Innovative monitoring of water quality for urban water systems and moorland pools

Advising Water Board Rivierenland on the use remote sensing technology for the monitoring of optical water quality parameters.

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Introduction

Water issues are since history one of the biggest issues in the Netherlands. Nowadays, the problems are not only related to water quantity and flooding but also to water quality, both in urban and natural areas. Municipalities and nature organizations in the river area are advised by Water Board Rivierenland and consultancy bureau KnowH2O about the water quality of small scale waterbodies. The current methods of monitoring lakes and rivers are limited to field measurements with the use of some ground instruments, such as Secchi disks, probes, nets, gauges and measurement tapes. Because these field measurements are time consuming and costly, and usually aim at point-scale information, the commissioners are inquiring a detailed inventory of available remote sensing tools to obtain water quality data. Therefore, and also due to the increasing advancement on the remote sensing domain, they are interested if innovative monitoring techniques could be adopted in the near future.

Objectives

- Making an inventory of possible spaceborne, airborne and field remote sensing techniques, that could be used for monitoring water systems on water quality and their respective costs.
- Perform a feasibility study and assess the usability and quality of different remote sensing techniques.
- Formulate a recommendation for the Water Board on how to use RS technology for monitoring water quality parameters of small fresh water bodies, based on the added value of spatially distributed information on water quality as observed from space or air.

Inventory Table

Overview of RS techniques, their properties and the feasibility for detecting quality parameters.

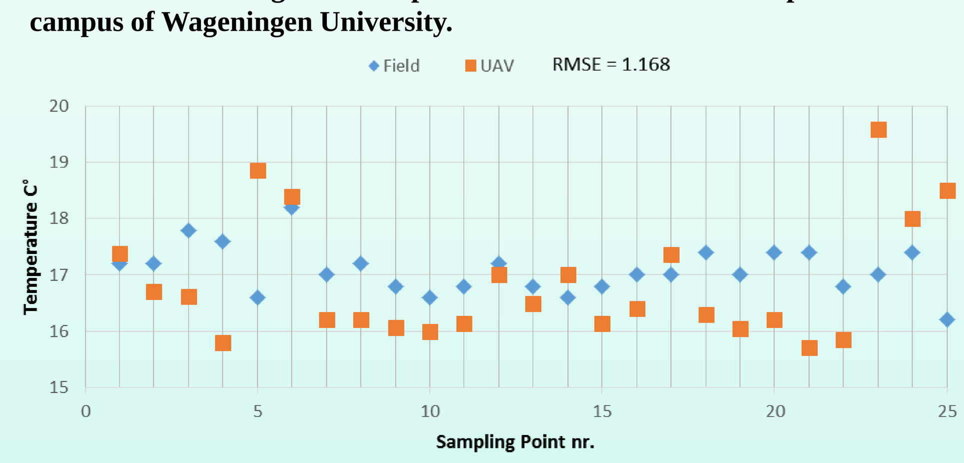
Legend: Possible to derive (green) / Possible, with drawback (orange) / Not possible to derive (red)

