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# POLWET – system for new space-based products for wetlands under Ramsar Convention

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**Abstract:** The main objective of the POLWET project is to establish wetlands monitoring system and to create the dedicated EO-based information service as a platform enabling on-line accessibility of the final products to the end-users. The service will be useful for appropriate sustainable wetlands management and conservation, by offering the products such as: land use/land use changes, changes of water surface, floods extent, moisture conditions, biomass development and changes.

Within the POLWET project various EO-based products will be generated for the selected wetland areas in Poland included to Ramsar Convention. High and low resolution optical satellite data derived from Landsat mission (1984–2015) and Terra.MODIS (2001–2015) will be applied. Radar images derived from Envisat.ASAR (2003–2011) will be exploited as well. The satellite observations derived from Sentinel mission (2015–2016) will be used to elaborate the latest maps. Data collected by the satellites characterize diversified spatial, temporal and radiometric resolution. The satellite observations allow to elaborate comprehensive information service, performed at a local as well as global level.

For each of thirteen Ramsar Convention protected areas in Poland, series of maps presenting vegetation indices and surface temperature will be produced on the basis of satellite observations. The maps of vegetation indices enable spatiotemporal analysis of vegetation condition and support on monitoring of environmental hazards. The maps of surface roughness and soil moisture will be elaborated on the basis of archival and actual Sentinel-1 radar images. The relationship between backscatter  $\sigma_0$  and vegetation parameters will be established for each of the wetland land cover class. The canopy height model will be developed from radar images as well.

Within the research the methodology on change detection using Landsat time-series covering period 1987–2014 was developed. The results on land cover changes over Narew valley were firstly verified analyzing the maps derived from Narew National Park headquarters. Next the results on changes were validated using the numerical data derived from the CORINE Land Cover database. The accuracy of properly detected changes over Narew National Park has been achieved at 86.3%.

The project POLWET, funded by European Space Agency ESA is in the stream of researches where multi-temporal and high-resolution satellite data Landsat and Sentinel are exploited in order to monitor global land cover changes. The information system built within the project of Ramsar wetland sites in Poland, will support future GlobWetland III project, which is international initiative aimed to build information service for two hundred wetland areas covered in the Mediterranean Basin.

**Keywords:** environmental monitoring, Ramsar, satellite images, wetlands

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## 1. Introduction

The Copernicus Land Monitoring Service provides geographical information on land cover/ land use and on variables related to vegetation state and the water cycle. It supports applications in a variety of domains including water management directing to wetlands. Wetlands play important role in storing water, recharging natural aquifers when there is low water, retaining nutrients, controlling flooding. POLWET project will contribute to the fulfillment by Poland a national strategy for the conservation, restoration, establishment and management of wetlands production. The activities proposed in the project will use the results obtained in the project in consultations offered by users which will enhance the entity offer. The innovative information will contribute to the development of wetlands values for users.

The Ramsar Convention on Wetlands helps in conservation and sustainable utilization of wetlands to stem the progressive encroachment and loss of wetlands. It is important to accept the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value. The convention became effective in Poland on 1978, the designation of Wetland of International Importance has been applied to thirteen locations in the country, which combine into an area of 145 075 ha. The Convention's mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world". Wetlands in the world are threatened in spite of numerous international agreements and national policies (Turner et al., 2000). This is caused by the: 1) public nature of many wetlands products and services, 2) user externalities imposed on other stakeholders, 3) policy intervention failures that are due to a lack of consistency among government policies in the areas of economics, environment, physical planning etc. All three causes are related to information failures linked to the complexity of spatial relationships between groundwater, surface water, and wetland vegetation. The integrated data based on satellite information supported by other ancillary data can integrate the needed information for the stakeholders in multi-criteria analysis (Turner et al., 2000) and performed

on the created by the Project platform which is dedicated to the system for new space-based products over wetlands under Ramsar Convention.

