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THE WEQUAL PROJECT: A WEB PLATFORM FOR MULTIDIMENSIONAL EVALUATIONS OF GREEN INFRASTRUCTURES

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SUMMARY

The aim of WEQUAL project "Web service centre for QUALIty multidimensional design and tele-operated monitoring of Green Infrastructures") is the development of a system able to support a quick environmental monitoring of riparian areas subjected to the realization of new green infrastructures (GI). The Wequal´s idea is to organize a service center managing both the Web Platform and the whole data collection and analysis process. Each user (designer, technician, researcher), through a personal account, can access at the service and require the evaluation of alternatives GI projects.

On the Web Platform a set of algorithms runs in order to calculate, through automatic procedures, all the ecological criteria required to evaluate a quality environmental index which describes the ecological state of the monitored riparian areas. For this aim the WEQUI index was developed. In this paper the approach followed to collect the environmental data and the procedures to perform the automatic assessment of the ecological criteria are described. For the computation, the implemented algorithms use data regarding the NDVI index, Digital Terrain Model (DTM), Digital Surface Model (DSM) and a 3D point cloud classification. All the raw data are collected by an UAV (Unmanned Aircraft Vehicle) equipped with a 3D Lidar, multispectral camera and RGB camera.

The computed ecological index is then used to assess the riparian environmental quality at ex-ante and ex-post river stabilization works. This index, integrated with additional not-technical or not-ecological indicators such as investment required, maintenance costs or social acceptance, can be used in multicriteria analyses in order to evaluate the intervention from a wider point of view. The platform is expected to get the interests of GI designers and policy makers, providing a shared environment able to integrate the way some complex indexes can be detected and evaluated and an environment for multidimensional evaluations supported by an expert guide.

Keywords: *Remote sensing, Environmental monitoring, Web Platform, Ecological Index*

INTRODUCTION

In the recent years, the European environmental policies aimed to safeguard the biodiversity of the ecosystems, through the promotion and use of Green Infrastructures (GI) for river stabilization works. For instance, the Water Framework Directive (WFD-2000/60/EC) aims to classify the water bodies and to identify the anthropogenic impacts on that, in order to carry out a qualitative and quantitative evaluation of the improvement of river systems. Meanwhile, the Floods Directive (2007/60/EC) focuses on the design and planning phases of hydraulic works with the aim of reducing the risk of natural disasters due to floods, landslides or erosion and of safeguarding aquatic ecosystems (Rinaldi et al., 2016). The European project EFRE-FESR Südtirol-Alto Adige WEQUAL "Web service centre for QUALIty multidimensional design and tele-operated monitoring of Green Infrastructures" aims at the development of a series of methodologies, integrated in a web platform, able to quickly and automatically assess the environmental impact of longitudinal and transversal hydraulic infrastructures. Therefore, the goal of the research, is to develop a tool, as much objective as possible, to support decision making to various stakeholders in the design and evaluation of river works, such as technicians, administrators or researchers.

The web platform, the heart of the entire evaluation system, has been organized in such a way to guarantee two distinct evaluations:

- The current status of the river, which assesses the environmental quality of a section of river, where a river management system is already installed.
- Forecast state, where the environmental impact of hydraulic infrastructure that could be hypothetically built with the scope of river regulation is evaluated; this evaluation system allows users to compare, through multi-criteria analysis, multiple design alternatives, evaluating the best proposal not only from an environmental impact point of view.

The proposed system, through the use of specific environmental indicators and through a multi-dimensional analysis will be able to assess the level of environmental quality of the evaluated area. The best indicator chosen for this purpose is the River Functionality Index (IFF) (APAT, 2007), which has been re-adapted for project purposes and has taken the name WEQUI Index (Wequal Environmental QUality Index). The development of the new index was necessary in order to obtain a new tool able to perform the assessment in a semi-automatic procedure. In conclusion, the WEQUAL project aims to create automated procedures capable to process raw data from different sensors installed on Unmanned Aircrafts Vehicles (UAV) and to calculate, through the implementation of specific algorithms, the scores to be assigned to the individual criteria provided by the WEQUI index for the evaluation of the status of the rivers environment both *ex-ante* and *ex-post* the Green Infrastructures (GI) installation.

MATERIAL AND METHODS

The WEQUI index, developed for this purpose, is made of 15 criteria. Those criteria define the WEQUAL evaluation matrix. Following a feasibility analysis, 9 of these can be automatically evaluated using specific algorithms, while the rest require a direct manual survey in the field (Table 1).

Table 1 Indicators to be evaluated for the ecological assessment of fluvial areas. In the present table the indicators are divided in automatically assessable or not.

