A framework to quantify 50-100 year human-driven channel changes at regional level: the case of the Piedmont region, Italy

Un cadre pour quantifier les modifications humaines des chenaux remontant entre 50 et 100 ans à l'échelle régionale : le cas de la région du Piémont, en Italie

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RÉSUMÉ

Nous nous appuyons sur la loi caractéristique de l'échelle hydraulique (HSL) en utilisant une base de données régionale des caractéristiques géomorphologiques des rivières. Nous étudions comment la profondeur du canal au niveau du débordement (eBCD), la largeur du canal actif (ACW) et la largeur du canal à faible débit (LFCW) se comparent au débit de l'écoulement. Ce dernier est ici calculé par rapport à la surface du bassin à travers une régression basée sur les stations de mesure disponibles. Ce faisant, nous relions uniformément le flux avec les caractéristiques géométriques des canaux (eBCD, ACW, LFCW), disponibles en continu à partir des données RS le long du cours de la rivière. Nous utilisons ensuite des informations historiques et des sources externes d'informations sur les chenaux relativement peu affectés par l'action humaine sur quelques décennies et jusqu'à un siècle (mesure dans des zones géographiques comparables) pour en déduire des HSL relativement non altérées (rUHSL). En adoptant les rUHSL validées avec des preuves historiques locales disponibles sur la géométrie du chenal, nous sommes en mesure d'évaluer les changements historiques de la géométrie du chenal de manière cohérente sur toute la région et dans la fenêtre temporelle étudiée. Cette méthodologie fournit des informations fiables, nouvelles et quantitatives sur les modifications humaines subies par les chenaux sur plusieurs décennies et jusqu'à un siècle, à l'échelle de la région. Ce nouveau niveau d'information enrichit notre capacité à traiter rationnellement l'évaluation des trajectoires passées et futures des chenaux et à adapter les développements humains futurs en conséquence.

ABSTRACT

We derive characteristic Hydraulic Scaling Law (HSL) using a regional database of river geomorphic features. We investigate how Bankfull Channel Depth (eBCD), Active Channel Width (ACW), and Low Flow water Channel Width (LFCW) scale with flow discharge. The latter is here approximated with basin area through a regression based on available gauging stations. In doing so, we consistently link discharge with channel geometry features (eBCD, ACW, LFCW), continuously available from RS data along the river course. We then use historical information and external sources of information about channel reaches relatively unaffected by human pressure over a few decades to a century (measured in comparable geographical areas) to infer relatively Unaltered HSLs (rUHSL). Adopting rUHSL validated with available local historical evidence on channel geometry we are able to assess historical changes in channel geometry consistently over the entire region and within the studied temporal window. This methodology provides robust, novel and quantitative information about decadal to secular human-induced channel changes occurred at regional scale. This new layer of information enriches our ability to rationally address the assessment of past and future channel trajectories and to adapt future human developments in accordance to that.

KEYWORDS

Channel incision, LiDAR, Human induced changes, Remote Sensing, River Management

1 INTRODUCTION

River surveys nowadays require characterization of recent past conditions as an essential task. These surveys are nowadays commonly proposed as legal requirement to characterize fluvial systems and support river management (Gurnell et al., 2016). In this context, there is a need for river surveys to be implemented on large administrative scales, such as regional or national. Surveys should then be based on common criteria to consistently characterize different regional contexts and assess where specific human-driven patterns occurred. Knowledge of the past process dynamics provides the basis for designing realistic and sustainable restoration scenarios and helps eventually to improve the current conditions in the existing geographical context.

Indeed, the historical trajectories of channel adjustments over the last half of century have been significantly worldwide-driven by the severe increase of human pressures. This is the case in Italy, where the case-study of this paper is located. Here, channel narrowing and river bed incision have been particularly severe over the last century.

Though the understanding of human-driven river changes is a critical step to design appropriate restoration measures and properly manage fluvial resources, it currently represents a major research challenge which is far from being solved. There is a lack of a coherent methodological framework for the analysis of recent historical changes (e.g., 50 to 100 years) suitable to be adopted consistently over large regional and institutional scales. So far, analyses are mostly carried out for single rivers based on ad-hoc qualitative interpretations of the few available historical evidences.

In this paper, we investigate the possibility to calibrate characteristic hydraulic scaling laws of natural rivers, traditionally referred also as hydraulic geometry, using a regional database of river geomorphic features, derived by a recent research study (Demarchi et al. 2016). We focus on how estimated Bankfull Channel Depth (eBCD), Active Channel Width (ACW), and Low Flow water Channel Width (LFCW) scale with basin area. We then collect available scattered historical field evidences and external sources of information on channel geometry from a set of reaches relatively unaffected to human pressure in the region or nearby (e.g. west French side of the Alps), to infer the same characteristic hydraulic scaling laws for historical and relatively unaltered conditions. Comparing current, historical and relatively unaltered hydraulic scaling laws, we aim at quantifying changes in channel depth and width occurred since major human pressures have acted in the region. This paper proposes a notable advance compared to previous large-scale analysis of RS data for river characterization since here we do not simply assess current conditions but we aim to assessing magnitude in recent historical channel change and to locating concerned reaches.

