Use of remote sensing techniques for mapping aquatic vegetation

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Norwegian University of Science and Technology

Use of LAI for characterization of aquatic vegetation

LAI field measurements:

- Direct methods: taking samples of foliage from a plant canopy, measuring the leaf area per sample plot and dividing it by the plot land surface area
- Indirect methods: measure canopy geometry or light extinction and relate it to LAI

Leaf area index (LAI) = «one sided green leaf area per unit ground area»

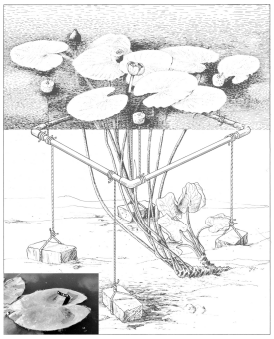
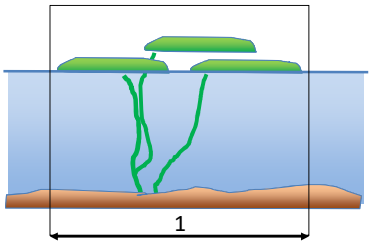


Image: Klok & Velde (2017), for *Nuphar lutea*

- Important plant parameter, often used to predict photosynthetic primary production
- Can be correlated with biomass and other parameters for a given species or plant community



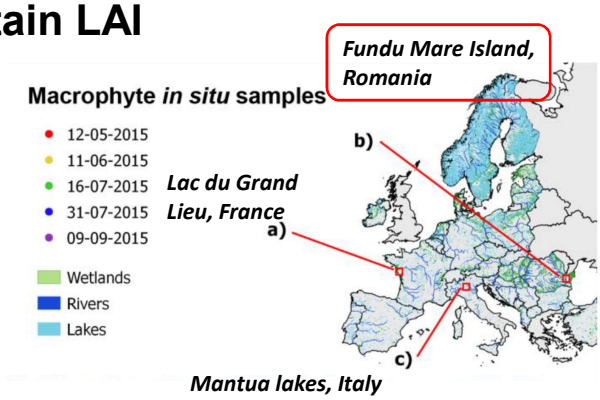
Water lilly (*Nymphaea alba*): typical LAI values = 0.8 .. 2 m^2/m^2

Use of satellite images to obtain LAI

Since July 2017:
ESA's Sentinel-2, provides medium resolution satelitte data (10-20 m ground pixel, revisiting time 5-10 days)

Objectives of the study by Villa et al. (in review):

1. Calibrate a semi-empirical model for deriving macrophyte Leaf Area Index (LAI) time series from satellite spectral reflectance data
2. Map macrophyte phenology metrics and assess their spatial and species-dependent variability
3. Evaluate influence of input dataset characteristics in terms of cloud cover amount, temporal resolution and missing acquisitions on key seasonality metrics mapped from satellite



Study areas, data from test in 2015 (Villa et al., in review)

2015: training data
SPOT5 experiment, 150 sites every 5 days

http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2

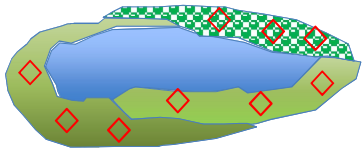
Spot-take5.org

Methods

Landsat (30 m, 16 days)

Spot5 / Sentinel (10-20 m, 5-10 days)

Mantua lakes



Satellite data pre-processing
- ✓ Data correction / calibration / checks
- ✓ Retaining homologous spectral bands (four broadband spectral ranges)
- ✓ Acquiring absolute radiometric accuracy by assessing against *in-situ* spectra

$$LAI\ (m^2\ m^{-2}) = 2.015(EVI2) + 0.048$$

Range: $[0.0–2.0\ m^2\ m^{-2}]$
error level of $0.11\ m^2\ m^{-2}$

Modelling macrophyte LAI
- ✓ Extracting Spot5 HRG spectra from 3 x 3 m pixel window centered on the location of *in-situ* samples
- ✓ Testing regression of 10 spectral indices (SI) with in situ macrophyte LAI
- ✓ Derivation of a semi-empirical regression model (best SI: EVI2)

LAI maps → LAI time series maps → Seasonal dynamics metrics

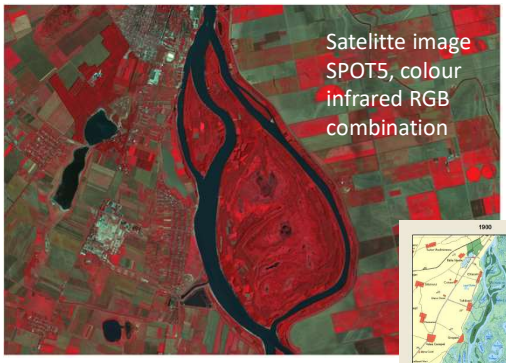
Homogenization, resampling (20m)

