Algal Bloom Monitoring Using Multi-Spectral Satellite Data

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Abstract

Algal and cyanobacterial blooms are a natural phenomenon that are caused by the sudden proliferation of algal and cyanobacterial biomass. These organisms take up carbon dioxide and release oxygen during photosynthesis. The blooms result in low water transparency and limit light penetration to deeper water layers. Thus, ecosystem structure changes and benthic plants may disappear. Currently, bloom monitoring is based on in situ data, that are collected infrequently. Remote sensing allows monitoring of the situation on a weekly basis. We collected and analysed in situ data of chlorophyll-a concentration and water transparency from national environmental agencies of Lithuania, Latvia, and Estonia for the years 2017–2021. The machine learning models that use optical Sentinel-2 Multispectral Imager (MSI) data for predicting the blooms and chlorophyll-a concentration were successfully created. Finally, the monitoring dashboard was created and deployed for weekly blooming and chlorophyll-a concentration predictions.

The problem

Climate change brings more challenges to ecosystems and water use to people as increased temperatures, longer stratification periods, decrease of ice cover will lead to more suitable conditions for algal and cyanobacterial blooms across the world. Thus it is important to observe algal blooms, their frequency, onset, length, intensity, and extent. Satellite data can also improve the reporting of algal blooms [1] by member states to European Union as now they are under-reported due to manual tracking of limited in situ data collection. Usually satellite-based algorithms for water parameter retrieval use band difference or band ratio expressions and are related to the parameter value using the linear regression, which is limited to very limited monitoring conditions when there is one type of prevalent optically active substances in water.

The aim of this study was to create a monitoring tool which contain classification models that using satellite data separates the blooming waters from non-blooming waters and then quantitatively estimate the intensity of blooms using the derived chlorophyll-a concentration from satellite data.

Data

We used optical Sentinel-2 MultiSpectral Imager (MSI) data. We extracted pixels around monitoring sites using Google Earth Engine python API. Sentinel-2 MSI has 13 bands in visible (443-665 nm, B1-B4), near-infrared (705-865 nm, B5-B8A), and short wave infrared range (940-2190 nm, B9-B12). Our dataset comprised of 1346 corresponding in situ and satellite observations. The observations were considered corresponding when there was no more than three days time (backwards or forward) difference between in situ measurement and satellite acquisition.