2 METHOD

The proposed analysis framework is composed of three steps. First, we use a database on river geomorphic features available at the regional scale from a previous research (Demarchi et al. 2016) to calibrate the characteristic HSLs for the Piedmont region. We investigate how estimated eBCD, here defined as floodplain height above low flow channel, see following section, ACW, and LFCW scale with discharge, and how they are influenced by orographic, geological and climate regional contexts. We used basin area (a) as a proxy of the hydrological condition. We used 27 flow gauging stations in the region having consistent discharges series over a period of 10 years, between 2004 and 2014. We used the fit tool in Matlab and obtained strong relationships between $Q_{1.5}$ and basin area ($Q_{1.5}$=0.59$a^{0.88}$, R^2 0.97). This step allows to characterize current configuration of channels at the regional level. Second, we use HSLs derived from river reaches which are not considered significantly altered by human pressures (referred from now on as relatively Unaltered HSLs, rUHSLs) existing in other systems with similar characteristics. We use the regressions established by Gob et al. (2014) for a set of western Alpine rivers considered as being relatively unaltered by human pressure. We then validate the suitability of the derived rUHSLs for the Piedmont context using available scattered historical information in the study area. We used available historical field evidences about riverbed elevation and active channel width. The third step compares relatively unaltered reference conditions (rUHSLs) with existing HSLs and generates a map of human-induced channel width and depth changes occurred in the last century.

3 RESULTS AND MAIN CONCLUSIONS

The case study is the Po basin in the Piedmont region, located in the north-west of Italy. In this area, current channel conditions have been severely shaped by the legacy of human pressures. From our analysis, it emerges that regionally 74% of the river network has a riverbed incision greater than a meter and 66% of channels have halved their historical widths, in total 617 ha of land have been subtracted to the active channels. The rate of channel narrowing (up to 100%) and severity of river bed incision (up to 3-4m) showed in Figure 1 are in lines with estimates provided in literature for this part of Italy, and they are here estimated for the first time regionally and based on common references.

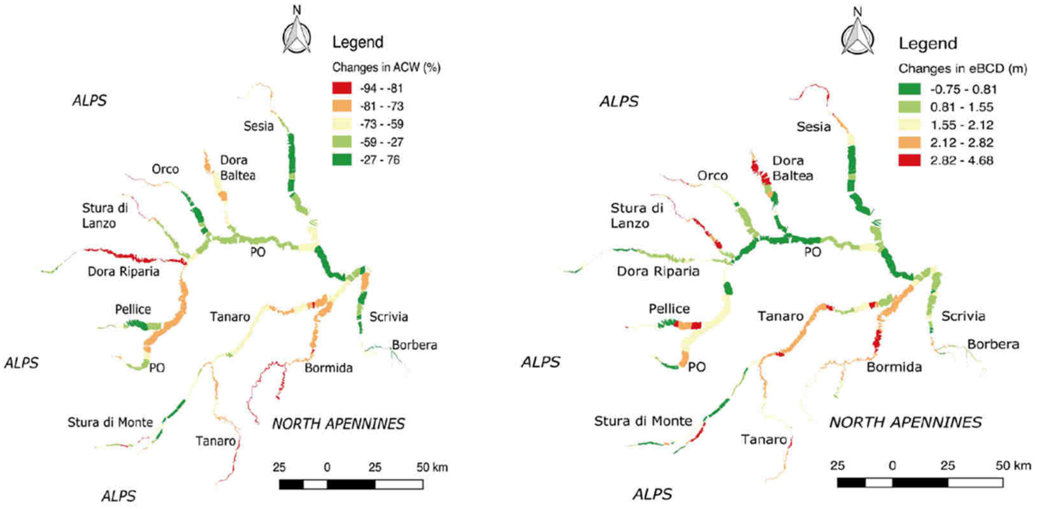

Figure 1 - Spatially distributed historical changes of eBCD (left, units in m compared to the current altitude) and ACW (right, in % compared to the current width)

Our analysis shows that rUHSL and historical evidences fits nicely for both eBCd and ACW. HSL, historical evidences and rUHSL all support the hypothesis that a single reference is suitable to describe characteristic scaling laws of channel geometry across the region. It confirms, that the reference conditions from the France dataset seems appropriate and match coherently historical information and proxies of channel processes such as the riparian corridor width. Despite that and the universal applicability of HSL to assume a single reference for the entire region, using basin area as the single criteria to discern amongst channel types is clearly a limitation. At this stage, it is not possible to provide a robust confidence interval for the uncertainty beyond this assumption. However, to provide a first assessment of historical channel changes at regional scale, consistently derived, we believe this is suitable and can support the identification of most severely altered reaches where deeper field geomorphic diagnosis are needed.

The generated evidences coherently link historical information, characteristic hydraulic scaling laws, evidences from relatively unaltered systems, and available literature on local fluvial systems and they provide a consistent assessment at regional scale of human-induced 50-100 year channel changes. These estimates currently cannot still be consistently validated at the regional scale. Additional effort is needed to provide more comprehensive historical evidences allowing to infer more accurately historical channel changes consistently at large scale. This effort should be organized and undertake at national level to support the calibration of rUHSL, and then to assess recent severe channel changes and prioritize restoration actions. We also expect that new RS acquisitions available at regional scale will allow to better investigate these estimates and to generate new more accurate ones about recent channel adjustments.

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