## 2. Objectives of the POLWET

The objectives of the project are as follows: 1) to establish wetlands monitoring system and to create the dedicated EO-based information service as a platform enabling on-line accessibility of the final products to the end-users, adjustable to user's needs at local, regional and national level, 2) the information service on special portal based on Earth Observation (EO) data, capable to generate in an operational way a set of products as geo-information maps and indicators for the Ramsar sites in Poland. These will be useful for appropriate sustainable wetlands management and conservation, by offering the products such as: land use/land use changes, changes of water surface, floods extent, moisture conditions, biomass development and changes, 3) to focus on user driven development and demonstration of Earth Observation Products dedicated for decision makers, for Ramsar Contracting Parties, regional stakeholders education opportunities, 4) evaluation of operational value of EO-based products proposed for wetland management, considering feedback from end-users and validation activities.

The activities within the project will be concentrated on creation of a dedicated EO-based information service as a platform enabling on-line accessibility of the final products to the end-users, adjustable to user's needs at local, regional and national level. In addition gathering of Users Requirements for the satellite based products delivered as a service for improving wetland habitat monitoring will be performed. Next the activities will be concentrated on preparation of a set of EO-based products, derived from satellite images received from Copernicus Services: existing satellites, Landsat-8 data, Sentinel-1 and Sentinel-2 images. Then delivery of information on status in wetlands ecological character through mapping biophysical variables of soil / plant communities will be done. At last the evaluation of operational value of EO-based products proposed for wetland management, considering feedback from end-users and validation activities will be carried out.

### 3. Study area

In order to achieve the objectives various EO-based products will be generated for the selected wetland areas in Poland included to Ramsar Convention. This convention covers 13 wetland sites located in various parts of Poland representing unique wetland habitats (Figure 1). The total area of all 13 sites is 145 075 hectares.

The largest wetland site is Biebrza National Park with the area in excess of 59 000 ha. It is also the most well-preserved area of low bogs and forest raised bogs in the temperate zone. Habitats include various types of swamps, tussock communities, alder forest and some cultivated land. The proper water management is of special importance for remaining the environment. Druzno Lake Nature Reserve with an area of 3 068 ha is a shallow and largely overgrown lake in the Vistula Delta region near the Baltic Coast, with surrounding wetlands, reed beds and swampy alder forests which are a relict of a much larger water body formerly part of the Vistula Lagoon. The aquatic vegetation is extensively distributed. The site is important for birds migrating along the Baltic coastline. The region has been influenced by man draining and damming activities. Karas Lake Nature Reserve with an area to be around at 815 ha, is a shallow freshwater lake of glacial origin, surrounded by forest, extensive peat bogs, marshes and drainage ditches. The site exhibits a rich floral diversity. Human activities at the site and in the surrounding area in-

clude commercial fishing, forestry, and agriculture. Lake of Seven Islands Nature Reserve is the site located on the border with the Kaliningrad region of Russia and includes a freshwater lake with submerged vegetation and overgrown by reed beds, associated marshland, meadows, woodland. Two northern tree species reach the southern limit of their distribution. Human activities include forestry and intensive agriculture in the surrounding areas. The threats for the site include urban, nutrient-rich agricultural inflow, and vegetation encroachment. Luknajno Lake Nature Reserve with an area of 1 189 ha is a region with freshwater lake of glacial origin, fed by numerous channels, surrounded by marshes and meadows and fringed by reed beds. Human activities include extensive commercial fishing and regulated tourism. Milicz Fishponds Nature Reserve with an area of 5 324 ha encompasses various fishpond complexes in the Barycz River valley surrounded by forests, meadows, pastures, and fields. There is an intensive fishing and tourism observed. Narew River National Park covers 7 350 ha of natural swampy valley several vegetation zones from aquatic, immersed with mosses and sedges to softwoods, reeds, aquatic plants and willow shrubs and forest communities. The main potential threat is a diminished water input upstream at the Polish-Belarus border and the water pollution caused from towns upstream. Poleski National Park covers 9 762 ha of a unique complex of shallow lakes and mires, ranging from raised bogs to transitional and calcareous mires and rare alkaline fens with vegetation indicating features of tundra, bordering with Ukraine. Forest communities vary from pine woods to alder with swamps. There is an extensive agriculture, fishing and forestry. Agricultural facilities in the surrounding area are affecting the site through water pollution. Slowinski National Park covers 32 744 ha and it is the second largest site under Ramsar Convention in Poland. There are mobile dunes, coastal lakes, peat bogs, marshes and forests. Cattle grazing and tourism are the main human uses. Potential threats come from river pollution, peat mining, and recreational pressure. Subalpine peat bogs in Karkonosze Mountains cover 40 ha and are situated on mountain flats in the dwarf pine zone, along the Polish-Czech border in the Karkonosze Mountains. Situated at the European watershed dividing the Baltic Sea and

