Project Water Bodies Without Borders (EstLat 66)

JOINT MONITORING PROGRAM FOR KOIVA/GAUJA AND SALATSI/SALACA RIVER BASIN

Activity T3. Joint monitoring program for Gauja/Koiva and Salaca/Salatsi river basins

Annex 1

PILOT STUDY

2020

Introduction

Currently the status of small lakes is been evaluated after 3-6 years prior to availability of the funding. But as the funding is limited we see that there is a need to prioritize the water bodies that we select into our annual in-situ monitoring campaign.

One of the general goals in WRD monitoring program is to analyze and identify the changes in water body status - both man induced and natural changes. In current pilot study we analyzed datasets from different monitoring programs that provide operational information about man induced pressures like clear-cuts and wastewater outlets. To identify the possible sift in water status class also water quality parameters from remote sensing imagery were analyzed. The main goal of the pilot study was development of analysis that help us in prioritization of water bodies that we include into our annual in-situ campaign relying on different operational information in our datasets.

1. Analysis on clear-cut areas from remote sensing dataset

1.1 Background

Clear-cutting, soil preparation, ditch cleaning, and fertilization increase nutrient concentrations and loads in receiving waters (Ahtiainen and Huttunen 1999; Kreutzweiser et al. 2008; Nieminen et al. 2010) which may result in degradation of water quality, eutrophication, and formation of harmful algal blooms (Conley et al. 2009). Palviainen et al. 2015 showed that significant increases in the concentrations of total nitrogen, nitrate, ammonium, and phosphate occurred between 2 and 6 years after clear-cutting in water body catchment basin. Therefore the identification the amount of clear-cut in the catchment area helps us to identify the man induces pressure change to the water body.

1.2 Methodology

Under the Estonian national landscape monitoring program we monitor annually the clear-cut areas. These areas are identified using the remote sensing imagery (Sentinel 2 and Landsat) with the change detection technique. The work is done by the Tartu Observatory and the GIS layer with annual clear-cut areas is provided to the Estonian Environment Agency.

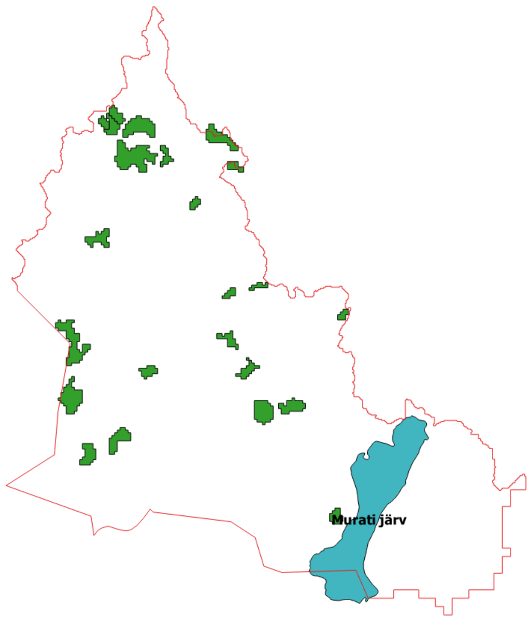
In current study we analyzed clear cut area maps from 2013-2018 for the catchment area of 8 lakes located in Koiva water district. We calculated the presenting of the catchment area that has been cut down.

1.3 Results

On Fig1 are shown the locations of clear-cut areas inside the catchment area of lakes Murati järv, Pulljärv, Kirikumäe järv, Hino järv and Pabara järv in 2013-2016. In Table 1.1 is shown percentage of clear-cut in catchment basin of the lake. On Fig 1.1 and Table 1.1 is well seen that in the catchment areas of lakes Aheru, Köstrejärv and Murati järv have occurred the largest clear-cuts and the most significant clear-cut ~9.5 % of the total catchment area have performed around Lake Aheru.

Table 1.1 Land use changes in 2016-2018 in the catchment area of lakes in monitoring program:

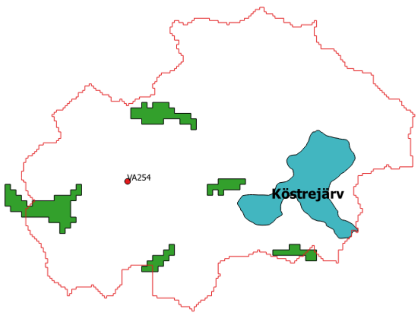
Lake name	**Catchment area (ha)**	**Clear-cut between 2013 -2016 (ha)**	**% of clear-cut in catchment area**	**% of clear-cut in catchment (2013-2016) area without lake area**	**Clear-cut in catchment area (ha)2016-2018 march**
Aheru järv	852	58,4	6,9	9,42	7,3
Hino järv	611	1,31	0,2	0,32	6,0
Kirikumäe järv	288	0	0	0	0
Kösterjärv	153	5,4	3,5	3,83	0
Murati järv	1196	47,9	4,0	4,24	11,5
Pabra järv	1843	15,2	0,82	0,86	13,5
Pulljärv	183	0	0	0	0
Ähijäev	1544	7,1	0,45	0,52	0