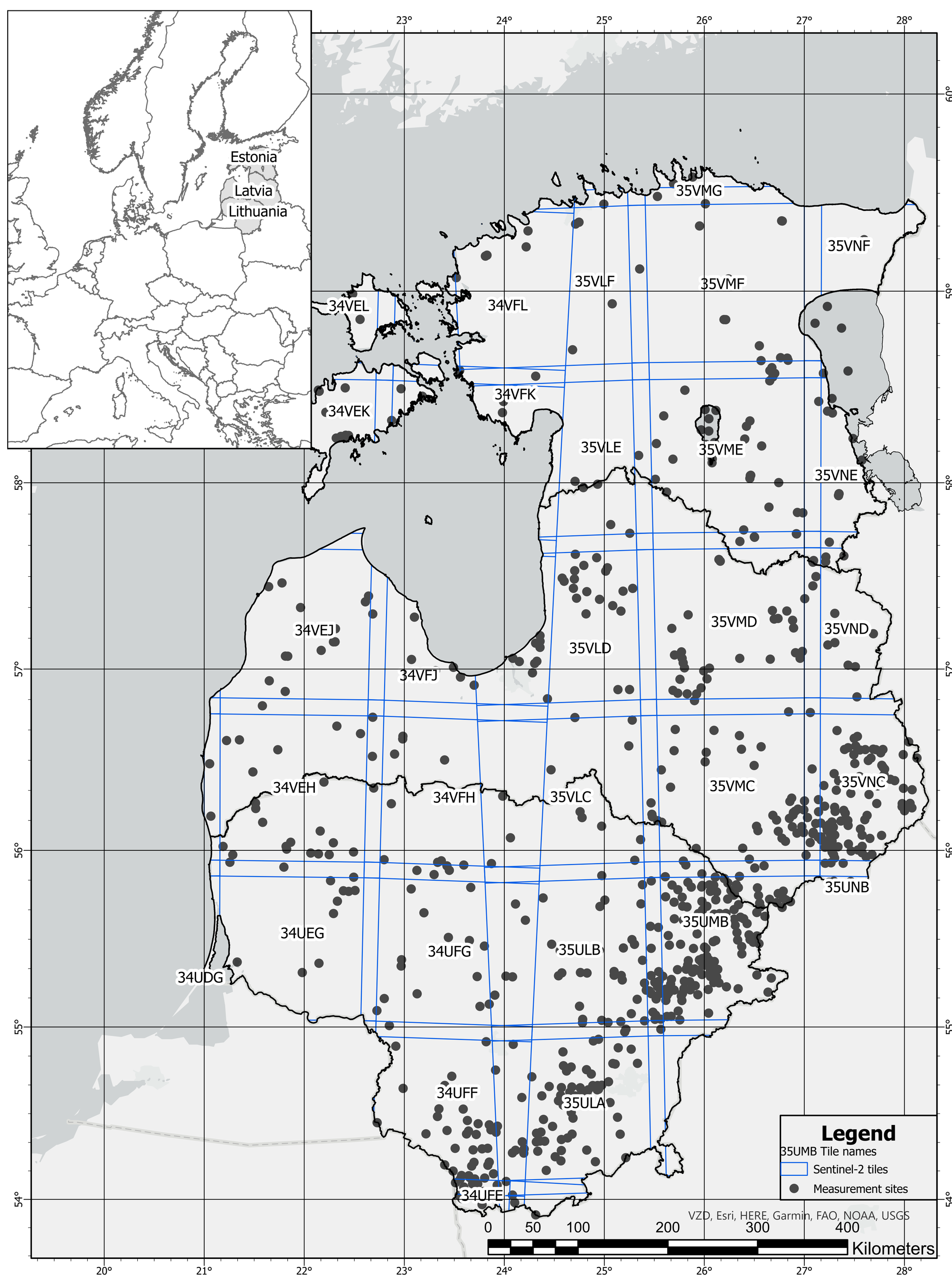

Figure 1: The location of monitoring sites in Lithuania, Latvia, and Estonia

Deep neural network for chlorophyll-a prediction

Within the investigation of machine learning models, the Variable selection approach proposed by Lim et al. [2] neural network was used as main deep learning model.

Model	Accuracy	AUC	F1
DNN-VS	0.72	0.82	0.72

Table 1: Model classification performance metrics

			error	
		count	mean	MAPE, %
bloom	Type			
non-bloom	shallow	84	9.1	344
	mid	121	5.3	221
	deep lake	13	2.6	83
bloom	shallow	118	11.0	38
	mid	96	10.2	37
	deep lake	2	9.0	83

Table 2: Model regression performance metrics for lake types

Chlorophyll-a prediction and monitoring dashboard

The bloom classification and chlorophyll-a prediction models were integrated to the dashboard, which was created using R shiny. The app server and functionality for interactive monitoring of Baltic states' lakes was created. The monitoring tool allows to investigate historical data, see in situ measurements, and predictions of bloom/chlorophyll-a in lakes.

