Satellite monitoring of the timing and extent of dry conditions in the Tagliamento River

Suivi satellitaire des dates et de l'étendue des conditions sèches dans le fleuve Tagliamento

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RÉSUMÉ

Ces dernières années, de nombreux rivières ont connu une augmentation des périodes de totale absence de ruissellement superficiel, un phénomène attribué à la fois au changement climatique et à l'utilisation intensive des ressources en eau. Les approches basées sur l'utilisation d'images satellitaires multispectrales des missions Landsat et Sentinel-2 émergent pour surmonter les limites des instruments de mesure traditionnels, qui ne donnent que des mesures ponctuelles et sont peu exploitées dans le réseau hydrographique mineur. L'utilisation d'images en fausses couleurs, obtenues en combinant les bandes multispectrales SWIR, NIR et RED, a permis de différencier l'eau des autres types de couverture du sol présents dans les corridors fluviaux. L'application d'une méthode semi-automatique, basée sur l'analyse de la réflectance acquise dans la bande NIR, a permis de mesurer la longueur des tronçons de rivière secs et leur évolution dans le temps. L'analyse menée sur une période de 40 ans, le long d'un tronçon de 6 km du fleuve Tagliamento en Friuli-Venezia Giulia, a montré des tendances significatives vers une augmentation des périodes sèches. En particulier, on a observé une plus forte discontinuité longitudinale du flux et une augmentation de la durée totale des périodes sèches pendant les mois d'hiver.

ABSTRACT

In recent years, many rivers have experienced an increase in periods of total absence of surface runoff, a phenomenon attributed both to climate change and intensive use of water resources. Approaches based on the use of multispectral satellite images from the Landsat and Sentinel-2 missions are emerging to address the limitations of traditional measurement tools, which provide only point measurements and are sparsely distributed across the minor hydrological network. The use of false-color images, obtained by combining the SWIR, NIR, and RED multispectral bands, has allowed for distinguishing water from other land covers in river corridors. The application of a semi-automatic method, based on the analysis of reflectance in the NIR band, enabled the measurement of the length of dry stretches and its evolution over time. The analysis, conducted over a 40-year period along a 6 km stretch of the Tagliamento River in Friuli-Venezia Giulia, revealed significant trends in the increase of dry conditions. Specifically, greater longitudinal discontinuity of the flow and an increase in the total length of dry conditions were observed during the winter months.

KEYWORDS

Climate Change Impact, Flow Intermittency, Landsat, Remote Sensing, Tagliamento River

Fleuve Tagliamento, Impact du changement climatique, Intermittence du débit, Landsat, Télédétection

1 INTRODUCTION

In recent years, an increasing number of rivers are experiencing long periods of total absence of surface runoff (Messager et al., 2021; Mimeau et al., 2024). Traditional water level and flow measuring stations, provide point information and are not adequate to monitor changes in surface runoff along river reaches. Satellite data represent a promising resource to study the effects of climate change on runoff conditions, allowing analysis of large areas. Among the main free data sources are the NASA/USGS Landsat and ESA's Sentinel-2 missions. These offer images with moderate spatial resolution, 30 m and 10 m respectively, and an acquisition frequency of 9 and 5 days, although the actual observation interval is increased by the eventual presence of cloud cover. Based on the study by Cavallo et al. (2022), satellite monitoring is possible when the active river channel has a width of more than three pixels and there is no vegetation cover.

2 CASE STUDY

The Tagliamento River drains an area of approximately 2580 km² and is 178 km long, from the Carnic Alps to the Adriatic Sea. It is the longest river in Friuli-Venezia Giulia and constitutes an important ecological corridor connecting the Alpine region with the Friulian and Veneto coastline. Is one of the few European rivers that has preserved the characteristic braided channel morphology (Tockner et al. 2003). The objective of the study was to analyse the effects of climate change on runoff conditions over 40 years on a 6 km long reach of the river, between the confluence with the Cosa stream and the Delizia bridge over the Tagliamento.