TIMESAT

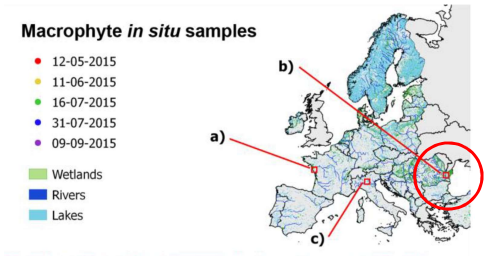
Testing influence of input variables
- Cloud cover amount
- Temporal resolution
- Missing aquistions

Macrophyte plots, field data
- ✓ Species sampling 10m x 10m
- ✓ Photo 1m x 1m for LAI
- ✓ Spectral response measurements (Spectroradiometer)

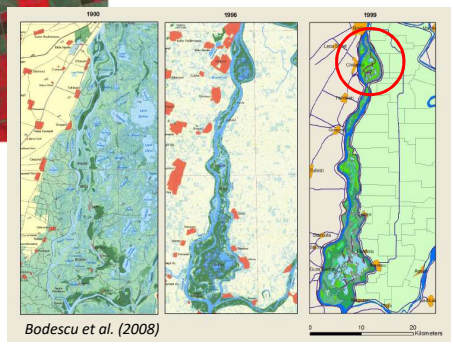
Test site Fundu Mare Island



One of few nearly natural Danube islands of the Inner Delta; RAMSAR area



Background: EEA Grant Project "Restoration of the aquatic and terrestrial ecosystem complex of Fundu Mare Island (RFM)" 05/2015-04/2017

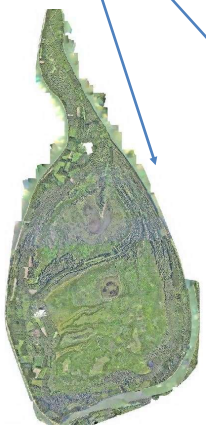


Bodescu et al. (2008)

Danube Delta

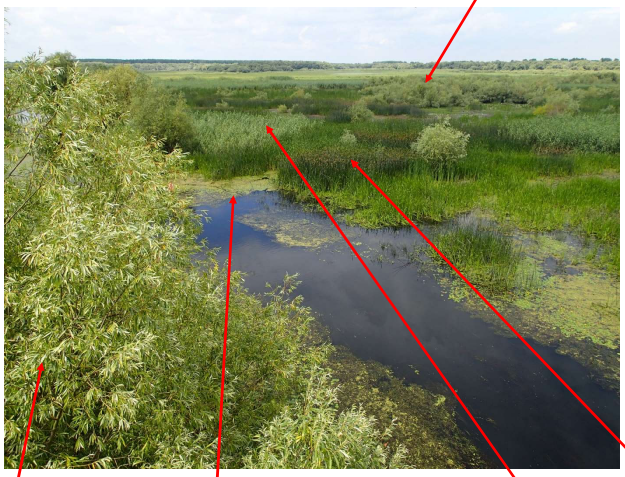
Methods and data for describing vegetation in 2015

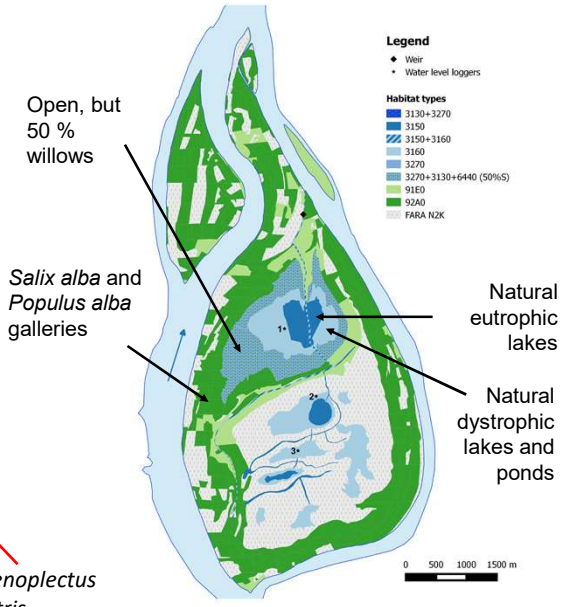
1. boat- and land based spot-wise survey (June, July; NTNU/SINTEF with SWB)
2. Images from drone flight (September, UGAL)