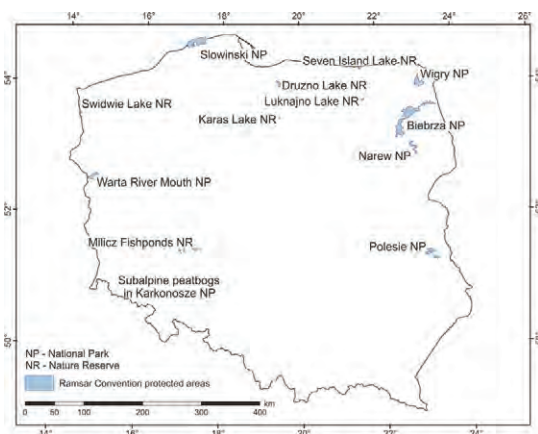


Fig. 1. Wetlands sites under the Ramsar Convention in Poland

North Sea basins, the area has special importance for groundwater recharge and flood control in the mountains. The vegetation is dominated of endemic dwarf pine with cloudberry vegetation, surrounded with spruce forest growing on hanging bogs. Bog moss resemble subarctic tundra with a combination of alpine and arctic species. Numerous permanent pools that support a unique flora of algae. The major threat for the bogs is deterioration by tourist, water pollution. Swidwie Lake Nature Reserve with an area of 891 ha is an nutrient-rich freshwater lake near the Polish-German border. Vegetation is dominated by reed and sedge beds with the problem of reed expansion. Tourism and agriculture is main human influence. Warta River Mouth National Park covers 7 956 ha. It is an artificial reservoir near the German border which is subject to wide seasonal variations. The site is set in the Warta River floodplain and surrounded by marshes, meadows and pasture. Human activities include cattle grazing, fishing, Warta River regulation and polluted inflow gave negative influence on the area. Wigry National Park with an area of 15 085 ha is a diverse wetland system around the Wigry Lake and 42 smaller lakes of glacial origin and associated peat bogs. The region is dominated by the woodlands of boreal character with a majority of the swampy forest and aquatic mire vegetation in close to natural state. There are important mire communities with transitional bogs. The human activities are timber production, crop production and tourist to be bringing the threat for the site.

## 4. Materials and methods

The EO-based products will be integrated with other types of spatial information. The preparation and refinement of final products will be conducted by team of remote sensing specialists. Evaluation of these products will be performed in the course of the project and necessary adjustments will be done as a result of feedback from end-users. List of products, accompanied by satellite data used for product generation is presented in Table 1.

The most important part of activity within the project is devoted to operational use of Earth Observation data, to be collected by new generation satellites within ESA's Sentinel missions. Especially, three types of Sentinel data will be exploited:

- Sentinel-1 data – particularly useful for monitoring soil moisture conditions within wetland habitats – has been launched;
- Sentinel-2 data – indispensable for wetland mapping and vegetation monitoring in local scale with high temporal frequency and high spatial resolution;
- Sentinel-3 data – useful for monitoring vegetation temperature and its changes during long period of time to be later used for assessing vegetation condition.

As Sentinel missions are based on constellation of two satellites, they will fulfil the needs for high revisit frequency and wide coverage, thus providing robust datasets for GMES/Copernicus services. The project will contribute to full exploitation of Sentinel data, validating at the same time their usefulness for operational application for wetland monitoring. Operational solutions, prepared within the project for Polish wetlands, can be transferred to other EU countries, thus justifying usage of data collected by ESA's Sentinel missions on a pan-European scale. Products prepared within the Project will come from the elaboration of new methods to obtain soil moisture and roughness using Sentinel 1 data and can be used as the product supporting for ESA GlobWetland III – project of the Ramsar Convention on Wetlands.

