Artificial wetlands on the Rhône River: a comparative approach to investigate their evolution and hydro-sedimentary functioning

Zones humides artificielles sur le fleuve Rhône: une approche comparative pour étudier leur évolution et leur fonctionnement hydro-sédimentaire

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RÉSUMÉ

Les systèmes fluviaux profondément modifiés par des aménagements présentent des milieux « artificiels » encore insuffisamment étudiés en termes d'évolution et de fonctionnement. Le fleuve Rhône a subi en France deux principales phases d'aménagement – une phase de rectification, impliquant la construction d'un système étendu de digues longitudinales submersibles et de digues transversales à la fin du 19ème siècle ; et une phase de dérivation liée à la production hydroélectrique dans la seconde moitié du 20ème siècle. Dans ce travail on analyse la variabilité des patrons spatio-temporels de l'atterrissement des zones humides artificiels associés à l'endiguement (au sein des casiers Girardon). Quatre Rhône court-circuités (RCCs) ont été analysés comparativement à partir de procédures géomatiques et d'études de terrain. Une typologie de l'évolution morphologique des zones humides a été établie. L'intensité et l'organisation spatiale de la sédimentation/de l'atterrissement ont montré une variabilité inter- et intra-RCC importante, avec des conditions stationnelles allant d'encore aquatique (1% des casiers étudiés) au terrestre (78% des casiers analysés). La temporalité et l'intensité de cette sédimentation varient également significativement selon les casiers et les RCC. Les résultats de cette étude alimentent les discussions relatives à l'aménagement durable des marges du fleuve Rhône.

ABSTRACT

Highly modified river systems feature "artificial" milieus which are to date insufficiently understood in terms of their evolution and functioning. The Rhône River experienced two principal historical management phases in France—a rectification phase, entailing the installation of a vast system of longitudinal submersible and transversal dikes in the late 19th century; and a derivation phase related to hydropower production in the second half of the 20th century. In this study we investigated the variability of spatio-temporal terrestrialisation patterns in artificial wetlands associated with the dike system. Four by-passed reaches were comparatively analysed based on both GIS and field approaches. A typology of the morphological evolution of the wetlands was derived. The intensity and organisation of sedimentation/terrestrialisation were variable among as well as within the individual by-passed reaches, with present conditions ranging from fully aquatic (1% of analysed dike fields) to fully terrestrial (78% of analysed dike fields). Principal sedimentation phases and mean annual sedimentation rates likewise varied significantly between reaches. The results of this study provide a basis for the discussion on the future sustainable management of the margins of the Rhône River.

KEYWORDS

By-passed reaches, Comparative approach, Girardon dike fields, Retrospective approach, Sedimentation patterns

1 BACKGROUND

Human intervention has profoundly modified rivers worldwide. Their hydro-morphological functioning is generally highly altered, leading to the evolution of different, “artificial” habitats. The Rhône River, France, experienced two principal historical management phases—a rectification phase, entailing the installation of a vast system of longitudinal submersible and transversal dikes in the late 19th century (Girardon, 1894); and a derivation phase related to hydropower production in the second half of the 20th century. It is today highly confined in its lateral dimension and many aquatic compartments within the flood plain have vanished as a consequence of terrestrialisation processes, i.e. sedimentation, channel incision, and modified discharge conditions (Fruget & Michelot, 1997). Thereby, new “artificial” wetlands have evolved within the space confined by the dikes. The question about a sustainable future management and ecological improvement of the river within the framework of contemporary constraints entails the need to analyse the character and potential heterogeneity of these modified conditions in order to evaluate associated risks and ecological potentials.

The principal objective of this study is to derive a morphological characterisation of the dike field wetlands using a comparative and diachronic approach. Four by-passed reaches located along the river and subjected to derivation at different periods were chosen and the evolution of the artificial wetlands investigated.