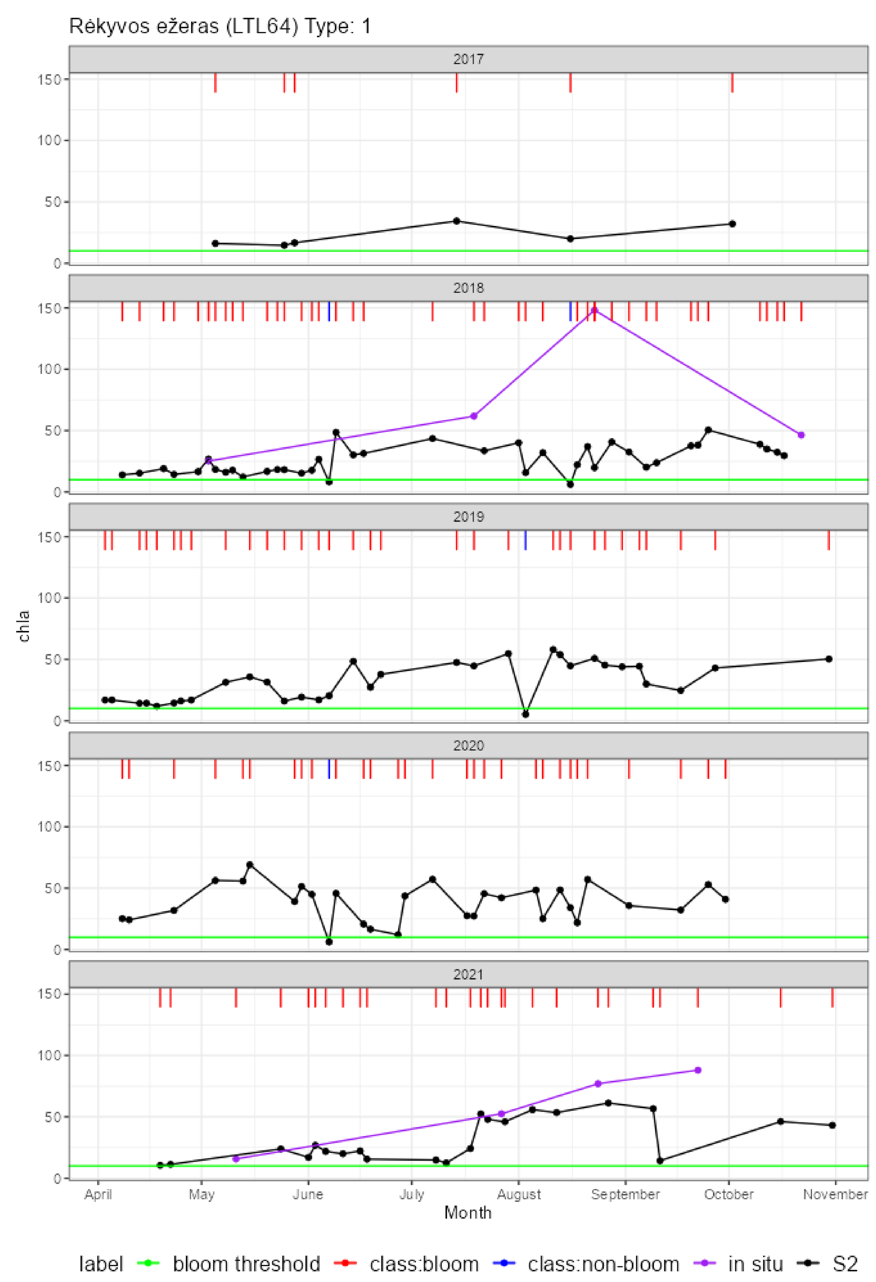

Figure 2: Illustrative example of Dashboard predictions from satellite data for Rėkyva lake.

The dashboard is hosted on zydi.lt is accessible for general public and researchers for future usage. The tool will help monitor lakes' water quality and optimise the system of in situ monitoring of lakes.

Conclusions

A tool for monitoring chlorophyll-a concentration based on satellite data covering a large region was created. The created dashboard, contains developed novel neural networks for both bloom classification and chlorophyll-a concentration estimation in the lakes in Baltic states which is accessible at zydi.lt.

References

[1] D. Grendaitė, E. Stonevičius, J. Karosienė, K. Savadova, and J. Kasperovičienė, *Chlorophyll-a concentration retrieval in eutrophic lakes in lithuania from sentinel-2 data*, Geologija. Geografija, 4 (2018).

[2] B. Lim, S. Ö. Arik, N. Loeff, and T. Pfister, *Temporal fusion transformers for interpretable multi-horizon time series forecasting*, International Journal of Forecasting, 37 (2021).