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Calibration of Flow Resistance Models in Vegetated Ditches Based on UAV Remote Sensing †

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Abstract: Vegetation has a paramount impact on water flow resistance and water quality in vegetated open channels. Defining the most appropriate management practice of riparian vegetation inside both natural and manmade water bodies is crucial for assuring a high environmental value of water resources. The presence of riparian vegetation significantly affects water fluid dynamic fields, with important implications on oxygen production and transport of nutrients within vegetated open channels. Experimental analysis and modeling were performed in the present study, aiming at providing an additional understanding of the hydrodynamic interaction between riparian vegetation and water flow at field scale in an Italian ditch vegetated by rigid and emergent riparian plants. The calibration of predictive models of flow resistance in vegetated water bodies was performed by using Unmanned Aerial Vehicle (UAV)-multispectral acquired images, from which it was feasible to cover the whole water bodies and to correlate ground-based and UAV-derived Leaf Area Index (LAI) estimations. The outcomes of this study represent a useful tool when dealing with riparian vegetation management at different temporal and spatial scales in both agricultural and urban scenarios.

Keywords: Ecohydraulics; riparian vegetation; LAI; scanning; UAV; modeling

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1. Introduction

Riparian plants, and in general riparian areas, embody the physical and biological borders between vegetated water bodies and surrounding ground [1,2]. The hydraulic dynamics of both manmade and natural vegetated channels is largely dependent on the riparian vegetation structure and architecture, which affect its main bio-mechanical and morphometric features [3–5]. In the field, these features can be retrieved from other parameters as Leaf Area Index (LAI), representing a good predictor of riparian vegetation canopy and distribution. The recent technological improvements connected to 3D scanning are considered by forestry and hydraulic engineers as a very useful tool for easily retrieving LAI of vegetated channels. The accuracy of this method in retrieving LAI of extremely rigid riparian plants was compared to those derived by HD digital photography associated with Unmanned Aerial Vehicles (UAV). This is a starting research point in the calibration of vegetative flow resistance formulas for predicting the main hydraulic features of vegetated channels covered by very rigid riparian plants [6,7].

In Figure 1 is reported the Ecohydraulic classification of riparian plants: emergent, floating, and submerged riparian vegetation.

Figure 1. Ecohydraulic classification of riparian plants in vegetated flows. (1) Emergent, (2) Floating, and (3) Submerged, respectively occurring when plants develop above, on, and below the water level inside the vegetated channel.

2. Methods

Thirty very rigid riparian plants were monitored to compute LAI through 3D scanning (gaming type) and UAV photos. Figure 2a,b display frontal and above 3D scanning of the examined riparian plants. Each scan was then processed through a freeware image processing software [8] to calculate LAI from 3D point clouds of the examined riparian plants.

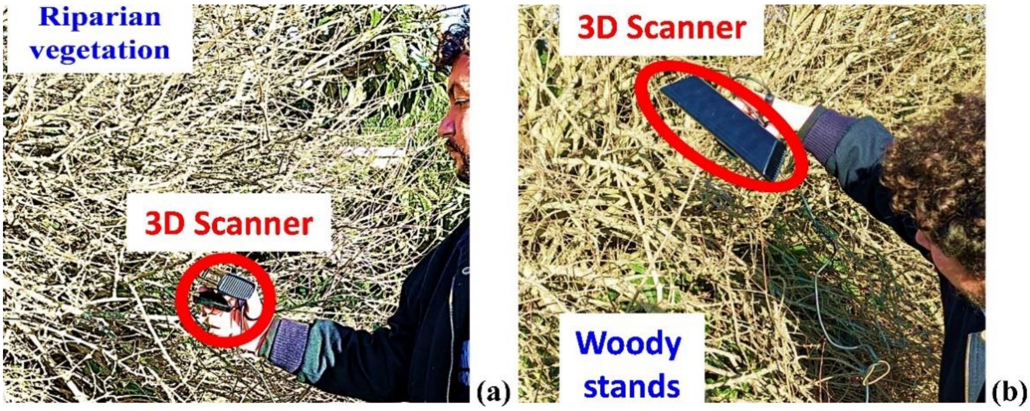

Figure 2. Examples of 3D scans associated with rigid riparian vegetation covering vegetated drainage channels: (**a**) Frontal and (**b**) Above scans of vegetation canopy and stems. The red ellipse indicates the 3D scan sensors.

The riparian vegetation was then monitored by means of UAV acquisitions. In detail, the UAV-based LAI were retrieved from the acquired HD multispectral photos as described in many ecohydraulic studies [8,9] to be then employed in the calibration of vegetative flow resistance models of real vegetated water flows.

In Figure 3 is shown an example of the UAV device employed in the present study. After a step of radiative calibration to the environment sunlight of the multispectral camera employed here, the riparian plants' stems and canopies were then monitored to obtain LAI via raster-algebra digital processing.