2 MATERIAL AND METHODS

2.1 Material

We used both planimetric and topographical data to characterise the sediment deposits within the dike fields. The Rhône Atlas (1857–1876, source: administration des Ponts et Chaussées, Service Special du Rhône) was used to depict conditions before construction of the dikes, historical bathymetric maps (1897–1902), the Branciard map (1905), and aerial photographs (source: IGN, from 1938 onwards) were used to investigate the planimetric evolution of aquatic and terrestrial zones following their installation. Orthophotos (source: IGN, from 2006 onwards) and LIght Detection and Ranging (LiDAR, source: IGN) data derived Digital Elevation Models (DEMs) were applied to characterise present conditions.

2.2 Study sites

Subject of our investigation were the four by-passed reaches of Pierre-Bénite (PBN, river kilometres 4.0–15.0, downstream distance from the city of Lyon), Péage de Roussillon (PDR, r. km 50.5–63.0), Montélimar (MON, r. km 153.0–166.0), and Donzère-Mondragon (DZM, r. km 170.5–200.5). They were by-passed at different dates (PBN: 1966, PDR: 1977, MON: 1956, DZM: 1952).

2.3 Methodology

2.3.1 Analysis of spatial terrestrialisation patterns

Dike fields, as well as landscape units within their boundaries, were manually digitised in a GIS environment based on historical maps and recent orthophotography, respectively. A total of 523 dike fields were identified within the four study reaches. We segmented 292 dike fields located in the main by-passed channel into transects of 4 m length and extracted their degrees of terrestrialisation, as well as mean values and the ranges of relative altitudes. This facilitated the analysis of the longitudinal organisation of these variables within each dike field and a comparison of patterns between dike fields and between study reaches. We here adapted a morphological-hydraulic classification of groyne fields established for the Elbe River, Germany (Sukhodolov et al., 2002), to the conditions in the Rhône dike fields using quantitative methods.

2.3.2 Diachronic analysis and sedimentation rates

Landscape units were digitised based on a series of historical maps and aerial photographs in order to reconstruct the evolution of the sediment deposits. Mean annual planimetric expansion rates of the deposits were calculated and the dike field segments (paragraph 2.3.1) were used to analyse the longitudinal pattern of deposit evolution. Measures of fine sediment depth were then carried out in the field, in order to estimate mean annual rates of vertical sedimentation in a sub-set of randomly chosen dike fields within the four reaches.

3 RESULTS

The dike fields feature surface areas between 0.04 ha and 110.63 ha and variable dike characteristics. Those dike fields within the study reach of DZM are significantly larger than dike fields in the other three reaches, whose size distributions are relatively homogeneous.

3.1 Spatial patterns of artificial wetland terrestrialisation

Only 1% of the artificial wetlands are still fully aquatic at present. Most wetlands, i.e. 78%, have become fully terrestrial at minimum flow conditions imposed by dam regulation. This is particularly the case for the reach of PBN, where very few aquatic zones remain, while PDR features the most heterogeneous conditions. The degree of terrestrialisation does not show any particular longitudinal pattern within individual reaches, but is related primarily to local phenomena. Several types of dike fields were distinguished with respect to their degree of terrestrialisation (fully aquatic, partially terrestrial, fully terrestrial) and the longitudinal distribution of the deposits.

3.2 Artificial wetland evolution

Mean annual rates of sedimentation ranged between 0.2 cm/yr and 10.8 cm/yr and differed significantly between the four study reaches. The two most downstream reaches further presented significant variations in sedimentation rates prior to and following derivation. This was likewise shown by the planimetric analysis, where the timing of the major terrestrialisation phase was not the same between reaches.

4 CONCLUSIONS

The variability of dike field terrestrialisation patterns shown by this contribution highlights the need for more detailed studies both of the ecological potential and the associated risks in terms of contamination. The established classification serves as a starting point for further studies and can provide guidance in the selection of dike fields for future Rhône margin re-dynamisation projects.

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