Automatic survey	Manual survey
1) Land use	3) Vertical continuity
2) Lateral continuity	7) Hydrologic regime
4) Longitudinal continuity	8) Chemical quality
5) Morphological heterogeneity	9) Macrobenthos community
6) Retention capability	10) Fish suitability
11) Riparian strip vegetation	15) Carbon footprint
12) Riparian strip width	
13) Riparian strip continuity	
14) Carbon sequestration	

To assign a score for each indicator it is necessary to choose the most representative answer in a list of 4 or 5 possibilities, depending on the situation to be evaluated. According to the indicator, the answer can require the evaluation of the whole riverbeds or the river bank only. Each answer is associated with an exponential score on basis two, from a minimum of 1 to a maximum equal to the base raised to the number of the reference question minus one. Through this approach it is possible to assess the conditions of low or high naturalness. Adding up the result obtained for each criterion the total index of environmental quality for right and left orographic river banks or for the riverbed is calculated.

As previously mentioned, most of the monitoring activities take place using a drone. During a field survey, several missions are planned according to the requests done by the user in the Web Platform. Generally, when a survey is defined, one flight with a LiDAR YellowScan Surveyor sensor, one with multispectral camera Micasense RedEdge and one with RGB digital camera are planned. Thanks to these combinations, it is possible to monitor the portion of the river and riverbanks to be evaluated even in case of difficult access. The collected data are then processed by specific algorithms capable of extrapolating the information needed to compile the individual criteria. For this scope, some of the automatic procedures have been implemented taking inspiration from methodologies already present in the literature (Cavalli et al., 2008; Michez et al., 2013; Tompalski et al., 2017) and adapted to our case, while others have been developed specifically for this study.

Currently the implementation and development phases of the algorithms are being studied. In fact, so far only two algorithms have been developed. Thanks to these algorithms it is possible to classify the use of land (criteria 1 of Table 1), identify the banks and classify the riparian vegetation (criteria 11 of the Table 1). In this preliminary phase, the algorithms have been implemented entirely in MATLAB, then they will be translated into open-source coding language implementable in an easy way on the Web Platform.

Both algorithms use as a starting point the images collected by the multispectral camera and the point cloud obtained from the LiDAR survey. The data obtained from the multispectral images are used for the calculation of different indices for the identification of vegetation, water and ground (e.g. NDVI, NDRE, GNDVI, BNDVI, CCCI, SAVI and OSAVI). While the data obtained from the other sensor are used to obtain 3D models of the terrain (Digital Terrain Model, DTM), of the surface (Digital Surface Model, DSM) and therefore of the vertical profile (Canopy Height Model, CHM) on the monitored area. The RGB camera is used just to take pictures and videos of the monitored area in order to collect a repository of information in case of necessity.

RESULTS AND DISCUSSION

The survey requirement starts with the boundary contouring of the Region Of Interest (ROI) on the Web Platform done by the user. Then all the external operations of field survey for raw data collection can be started. At that point the collected data are updated on the server where all the algorithms can process them to achieve the WEQUI index.

The algorithm used to classify the land use is shown in Figure 1. The evaluation procedure starts considering the region of interest previously drawn by the user. The polygon is used to clip (cropping procedure) both the images obtained from the multispectral, and the cloud of points collected by the LiDAR. Once the analysis area has been extracted, the algorithm proceeds with the following steps:

1. Request to draw a sample area on vegetation and water surface;
2. Calculation of vegetative indices for the determination of threshold values for the discrimination of the vegetative layer from the water layer previously drawn;
3. Classification in the entire ROI, based on the previously calculated threshold values, of the surface where vegetation is present from that where water is present;
4. Calculation of the surface area covered by ground, considering it as the difference between the total analyzed area and the areas calculated in point 3;
5. Characterization of the raw point cloud (using GlobalMapper) for the extraction of the DTM and DSM;
6. CHM calculation by raster subtraction operation between DTM and DSM;
7. Cross-reference of the information obtained in points 3, 4 and 6 to obtain the classification of vegetation and the presence of civil infrastructures;
8. Calculation of the land use percentage for each analyzed type.

