Digital image analysis for studying eco-hydraulic processes in open channels

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Abstract

The long-distance dispersal of weeds through open water channels has been poorly studied despite its primary importance for understanding weed spread in agro-ecosystems and its negative impacts on crop production. We proposed here an experimental study focusing on the quantification of external factors affecting the seed dispersal kernel during an irrigation event in a vegetated channel. We chose Johnsongrass seeds, one the most widespread weeds in the world that affects production of high-quality hay in permanent grasslands. We used a photogrammetric approach combined to differential GPS surveys to finely estimate the external factors susceptible to affect seed dispersal, either biotic or abiotic. We used fluorescent powders to efficiently detect the seeds after a dispersal event using UV lights.

1. Introduction

Hydrochorous dispersal is a fundamental process affecting weed spread in agro-ecosystems (Johansson et al., 1996). For many species living next to open channels, such as irrigation channels or surface drainage ditches, water is a major vector of transport (Soomers et al., 2010), and this can occur for both hydrochorous and non-hydrochorous species. The Johnson grass (*Sorghum halepense*) is one of the weeds commonly found in open-channels, especially in Mediterranean areas. The plant can disperse by both rhizomes and seeds but its hydrochorous dispersal mechanism is still poorly understood.

Experimental assessment of seed dispersal can be studied using three main methods: the tracking, the trapping and the re-locating. The latter method is the best method for water ecosystem but it necessitates a relocation accuracy sufficient to detect small seeds such as those of Johnsongrass. To that end, we tested a method initially developped by Tekiela & Barney (2013) based on fluorescent powders sensitive to UV lights.

The external factors affecting seed dispersal in open channels, either biotic or abiotic, are related to water flow. Abiotic factors referred to the channel morphology, micro-topography and indentation. Biotic factors gathered the amounts of living or dead vegetation inside the channel. It is important to measure accurately the biotic and abiotic properties of open channels to link fine-scale factors to seed dispersal.

Amongsts the sampling methods for measuring fine-scale topography of open channels, the Structure-From-Motion combined to Multi-View Stereo (SfM-MVS) method is promising but has never been tested in the complex environment formed by a ditch. It consists in taking images from multiple points of view and reconstructing the 3D point cloud of the scene using digital image matching.

The study presents preliminary results on characterisation of seed deposition kernel and their external factors. It uses an innovative method involving seed relocating and SfM-MVS approach for reconstruction of channel properties.

2. Material and methods

The study site is based on the Crau plain (France), an agricultural area devoted to high-quality hay production in permanent grasslands. The zone is irrigated through a channel network, the water being conveyed across successive channels that border the grassland plots. For the experiment, the irrigation water was released in the channel of length 400 meters using the upstream valve. The flow became steady after approximately 20 min, and the upstream valve was closed after 50 min. Seeds of Johnsongrass were coated using Ultraviolet Ultrabright Fluorescing Powders. As the buoyant properties of the seed greatly influence its dispersal behaviour, we splited the samples according to their buoyant/non buoyant behaviour. A mix of buoyant (green colour) and non buoyant (blue colour) seeds were released before opening the upstream valve, and a mix of buoyant/non buoyant seeds (red color) during the steady flow. All seeds were released 30 meters after the upstream valve. We also measured the water level every 5 meters during the steady flow.

After stopping the upstream valve and waiting for the drainage time, we took a series of photos along the channel to detect the coated seeds. A fluorescent wooden frame was used to delimit a surface for counting the deposited seeds. The photos were taken every meter until 60 meters after the upstream valve, then every 5 meters until the end of the channel. The following day, an extensive survey of the channel topography was realized with a camera to realize a fine-scale Digital Surface Model (DSM) and its corresponding orthophoto in red, green, blue channels (RGB). The DSM and RGB numeric models were

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constructed using SfM-MVS method. Then external factors relating to channel topography and its embedded vegetation cover were calculated from both DTM and RGB models.

