A new IT tool to identify and classify non-perennial rivers

Un nouvel outil informatique pour identifier et classer les rivières non pérennes

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RÉSUMÉ

La quantification de l'intensité de l'intermittence des débits et de l'extension spatiale et temporelle des lits de rivières asséchés reste l'une des lacunes les plus importantes dans la conservation et la gestion des rivières non pérennes (NPRs). Dans ce contexte, les images satellite et les données de télédétection peuvent être utilisées pour identifier et classifier l'intermittence des débits, en détectant l'apparition de l'eau le long des tronçons fluviaux. Les données satellitaires ont un temps de revisite court (environ une semaine) et la récente disponibilité de données gratuites à haute résolution spatiale (par exemple, la mission Sentinelle-2 de l'ESA) a déjà ouvert la possibilité d'applications innovantes pour les NPRs. Sur la base des résultats du projet RIVERTEMP Erasmus+, nous présentons une nouvelle plateforme web qui analyse les images multispectrales Sentinel-2. La composition en fausses couleurs des bandes SWIR, NIR et RED est générée automatiquement par la plateforme. Des images en fausses couleurs peuvent être utilisées pour distinguer clairement la présence d'eau afin d'identifier les conditions hydrologiques des tronçons de rivière, qui peuvent être : des conditions «coulantes» (F), «stagnantes» (P) ou «sèches» (D). L'outil Web génère des séries chronologiques de conditions hydrologiques, permettant la classification automatique des NPRs en fonction de la fréquence et de la durée des classes F, P et D. Un manuel d'utilisation et du matériel de formation pour les étudiants universitaires sont également disponibles gratuitement sur la page Web du projet.

ABSTRACT

Quantifying the intensity of flow intermittency and the spatial and temporal extension of dry riverbeds remains one of the most important gap in non-perennial rivers (NPRs) conservation and management. In this context, satellite images and remote sensing data can be used to identify and classify flow intermittency, detecting flow occurrence along river reaches. Satellite data have a short revisit time (about one week), and the recent availability of free of charge, high spatial resolution data (e.g., ESA Sentinel-2 mission) has already opened up the possibility of innovative applications for NPRs. Based on the results of the RIVERTEMP Erasmus+ project, we present a new web platform that analyses Sentinel-2 multispectral images. The false color composition of the bands SWIR, NIR and RED is automatically generated by the platform. False color images can be used to clearly distinguish water presence and identify the hydrological conditions of river reaches, that can be: "flowing" (F), "ponding" (P) or "dry" (D) conditions. The web tool generates time series of hydrological conditions, allowing the automatic classification of the NPRs based on the frequency and duration of F, P and D classes. A user manual and training materials for university students are also freely available on the website of the project.

KEYWORDS

Dry riverbeds, Hydrological conditions, Non-perennial rivers, Satellite imagery, Sentinel-2 mission. Lits de rivières asséchés, Conditions hydrologiques, Rivières non pérennes, Images de satellite, Mission Sentinel-2.

1 INTRODUCTION

Non-perennial rivers (NPRs) are becoming more and more common in this era due to the combined effect of climate change and increasing water demand (Messager et al., 2021). The increased future probability of rainfall deficit (seasonal or multi-year droughts) elevates the probability of flow intermittency in a large portion of the European territory, in both natural and regulated rivers (Skoulikidis et al., 2017).

Flow intermittency, that characterizes NPRs, can have a large range of intensity depending on the local context and a clear hydrological characterization of NPRs is not available at the moment. Despite their large prevalence all over the world (Messager et al., 2021), most freshwater research has been focused on the functioning and conservation of perennial rivers (i.e., rivers that continuously flow, Allen et al., 2020), and very rarely water managers, professionals and the academic community developed sufficient science-based methods to easily identify and classify these unique ecosystems (Acuña et al., 2017; Datry et al., 2014; Leigh et al., 2019).

Management frameworks, at a regional, national or European scale, still need to be adapted to effectively manage and conserve NPRs. But perhaps the most important gap until now has been the inability to easily map and quantify the spatial and temporal extension of water presence in NPRs. In this study we propose a new IT tool to perform accurate mapping of the NPRs network using multispectral satellite imagery. Satellite imagery has been successfully exploited for the monitoring of perennial rivers with short revisit time (about one week), and the recent availability of free of charge, high spatial resolution data (e.g., for ESA Sentinel-2 data, Seaton et al., 2020; Cavallo et al., 2022) has already opened up the possibility of innovative applications to NPRs. The proposed IT tool can provide crucial baseline information about flowing and stagnant water occurrences along NPR reaches, as well as the spatial and temporal extension of dry riverbeds.