Murati järv

Hino järv

Kirikumäe järv



Kösterjärv

Aheru järv

Ähijäev

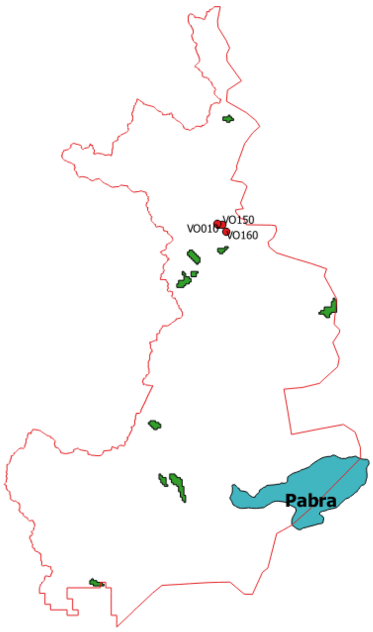
	
Pabara järv	Pullijärv

Figure 1.1 Locations of clear-cuts during 2013-2016 inside the catchment area of lakes Murati järv, Hinojärv, Kirikumäe järv, Köstrejärv, Aherujärv, Ähijärv, Pabra järv and Pullijärv. Red dots are locations of waste-water outlets in catchment area of Lake Pabra and Köstrejärv.

2. Analysis of pressure from waste-water outlets in catchment area

2.1 Background

Wastewater outlets are known source of nutrient load info the water body which may result in degradation of water quality and eutrophication.

2.2 Methodology

In Estonia owner of the waist water outlet has to monitor the load of the nutrients and the flow rate according to the guidelines given by Estonian Environmental Board. We analyzed the changes of waste water flow rate and concentration of nutrients in every lake catchment area for years 2013-2016.

2.3 Results

As seen on Table 2 only inside Lake Pabra and Köstrejärv catchment area are working wastewater outlets. The outlet in Köstrejärv is 600 m meters away from the lake (Fig 1.1) and the outlet is not directly to the lake and is not considered as pressure to the lake in general. However, we analyzed the nutrients input from the outlet to the catchment area. The load of total nitrogen from outlet VA 254 is shown on Figure 2.2. As seen on Fig. 2.2 there have been fluctuations of N input but there is no increasing trend of N(tot) load into the catchment area. On Fig 2.3 is shown the load of P(tot) from the outlet and there we can see increase of P(tot) load during 2013-2016. The concentrations of N(tot) been within the limits set by Estonian

Environmental Board with the water permit but the concentrations of P(tot) have not been within the limits set in water permit. As the outlet is quite close to the lake we consider increase of P load as possible pressure change to the lake.

Table 2.1. Number of waste-water outlets in catchments areas.

Lake name	Waste-water outlets on catchment area
Aheru järv	-
Hino järv	-
Kirikumäe järv	-
Kösterjärv	1 (VA254)
Murati järv	-
Pabra järv	4 (VO140, VO110, VO150, VO160)
Pullijärv	-
Ähijäev	-

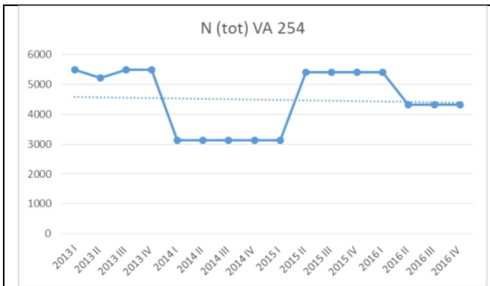


Figure 2.2. Pressure change in 2013-2016 (N input) form outlet VA 254

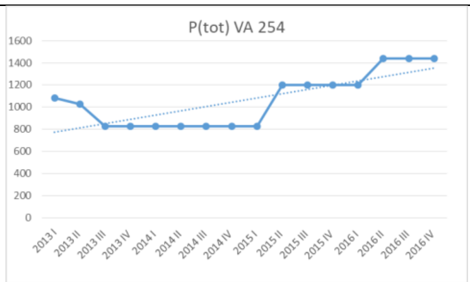


Figure 2.3 Pressure change in 2013-2016 (P input) form outlet VA 254

The outlets VO 110, VO140, VO150, 160 in the catchment area of the Lake Pabra are rainwater outlets, so the flow rate from these outlets are directly related the precipitation. All the outlets are very remote (more than 3 km) from the lake Pabra (Fig 1.1). The concentrations of oil products and suspended sediments are monitored regularly by the owner of the outlet. For the outlets VO140 and VO110 concentration have been within the limit set in the water permit given by Environmental Board. In the outlet VO150 and VO160 the concentrations of suspended sediments exceeded the limits set in water permit. However, we do not consider this as pressure change to the lake in our analysis.