The methods for generating EO-based information products have been developed at the Institute of Geodesy and Cartography, Warsaw, in the course of several projects conducted within national and international research programmes. Earth Observation gives wide range of methodologies for monitoring of land cover areas. Spatial and temporal changes in ground and underground water levels of the wetlands areas demands good qualifications.

### 4.1. Land Cover/Land Cover Change Maps

The Remote Sensing Team of the Institute of Geodesy and Cartography has elaborated the land cover maps during the projects Geoland2, MS.MONINA and concluded that the most effective method for land cover classification of wetlands is object based analysis (Bochenek and Turlej, 2010; Ziolkowski et al., 2013; Bochenek et al., 2014). Object based analysis allows to use many indices describing land surface and combine wide range of approaches.

Table 1. List of the EO-based products to be delivered under POLWET project

Type of service for wetland habitats	Type of EO-based product	Satellite data to be applied for
Wetland mapping	<ul style="list-style-type: none"> <li>– maps of wetland areas (land cover/ land cover change)</li> <li>– maps of vegetation habitats</li> <li>– maps of wetlands boundaries</li> <li>– maps of soil moisture and soil moisture changes</li> <li>– maps presenting the extent of water / change of surface water area</li> <li>– maps of spring floods extent</li> </ul>	SPOT 4/5 Landsat TM Landsat ETM+ Landsat OLI + TIRS Proba-V Sentinel-1 Sentinel-2 Envisat MERIS Envisat ASAR
Vegetation status mapping	<ul style="list-style-type: none"> <li>– maps of distribution of vegetation indices (NDVI, VCI) characterizing development of plant communities</li> <li>– changes in plant communities and habitats</li> <li>– maps of distribution of surface temperature, temperature condition indices (TCI) characterizing conditions of vegetation growth</li> <li>– maps of surface roughness characterized by vegetation height and plant structure applying C and X band</li> </ul>	Proba-V SPOT-VEGETATION Terra MODIS NOAA AVHRR Envisat ASAR TerraSAR-X Sentinel-1 Sentinel-2 Sentinel-3 GlobTemperature project products

It is an important advantage of the method that it can use the groups of pixels as objects and recognize the spatial connections between classes. Using objects instead of particular pixels allows to apply more advanced features for describing spectral and textural characteristics of vegetation. The general type of classes representing wetlands are: deciduous forests; coniferous forests; shrub communities; sedge communities; moss-sedge communities; wet grasslands; rushes; reeds; water. During the MS. MONINA project, the methodology created in IGiK for land cover classification of wetlands the WorldView-2 data were used. Developed method using WorldView-2 will be converted for the usage of Landsat images. The classification will be done in 5-year step starting from 1984. Classification for year 2015 will be done using Landsat-8 images and later using Sentinel-2 data. It is taken into account that the Sentinel-2 spectral bands and resolution of 10, 20 and 60 meters will be very useful for better recognition of vegetation habitats in comparison to data from present satellites. Also for one of the wetlands area the SPOT5 for two different times of acquisition will be applied. Classification process will take

place in object based environment of eCognition software. The segmentation process will be the first step. This process groups pixels into objects and aims to produce solution which allows to work with fairly large homogenous areas. Next, rule-based approach will be applied supported by expert knowledge. NDVI, values obtained after Lee Sigma filtering, values and ratios of particular bands and textural measures will be used as classification features. As the result, two types of classification maps will be prepared: 1) general classification of land cover which contains information on general classes of Wetland Sites; this dataset will be useful for comparison of Ramsar Wetland sites in Poland; 2) classification of vegetation habitats – which is extended version and contains information about vegetation types being specific to wetland environment; this dataset will be important to describe characteristics of each wetland site.