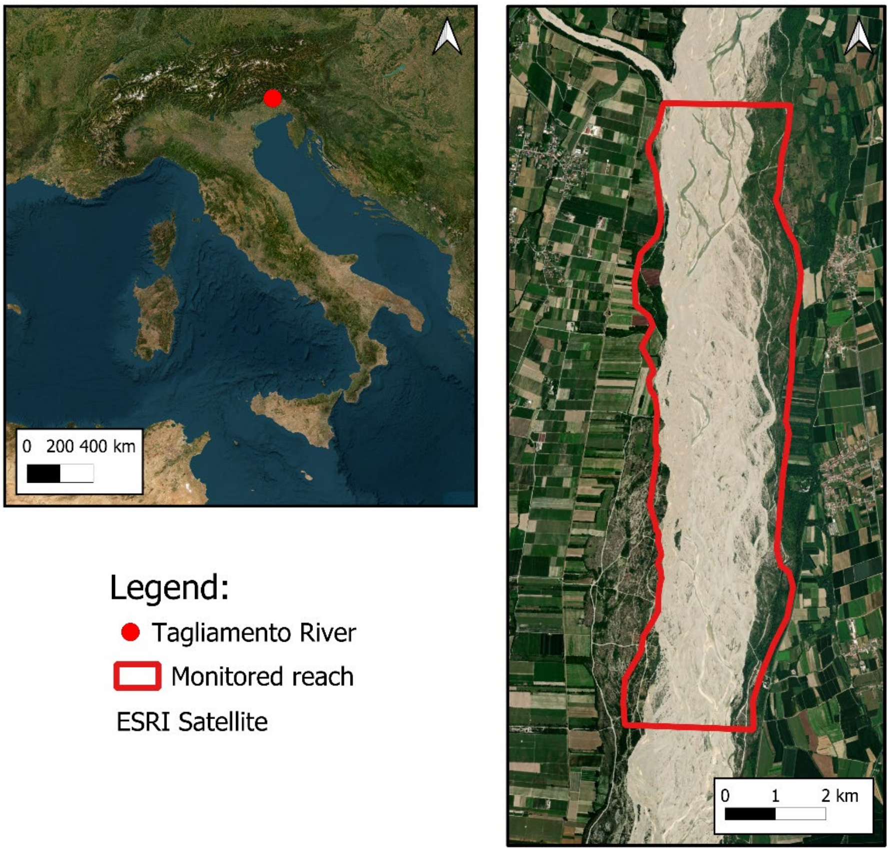

Figure 1 - Location of the Tagliamento river and identification of the reach under study

3 METHOD FOR THE DETECTION OF WATER PRESENCE

In this work, freely available satellite images from Landsat-5 (L5, 1984 to 2011), Landsat-8 (L8, 2013 to 2024) and Sentinel-2 (S2, 2017 to 2024) were used. As ground truths very high resolution (0.5 m) images were used such as the orthophoto provided by the Italian National Geoportal and by satellite images freely available on Google Earth Pro. The comparison revealed that due to the limited resolution of L5, L8 and S2, the RGB (Red, Green and Blue) composition is not sufficient to effectively differentiate water. To overcome this limitation, Cavallo et al.

(2022) analyzed the spectral signatures of the different types of land cover present within river corridors, i.e. typically water, sediment and vegetation, and identified the bands in which water differs most from others. They found that a false-colour composition of the SWIR (Shortwave Infrared), NIR (Near Infrared) and RED bands, allows water to be clearly distinguished from sediments and vegetation. In the false-colour combination shown in Figure 2, the vegetation appears green in colour, sediment and soil without vegetation are easily identifiable by their pink hue and water is clearly distinguishable by its dark blue colour. Thus, the false-colour composition allows the images to be visually interpreted, facilitating the analysis and determination of flow (Wet) or dry (Dry) conditions. This approach is particularly useful for detecting variations that may not be immediately apparent in natural colour images.