3. Analysis of lake water quality indicators from satellite data.

3.1 Background

Remote sensing enables collect information about interesting objects from the distance. The oceanic waters have monitored with remote sensing data for decades now. With the launch of high resolution sensor Sentinel 2 in 2016 also the operational lake monitoring has become an interest. However, lakes cannot compared to the oceanic water and need special/different algorithms for estimation of concentrations of optically active substances From the optical satellite imagery water transparency and concentrations of optically active substances (suspended sediments, phytoplankton pigments and dissolved organic matter) can be derived. Out for these parameters that can be derived from the satellite data the water transparency and Chlorophyll a concentration are indicators of ecological status. Every indicator of ecological status (biological, physio-chemical and hydromorphological) have been associated with certain thresholds to assign ecological status of water. Type specific thresholds for Secchi disk depth are showed on the Table 3.1. To estimate the ecological status of water, then at least seven quality parameters should be considered, therefore all the parameters are equally important (Ministry of Environment, Regulations 2009).

Table 3.1 Thresholds for Secchi disk depth (m) estimating ecological status of for different lake types (Ministry of Environment, Regulations 2009).

Lake type	Very good	Good	Moderate	Bad	Very bad
Type I	>6	4-6	3-4	2-3	<2
Type II	>3	2-3	1-2	<1	<1
Type III	>3	2-3	1-2	<1	<1
Type IV					
Type V	>5	3-5	2-3	2	1

3.2 Methodology

In Estonia many studies (Alikas et al. 2015, 2016, 2017) have made to apply/validate different remote sensing algorithms for lakes. Study by Ansper 2018 showed that most appropriate processor for estimation of lake water quality in Estonian small lakes at the moment is C2RCC (Case-2 Regional CoastColour). The Case–2 Regional processor, originally developed by DOERFFER and SCHILLER, uses a large database of radiative transfer simulations inverted by neural networks as basic technology. The processor is available in ESA Sentinel toolbox SANP. However, the processor has its limitations, adjacency effect can be noted in case of narrow lakes

(Ansper 2018) and in very brown lakes the reliability of the atmospheric correction can be low. The processor needs to be adjusted according to the lake optical properties if possible.

We used the C2RCC toolbox for processing the Sentienl 2 data over the Koiva district lakes for years 2017- till May 2018. The toolbox derives water transparency indicator Kdz90 (the averaged attenuation coefficient at wavebands), which is a measure of water depth where 90 % light is attenuated. This parameter generally compares to Secchi disk depth measured in-situ. Still, one have to keep in mind that this is a satellite measurement not directly Secchi disk depth.

3.3 Results

<u>Aheru järv</u>

The map of Lake and location of national monitoring station is shown on Fig. 3.1. Lake Aheru has been evaluated as WRD water Type II. For this water type the good water transparency is 2-3 meters (Table 3.1). In-situ measurements of lake water transparency (Secchi disk depth) has been performed between 6 times between the 2004 and 2010 it varied between 0.8 and 1.4 m (Fig 3.1). We could obtain 7 Sentinel 2 MSI images from years 2017-2018 where transparency of lake could be evaluated. On Fig 3.2 is shown transparency in national monitoring station as observed from in-situ measurements and from satellite data between the years 2004-2018. On figure is seen the decrease of water transparency observed from satellite data in 2017 at national monitoring station. Overall water transparency as KdZ90 (satellite) in 2017 varied from 0.6 to 0.9 meters (Fig 3.2) what represents the status class “bad”.

Figure 3.1. Location of sampling stations from national monitoring programs (blue dots) and location of data output from satellite images (green dots).

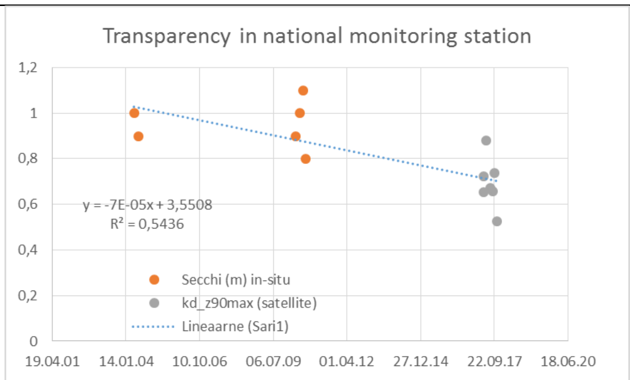


Figure 3.2. Transparency obtained from in-situ measurements and from Sentinel 2 data in national monitoring station

