Into human-disturbed landscapes: functional linkages between land-use, geomorphology and the diversity of riparian plant ecosystems

Vers des paysages anthropisés : connexions fonctionnelles entre l'usage des terres, la géomorphologie et la diversité des écosystèmes végétaux riverains

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RÉSUMÉ

Les rivières et les humains partagent le territoire, l'eau et les ressources écologiques. Les altérations hydrologiques et de l'occupation et de l'usage des terres (LULC) modifient le fonctionnement des écosystèmes riverains. Nous avons étudié les changements écologiques et géomorphologiques induits par la régulation des débits et le LULC dans trois rivières avec un usage hydroélectrique du nord et du centre du Portugal et dans une très grande rivière du sud-est (rivière Guadiana). Cette dernière est impactée par le barrage d'Alqueva, l'un des plus grands lacs d'irrigation d'Europe occidentale. Pour les rivières avec un usage hydroélectrique, nous avons effectué une comparaison temporelle en aval des barrages, avant et après la mise en service (1965 et 2013, respectivement) en utilisant de l'imagerie à haute résolution. Pour la rivière Guadiana, il a été possible d'analyser les images des périodes pré- (2000) et post-régulation (2013), et les données floristiques à des dates comparables (1987-1999 et 2017, respectivement). Les forêts riveraines de l'aval des rivières à usage hydroélectrique occupent plus de surface qu'auparavant, mais elles présentent des pertes significatives de complexité et de diversité de la végétation. Au contraire, la régulation des débits par le grand barrage d'Alqueva a entraîné d'importantes modifications du cadre géomorphologique et de forts déclins des valeurs d'abondance et biodiversité, en particulier dans les strates ligneuses ripicoles.

ABSTRACT

Rivers and humans compete for territory, water and ecological resources. Hydrological alterations and land-use and land cover (LULC) are known to alter riparian ecosystem functions and processes. We studied ecological and hydromorphological alterations by regulation and LULC in three hydropower rivers of north and centre Portugal and in a very large river in the southeast (River Guadiana). The latter is impaired by Alqueva dam, one of the largest irrigation dams in Western Europe. For the hydropower rivers, we performed a temporal comparison using pre-dam (1965) and post-dam (2013) high-resolution airborne imagery downstream of dams. For River Guadiana, it was possible to analyze airborne imagery before and after the commissioning year (1990 and 2013, respectively), and floristic data in comparable dates (1987-1999 and 2017, respectively). Riparian forests of hydropower rivers occupy more area than in pre-dam times, but statistically significant losses in complexity and diversity of riparian patches were observed. In contrast, the streamflow regulation by Alqueva dam resulted in large alterations in hydromorphological setting and dramatic declines in riparian abundance and biodiversity values, especially in the woody strata.

KEYWORDS

Portugal, reservoirs, riparian forests, rivers, temporal analysis

1 INTRODUCTION

Rivers and humans compete for territory, water and ecological resources. Dams are undoubtedly one of the major factors that unbalance those disputing relations. Damming affect river hydrology in quality, quantity and timing, interrupts the longitudinal connection of habitat patches and consequently disrupt functions and processes of river and riparian ecosystems. The backwater effect of dams produces ponding in upstream segments up to a certain extension, and river dynamics experience abrupt changes from a lotic system to the lentic environment of the reservoir. Downstream of dams, the impacts are manifold, including sediment depletion and rearrangement of the biogeomorphological stream components (Nilsson and Berggren 2000). There is a growing number of studies worldwide on the effects of streamflow regulation on aquatic and riparian biota and on the biogeomorphological sucession (e.g. Corenblit, Steiger and Tabacchi 2010). However, understanding damming effects is a local context-based challenge. With this study, we aim to relate river dynamics, geomorphology, vegetation and land-uses in dammed rivers. For this, we selected three rivers in Portugal regulated for hydropower generation (rivers Alba, Lima and Homem), and one large river regulated mainly for irrigation (River Guadiana) as case studies. We resourced to geospatial mapping and interpretation of historical and contemporary imagery metrics and field-based data from pre- and post-regulation periods.

2 METHODS

We used a temporal comparison of pre-dam (1965) and post-dam (2013) high-resolution airborne imagery for the hydropower rivers regulated by Touvedo dam (run-of-river dam), Vilarinho das Furnas and Fronhas (storage reservoirs). A new approach was devised to correct the spatial offset between historical and contemporary imagery. Riparian vegetation and land-use and land cover (LULC) were mapped (Fig.1). Indicators of hydrological alteration were calculated for both periods. For River Guadiana we used pre-dam airborne images from 1990 and post-dam ArcGIS Online World Imagery map from 2016 (Fig.2) to extract data on riparian vegetation, geomorphological features and LULC data. Vegetation data from historical floristic surveys was gathered (1987-1999) and field surveys were performed for the same locations in spring of 2017.