After preparation of land cover maps change detection will take place. For each time period 1984–1990, 1990–1995, 1995–2000, 2000–2005, 2005–2010 and 2010–2015 areas where changes in land cover appeared will be detected. To accom-

plish this task GIS analysis will be used. For each of five year time step land cover maps will be intersected and compared. Areas where land cover class differs will be marked as changed. At the same time the type of the changes will be indicated. For example if area covered with shrubs will change to forest, this place will be marked and classified as change from shrubs to forest. The presented method is simple and efficient. Delineation of wetland areas is a common topic that is studied in many research works. In the frame of this project boundaries of wetland areas will be set on basis of two factors: 1) range of very humid conditions, observed at the beginning of vegetation period; lack of developed vegetation allows for delineation of wet areas that are additionally increased by waters from snow thaws, and 2) analysis of vegetation habitats classified on the images taken for middle of vegetation period. Information about localization of habitats typical for wetlands will be used for setting the boundaries. Combination of factors presented above will give the maximum area fulfilling both conditions and will be marked as wetland.

#### 4.2. Vegetation indices

Low resolution satellite data as NOAA AVHRR, SPOT-VEGETATION, Proba-V and Terra.MODIS will be used for calculating vegetation indices NDVI and EVI for the period of 2000–2015. Then, changes of these vegetation indices during the observation cycles will be determined, the reasons of the changes will be analysed (lack of moisture, meteorological conditions, human impact) and will be referred to land cover classes and land cover changes. Derived indices will be used for the calculation of LAI for different classes (Dabrowska-Zielinska et al., 2010). The maps of vegetation indices will be done and delivered to the Portal. The vegetation indices will also be calculated for each wetland using Landsat TM, Landsat ETM, Landsat OLI + TIRS, and Sentinel-2 for the years 1984–2015.

#### 4.3. Surface roughness

For each land cover class mapped using Landsat ETM+ and Landsat OLI + TIRS the vegetation will be described by the height, NDVI and LAI.

The backscatter derived from Envisat and Sentinel-1 will be overlaid on land cover map. The relationship between backscatter  $\sigma_0$  and vegetation parameters will be established. The canopy height model will be developed from VH polarization (Dabrowska-Zielinska et al., 2014).

#### 4.4. Soil moisture

New microwave data acquired in C (Sentinel-1) and X (TerraSAR-X) bands and ALOS-2.PALSAR if available will be applied for the chosen test sites for soil moisture assessment using developed models in ESA PECS Project (Dabrowska-Zielinska et al., 2013). The maps of Soil Moisture for the period 2002–2012 and based on models elaborated for Biebrza Wetlands in ESA PECS 98101 Project will be done for the areas where the Envisat data are available. The relationship between backscatter  $\sigma_0$  HH from Envisat and soil moisture has been elaborated for each of the wetland land cover class and LAI for Biebrza wetland (Dabrowska-Zielinska et al., 2012). Since 2015 the actual soil moisture product will be processed from the single (HH) and the dual polarized (HH+HV or VV+VH) of Sentinel-1A and later Sentinel-1B using the models developed at the Institute of Geodesy and Cartography (Dabrowska-Zielinska et al., 2016). When having the Sentinel-1 data the algorithms will also be elaborated for each of the land cover class.

#### 4.5. Surface temperature

Land surface temperature will be delivered from MODIS (2000–), NOAA AVHRR (1997–), Landsat (1984–2015) and later Sentinel-3 for all wetlands areas. The monthly temperature will be deduced from decadal data. The changes in temperature at the seasons will be presented for all wetlands and years. Also the maps of the temperature will be presented from the product delivered to users from the GlobTemperature DUE Project.

#### 4.6. Floods

The extent of floods in spring will be monitored using radar data derived from historical Envisat ASAR and actual TerraSAR-X or Sentinel-1 observations. Low values of backscatter comparing to

vegetation will give the flooded areas. The flooded area will be calculated and presented at the portal. This information is important to monitor the amount of water for infiltration at the wetlands.

