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On the generalization of image-based river turbidity monitoring under different hydrological conditions

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ABSTRACT

Digital cameras could provide significant advantages to existing river monitoring techniques, enhancing the temporal and spatial resolution of observations. In this work, an image processing procedure for estimating river turbidity was tested in a real-scale experiment carried out in Germany, along the Selke River, within the Bode catchment, instrumented and managed by the Helmholtz Centre for Environmental Research (UFZ), Germany. The field campaign was conducted using different tracers, camera models and installation settings to understand the full potential of the camera systems in operational water quality monitoring. The gathered data were compared to the measurements of the turbidimeters installed in the river cross-section. The results prove that this procedure can properly represent the water turbidity trends employing an RGB camera in a real case study under natural conditions. Nevertheless, further investigations are necessary to select the best camera setup and to detect the most fitting spectral indexes for a reliable long-term image-based river turbidity monitoring system.

1. Introduction

Turbidity is a key optical property of water. High turbidity values can be a proxy for the presence of suspended organic and inorganic matter in rivers. The on-site experiment of June 2023, represented in Figure 1, aimed to change, within the river, both the duration and intensity of three synthetic turbidity events, generated by adding different natural clay tracers, as suspended solids with varying reflectance properties. The main objective of this field campaign was to generalize, as much as possible, the camera monitoring methodology recreating many real river pollution events, also for minimizing the long-term effects on lighting and hydrological conditions of the experimental site, better described in Miglino et al. 2022.

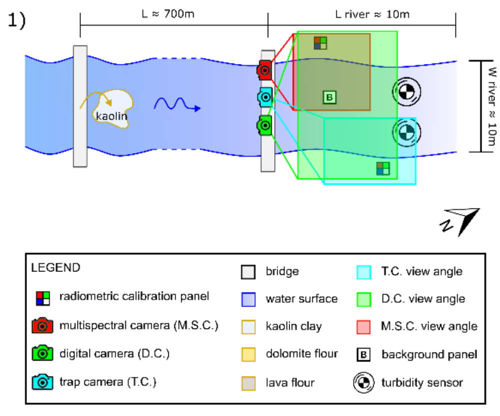

Figure 1. Plan of the monitored river section during the experiment of 30/06/2023, showing the generated synthetic turbidity events, using three different natural clay tracers: kaolin (**1**), dolomite (**2**) and lava (**3**) flours.

2. Methods

During the experiment, three different cameras were installed on the bridge: one trap camera, Ceyomour CY50, with a frame rate of 15 seconds; another multispectral camera (MSC), Tetracam ADC Snap, with a frame rate of 2 seconds; a third camera, Nikon Coolpix P950, with a frame rate of 6 seconds. At the same time, the turbidimeter was installed on-site and had a frame rate of 2 seconds. The results were homogenized, considering all the sensors and camera measurements recorded simultaneously. River flow velocity was around 0.3 meters per second and the water depth was approximately 25 centimeters, while the clay tracers was poured far enough from the monitoring cross-section, to ensure the complete mixing between clay and water. The generated turbidity events allowed us to explore the image-based procedure potential by varying water optical characteristics and suspended solids concentration, simulating the real river conditions.

3. Results and discussion

As shown in some preliminary results in Figure 2, there is a good matching between camera bands reflectance and measured turbidity, especially considering the RED band, for all three turbidity peaks.

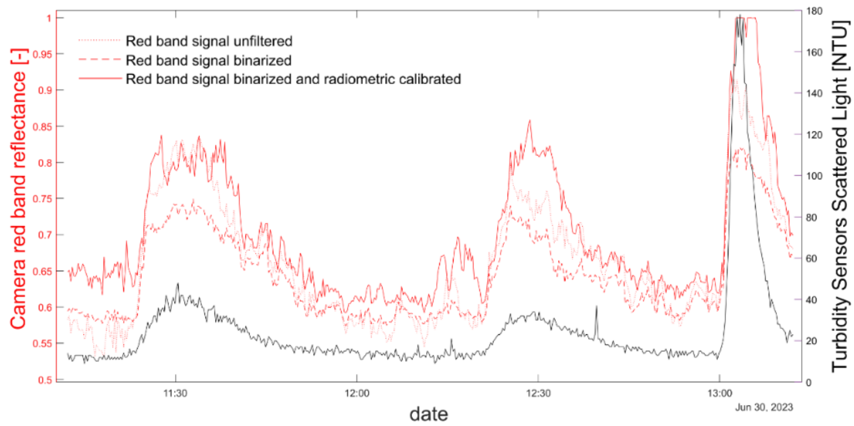

Figure 2. Comparison between the reflectance of the trap camera red band and the turbidity measurements of the sensor installed on site, during the short-term experiment of 30/06/2023.

Besides, it is essential to consider the issue of background reflectance, particularly in shallow waters, as those of the experiment, to fully understand the range of applications of the procedure. The removal of the background component from the total water-leaving reflectance can lead to a better estimate of the real water turbidity level. Finally, for single short-term monitoring (hours) the RED band reflectance seems to be the most reliable index for turbidity monitoring, better than spectral indexes (Table 1) coming from existing bands ratios in literature (e.g., R/G, NDTI, NDWI, etc.).

Table 1. Spectral indexes, used to compare camera bands reflectance and turbidity measurements, and their R^2 values of coefficients of determination, considering trap camera and multispectral (MS) camera results.

	M.S. CAMERA	TRAP CAMERA
SPECTRAL INDEX	R^2	R^2
RED BAND	0.93	0.87
GREEN BAND	0.68	0.83
NDTI	0.48	0.59
NDWI	0.41	

On the other hand, considering long-term monitoring (days, months), the single bands reflectance tends to be more influenced by different light and flow conditions, which is even more true using low quality cameras. Hence, it is better to use indexes and multiple bands in this case.

4. Conclusions

In conclusion, it is necessary to find the best spectral indexes to properly detect the water turbidity variations for changing light conditions and river flow characteristics, while factoring different camera capabilities. As future research directions, additional experiments will test the method under different hydrological and environmental conditions. The final goal of this work is to provide a new monitoring solution for inland water security and water resources management practices.

References

Miglino, D., Jomaa, S., Rode, M., Isgro, F., & Manfreda, S. (2022) Monitoring Water Turbidity Using Remote Sensing Techniques, Environmental Sciences Proceedings, 21(1), 63.