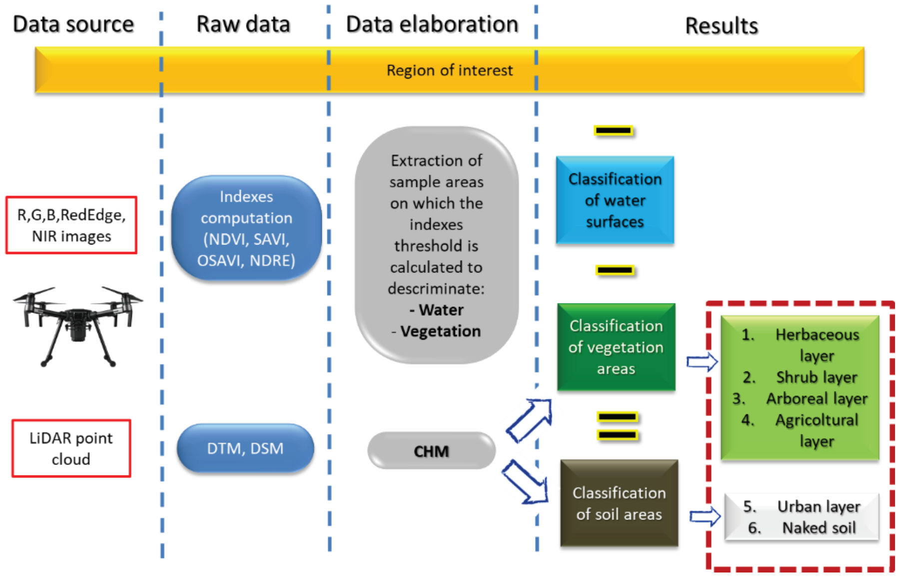

Figure 1 Schematic representation of the algorithm for the automatic classification of land use in the river portion covered by the monitoring

The following image (Figure 2b) shows the result obtained by the automated classification of land use. Here only the macro-items of vegetation, water and ground necessary for the validation of the procedure are considered. In addition to the map, the algorithm can calculate the area of the surface covered by the different types of use.

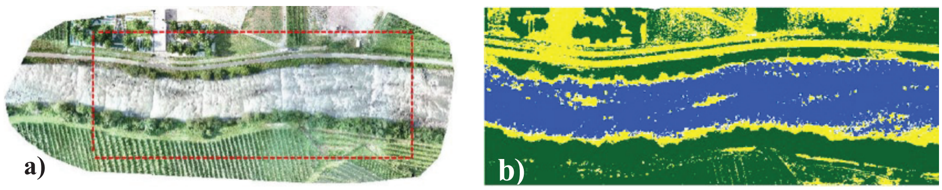

Figure 2 a) The orthophoto acquired by the multispectral camera is shown. on this picture the polygon for the clipping operation can be drawn.
2 b) The result of the automatic computation procedures for the classification of the land use is reported (in green the vegetation, in blue the water and in yellow the ground)

Figure 3 shows the scheme of the computational procedures of the algorithm implemented for the extraction of the banks and the characterization of the vegetation present on them.

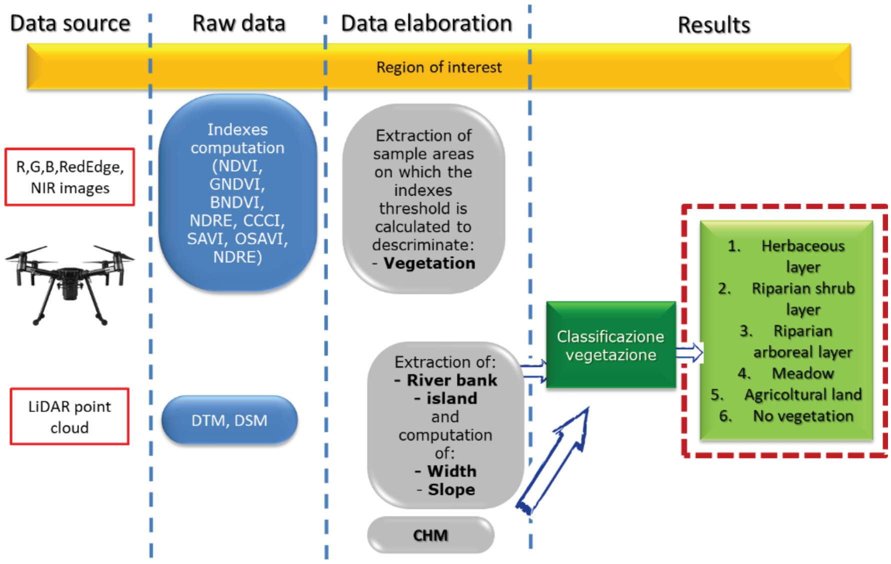

Figure 3 Schematic representation of the algorithm for automatic identification of the banks and classification of riparian and floodplain vegetation in the portion of river affected by the monitoring

Like the previous, this algorithm is based on a first clip operation to extract, from the raw data, those related to the area interested by monitoring. Once this first analysis has been carried out, the algorithm proceeds with:

1. Request to trace a sample representative area for vegetation and water;
2. Calculation of the vegetative indexes for the determination of the threshold values necessary to identify the vegetative layer and the watercourse;
3. Identification of the vegetation layer and river over the entire area of interest;
4. Characterization of the raw point cloud (by GlobalMapper) for the extraction of the DTM and DSM;
5. Identification of banks and islands through the analysis of the frequency distribution of the inclination of the land near or inside the river, considering the cross-section of the river (Figure 4).
6. CHM calculation by raster subtraction operation between DTM and DSM;
7. Cross-reference of the information obtained under 3, 5 and 6 to obtain the classification of vegetation on the banks or islands within the river;
8. Calculation of the percentage of coverage for each analyzed type.