3. Results and discussion

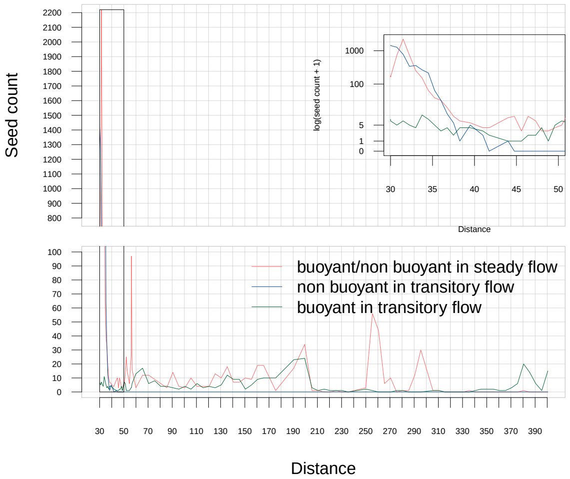

Figure 1: Plot of the seed counting against upstream channel distance

Considering shapes of dispersal kernels of seeds, the maximal peaks of re-location were situated between 0 and 10 meters after the release point, especially for non buoyant seeds, i.e. the seeds coated in blue and the non buoyant seeds coated in red (Figure 1). We observed also a very different behaviour according to the buoyant properties of the seeds regarding their dispersal kernels in transitory flow, as expressed by blue and green lines on the graph. As seeds released in steady flow gathered a mix of buoyant and non buoyant particles, we could suppose that the first peak of the red line corresponded to the non buoyant seeds and the following peaks to the buoyant seeds. We observed a significant part of relocated seeds at the end of the channel, i.e. more than 300 meters after the release, revealing the long distance dispersal of the Johnsongrass seeds in irrigation channels (Figure 1).

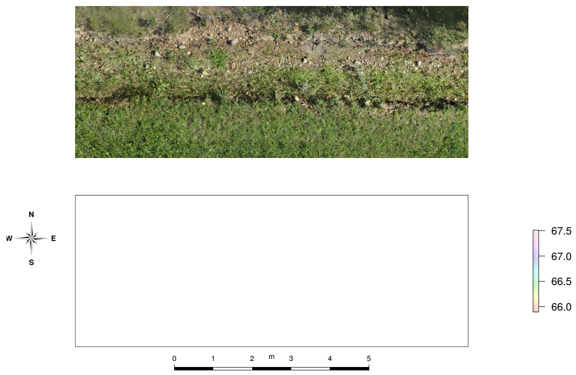

Figure 2: Illustration of the RGB and the DSM at 1 cm resolution using SfM-MVS approach

Regarding the numerical models issued from the SfM-MVS method, both vegetation height and density could be estimated in the channel (Figure 2). Shape of hydraulic structures could also be estimated finely, and micro-topography of the channel bottom.

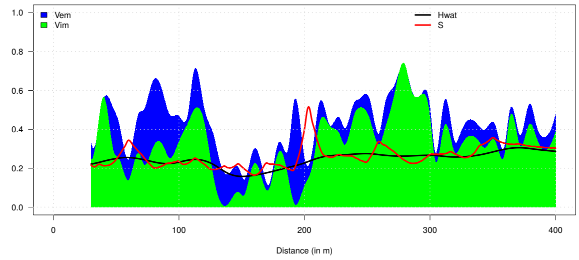

Figure 3: Plot of the explaining variables sampled across the channel section

The variables derived from the SFM-MVS method and from the measures of water level are presented in Figure 3. They exhibited large variations across the channel, with an significant evolution of the percentages of vegetation cover above the level of the water level (*Hwat*), noted *Vem* and below the level of the water,noted *Vim*. The section *S* of the channel exhibited variations, in particular at the position of hydraulic structures.

4. Conclusion

The preliminary experiment presented here constituted the first step for a thorough knowledge of hydrochorous dispersal in open channels. It implies innovative methods that are non intrusive and could be supported in experimental studies needing repetitions. A perspective of this work would be to link seed dispersal kernels to the external factors highlighted in the study using adapted statistical tools, such as partitioning trees and 1D spatial kriging.

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