Modelling carbon dioxide flux applying in-situ and satellite data at peatland ecosystem

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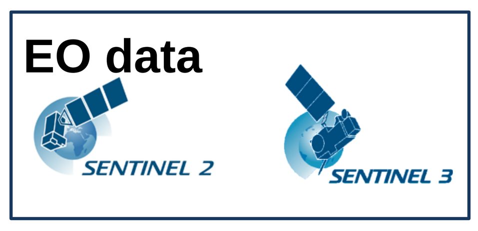
INTRODUCTION

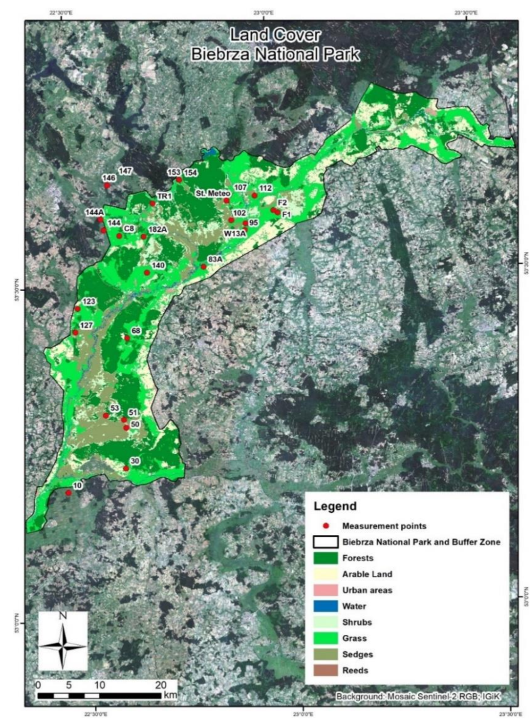
The main goal of this study was to determine the GPP at the Biebrza Wetlands for sedges, reeds and grasses habitats, applying satellite data. The ground measurements of Net Ecosystem Exchange (NEE) and respiration (RESP) were conducted at 26 sites at the peatland using chamber method during the vegetation growth from April to October 2015-2020. Applying round-the-clock registrations of Photosynthetically Active Radiation (PAR) and one ground measurement of NEE and RESP the simulation of the daily course of GPP was performed. GPP daily mean values were the object of estimation applying the models based on the satellite data derived from Sentinel 2, Sentinel 3 and MODIS. The main factors of photosynthetic carbon uptake – greenness and moisture were described by satellite vegetation indices Normalized Difference Vegetation Index (NDVI), Normalized Difference Infrared Index (NDII), Accumulated Photosynthetically Active Radiation (APAR), evapotranspiration, latent heat and the differences of surface temperature (Ts) and air temperature (Ta). The models presented as a result of this research can be used applying solely the satellite data.

*The approach of the 2006 **IPCC Guidelines** allows countries with more information and resources to use more detailed country-specific methodologies and country-specific data. The report includes land-use and management activities occurring in lands with wet and drained soils. The extended approach of the **CO2 inventory for Poland** is presented in **"Framework Convention on Climate Change and the Kyoto Protocol"**. Total CO2 emissions from wetlands are estimated as the sum of emissions from the two types of managed wetlands: emission from peatland managed for peat production and from flooded land. However, still emissions from unmanaged wetlands are not estimated.*



STUDY AREA IN POLAND

The study was carried out at Biebrza Wetland test site, which is located in North-East Poland. The Biebrza Wetland is unique in Europe for its marshes and peat areas, high biodiversity rich plant habitats and diversified fauna, especially birds. The Park has been established as wetland site of global significance - NATURA 2000 and since 1995 is under RAMSAR Convention. The study site is located at the Biebrza National Park established in 1993 with a total area of approximately 60 000 ha of which 45% are wetlands- the most valuable habitats of the park. It is a flat area with an average elevation of about 105 m above sea level. The Biebrza River is practically natural lowland river creating a unique reference area for lowland valley mires and river floodplains.



