Efficient vegetation management through remote sensing in small streams

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Introduction

Vegetation development can be a challenge for managers that aspire to decrease mowing intensity as a 'building-with-nature' measure. Particularly in unshaded low gradient streams with nutrient rich water aquatic plants can completely and very rapidly clog the stream channel, severely hindering its drainage function and increasing the risk of flooding the adjacent lands. For this reason, the instream vegetation is mowed frequently using crane or boat operated mowing-baskets. While seemingly an effective way to solve the problem, mowing is both expensive and has a considerable impact on the stream ecosystem.
Instead of waging a costly war on vegetation, our aim is to only selectively remove the vegetation that is most problematic in terms of flood risk. To reach this goal, we need to be able to (i) detect the spatial distribution of vegetation and (ii) assess the hydraulic impact of that vegetation. Progress in both fields has been made in previous small-scale pilot studies (Penning et al., 2018; Van den Eertwegh et al., 2017). In this paper, we report the findings of a larger scale study in the Leijgraaf stream, managed by regional water authority *Waterschap Aa en Maas*.

Spatial distribution of vegetation

The most common method to determine vegetation patches from remote sensing is multispectral analysis. In contrast to our eyes, and most commercial cameras, multi- or hyperspectral cameras capture not only the visible spectrum (wavelengths of 380nm – 750nm), but also near infrared (NIR, 750-1400 nm) and infrared (> 1400 nm). This allows us to detect things that the eye cannot by combining several wavelengths from both the visual spectrum, as well as the (near) infrared spectra.

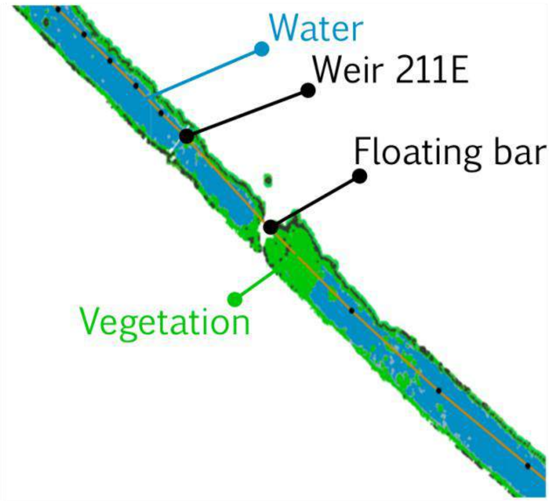

Figure 1. Vegetation (green) detected through multispectral analysis up- and downstream of weir 211E in the Leijgraaf stream.

Unfortunately, the resolution of multispectral free satellite imagery is currently not high enough to detect vegetation in small streams. To obtain these images for small stream stretches, a multispectral camera can be attached to a drone. However, a drone-based approach does not easily scale up to entire streams. Therefore, in this study we used an airplane to obtain the images for the entire 20 km of the Leijgraaf stream with a resolution of 0.25 m.
We use a combination of spectral indices like the Normalized Vegetation Density Index (NDVI) and the Normalized Difference Water Index (NDWI), to differentiate water, trees and aquatic vegetation in various stages of submergence. In general, results suggest a high level of non-uniformity along the stream: aquatic vegetation has a very patchy distribution. A close-up near one of the weirs (211E) in the Leijgraaf system shows that there is a concentration of vegetation just upstream of the weir (Figure 1). This might be explained by mowing activities; after mowing vegetation is often left to drift downstream and to be collected at a floating bar at the downstream end.

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To improve and validate the classification of the vegetation from spectral imagery, in-situ measurements of the vegetation were taken. For structurally homogenous patches of the dominant aquatic plant species present, stem density, submerged and emergent biomass were determined. These analyses are still ongoing.

Hydraulic impact of vegetation

The hydraulic impact of vegetation on flow is superficially easy to understand: vegetation increases flow resistance and will increase water levels. However, it is not straightforward to determine to what extent the vegetation increases roughness. The contribution of artificial vegetation (e.g. rigid cylinders) to roughness is reasonably well understood and adequately modelled by various (semi-empirical) formulas. However, there are severe technical challenges for predictive use of those models in the field. These include unknown plant composition, plant species specific traits, spatial non-uniformity, dynamic reconfiguration, seasonal variability and the effect of human-induced changes (i.e. mowing).

Therefore, we used an inverse, data-based approach. Based on fifteen years of hydraulic data, we computed the Manning's roughness coefficient with a 1D-hydrodynamic model for every other day. This resulted in a high-resolution dataset for multiple sections along the Leijgraaf stream. Results show two main factors explaining the roughness in the system. First, the Manning coefficient is highly dependent on discharge (Figure 2), which is in line with the general conception that vegetation dynamically reconfigures depending on the flow velocity in the system. The second explaining factor is seasonal variability. Even after accounting for discharge dependency (discharge tends to be lower in summer) roughness values were significantly higher in summer compared to winter, which suggest vegetation growth. Surprisingly, human-induced events (i.e. mowing) did not seem to be a major explanatory variable. We have two hypotheses which might explain the latter. First, it could have been caused by a time lag between the mowing event and the removal of vegetation biomass from the system, which complicates attribution of an effect on roughness to a specific event. Second, not all (local) mowing events will be effective for decreasing the impact that the vegetation has on the overall roughness in the entire stream section.

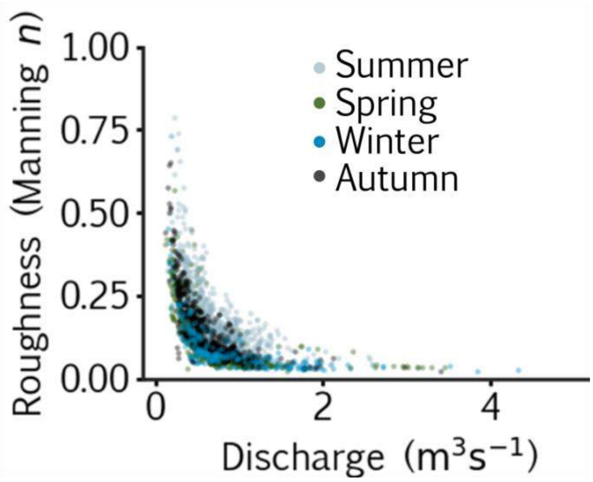

Figure 2. Result show that roughness has a high dependency on discharge.

Conclusion and future work

In order to be able to selectively remove vegetation, we need to detect the vegetation and we need to assess what effect removal will have on management goals. The results of this study contribute to both of these goals. Future work focusses on automation, generalisation and upscaling the temporal resolution of remote imagery, and to create a practical predictive system for vegetation management guided by remote sensing of the spatial distribution of vegetation within the stream.

Acknowledgement

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