## 5. Results and discussion on products

Presented maps will be validated at the chosen test sites. The parameters such as LAI measured by field instrument Plant Canopy Analyser2000 from LI-COR company, soil moisture derived from TRIME-FM analyzers, APAR and height of vegetation will be measured five times during 24 months. Ground truth data will be used for validation and verification of the models and equations that use satellite-derived data for the calculation of such variables as soil moisture, LAI, biomass. The relationships between vegetation parameters, soil moisture and Sentinel-1 satellite data  $\sigma_0$  will be established as well. The developed methodology for soil moisture and soil moisture changes using radar data, method for establishment of the surface roughness and changes in roughness, monitoring the surface temperature and its seasonal and annual changes may help in understanding the complexity of wetlands changes and may support the methodology in the future ESA GlobWetland III project.

## 6. Case study – Land cover changes map on Narew National Park

Information on localization of land cover changes is crucial for monitoring vegetation condition and protecting vegetation habitats over wetland sites. Remote sensing techniques enable to detect the changes in the nature with high spatial precision of delineation of its. Very high resolution satellite data, derived from satellites such as Landsat, Sentinel-2, SPOT 5 allow users to map the changes at geometric precision of about 10–30 m. For mapping of land cover changes over Narew NP, Landsat images at 30 m of spatial resolution were acquired on 25 August 1987, 27 August 2011 and 3 August 2014. In order to limit the errors of recognition of land cover changes, cloud-free satellite records acquired within the same month of growing season have been applied. In addition, all acquisitions were derived from the Thematic Mapper sensor, mounted

onboard Landsat 5 satellite. Three acquisitions covers almost twenty years of satellite observations. As a joint initiative between United States Geological Survey (USGS) and NASA, Landsat observations reception, satellite images archiving, product generation and distribution is managed by USGS.

The SPEAR Change Detection tool, providing a way to compare imagery over the regions of interest at different times was applied. The SPEAR tool enables to highlight changes through analyzing spectral angle between corresponding pixel spectra in the time “before” and the time “after”. The spectral angle measures the spectral similarity between two spectra. Hence it measures relative change. The results driven from spectral angle change mapper show that something has changed but does not specify what that change is. SPEAR tool provides a fast and straightforward method for quickly comparing images. For computing the spectral similarity, the following Landsat channels were chosen: band 1 (with the center wavelength at 0.4856  $\mu\text{m}$ ), band 2 (0.5702  $\mu\text{m}$ ), band 3 (0.6610  $\mu\text{m}$ ), band 4 (0.8384  $\mu\text{m}$ ), band 5 (1.6759  $\mu\text{m}$ ) and band 7 (2.2160  $\mu\text{m}$ ). The Landsat images were acquired at Level-1 standard data products, thus atmospheric correction was applied to compute spectral measures in surface reflectance units [%]. The atmospheric correction procedure was performed using ATCOR 2/3 system (ATCOR-2/3 User Guide, Version 9.0.2, March 2016).

As the result, Spectral Angle Change maps 1987–2011 and 2011–2014 were elaborated (Fig. 2). Spectral Angle Change values varies from 0.0 to 1.0, which characterize the probability of land cover/use change. The higher value of change the bigger probability of occurring change is in spectra responses between the time “before” and the time “after”. Two types of land cover changes, related to water conditions and land use transitions have been recognized. The maps depict land use change occurred on the right meander of the Narew River. The change is concerned with building fishponds in Topilec country that were built in 1989, and next to be widen after 2011. Another land cover change is related to encroachment on left river bank, that could be identified on the basis of different spectra responses of water and vegetation at bands 5 and 7.