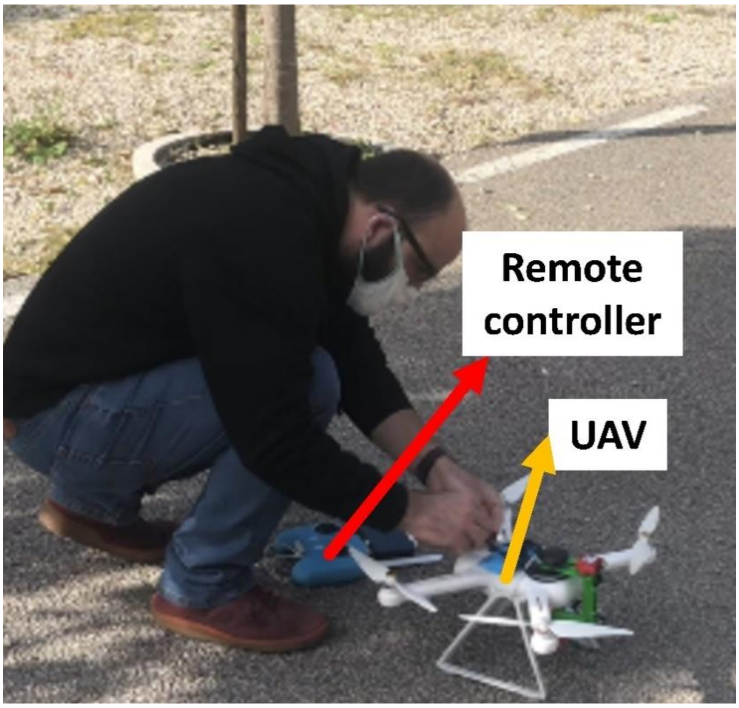

Figure 3. View of UAV used in this work. The yellow and the red arrows indicate the UAV device equipped with a multispectral camera and the remote controller, respectively.

3. Results and Discussion

Figure 4 reports the point clouds resulting from the 3D scanning of one of the thirty riparian plants examined in this study. The LAI retrieved from the points represents support for modeling the hydraulic behaviour of real vegetated open channels, as described in previous researches and reviews on both experimental and modeling Ecohydraulics [9,10].

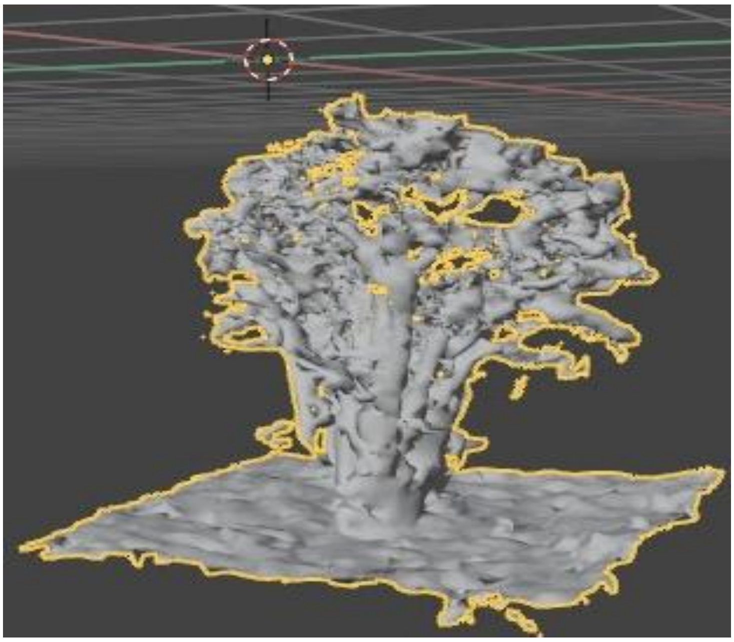

Figure 4. Example of 3D point cloud associated with one of the thirty riparian vegetation plants analyzed here.

LAI retrieved from 3D scan processing (hereinafter indicated as LAI_S) were then compared to those retrieved from the digital processing of UAV-based HD images (hereinafter indicated as LAI_U) to find out a simple linear law between the examined parameters. In Table 1 are reported the LAI_S and LAI_U values corresponding to the thirty riparian plants monitored in this study case.

Table 1. LAI_S and LAI_U values corresponding to the thirty riparian plants.

LAI_S	LAI_U
3.20	3.14
3.07	3.12
2.50	3.00
2.76	2.81
3.10	3.21
3.21	3.25
3.32	3.51
3.45	3.33
3.63	3.71
3.51	3.44
3.27	3.29
3.28	3.34
3.43	3.28
3.51	3.63
3.41	3.45
3.50	3.48
3.40	3.51
3.46	3.55
3.53	3.46
3.42	3.48
3.38	3.41
3.43	3.53
3.39	3.44
3.36	3.29
3.41	3.37

The linear law observed between the previous values can be expressed as follows:

$$LAI_U = 0.70 \times LAI_S + 1.05. \tag{1}$$

A good correlation was identified by comparing LAI_S to LAI_U, testified by a coefficient of determination $R^2 = 0.75$.