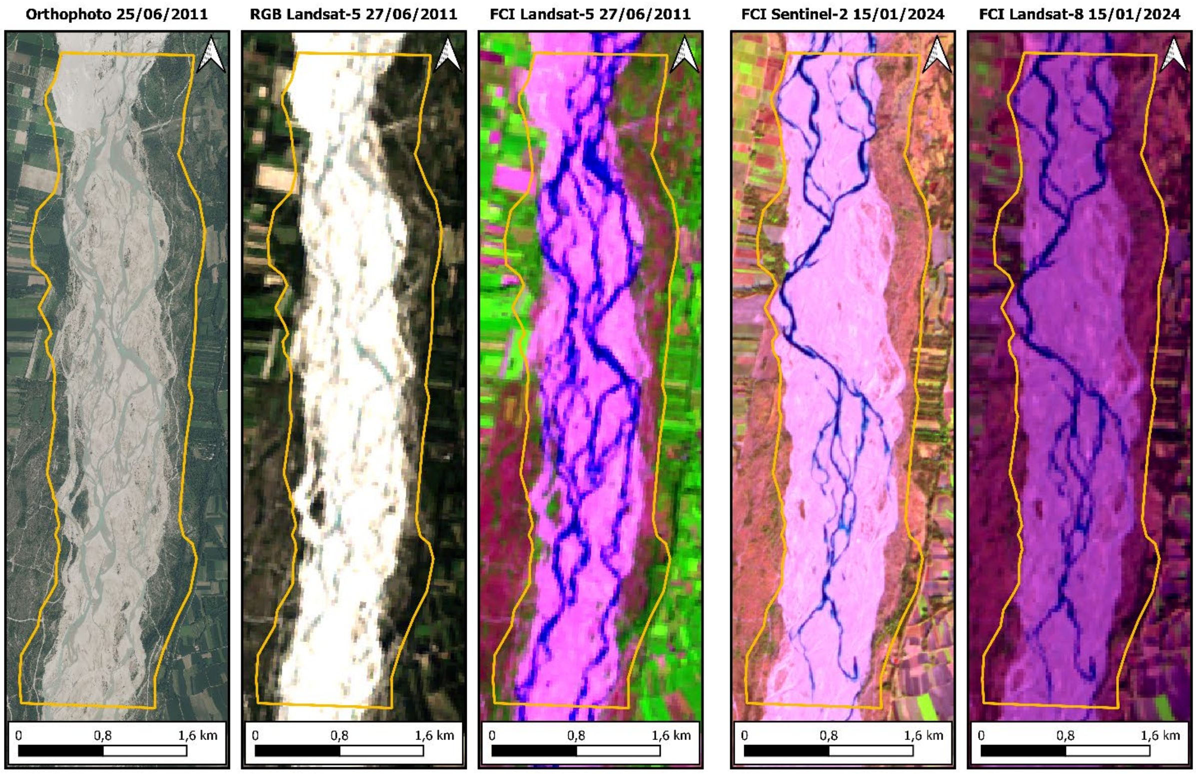

Figure 2 – First three images from the left: comparison between the very high resolution orthophoto, the RGB and FCI image of Landsat-5 on 27/06/2011. Last two images from the left: comparison between the FCI image of Sentinel-2 and Landsat-8 on 15/01/2024. The Yellow line shows the ensemble of the active channels in the period 1984-2024

As the number of images to be processed increases, it becomes progressively more time consuming and impractical to identify the runoff conditions by visual inspection of the images. Therefore, an automatic method was sought to distinguish the conditions of presence or absence of water. The analysis of spectral signatures by Cavallo et Al. (2022) showed that the band in which the difference between the reflectance of water and that of other ground covers is most pronounced is the NIR band as, in the NIR band, water has a particularly low reflectance. The developed method takes advantage of this feature and is based on the analysis of the cumulative frequency distribution of the NIR reflectance of the pixels in the study area (Cavallo et al. 2024). The study area is defined as the ensemble of areas occupied by the active channel throughout the observation period. Comparison of the characteristics of the cumulative frequency distribution with experimentally determined threshold values allowed to identify the conditions Wet and Dry. A subset of the available images and in particular the images acquired in 1984-1987 for L5 and 2023-2024 for L8 were used to validate and calibrate the method. These images were manually classified by visual inspection and were used as “ground truth”. The comparison showed an accuracy of 85%.

4 TEMPORAL MONITORING OF RUNOFF CONDITIONS

The classification tool was applied to all satellite images in the Landsat dataset without cloud cover. A total of 294 images acquired from L5 were classified for the years from 1984 to 2011 and 216 L8 images acquired from 2015 to 2024. The reach of the Tagliamento River analysed was divided into strips of length equal to 150 m. Each strip was classified Wet or Dry, and the sum of the lengths of the Dry strips (dry lenght) and the sum of the lengths of the Wet strips (wet length) were calculated. Fig.3 shows the percentages of dry lenght and wet length out of the total of the length of the analyzed reach. The results shows a negative trend of the wet length during the months of December, January, February and March, indicating a progressive reduction of surface water. In contrast, relative stability in the summer months is observed. This observed expansion of dry conditions is potentially linked to a combination of climatic factors such as decreased precipitation and increased temperature and other factors like, increased water withdrawals and land use changes at catchment scale.