<u>Ähijärv</u>

The map of Lake and location of national monitoring station is shown on Fig. 3.3. Lake Ähijärv has been classified to WRD type II. For this water type the good water transparency is 2-3 meters (Table 3.1). In-situ measurements of lake water transparency (Secchi disk depth) has been performed every year between the 1996 and 2017 it varied between 0.9 and 3.3m (Fig 3.4). On Fig. 3.4 is seen that the trend of the water transparency is decreasing although it is statistically insignificant. Form the 2017 satellite images the transparency observed in national monitoring station was between 0.8-1.56 in 2017 (Fig 3.4) and indicates the status class “moderate” only in one occasion on 22.10.17 satellite imagery it was “bad”.

Figure 3.3. Location of sampling stations from national monitoring programs (blue dots) and location of data output from satellite images (green dots).

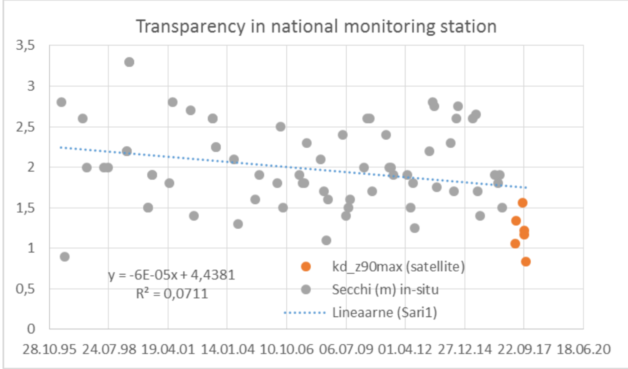


Figure 3.4. Transparency obtained from in-situ measurements and from Sentinel 2 data in national monitoring station

<u>Lake Murati</u>

The map of Lake and location of national monitoring station is shown on Fig. 3.5. Lake Murati has been evaluated as WRD water type III. For this water type the good water transparency is 2-3 meters (Table 3.1). In-situ measurements of lake water transparency (Secchi disk depth) has been performed 6 times between the 2004 and 2010 it varied between 0.7 and 1.4m (Fig 3.6). We could obtain 6 Sentinel 2 MSI images of from years 2017-2018 where transparency of lake could be evaluated. However, as the lake is very narrow the adjacency effect is strongly influencing the satellite data and also the lake water is yellow and Ansper 2018 have shown that in this case the reliability of C2RCC can be low. On Fig 3.6 is shown transparency in national monitoring station as observed from in-situ measurements (2004-2010) and satellite data (2017-2018). From Fig 3.6 is seen that satellite data indicates the increase of transparency compared to field measurements in 2004 and 2010 in national monitoring station, but as the national monitoring station is close to the coast the adjacency effect is probably influencing the result strongly. Therefore, we also analyzed the variability of transparency in central part of the lake. On Fig 3.5 is shown the variability of transparency (satellite) in transects shown on Fig 3.1. The water transparency as KdZ90 varied from 0.6 to 3.8meters (Fig 3) being 1.9 meters on average. On Figure 4 are shown the status class of transparency measurements as observed from satellite data (transect). In more than 51 % of the cases the status class of Lake Murati was “moderate” as also observed during in-situ campaigns in 2004 and 2010 (Fig 3.7).

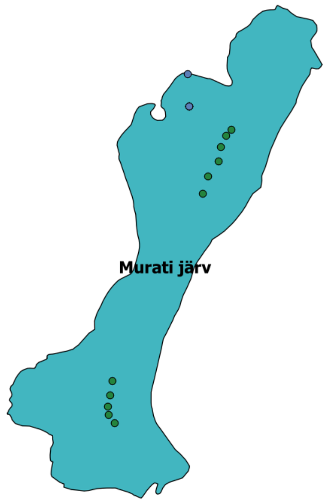


Figure 3.5. Location of sampling stations from national monitoring programs (blue dots) and location of data output transects from satellite images (green dots).

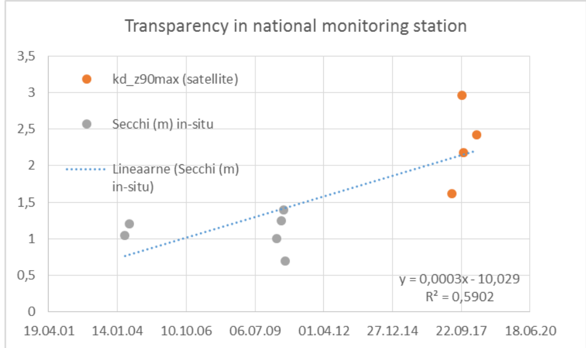


Figure 3.6. Transparency obtained from in-situ measurements and from Sentinel 2 data in national monitoring station