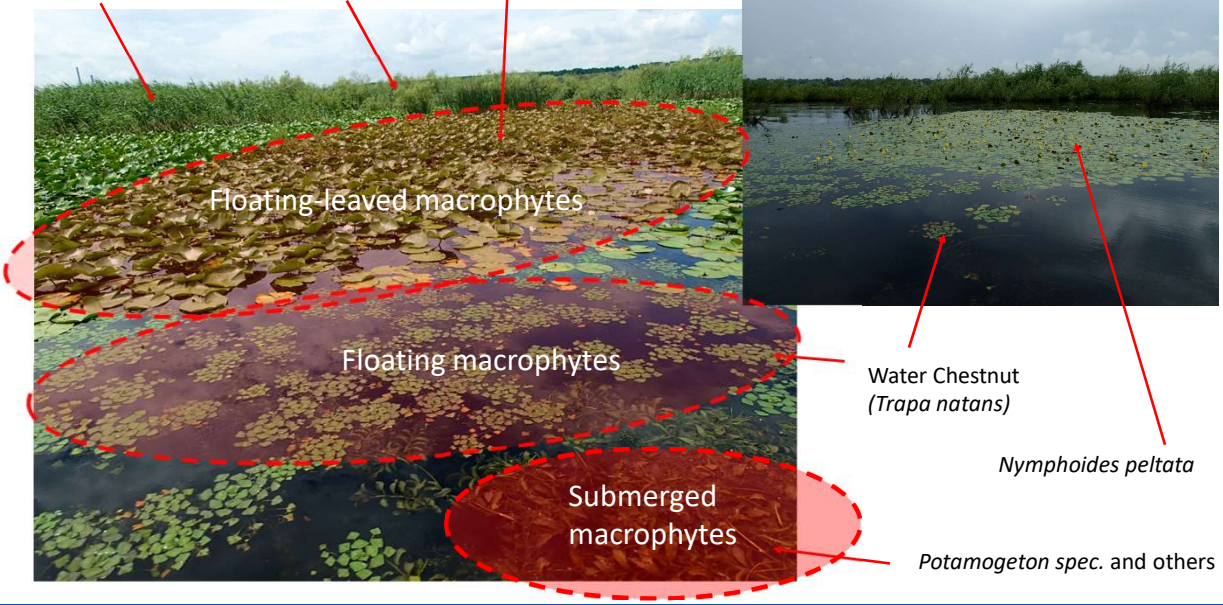
Images; Ortho-mosaic

Vegetation

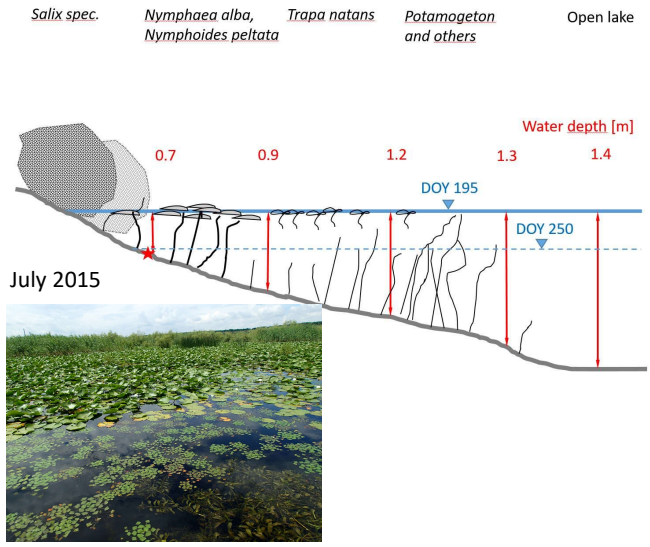


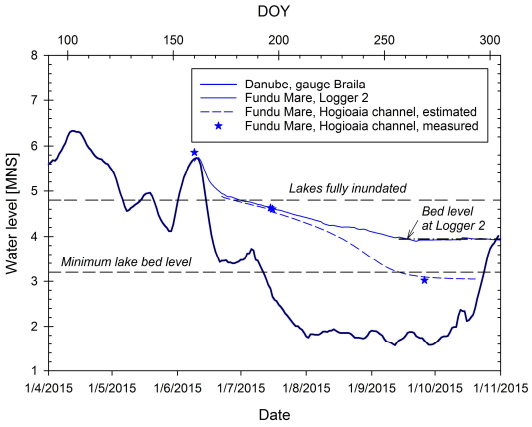


Habitat map (situation <= 2010)