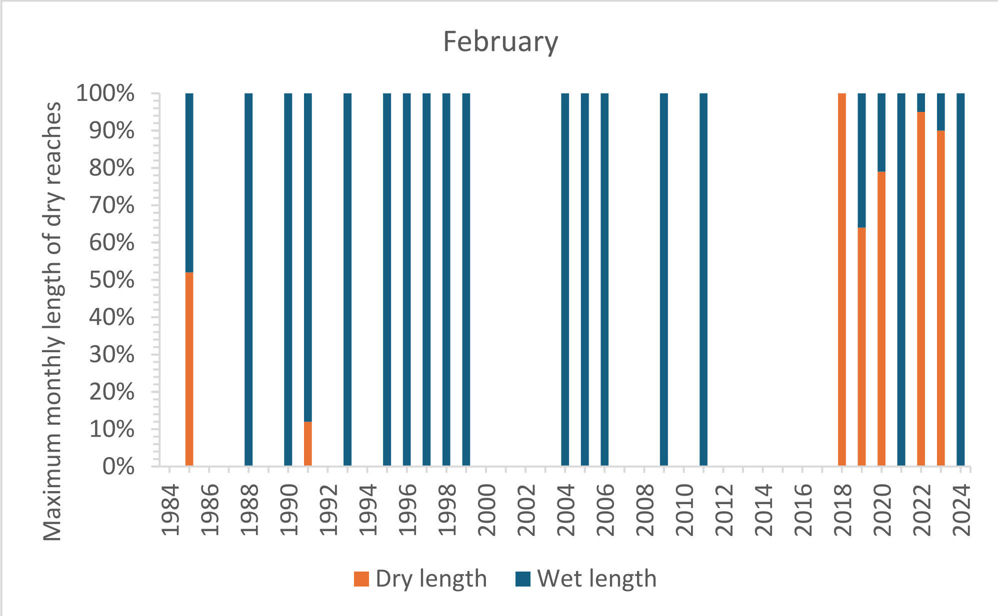

Figure 3 - Result of the semi-automatic classification of Wet and Dry reaches for the month of February

5 CONCLUSIONS

The analysis showed that Landsat data can be used to monitor dry conditions in rivers with an adequate width of the active channel (greater than 90 m). Thanks to the long historical archive of the Landsat mission and the use of a semi-automatic classification method, it is possible to monitor and analyse the drying trends in river over the last 40 years. The results of the observation of Tagliamento river show that, over the last 40 years, the reach between the confluence with the Cosa stream and the Delizia bridge over the Tagliamento, experienced increasing length and duration of dry condition In particular, the changes in length and duration of the dry condition were not particularly significant during summer periods, while during winter periods there was a relevant increase in the dry-out tendency, with a consequent increase in longitudinal discontinuity.

LIST OF REFERENCES

Messager, M.L., Lehner, B., Cockburn, C. et al. Global prevalence of non-perennial rivers and streams. Nature 594, 391–397 (2021).

Mimeau, L., Künne, A., Devers, A., Branger, F., Kralisch, S., Lauvernet, C., Vidal, J.-P., Bonada, N., Csabai, Z., Mykrä, H., Pařil, P., Polović, L., and Datry, T.: Projections of streamflow intermittence under climate change in European drying river networks, Hydrol. Earth Syst. Sci. Discuss (2024).

Tockner, K., Ward, J.V., Arscott, D.B. et al. The Tagliamento River: A model ecosystem of European importance. Aquat. Sci. 65, 239–253 (2003).

Cavallo, C., Papa, M.N., Negro, G. et al. Exploiting Sentinel-2 dataset to assess flow intermittency in non-perennial rivers. Sci Rep 12, 21756 (2022).

Cavallo, C., Papa, M.N., Vezza, P. et al. An automatic method for classifying non-perennial rivers through the use of satellite imagery [Manuscript in preparation] (2024).