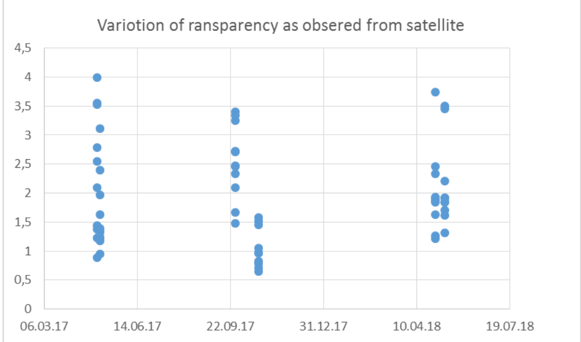


Figure 3.6. Variability of KdZ90 from satellite measuremts in trasects.

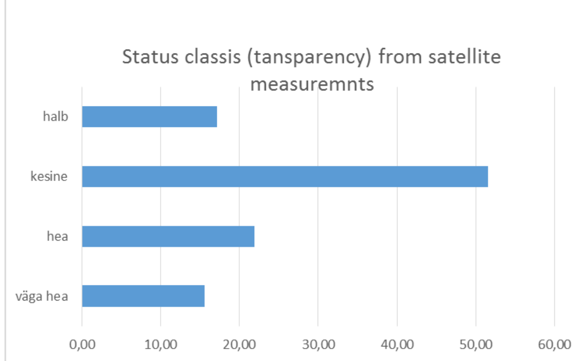


Figure 3.7. Status classes from satellite measurements

Lake Hinojärv

The map of Lake and location of national monitoring station is shown on Fig. 3.8. Lake Hinojärv has been classified to WRD type II. For this water type the good water transparency is 2-3 meters (Table 3.1). In-situ measurements of lake water transparency (Secchi disk depth) has been performed between 8 times between the 2008 and 2010 it varied between 2.25 and 4.1m (Fig 3.9). We could obtain 5 Sentinel 2 MSI images from years 2017-2018 where transparency of lake could be evaluated. On Fig 3.9 is shown transparency in national monitoring station as observed from in-situ measurements and satellite data between the years 2006-2018. There has not been significant trend in water transparency in national monitoring station during 2008-2018 but the variability of transparency has been large from 1.5 to 4.3 meters. Large variability (1.4-4.3) of transparency was also observed from satellite imagery in national monitoring station 2017-2018. On Fig 3 is shown the variability of transparency in transects shown on Fig 1. The water transparency as KdZ90 varied from 0.8 to 6.1 meters (Fig 3) being 2.5 meters on average in transects shown of Fig. 3.8. On Figure 4 are shown the status class of transparency as observed from satellite data. In more than 54 % of the cases the status class of Lake Hinojärv was “average” but 30% of the measures were in class “very good”. Indicating that the status class of lake relying on transparency depends largely on measurement location and timing. The average transparency of the lake observed from satellite data was 2.5m indicating status class “good”.

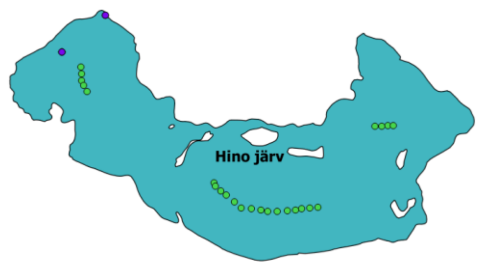


Figure 3.8. Location of sampling stations from national monitoring programs (blue dots) and location of data output transects from satellite images (green dots).

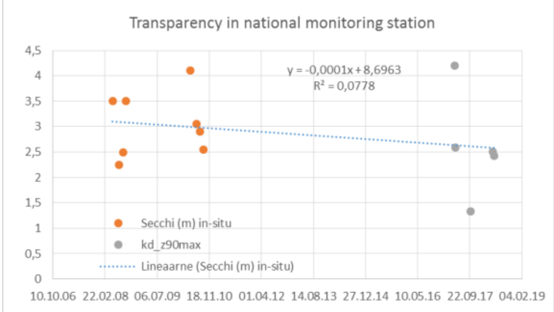


Figure 3.9. Transparency obtained from in-situ measurements and from Sentinel 2 data in national monitoring station

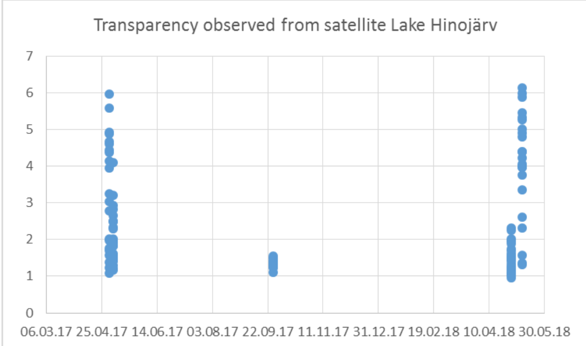


Figure 3.10. Variability of KdZ90 from satellite measuremts in trasects.