2 IT TOOL WEB PLATFORM

2.1 Satellite imagery analysis

Multispectral satellite imagery is exploited for NPRs observation and description. In particular, Sentinel-2 data are used to generate false color composite images, based on the SWIR, NIR and RED bands, to distinguish water presence from bare soil and vegetation within river channels. Indeed, the detection of water presence in NPRs is crucial to address the need of classifying one of the three possible hydrological conditions, that are: 1) “flowing” (F), the water flow is longitudinally continuous, 2) “ponding” (P), there is no surface flow but only isolated pools and ponds are present, 3) “dry” (D), the river bed is completely dry. The false color images are automatically generated by an IT tool as georeferenced raster datasets using Sentinel-2 data. The uploaded images can be analyzed by the user over a specific date range to perform a supervised classification of river hydrological condition (flowing/ponding/dry, or F/P/D, Cavallo et al., 2022). Using the proposed approach, it is possible to identify and map NPRs over space and time, and to quantify the dynamics of flow intermittency across river networks.

2.2 Web platform

A web platform and a user interface have been developed to easily process Sentinel-2 satellite images and generate false color images. After a login, the user can 1) access a global map to identify NPRs, 2) draw georeferenced polygons over the river reach of interest, 3) select a date range, and 4) classify all available Sentinel-2 satellite images into one of the three hydrological conditions (F/P/D). Cloudy images can also be classified and disregarded from further analyses. The access to the web platform is currently free and it has been incorporated into hydrology and river engineering courses held in four universities involved in the RIVERTEMP Erasmus+ project. To support its use, the development process of the IT tool and the web platform also included the production of the related training materials and a user manual.

2.3 GIS-based repository of classified images

The web platform stores the classified satellite images, along with their metadata, in a GIS-based repository, using the PostgreSQL open-source database. The online dataset is easily accessible to everyone through the web platform. High-resolution maps of selected river reaches, time series of hydrological conditions (Figure 1) and hydrotype classifications (Gallart et al., 2012; Munné et al., 2021) can be extracted from the web platform (Figure 2).

3 RESULTS AND DISCUSSION

More than 300 km of non-perennial rivers located in Italy, Spain and Greece have already been analyzed and classified by university students involved in the RIVERTEMP project. Until now, more than 100.000 satellite images have been classified as flowing, ponding or dry condition (Examples in Figure 1) and stored in the GIS-based repository. The hydrotype of more than 150 river reaches have been defined (Example in Figure 2)

Quantifying the intensity and spatial occurrence of flow cessation, is urgently needed for European rivers, to determine when and for how long surface water is available. Knowledge of the frequency, duration, and timing of flow cessation forms the basis of flow-alteration analyses that can inform strategies to mitigate the impacts of climate change.

Our research activity aimed to develop an innovative IT tool, together with a web platform, and a GIS-based repository, to identify and map NPRs. This tool has the potential to be used for describing and managing NPRs in EU and beyond.