CORINE Land Cover maps 1990, 2000, 2006 and 2012 have been used for verification the results

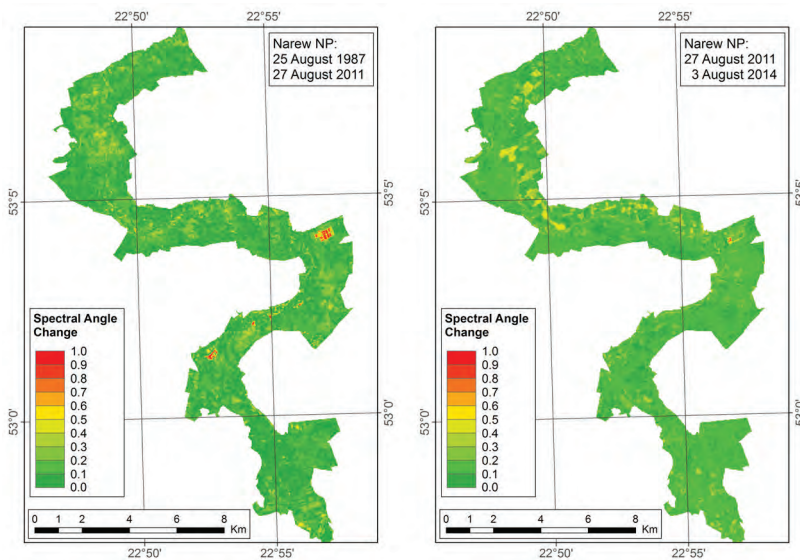


Fig. 2. Maps of land cover changes determined in 1987–2011 and 2011–2014 over Narew NP based on the Landsat images

on Spectral Angle Changes over Narew National Park. The recognition of detected land cover changes have been confirmed using a visual interpretation. The accuracy of change detection of 86.3% has been achieved with Spectral Angle Change analysis. The identified land cover changes are highlighted

on Landsat RGB 453 false colour composite images (Figure 3). The RGB 453 composite is a combination of bands infrared, mid infrared and red and offers added information of land-water boundaries and highlights subtle details not readily seen in the visible bands. The composites images demonstrate

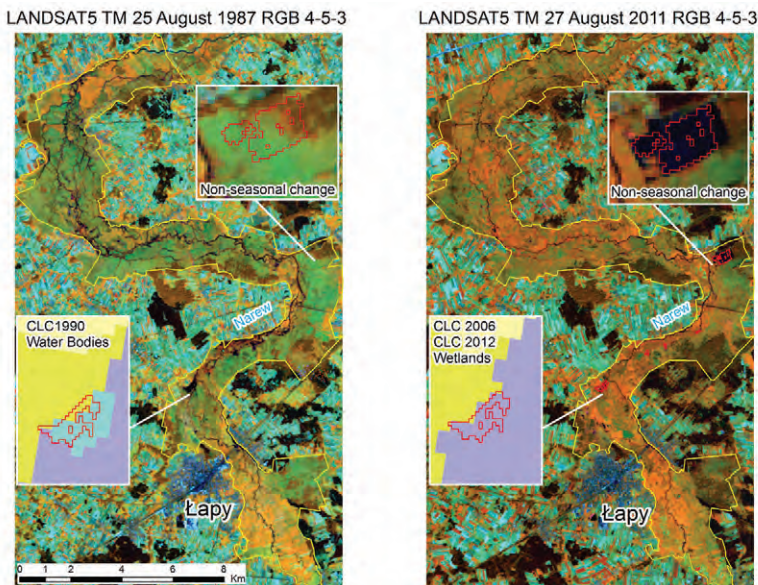


Fig. 3. Maps of detected non-seasonal changes overlaid on Landsat images



moisture differences and confirm presenting of detected land cover changes, delineated with great precision. The change map showed the ability of the method to capture both abrupt as well as gradual changes occurring in the wetlands. Different changes events such as building fishponds and encroachments on river bank were observed in the change map.

## 7. Summary and conclusions

The service proposed within the POLWET project is aimed at optimization of wetland management in Poland, through application of information derived from satellite sensors. The project aims at acting work in the entire information chain from data provider, through value added products and services and downstream to users. Various types of information based on EO products will support optimum decisions concerning wetland management and monitoring. Information on soil moisture conditions and vegetation status can support the proper practices related to management of wetlands and conservation of natural habitats. All these activities, implied by usage of EO-derived information will lead to increased monitoring capabilities of wetlands and thus to better protection of areas vulnerable to environmental changes.