Distribution of measurement points within the study area with land cover classification used in the research

MATERIALS AND METHODS

In-situ measurements

In the course of field campaigns the following in-situ measurements have been carried out in each test site:

1. The Eddy Covariance Technique for Evaluating Carbon dioxide exchange
2. Carbon balance using chamber method with AirTECH-vento (NEE, RESP)
3. Fraction of Absorbed Photosynthetically Active Radiation - AccuPAR LP-80
4. Leaf Area Index (LAI) - LAI2200 Plant Canopy Analyzer

1)

2)

3)

4)

METHODS - MODELING

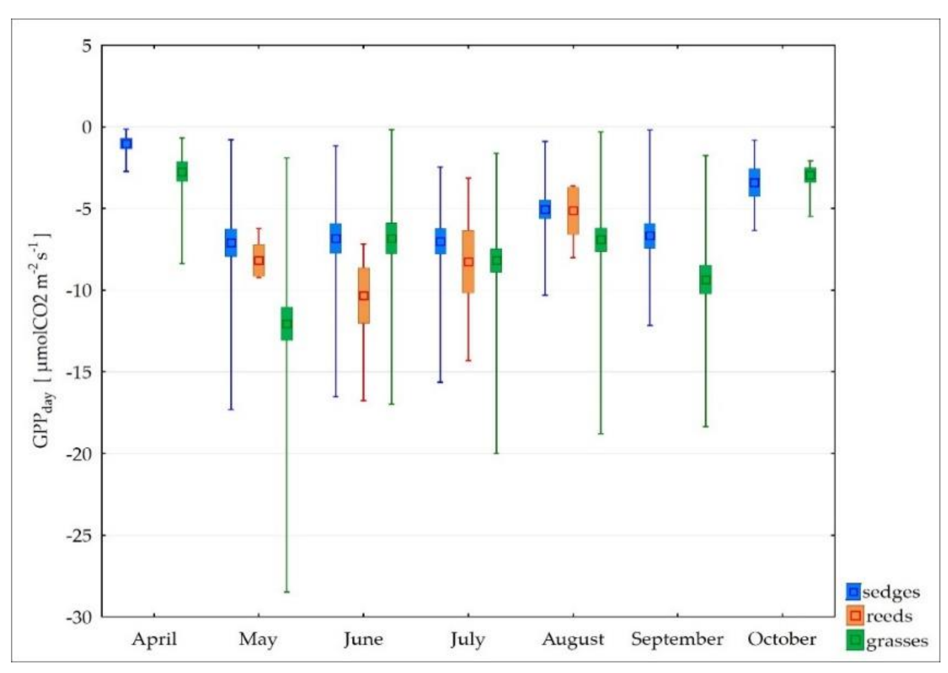
Concentration of CO_2 in the transparent chamber is the result of two processes occurring simultaneously: carbon uptake for photosynthesis of vegetation and carbon release to ecosystem during respiration. NEE is a value of instant net carbon uptake measured in transparent chamber. Measurement in dark chamber (RESP) concerns the respiratory activity of the ecosystem after the photosynthesis ceases. Instant value of NEE could be partitioned into gross photosynthetic production (GPP) and ecosystem respiration (RESP) and it is determined by the following equation:

$$NEE = GPP + RESP \quad (1)$$

where: GPP - gross primary production [$\mu mol\ m^{-2}\ s^{-1}$] as a negative value;
RESP – ecosystem respiration [$\mu mol\ m^{-2}\ s^{-1}$] as a positive value;
NEE – net ecosystem exchange [$\mu mol\ m^{-2}\ s^{-1}$]

$$\overline{\mathbf{GPP}}(\mathbf{P},\mathbf{t}) = \frac{\propto^{*} * \mathbf{GPmax} * \mathbf{PAR(t)}}{\propto^{*} * \mathbf{PAR(t)} + \mathbf{GPmax}} \quad (2)$$

where P is an observation point and t is a time point of the day from sunrise to sunset



GPP_{day} modelled by eq. (1)-(2) in monthly cross-sections for habitats of Biebrza wetland; Box-plots are (Mean; StdErr; Min-Max)