Five landscape metrics, measures of shape complexity, area and edge effect of riparian patches were calculated. We analysed whether the means between pre-dam and post-dam periods of the riparian and land-use variables-difference were significantly different, using paired t-tests. Redundancy analyses were used to evaluate the contribution of hydrology and LULC to riparian changes.

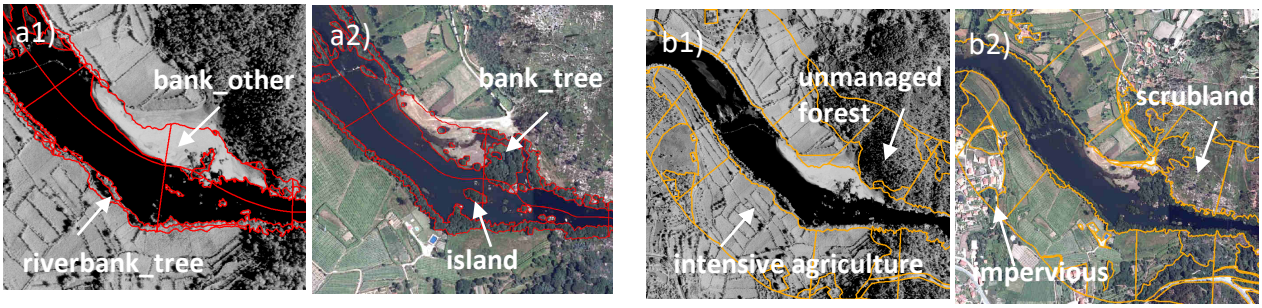

Figure 1. Panels a): illustration of delimitation of sampling units (red lines perpendicular to the thalweg divide continuous sampling units), riparian patches (tree and other) and river locations (riverbank, bank, island), a1) historical and a2) contemporary periods, for case study Touvedo (River Lima). Panels b): illustration of the LULC patches (yellow lines) within a 200m buffer for b1) historical and b2) contemporary periods, for case study Touvedo (River Lima).

3 RESULTS AND DISCUSSION

Rivers and their landscapes were highly altered by both hydrological alterations and LULC changes. Riparian forests of hydropower rivers occupy more area than in pre-dam times, but statistically significant losses in complexity and diversity of biogeomorphological units were observed. Reservoir rivers (Alba, Homem) experienced mostly vegetation encroachment towards the active channel while in the run-of-river case (Lima), an outward expansion towards the floodplain was observed (Aguiar et al., 2016). Regulation by Alqueva dam resulted in large losses in hydrogeomorphological setting and in biodiversity values. The disrupted sediment and flow regime altered significantly the river channel geometry, river sinuosity and the number and area of biogeomorphological features such as islands and banks. Riparian zones suffered a dramatic decline of native and Iberian endemic woody species (*Salix salviifolia* spp. *salviifolia*, *Flueggea tinctoria*, *Nerium oleander*) (Fig.2) and an increase in alien plant species both upstream and downstream of Alqueva dam. However, we found some 'reliquial habitats' in adjacent wetlands nearby the reservoir holding species-rich communities of riparian herbs. The mitigation of impacts of regulation and LULC changes should rely in the knowledge of the interactions between surrounding lands, ecological, biogeomorphological and hydrological components of rivers.

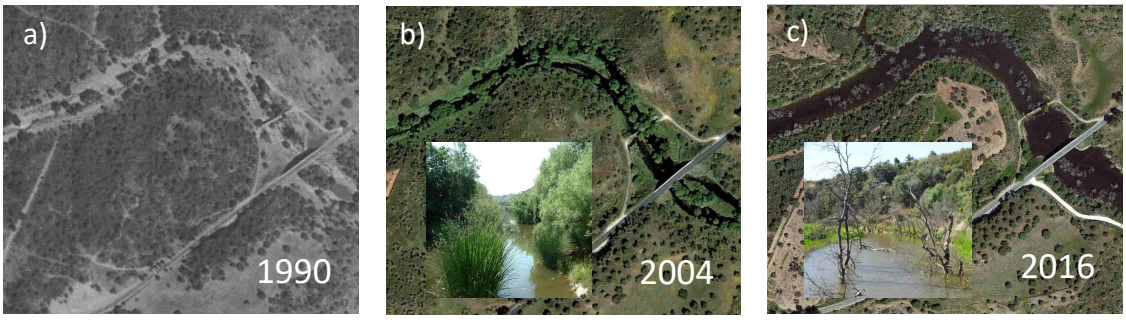

Figure 2. Landscape views from a tributary of River Guadiana upstream Alqueva dam before (1990) and after the commissioning year (2004; 2016). a) airborne image (Direção Geral do Território - Voo SOF10K 1999); b) Image - DigitalGlobe- Google Earth; c) ArcGIS Online World Imagery map 2016, Copyright © Esri; b) and c) photographs from field (2004; 2017)

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