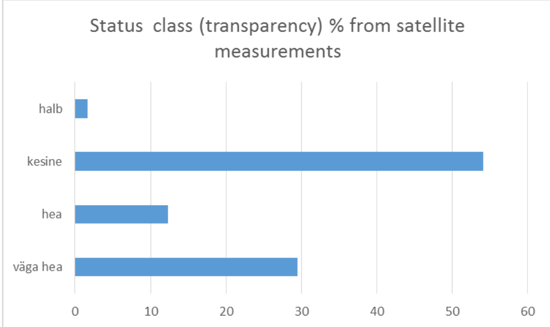


Figure 3.11. Status classes from satellite measurements

<u>Lake Kirikumäe järv</u>

The map of Lake and location of national monitoring station is shown on Fig. 3.12. Lake Kirikumäe has been classified to VRD type V. The lake water originates from the swan areas around the lake and therefore the colour of the lake is yellow and for this water class the good water transparency in 3-5 meters (table 3.1) which is more than the average mean depth of the lake (2.8 m). Lake Kirikumäe is yellow in color as the water in lake originates from swap areas surrounding the lake (Fig 3.14), therefore the relatability of the C2RCC algorithm can be low). In many satellite images we could also observe the mist or bottom reflectance on lake (3.14). Form satellite images we could observe that the transparency of the lake was between 0.7-2.5 meters in national monitoring station, Secchi disk depth measured at national monitoring station in 2010 varied from 1-1.4 meter. The average transparency observed from satellite at national monitoring station showed slight increase in transparency (Fig 2) however the overall water type status class according to transparency is “boor”.

Figure 3.12. Location of sampling stations from national monitoring programs

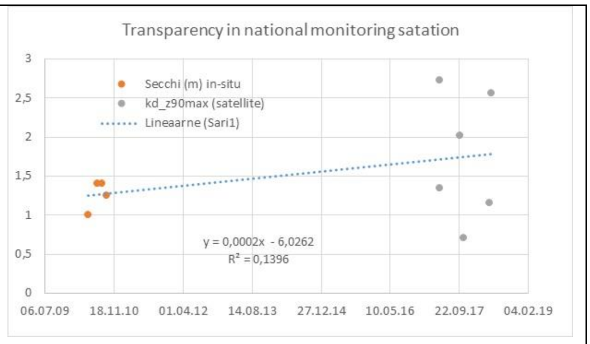


Figure 3.13. Transparency obtained from in-situ measurements and from Sentinel 2 data in national monitoring station

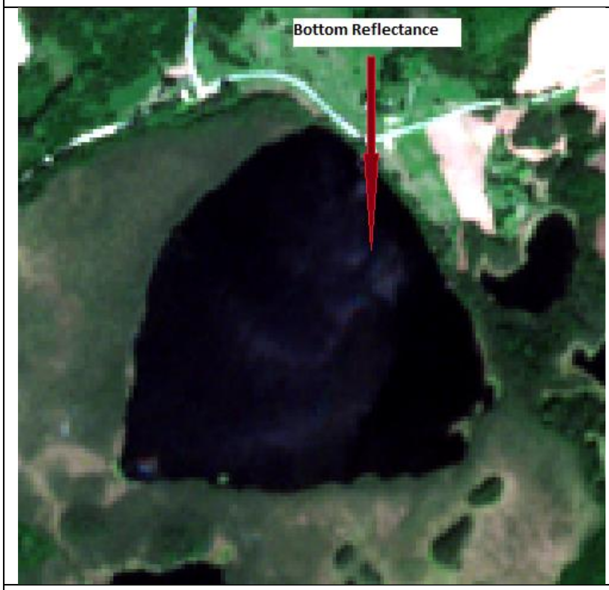


Fig. 3.14. Sentinel 2 RGB image 20.05.2018

Lake Pulli järv

The map of Lake and location of national monitoring station is shown on Fig. 3.15. Lake Pulli järv has been classified to VRD type V. For this water type the good water transparency is 3-5 meters (table 3.1) been close to the average mean depth of the lake (3.8 m). From satellite imagery is seen that the lake is and later it seems very green in autumn (Fig 3.18) but on May images we ofter observed the mist or bottom reflectance on images (Fig. 3.17). In-situ measurements of lake water transparency (Secchi disk depth) has been performed between 8 times between the 2008 and 2010 it varied between 2.0 and 4.0 m (Fig 3.16). Satellite data showed water transparency between 1 to 3.7 meters (Fig 3.16) and there is seen slight decrease of water transparency in national monitoring station compared to in- situ measurements made in 2008 and 2010 (Fig 3.16). The transparency status at national monitoring station evaluated from satellite data in 2017 was “good” in two occasions and “boor” in 4 occasions (3.16). In average the transparency assigned in class “moderate”.