	Sensor Type	Spatial resolution / at height	Minimum water body size	Chlorophyll a	Total suspended	Absorption coefficient	Secchi depth	Vegetation Cover	Temperature	Maximum Measurements / year	Price
Spaceborne											
Landsat 8[1]	Multi-Spectral	30m / 705km	$8100m^2$	Possible to derive	Possible to derive	Not possible to derive	Possible to derive	Possible to derive	Possible, with drawback	22	-
Landsat 7[1]	Multi-Spectral	30m / 705km	$8100m^2$	Possible to derive	Possible to derive	Not possible to derive	Possible to derive	Possible to derive	Possible, with drawback	22	-
Spot 7[2]	Multi-Spectral	6m/ 694km	$324m^2$	Possible to derive	Possible to derive	Not possible to derive	Possible to derive	Possible to derive	Not possible to derive	12	-[a]
Spot 6[2]	Multi-Spectral	6m/ 694km	$324m^2$	Possible to derive	Possible to derive	Not possible to derive	Possible to derive	Possible to derive	Not possible to derive	12	-[a]
UK DMC-2[3/4]	Multi-Spectral	22m / 666km	$4356\ m^2$	Possible to derive	Not possible to derive	Not possible to derive	Not possible to derive	Possible to derive	Not possible to derive	156	-[a]
RapidEye[5]	Multi-Spectral	6.5m / 630km	$380\ m^2$	Possible to derive	Possible to derive	Not possible to derive	Possible to derive	Possible to derive	Not possible to derive	365	€500 ($500km^2$)
Airborne											
Aisa Eagle[6]	Hyper-Spectral	0.52m / 1000m	$2.4m^2$	Possible to derive	Possible to derive	Possible, with drawback	Possible to derive	Possible to derive	Not possible to derive	Unlimited	Unknown
Aisa FENIX[7]	Hyper-Spectral	1.0m / 660m	$9\ m^2$	Possible to derive	Possible to derive	Possible, with drawback	Possible to derive	Possible to derive	Not possible to derive	Unlimited	Unknown
Aisa Owl[8]	Hyper-Spectral	1.1m / 1000m	$10.9m^2$	Not possible to derive	Not possible to derive	Possible, with drawback	Not possible to derive	Not possible to derive	Possible to derive	Unlimited	Unknown
Rikola[9]	Hyper-Spectral	0.065m / 100m	$0.38m^2$	Possible to derive	Possible to derive	Possible, with drawback	Possible to derive	Possible to derive	Not possible to derive	Unlimited	€40 000 (sensor)
OCI-UAV-1000[10]	Hyper-Spectral	/ 100m		Possible to derive	Possible to derive	Possible, with drawback	Possible to derive	Possible to derive	Not possible to derive	Unlimited	€12 000 (sensor)
OCI-UAV-2000[10]	Hyper-Spectral	/ 100m		Possible to derive	Possible to derive	Possible, with drawback	Possible to derive	Possible to derive	Not possible to derive	Unlimited	€12 000 (sensor)
Ground											
WISP-3[11]	Hyper-Spectral	0.05m / 1m	$0.00225m^2$	Possible to derive	Possible to derive	Possible to derive	Possible to derive	Not possible to derive	Not possible to derive	Unlimited	€20 000 (sensor)
ASD Fieldspec[11]	Hyper-Spectral	0.5m / 1m	$0.225m^2$	Possible to derive	Possible to derive	Possible to derive	Possible to derive	Not possible to derive	Not possible to derive	Unlimited	€10 000 (sensor)
TriOs Ramses[11]	Hyper-Spectral	0.123m / 1m	$0.14m^2$	Possible to derive	Possible to derive	Possible to derive	Possible to derive	Not possible to derive	Not possible to derive	Unlimited	€30 000 (sensor)
TACCS[11]	Multi-Spectral	-	-	Possible to derive	Possible to derive	Possible to derive	Possible to derive	Not possible to derive	Not possible to derive	Unlimited	€20 000 (sensor)
VOLTCRAFT IR 1000-30D[12]	Thermal	0.03m / 1m	$0.008m^2$	Not possible to derive	Not possible to derive	Not possible to derive	Not possible to derive	Not possible to derive	Possible to derive	Unlimited	€200 (sensor)

This table is showing the specifications of each Remote Sensing Instrument and their applicability for monitoring water quality parameters.

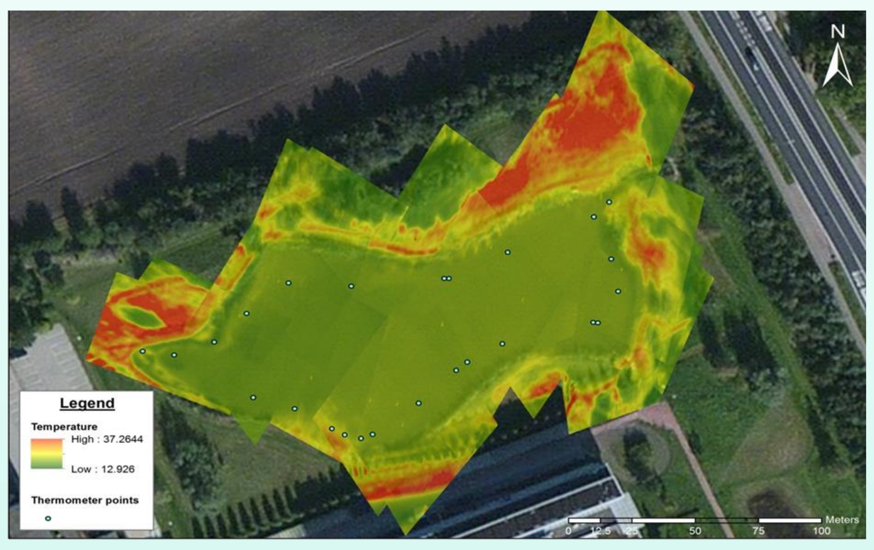
Airborne

Airborne remote sensing techniques using airplanes and unmanned aerial vehicles (UAVs) is a very innovative, versatile and flexible way of monitoring water bodies. To test the potential of airborne instruments we performed UAV flights in order to determine the quality of the findings. We tested a hyperspectral and a thermal camera mounted on a UAV. The flights were performed above the GAIA pond at the campus of Wageningen University.



The above graph depicts the difference between a field thermometer and the thermal camera mounted on a UAV at the same sampling points.

Temperature map derived from the UAV flight at the GAIA pond.



