between meteorological conditions and NDVI curves observed in 2013 and 2014 were confirmed while comparing temperature and vegetation index runs in 2006 and 2014.

Moreover, air temperature changes within vegetation period (March – October) were compared with radiation temperature derived from NOAA satellite data. First results of comparison indicated quite high compatibility of both temperature runs, which suggests possibility of using satellite-based temperature for determining anomaly weather periods.

In order to characterize stress conditions of tree stands field measurements were conducted within study areas. These measurements covered direct parameters describing plant state e.g. pigment concentration, heavy metal content, as well as spectral indices derived from measurements conducted with the use of field hyperspectral instrument. First results of correlation analysis performed between these two datasets revealed quite good relationships between pigment concentration and certain vegetation indices characterizing plant condition, e.g. narrowband greenness, canopy nitrogen or canopy water content. At the next stage of the works relations between broadband vegetation indices derived from field measurements and satellite data will be searched in order to determine possible stress indicators for forest stands at satellite level.

## REFERENCES

[1] Bokhorst S., Tømmervik H., Callaghan T., Phoenix G., Bjerke J.W., 2012. Vegetation recovery following extreme winter warming events in the sub-Artic estimated using NDVI from remote sensing and handheld passive proximal sensors. Environmental and Experimental Botany 81, pp. 18-25

[2] Ivits E., Cherlet M., Tóth G., Sommer S., Mehl W., Voght J., Micale F., 2012. Combining satellite derived phenology with climate data for climate change impact assessment. Global and Planetary Change 88-89, pp. 85-97

[3] Jepsen J.U., Hagen S.B., Høgda K.A., Ims R.A., Karlsen S.R., Tømmervik H., Yoccoz N.G., 2009. Monitoring the spatio-temporal dynamic of geometric moth outbreaks in birch forest using MODIS-NDVI data. Rem. Sens. of Environment 113, pp. 1939-1947

[4] Bojanowski J., Kowalik W., Bochenek Z., 2009. Noise reduction of NDVI time-series: a robust method based on Savitzky-Golay filter. Annals of Geomatics 2009, Volume VII, No 2 (32), pp. 13-21