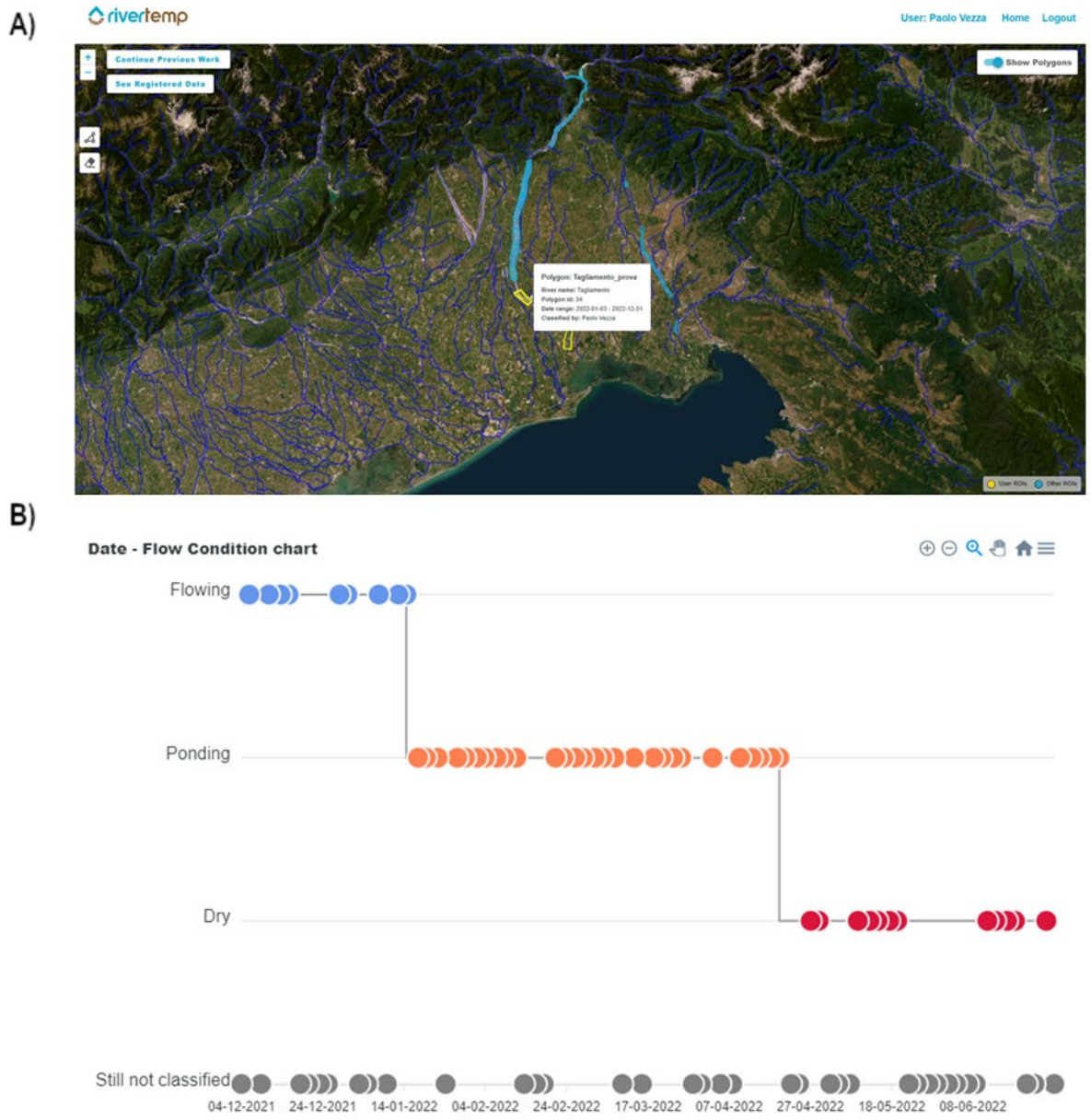

Figure 1. A) Web platform to identify and map non-perennial rivers (NPRs). B) Example of a time series of classified satellite images using the three hydrological conditions (flowing, ponding or dry). Cloudy and not-classified images are also reported at the bottom of the graph.

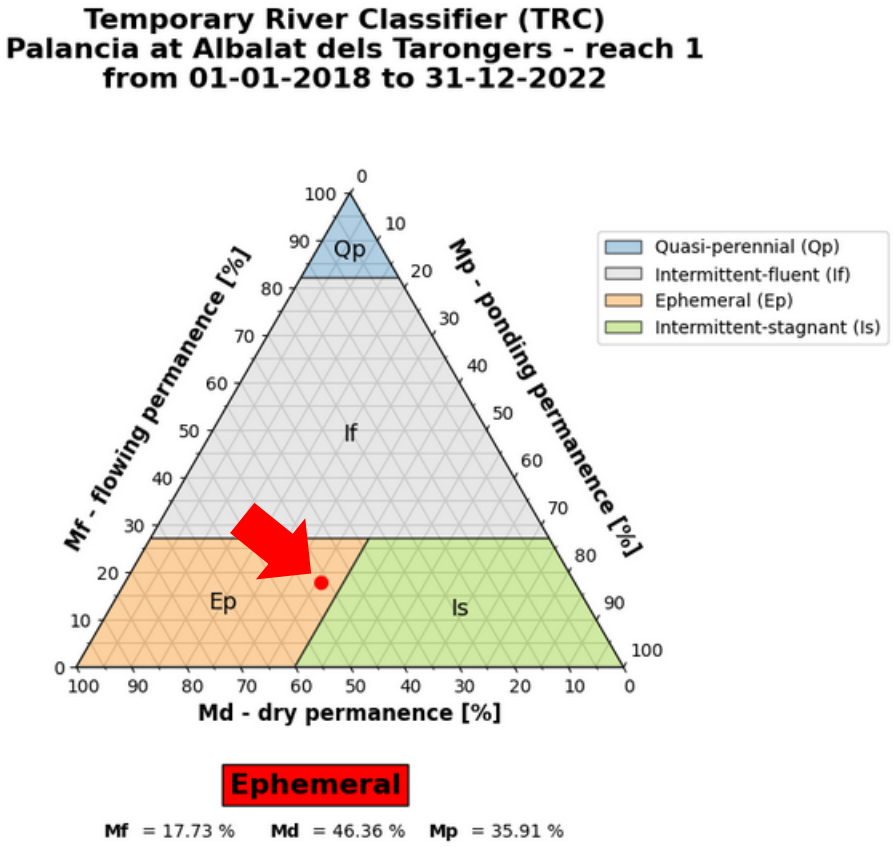

Figure 2. Ternary plot showing the classification of the Palancia River at Albalat dels Tarongers (reach n. 1). The selected date range by the user was from 1st of January 2018 to 31st December 2022. The four NPR hydrotypes (Quasi-perennial, Intermittent-fluent, Ephemeral and Intermittent-stagnant) refers to the classification proposed by Munné et al. (2021).

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