Daily evapotranspiration was calculated applying simple relation which was applied by:

$$E_d = \frac{R_{nd}}{R_n} LE$$

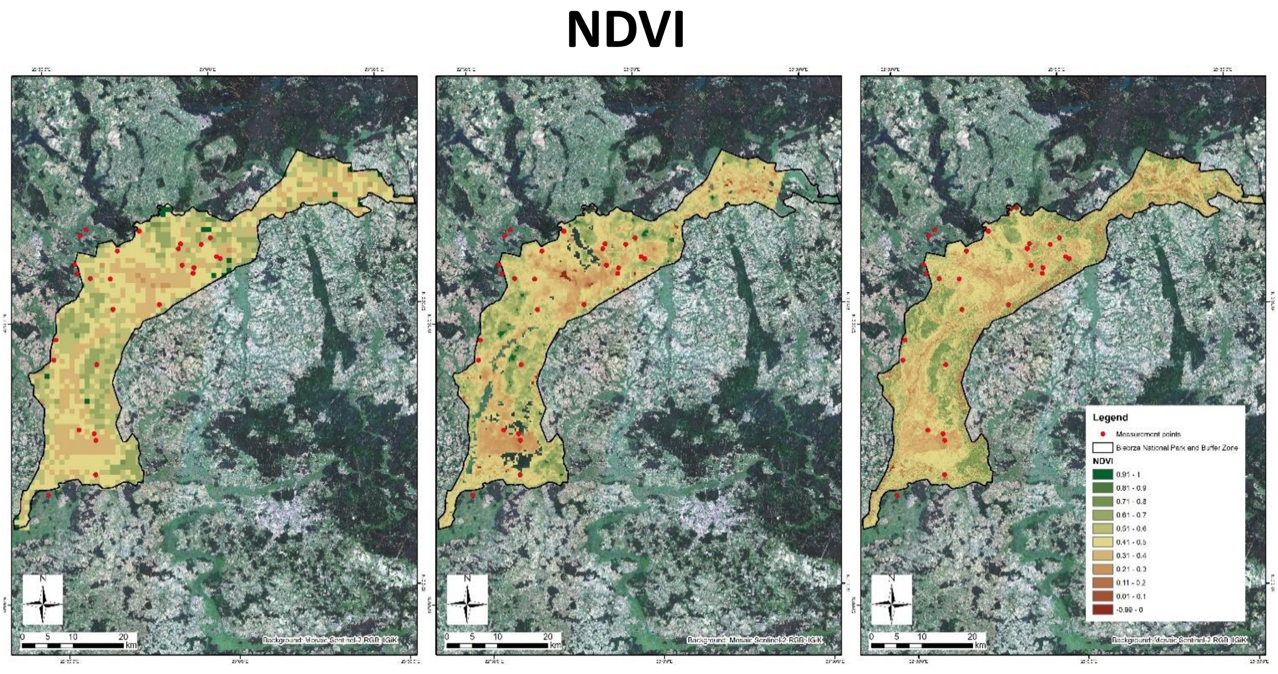
where: Ed – daily evapotranspiration [Wm-2d-1];
Rd – daily sum of radiation balance [J m-2d-1],
Rn – net radiation [W m-2],
LE – latent heat flux (actual evapotranspiration) [W m-2] calculted from Energy budget approach

$$E_{ad} = \frac{E_d}{\rho c_p} \cdot 1000$$

where: Ead - daily evapotranspiration [mm d-1]
ρ - water density [kg m-3]
cp – heat of vaporization of water [J kg-1]