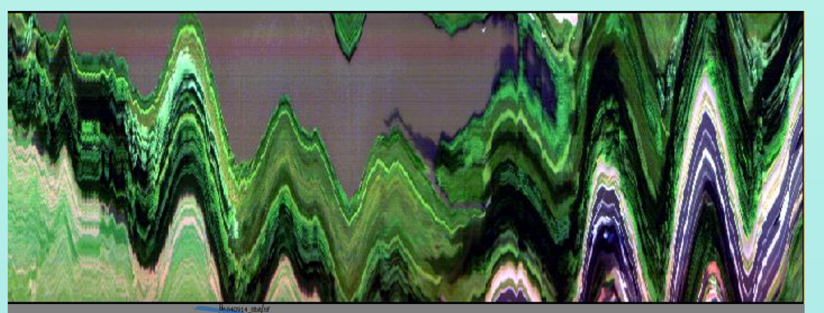
The mosaicking of the thermal images show the spatial temperature variation of the water body. This information is useful for indicating sources of algae blooms which affect water quality.

Pros/Cons of airborne remote sensing

+ Different sensors possible and thus able to derive all and more parameters
+ Thermal images possible
+ Full control over spatial, temporal and spectral resolution

- Needs favourable weather
- Geo- / Ortho-rectification is labour intensive for water surfaces
- Needs a trained pilot and co-pilot
- Flight regulations

The images below depict the challenges of pre-processing the data.



Spaceborne

Satellites are very suitable for monitoring purposes. There are however some challenges to overcome when using satellite imagery for deriving quality parameters, especially for small fresh water bodies. We have compared SPOT 6 imagery with ground sensors in order to test the feasibility of using spaceborne imagery for deriving water quality parameters.

Pros/Cons of Spaceborne Remote Sensing techniques

+ Most water quality parameters can be derived
+ A lot of free data available
+ Monthly image
+ Contracts with the government
+ No fieldwork required

- Coarse spatial resolution
- Atmospheric correction is labour intensive
- Temporal resolution dependent on clouds
- Thermal data is not feasible for small fresh water bodies

This map shows the mixed pixels (water-land) of SPOT 6 imagery of the GAIA pond.

1: Cloud/haze effect
2: Unusable mixed pixels
3: Pure water pixels

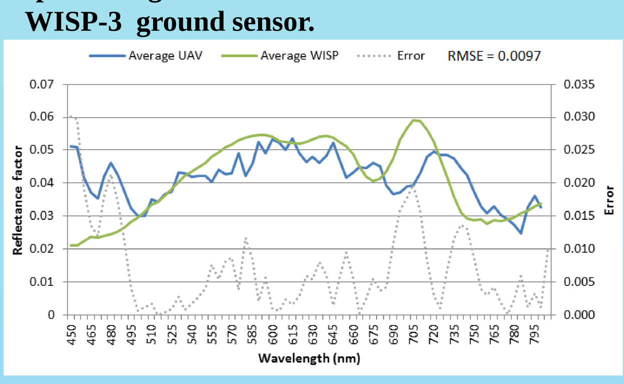
Base layer:
RGB mosaic obtained from UAV flight

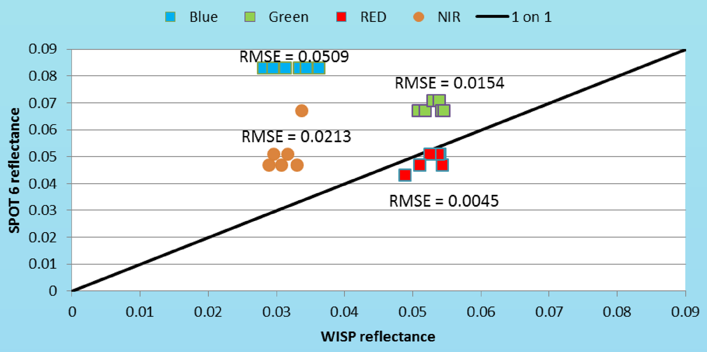
Top layer:
SPOT 6 false colour

Ground

Ground sensors can measure reflectance with a very high spatial, spectral and temporal resolution. They are really flexible due to the small size and the easy way of operating. Their measurements are not affected by the atmosphere like is the case with satellite and airborne sensors. Moreover, ground sensors can be used in less favourable weather conditions, like small cover which would obscure satellite imagery.

This graph shows the difference of the water spectral signature between the UAV and the WISP-3 ground sensor.





SPOT 6 image reflectance, plotted against the WISP-3 simulated reflectance.

This scatterplot shows a big difference especially in the blue band. This is happening because the SPOT-6 image that we acquired was not atmospherically corrected. This adds to the of spaceborne instruments that is mentioned above.