Hydrological conditions 2015





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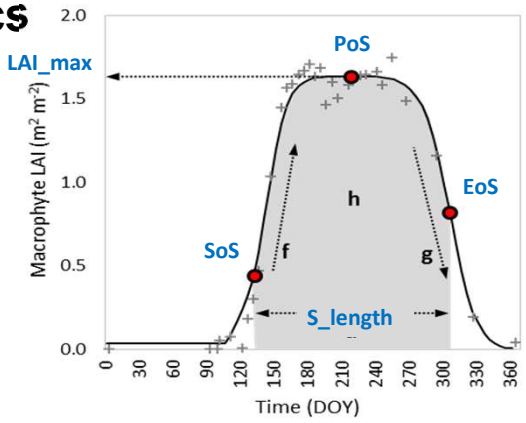
Metrics of seasonal dynamics

- ✓ Use of TIMESAT software with macrophyte LAI maps as input
- ✓ Output parameters = seasonal dynamics metrics (in DOY = day of the year)

Metrics of seasonal dynamics for aquatic macrophytes

- Time for start of the season (SoS)
- Time for peak of the season (PoS)
- Time for end of the season (EoS)
- Length of the season (S_length)
- Maximum LAI value reached during season (LAI_max)
- Rate of increase of LAI (LAI_growth; f)
- Rate of decrease of LAI (LAI_senescence; g)
- Seasonal integral (LAI_productivity; h)



Metrics of seasonal dynamics derived from macrophyte LAI time series using TIMESAT. Adapted from Eklundh and Jönsson (2015).

From Villa et al., in review

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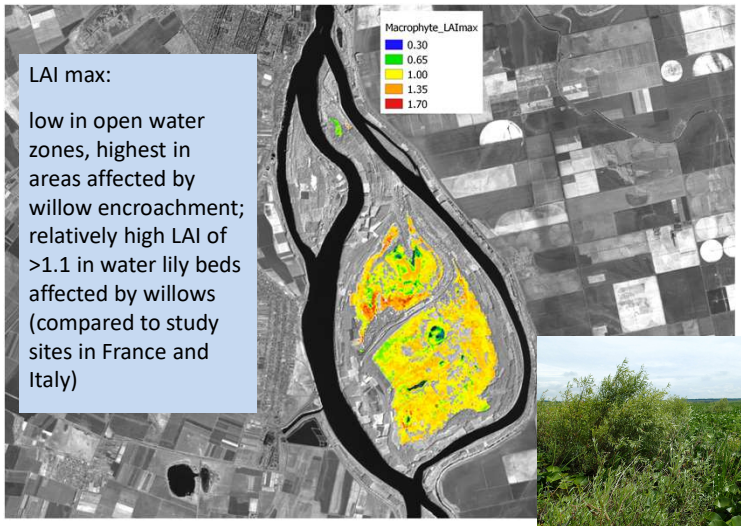
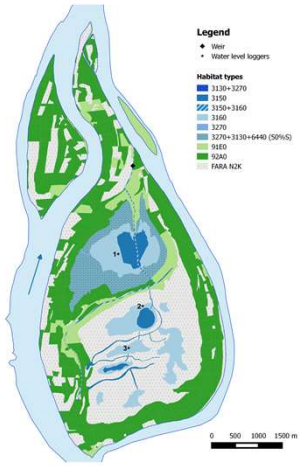
Seasonal vegetation dynamics from satellite data



LAI max:

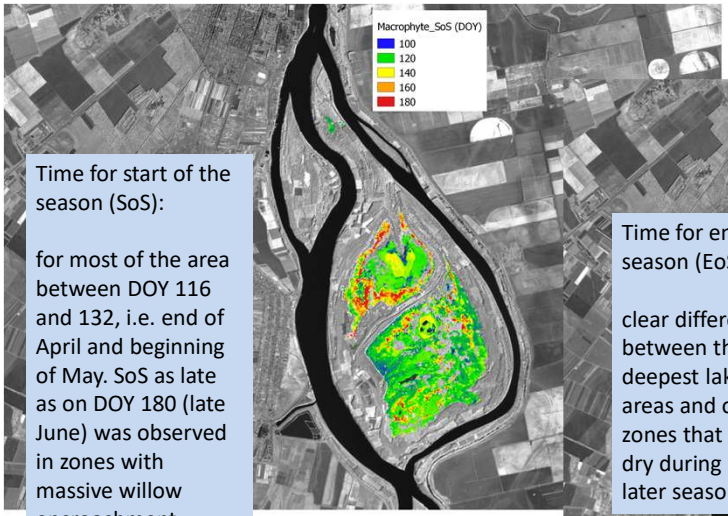
low in open water zones, highest in areas affected by willow encroachment; relatively high LAI of >1.1 in water lily beds affected by willows (compared to study sites in France and Italy)