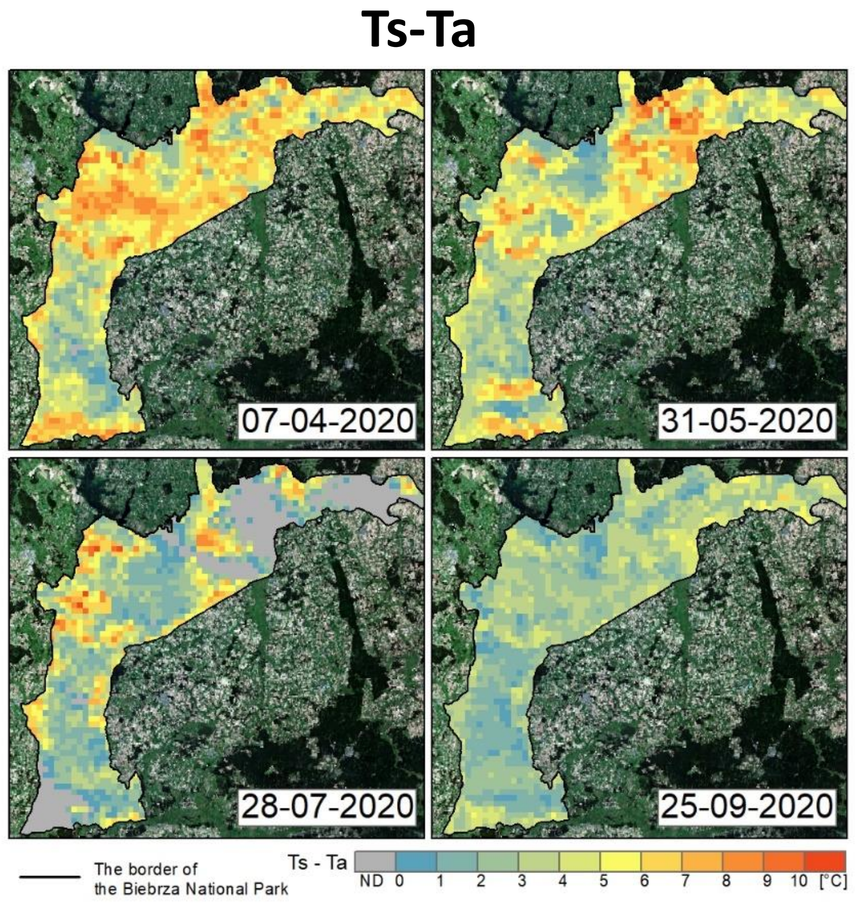
CONCLUSIONS

NDVI



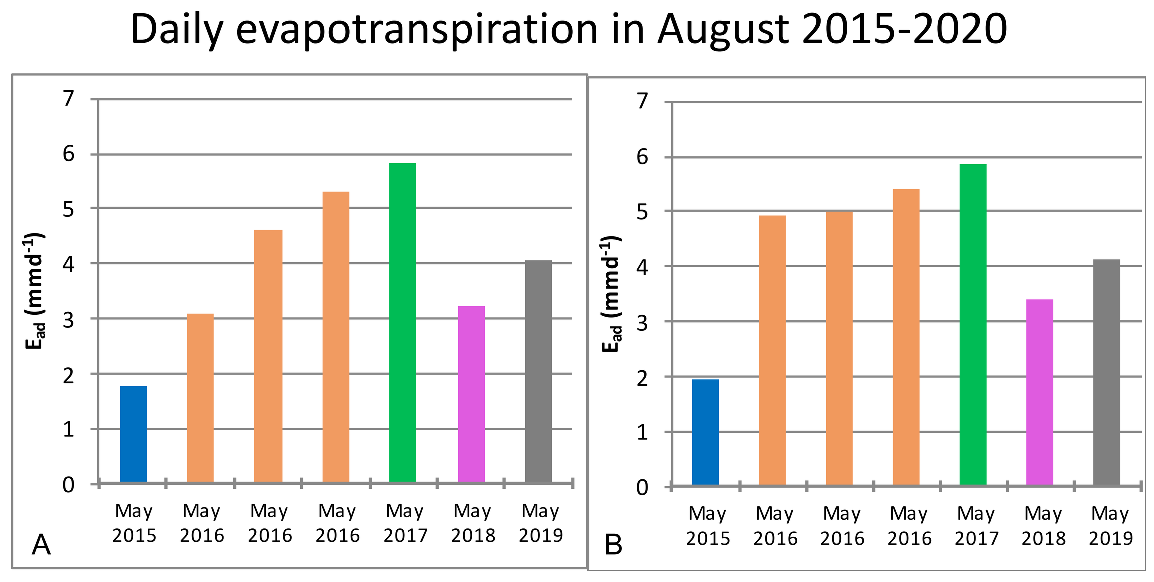
Maps of NDVI calculated from Terra MODIS, Sentinel-3 and Sentinel-2 images acquired in April 2019