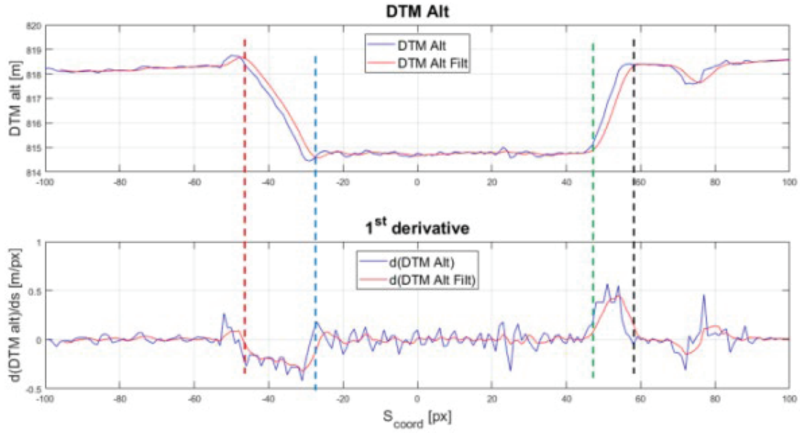

Figure 4 Riverbank extraction from DTM. The algorithm identifies the foot and the riverbank head by means of first derivative analysis of the transverse profile. The slope values of the banks are used for the physical characterization of the banks.

As in the previous analysis, also for this one, the result is a map on which the classification of the riparian and floodplain vegetation are reported (Figure 5). Besides this, the calculation of the areas occupied by the two vegetation types is performed.

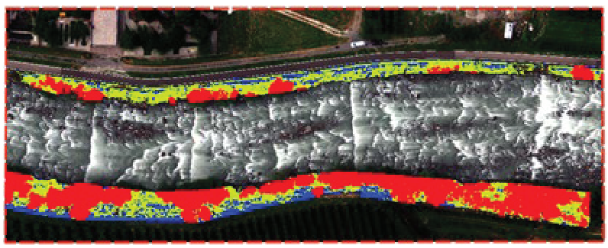

Figure 5 Graphical result of algorithm procedures for riverbanks, riparian and alluvial riparian vegetation (the green, blue and red colors refer to the herbaceous layer, riparian shrubs and riparian arboreal, respectively)

At this point of the research, unfortunately, the validation of the results could only be conducted for the algorithm of the land use classification. Using a GIS software, it was possible to perform a visual classification of the region of interest of the survey. The surface inside the red polygon displayed in Figure 2a, has been firstly identified as vegetation, water and ground, secondly for each classification the total surface has been calculated. The obtained results have then compared with the same results obtained by the automatic method. Table 2 shows the results.

Table 2 Validation of the automatic analysis procedure

	Manual survey	Automatic survey	Differences
Vegetations	53.2%	50.3%	-2.9%
Water	27.2%	21.0%	-6.2%
Ground	19.6%	28.7%	9.1%

The results in Table 2 highlight that the implemented algorithm for the automatic land use classification is capable to well recognize the areas where vegetation is present, while it has uncertainties in the identification of water and ground surfaces. This may be due to possible problems with the recognition of transition zones. In fact, according to the hour and the season in which the flights were carried out, a portion of the image is affected by a shaded band due to the presence of the foliage of the riparian plants. This shading causes a slight variation in the reflectance of these transitional bands which affects the data-processing causing an overestimation of the ground content. A further cause of soil overestimation may be due to the similar reflection between thin water layers within the river and the gravel of the riverbed causing mistakes is the assessment: part of water is identified as ground.

CONCLUSION

The final objective of the WEQUAL project is the realization of a Web platform able to provide decision support for the assessment of the environmental quality of fluvial environment through a semi-automated analysis of a matrix composed by 15 indicators. In this manuscript the preliminary results of the implementation of two algorithms capable of performing, through an automated procedure, the evaluation of i) land use and ii) riparian strip vegetation assessment have been reported. The algorithm for the land use assessment has shown to be enough accurate for identifying vegetation, less accurate in the distinction between ground and water, while the evaluation phase of the results obtained by the second algorithm still needs to be validated. The implementation of the remaining algorithms requires the identification of the river axle. Indeed, with the identification of the river axle it will be possible to distinguish between the right and left riverside and to track the cross sections along the monitored river portion. Thanks to the last information, the physical evaluations of the monitored watercourse can be carried out. Finally, as they cannot be automatically evaluated, the chemical-biological parameters are expected to be collected manually as well as the attribution of the respective scores and their inclusion in the web platform.

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