Pros/Cons of Ground sensors

+Easy parameter extraction
+Usable in most weather conditions
+Usable when needed

-Point based measurements
-Labour intensive to sample

Discussion

In our research we tried to find the Remote Sensing techniques that could be used for water quality monitoring. Our approach was to review the relevant literature and also to test and validate the instruments that were available to us. (WISP-3, Laser thermometer, SPOT-6 imagery, UAV with thermal and hyperspectral camera). To come up with our final recommendations we took into consideration the economical, the accuracy and the difficulty aspect or to form it in one word, the feasibility of each method.

What we have concluded is that the UAVs combined with ground measurements are a feasible option for the future but not for now. The flight regulations are strict and the UAVs are still facing technical and practical issues. However, the future is not so far away. The UAV technology is improving fast and UAVs with dedicated water quality sensors are been developing. What we can be sure about is that the Drones are going to play a big role in the next years. Not only in Science but also in our lives.

Recommendations

Now

Our proposed monitoring system with current technologies is the use of the WISP-3 ground remote sensor to derive the total suspended matter and chlorophyll-a without the need of processing. aCDOM and turbidity can be derived after the data is processed by Water Insight. In order to counter the lack of a built-in thermometer in the WISP-3, we recommend the use of a handheld laser thermometer which will complete the WISP-3 sensor. Furthermore a GNSS should be used in order to spatially reference the sampling points. The GNSS points are essential in order to construct difference and variability maps through interpolation. SPOT-6 satellite imagery can be used as an auxiliary input for interpolating the ground points by deriving total suspended matter, turbidity, chlorophyll-a and surface area covered by vegetation. In this way spatial variability maps can be derived. SPOT-6 images can be downloaded from the Dutch Space Agency portal and pre-processing can be done by Water Insight. In table 5 the cost and feasibility level of each remote sensing technique can be found. These levels take into consideration the available technology, the costs, the regulations and also the difficulty levels.

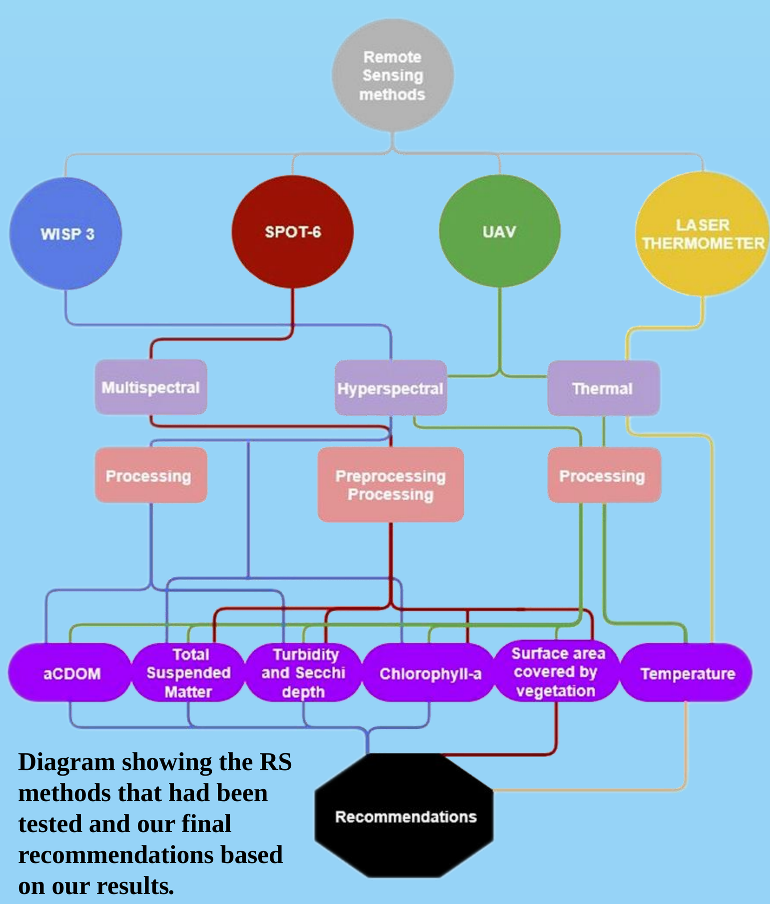


Diagram showing the RS methods that had been tested and our final recommendations based on our results.

Future

As remote sensing techniques are improving rapidly we believe that the developed technology will help to add new methods for water quality monitoring in the near future. Furthermore, there will be more integrated ground sensors, cancelling the need of using different ground remote sensors. An example of such fully integrated ground remote sensing device is the WISP-4. It will contain a thermometer and GNSS receiver which will make it more complete than its predecessor (WISP-3).

Furthermore regulations for UAV flights will change, permitting flights closer to urban areas and at higher altitudes. Also, the battery capacity and aerodynamics will improve, allowing for longer safe flying times. The payload capacity of UAVs will also improve, allowing for better sensors that are more sensitive for water surfaces. Lastly techniques will be developed to make rectifying and geo-referencing of water surfaces more easy.

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