Ts-Ta

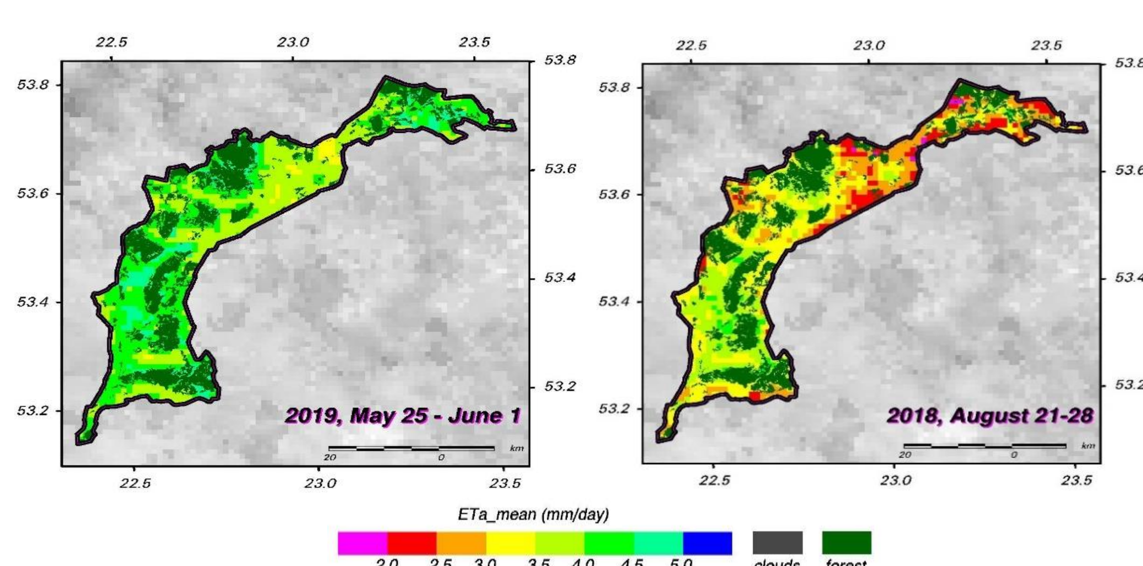


Maps of surface and air temperature differences

Daily evapotranspiration in August 2015-2020



Distribution of daily evapotranspiration for the whole area

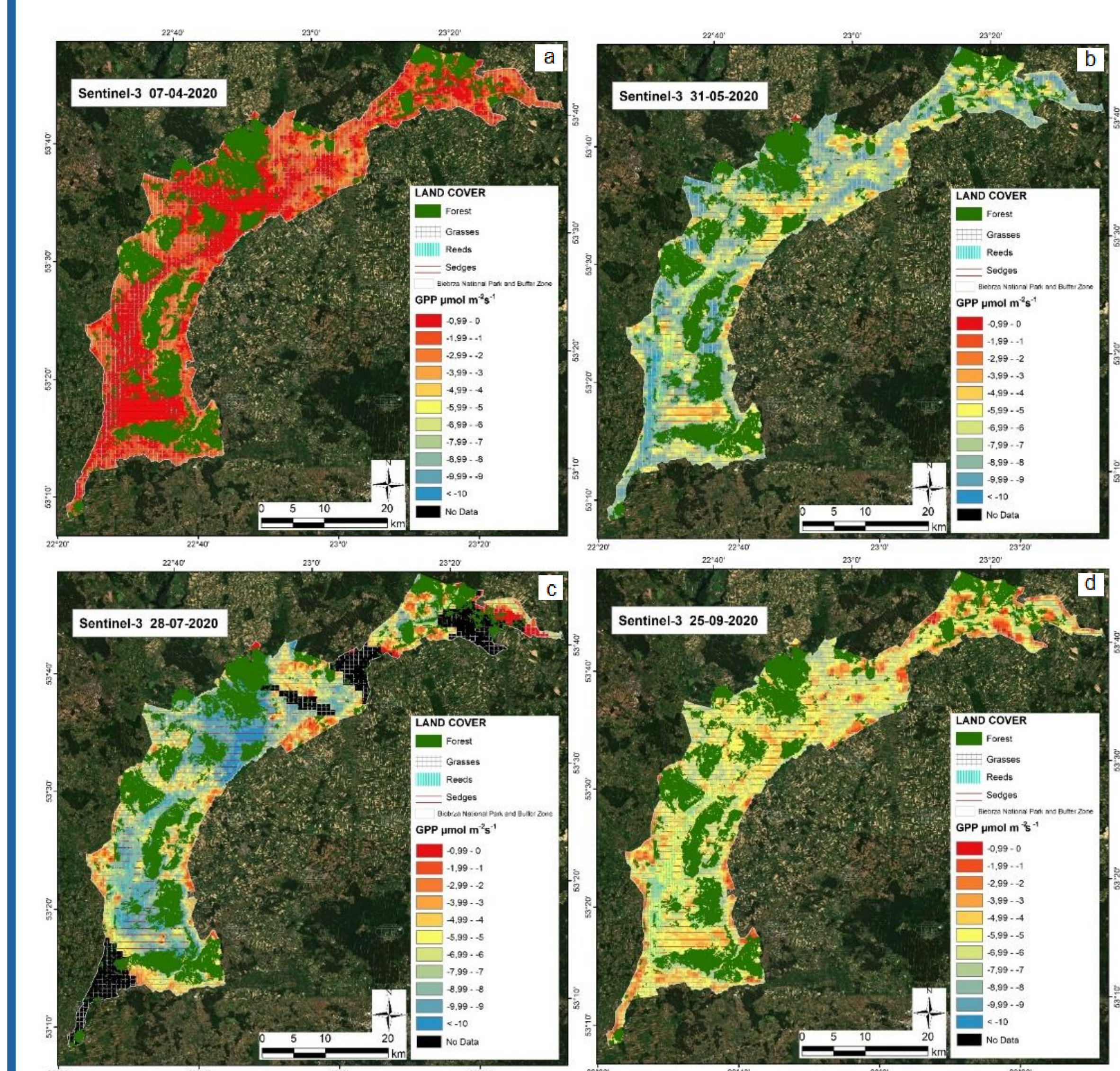


The presented approach allows to fill the **gaps in providing updated information about carbon** uptake by wetlands reflecting scientific advances in application of satellite data from the Copernicus Program. At this background the approach prepared as a result of the presented work can be valuable contribution to finding optimal solutions for using satellite derived indices and products in **GPP estimates.** The add-on value of this approach is that it enables to apply satellite data from Sentinels which creates long-term perspective for **GPP assessment**. Narrow-band indices and hyperspectral data should also be considered in future studies, particularly with the perspective of new satellite sensors.