Figure 3.15. Location of sampling stations from national monitoring programs

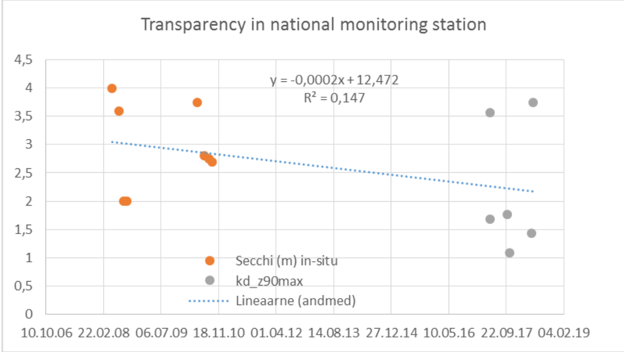


Figure 3.16. Transparency obtained from in-situ measurements and from Sentinel 2 data in national monitoring station

3.17. Sentinel 2 RGB image 20.05.2018

3.18. Sentinel 2 RGB image 22.10.2017

Lake Pabra järv

The map of lake and location of national monitoring station is shown on Fig. 3.19. Lake Pabra has been classified to VRD type V. For this water class the good water transparency is 3-5 meters (table 3.1) which is more than the average mean depth of the lake (2.8 m). On Fig 3.20 is shown Lake Pabra water transparency variations during 2008-2018. Field measurements of Secchi dick have been performed 7 times between the 2008 and 2010 and it varied between 1.4 and 1.9 m (Fig 3.20). Transparency observed from satellite data in national monitoring station

2017-2018 ranged from 0.8-2.7 m. The transparency status at national monitoring station evaluated from satellite data in 2017 was “moderate” in two occasions and “boor” in 3 occasions. According to previous in-situ measures the transparency of the water has been “boor”

Figure 3.19. Location of sampling stations from national monitoring programs

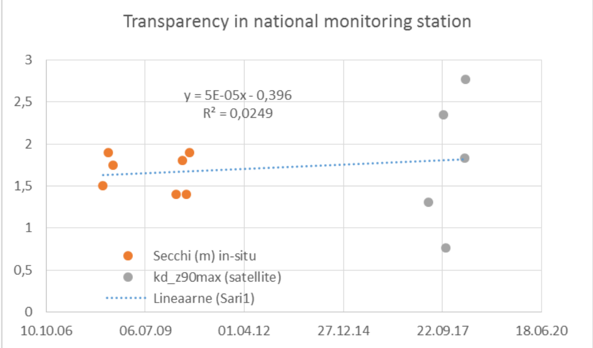


Figure 3.20. Transparency obtained from in-situ measurements and from Sentinel 2 data in national monitoring station

<u>Lake Köstrejärv</u>

The map of lake and location of national monitoring station is shown on Fig. 3.21. Lake Köstrejärv has been classified to VRD type II. For this water type the good water transparency is 2-3 meters (Table 3.1). The in –situ water transparency was measured 7 times between 2005 and 2012(Fig 2.22). In five cases in 2009 and 2012 the Secchi disk depth was not measured during field campaign because the water level was low and lake was transparent to the bottom in national monitoring station.

The evaluation of water transparency for Lake Köstrejärv from remote sensing data have very low reliability because the lake is small and with curved coastline. Also, in late summer large area of lake seems to be covered with macrophytes (Fig. 3.23) and in spring the lake water seems to be very green in color (Fig. 3.24). We could evaluate the water transparency from 6 images and it varied from 0.9-1.5 meters (Fig 3.22). Compared to previous in situ measurements there seems to be slightly decreasing trend of transparency (Fig 3.22).

Figure 3.21. Location of sampling stations from national monitoring programs

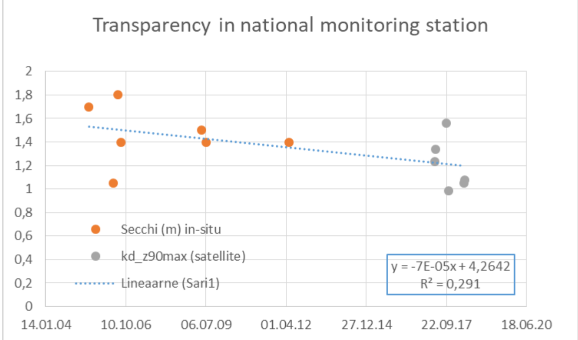


Figure 3.22. Transparency obtained from in-situ measurements and from Sentinel 2 data in national monitoring station