In order to adjust the proposed service to real needs of users, a feedback from user community will be required. Hence, close collaboration is planned within the project, in order to tune final products and services to user's requirements. There will also be conducted wide dissemination and promotion activities, in order to popularize new types of information derived from EO products by widely developed portal.

Outcomes of the project are pertinent to ESA GlobWetland project. The information system built within the project of Ramsar wetland sites in Poland, will support future GlobWetland III project, thus contributing to the establishment of a Global Wetlands Observing System. The system will support for Ramsar Secretariats, for Decision Makers as Regional Boards of Water Management, Local Governments responsible for Wetlands Management and Tourist Offices as well.

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## **POLWET – teledetekcyjny system monitorowania obszarów bagiennych objętych Konwencją Ramsarską w Polsce**

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**Streszczenie:** Projekt POLWET ma na celu zbudowanie serwisu wspomagającego zarządzanie obszarami przyrody chronionej objętymi Konwencją Ramsarską w Polsce. W ramach projektu jest opracowywany system monitorowania mokradel wraz z dedykowaną platformą, oferującą szeroką gamę modułów tematycznych. Pierwszą grupę tematyczną stanowią moduły z mapami pokrycia terenu i jego zmian, zbiorowisk roślinnych, wód powierzchniowych oraz wiosennych podtopień. Drugą grupę stanowią moduły z szeregami map prezentujących czasowo-przestrzenny rozkład wybranych wskaźników i parametrów charakteryzujących kondycję roślinności oraz warunki atmosferyczne.

Do opracowania map tematycznych zostaną wykorzystane wieloletnie zobrazowania optyczne z satelitów Landsat (1984–2015), Terra.MODIS (2001–2015) oraz radarowe z satelity Envisat.ASAR (2003–2011). Najnowsze opracowania będą przygotowywane na podstawie danych satelitarnych pochodzących z misji Sentinel (2015–2016), należących do Programu Obserwacji Ziemi COPERNICUS. Dane te charakteryzują się różnicowaną rozdzielczością przestrzenną, czasową i radiometryczną. Pozwalają one na opracowanie kompleksowego serwisu informacji, zarówno na poziomie lokalnym jak i krajowym.

Dla każdego z trzynastu obszarów ochrony przyrody, wpisanych na listę Konwencji Ramsar zostały przygotowywane serie map wskaźników roślinnych i temperaturowych opracowanych na podstawie obserwacji satelitarnych. Mapy wskaźników umożliwiają czasowo-przestrzenną analizę kondycji roślinności oraz dają wsparcie w zdalnym monitorowaniu zagrożeń środowiskowych. Na podstawie archiwalnych zobrazowań radarowych i aktualnych zdjęć satelitarnych Sentinel-1 zostaną opracowane mapy wilgotności gleby i jej zmian, a także szorstkości podłoża charakteryzujące wysokość i strukturę zbiorowisk roślinnych.

W wyniku realizacji dotychczasowych prac została opracowana metodyka detekcji zmian pokrycia terenu na podstawie szeregów czasowych Landsat. W oparciu o dane numeryczne, udostępnione przez Narwiański Parku Narodowy, weryfikowano wyniki śledzenia zmian w pokryciu terenu w latach 1987–2011. Następnie

na podstawie CORINE Land Cover zostały weryfikowane wyniki zmian. Dokładność rozpoznanych zmian osiągnięto na poziomie 86.3%.

Niniejszy projekt POLWET, finansowany przez Europejską Agencję Kosmiczną ESA, wchodzi w nurt badań stosowanych wykorzystujących możliwości wieloczasowych, wysokorozdzielczych zdjęć satelitarnych Landsat i Sentinel do monitorowania zmian pokrycia powierzchni Ziemi. Może stanowić wsparcie do lokalnych działań dotyczących ochrony i zarządzania obszarami mokradeł. Jak również może wesprzeć GlobWetland, międzynarodowe przedsięwzięcie, w ramach którego jest przygotowywany serwis informacji dla 200 obszarów mokradeł zlokalizowanych w basenie Morza Śródziemnego.

**Słowa kluczowe:** monitoring środowiska, obrazy satelitarne, obszary bagienne, Ramsar