This primary result is extremely interesting for further Ecohydraulic studies dealing with the prediction and the analysis of both mean and turbulent hydrodynamic features of vegetated water streams [11,12], since it allows to mimic and reproduce the actual morphometry of riparian vegetation to be employed in both flume laboratory and field scale experiments by considering many different riparian species.

4. Conclusions

It can be stated that UAV-based LAI can be considered as a good predictor of those obtained from 3D scan processing of hardly rigid riparian vegetation. This is a very promising outcome, to be taken into account in future researches on experimental and modeling Ecohydraulics.

An improvement to this study can be obtained by coupling together machine learning techniques for the indirect assessment of riparian vegetation traits to the methodology proposed in the present work, as indicated in previous studies dealing with hydrological and vegetational predictions of water resources availability based on the propagation of the uncertainty of rainfall and morphometric parameters [13,14].

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References

1. Lama, G.F.C.; Chirico, G.B. Effects of reed beds management on the hydrodynamic behaviour of vegetated open channels. In Proceedings of the 2020 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor), Trento, Italy, 4–6 November 2020; pp. 149–154, doi:10.1109/MetroAgriFor50201.2020.9277622.
2. Errico, A.; Lama, G.F.C.; Francalanci, S.; Chirico, G.B.; Solari, L.; Preti, F. Flow dynamics and turbulence patterns in a reclamation channel colonized by *Phragmites australis* (common reed) under different scenarios of vegetation management. *Ecol. Eng.* **2019**, *133*, 39–52, doi:10.1016/j.ecoleng.2019.04.016.
3. Tinoco, R.O.; San Juan, J.E.; Mullarney, C. Simplification bias: Lessons from laboratory and field experiments on flow through aquatic vegetation. *Earth Surf. Process. Landf.* **2020**, *45*, 121–143.
4. Lama, G.F.C.; Errico, A.; Francalanci, S.; Solari, L.; Preti, F.; Chirico, G.B. Evaluation of Flow Resistance Models Based on Field Experiments in a Partly Vegetated Reclamation Channel. *Geosciences* **2020**, *10*, 47, doi:10.3390/geosciences10020047.
5. Sarghini, F.; De Vivo, A. Analysis of preliminary design requirements of a heavy lift multirotor drone for agricultural use. *Chem. Eng. Trans.* **2017**, *58*, 625–630, doi:10.3303/CET1758105.
6. Jalonen, J.; Järvelä, J.; Virtanen, J.-P.; Vaaja, M.; Kurkela, M.; Hyyppä, H. Determining Characteristic Vegetation Areas by Terrestrial Laser Scanning for Floodplain Flow Modeling. *Water* **2015**, *7*, 420–437.
7. Lama, G.F.C.; Errico, A.; Francalanci, S.; Solari, L.; Chirico, G.B.; Preti, F. Hydraulic Modeling of Field Experiments in a Drainage Channel Under Different Riparian Vegetation Scenarios. In *Innovative Biosystems Engineering for Sustainable Agriculture, Forestry and Food Production*; Coppola, A.; et al., Eds.; Lecture Notes in Civil Engineering; Springer International Publishing: Cham, Switzerland, 2020; pp. 69–77, doi:10.1007/978-3-030-39299-4_8.
8. Thiemer, K.; Schneider, S.C.; Demars, B.O.L. Mechanical removal of macrophytes in freshwater ecosystems: Implications for ecosystem structure and function. *Sci. Total Environ.* **2021**, *782*, 146671.
9. D'Ippolito, A.; Calomino, F.; Alfonsi, G.; Lauria, A. Flow Resistance in Open Channel Due to Vegetation at Reach Scale: A Review. *Water* **2021**, *13*, 116.
10. Francalanci, S.; Paris, E.; Solari, L. On the vulnerability of woody riparian vegetation during flood events. *Environ. Fluid Mech.* **2020**, *20*, 635–661.
11. Poggi, D.; Porporato, A.; Ridolfi, R.; Albertson, J.D.; Katul, G.G. The effect of vegetation density on canopy sub-layer turbulence. *Bound. Layer Meteorol.* **2004**, *111*, 565–587.
12. Caroppi, G.; Västilä, K.; Gualtieri, P.; Järvelä, J.; Giugni, M.; Rowiński, P.M. Comparison of flexible and rigid vegetation induced shear layers in partly vegetated channels. *Water Resour. Res.* **2021**, *57*, e2020WR028243.
13. Furlani, S.; Vaccher, V.; Macovaz, V.; Devoto, S. A Cost-Effective Method to Reproduce the Morphology of the Nearshore and Intertidal Zone in Microtidal Environments. *Remote Sens.* **2020**, *12*, 1880.
14. Padulano, R.; Lama, G.F.C.; Rianna, G.; Santini, M.; Mancini, M.; Stojiljkovic, M. Future rainfall scenarios for the assessment of water availability in Italy. In Proceedings of the 2020 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor), Trento, Italy, 4–6 November 2020; pp. 241–246, doi:10.1109/MetroAgriFor50201.2020.9277599.