RESULTS OF GPP ASSESSMENT APPLYING SATELLITE DATA

NDVI parameter and soil vegetation humidity derived from satelitte for GPP model (GPP_{day} = daily Gross Primary Production).

Satellite	Formula	R[1]	N[2]
Terra MODIS	$GPP_{day} = -0.37 \cdot \exp(3.87 \cdot NDVI_{MODIS} + 0.000204 \cdot APAR)$	0.70	78
	$GPP_{11:00} = -1.66 \cdot \exp(2.87 \cdot NDVI_{MODIS} + 0.0008 \cdot LE_{MODIS})$	0.55	107
	$GPP_{day} = -2.72 \cdot \exp(0.13 \cdot LAI_{S2} + 0.089 \cdot Ead_{MODIS})$	0.57	73
Sentinel 2	$GPP_{day} = -0.37 \cdot exp(3.15 \cdot NDVI_{S2} + 1.71 \cdot NDII_{S2})$	0.78	60
Sentinel 3	$GPP_{day} = -0.16 \cdot \exp(4.39 \cdot NDVI_{S3} - 0.004 \cdot (T_s - T_a)^2)$	0.80	68
	$GPP_{09:00} = -0.12 \cdot \exp(4.87 \cdot NDVI_{S3} + 0.0008 \cdot LE_{S3})$	0.73	66



Modelled GPP for different day of the year (spring, summer, autumn)

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