From Villa et al., in review



Habitat map (SWB; situation before or around 2010)

Seasonal vegetation dynamics from satellite data

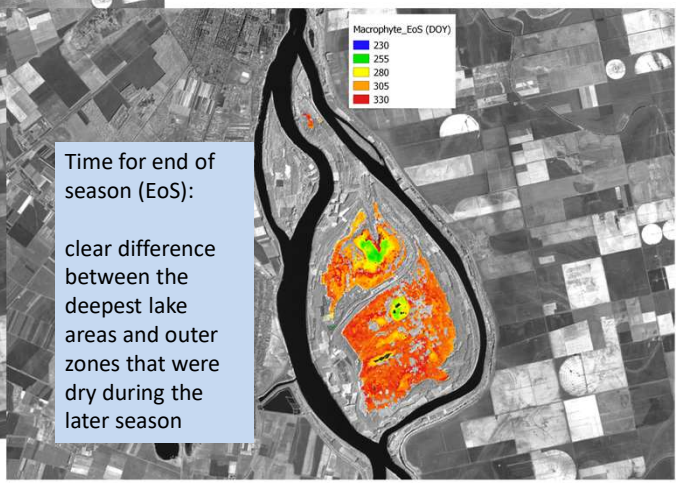


Time for start of the season (SoS):

for most of the area between DOY 116 and 132, i.e. end of April and beginning of May. SoS as late as on DOY 180 (late June) was observed in zones with massive willow encroachment.

20 m pixel size

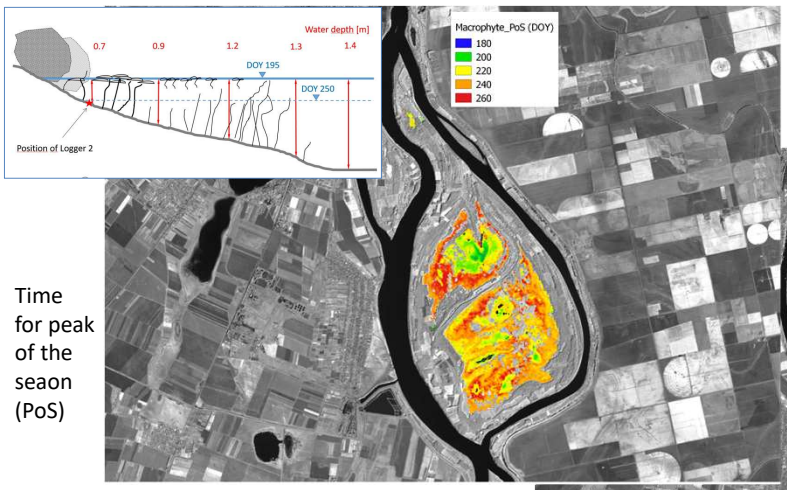
From Villa et al., in review



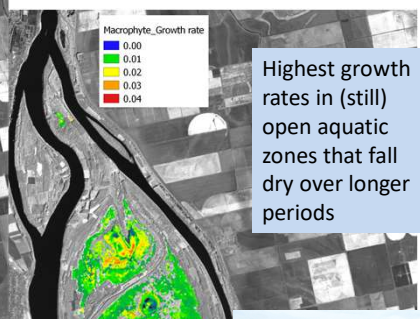
Time for end of season (EoS):

clear difference between the deepest lake areas and outer zones that were dry during the later season

From Villa et al., in review



LAI Growth rate



Time for peak of the seaon (PoS)

Highest growth rates in (still) open aquatic zones that fall dry over longer periods

The PoS of floating plants ranges between 195 and 220 (mid to late July), and between 230 and 265 (August to September) for the zones that dried up when the water level dropped by around 2 m with respect to seasonal maximum (early August).

Summary and outlook

- Dense time series of medium resolution satellite data can be integrated to provide consistent maps of macrophyte LAI and their seasonal dynamics, as shown for Fundu Mare Island in Romania.
- Seasonal dynamics of macrophytes that were mapped highlighted spatial-wise patterns and species-dependent variability for the year 2015, which were related to ecological and hydrological conditions.
- The use of satellite data for mapping macrophyte dynamics in quantitative way offers new possibilities for the monitoring of restoration and conservation actions in shallow aquatic ecosystems.
- Its application is restricted to areas where a spatial resolution of 10-20m is appropriate (in Norway: only larger rivers and floodplains and lakes).

Thank you!

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