Figure 3.23. Sentinel 2 RGB image 30.04.2018

Figure 3.24. Sentinel 2 RGB image 30.08.2018. Macrophytes are shown with the blue cercle

4. Conclusions

Our aim in current study was prioritization of lakes for in-situ monitoring. We introduced analysis that is based on different operational monitoring to identify the man induced pressure to the lake catchment area such as clear-cuts and wastewater flow rate. To get the indication of possible lake water status change we analyzed water transparency from satellite data. Lake got high priority for in-situ monitoring if the in-induced pressure (clear-cuts or waste-water flow rate) had changed significantly and also transparency evaluated from the satellite data showed decreasing trend. Low priority for monitoring got lakes were we could not see any significant change. Priority was set as average when man-induced pressure had changed or water transparency observed from satellite had decreasing trend.

The results of the analysis is shown in Table 4.1. High priority for in situ monitoring got lakes Aheru and Köstrejärv in our analysis. Lake Aheru have had significant man induced pressure by clear-cuts in catchment area and also decrease in water transparency was observed from satellite data in 2017 (Table 4.1). Therefore the lake is high priority for in-situ monitoring. Inside the Lake Köstrejärv catchment basin noticeable clear-cats have performed and also the load of total phosphorus from the wastewater outlet locating in catchment basin have exceeded the concentration set in the water permit. Also, the slight decreasing trend of water transparency can be observed from satellite data. So, we consider the lake as high prority for in-situ monitoring.

Lakes Kirikumäe and Pabra have had low or zero impact from man induced pressure (Table 4.1) and the lake water transparency status was similar to previous in-situ measurements and have slightly increasing trend (also it was insignificant statistically) therefore we consider these lakes low priority and maybe wait of one more WFD cycle and then evaluate the status of these lakes again.

The lakes Hino, Murati, Pulli and Ähijärv are sited as average priority for in situ monitoring. (Table 4.1). In case of these lakes we could see slightly decreasing (although statistically insignificant) trend of transparency or significant man incused pressure (clear-cut) and therefore the lakes are assigned as average priority for monitoring.

The results of the analysis are shown in Table 4.1.

Lake name	**% of clear-cut 2013-2016**	**Pressure from wastewater outlets 2013-2016**	**Change of water transparency status class**			**Priority in –situ campaign**
			Transparency status class as evaluated from in situ campaigns before 2012	Transparency status class as evaluated from satellite data 2017-2018	Trend of transparency	
Aheru järv	**9,42**	No outlets	boor	bad	↓↓	**High**
Hino järv	**0,32**	No outlets	good	good	↓	**average**
Kirikumäe järv	**0**	No outlets	boor	boor	↑	**low**
Köstrejärv	**3,83**	P load out of limits set in water permit	moderate	moderate	↓	**High**
Murati järv	**4,24**	No outlets	moderate	moderate	↑	**average**
Pabra järv	**0,86**	Remote rainwater outlets- no pressure	boor	moderate	↑	**low**
Pullijärv	**0**	No outlets	moderate	moderate	↓	**average**
Ähijärv	**0,52**	No outlets	moderate/good	moderate	↓	**average**

We compared our priority list with the overall status evaluation results that had been performed in 2016-2017 in Koiva water district lakes. In Table 4.2 are shown the overall change of status class for lakes in Koiva water district.

Table 4.3. Overall status of lakes as evaluated from in-situ campaigns.

Lake name	Overall status before 2013	Overall status evaluated in 2016-2017	Change of status
Aheru järv	good	moderate	worse
Hino järv	good	moderate	same
Kirikumäe järv	moderate	moderate	same
Köstrejärv	moderate	moderate	worse
Murati järv	moderate	moderate	same
Pabra järv	good	moderate	same
Pullijärv	good	moderate	same
Ähijärv	good	moderate	worse

High priority for in situ monitoring got lakes Aheru and Köstrejärv in our analysis. From the Table 4.3 we can see that also in-situ evaluation showed the change of status class for worse.

There was no change in overall status class in case of Lakes Hinojärv, Kirukumäe järv, Murati järv, Pabra and Pullijärv. From those lakes Pabra and Kirikumäe assigned as low priority in our analysis. Hinojärv, Murati järv and Pullijärv assigned as average priority for monitoring.

The overall status evaluation in 2017 for Lake Ähijärv indicated that the state of Ähijärv seems to be changing for worse as the status of Ähijärv has been "moderate" for last two years. In our analysis we could see the decrease of water transparency also from satellite data but as the man – induced pressures (clear-cuts) were not significant the lake catchment area the lake assigned as average priority for field campaign.

The analysis of man-induced pressures (clear-cuts and waste-water outlets) and water quality parameters from satellite data indicated adequately to the changes in lakes and therefore the introduced analysis might help to plan the filed-campaigns in future.