La mobilité latérale peut-elle être restaurée le long d'une rivière à lit de gravier à faible énergie fortement anthropisée ?

Can lateral mobility be restored along a low energy gravel-bed river highly domesticated?

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RÉSUMÉ

Ce travail s'intéresse à la question des effets des ouvrages sur la mobilité latérale d'une rivière à graviers de faible énergie (Cher, France). Nos principaux objectifs sont de : 1) estimer ce qu'il reste aujourd'hui de la capacité érosive latérale de la rivière, 2) identifier les facteurs de contrôle de la localisation et de l'intensité de l'érosion latérale, 3) déterminer le potentiel de préservation ou de restauration du corridor érodable, 4) examiner les mesures de gestion qui pourraient mises en œuvre. Pour cela, nous avons mis en place une approche méthodologique combinant relevés de terrain, analyses géomatiques et traitements statistiques. Nos résultats indiquent que la rivière est aujourd'hui composée d'une succession de tronçons courts contraints et non contraints. L'espace potentiellement érodable est ainsi résiduel. Les sédiments grossiers réinjectés dans le lit par érosion latérale au niveau de chacun des tronçons non contraints contribuent peu ou pas, à l'entretien de la dynamique latérale sur les tronçons non contraints plus aval. Enfin, la part du linéaire fluvial pour lequel un corridor érodable pourrait être préservé ou restauré est très faible. Cela implique que l'atteinte du bon état écologique sur toute la longueur de la rivière constitue un objectif vraisemblablement inatteignable en l'absence de réinjection artificielle de sédiments.

ABSTRACT

In this study, we investigate the issue of the control of ancient engineering works on the lateral mobility of a low energy gravel-bed river through a case study on a 146 long reach of the meandering Cher River. Our main objectives are 1) to estimate the remnant shifting capacity of the river, 2) to identify the controlling factors of the location and intensity of lateral erosion, 3) to determine the potential for preservation and restoration of the river shifting, and 4) to examine the management measures that could be implemented. For that, we used a methodological framework combining field surveys, geomatic analysis and statistical treatments. Our results show first that the river is today composed of a string of short constrained and unconstrained reaches with the erodible corridor reduced to its smallest portion. Then, coarse sediments re-injected into the bed by lateral erosion at a given unconstrained section would contribute little, if any, to the maintenance of lateral dynamics on the downstream unconstrained reach. Lastly, the proportion of the river length where the lateral mobility could be preserved or restored is very low. It implies that the achievement of the good ecological status on the entire river length is very unlikely without sediment augmentation.

MOTS CLES

Erodible corridor; Human constraints; Lowland river; Meander migration; Restoration

1. INTRODCUTION

Due to the relative slowness of the morphogenic processes in low energy gravel-bed rivers, it is often difficult to decipher the respective influence of human and natural pressures in the trajectory evolution of these systems. Such disentangling is yet essential to determine in which extent the river dynamics is disturbed and if measures of lateral mobility restoration could be implemented. We investigate these issues through a case study on the Cher River, whose the ecological status according to the Water Framework Directive is considered as moderate or poor. From an operational point of view, this study gives answer to the following questions: Is good ecological status achievable? If so, where and at what conditions?

2. STUDY REACH

The study reach is located on the Cher River (France), one of the main tributaries of the Loire River. It extends over 146 km in length. The Cher River is a low energy single thread river with a meandering pattern developed for the last millennia. In the study reach, the river has a surface D_{50} about 15-45 mm and a mean specific stream power of 20 W m^{-2} (calculated from the width of the active bed) for a discharge close to the bank-full level, that is exceeded 1% of time.

3. MATERIAL AND METHODS

Our methodological framework combines 1) GIS analysis, aiming at to reconstruct the planimetric evolutionary trajectory of the river from aerial photographs and to quantify the available space for river shifting with and without lateral constraints, 2) thorough field surveys, allowing localizing the current bank protections as well as the bars and riffles, considered as indicators of the coarse material available for bedload, 3) existing databases analysis to identify the current stakes in the floodplain 4) multiple regression to explain and predict bank retreat rates at the section scale from specific stream power and curvature.

4. RESULTS

4.1. Longitudinal pattern of historical changes

For both historical bank retreat rates and current geomorphic units, the studied reach has two distinct sub-reaches. In the upstream sub-reach, retreat rates between 1959 and 2016 are four times higher and the density of bars and alluvial riffles is much higher than downstream (respectively x 3.8 and x 3.5). The upstream mean spacing between rocky riffles is 8 times higher, whereas the mean length of bedrock sections and the distance between two consecutive bedrock sections are respectively 1.7 lower and 2.6 times higher than downstream.

4.2. Fluvial engineering works

Naturally, the Cher River is partially confined: 19.2% of its length is fixed by a terrace, an alluvial or colluvial fan, or a hillslope. Human constraints (bank protections, bridges, weirs, floodplain gravel pits) is also affecting channel shifting over 37 % of its length.

The bed is significantly fixed laterally and fragmented along its course. The distance between two consecutive fixed sections decreases sharply: it is 1190-800 m (mean-median) when considering only natural constraints, whereas it is 227-150 m when including human ones. The length of laterally constrained sections varies much less: it is 285-200 m with natural constraints against 290-200 m with all constraints.

The alluvial plain width, i.e. the maximum erodible width, is 707-678 m (mean-median). If the natural lateral constraints and all the human constraints (bank protections, bridges, weirs, gravel pits) are added, the erodible width decreases to 489-455 m, namely a reduction of 31-33% or by a factor of 1.45-1.49.

4.3. Preservation and restoration of the lateral mobility: elements of prioritization

The multiple regression models developed provide a relatively good explanation of the concave bank retreat rates between 1959 and 2016 on free-shifting sections. Over 50% of the variance in retreat rates is explained by the maximum specific stream power and the mean local curvature along the sections, both variables playing a significant role.

Twenty-four sections of the river are of particular interest in terms of erodible corridor preservation (Figure 1). They extend over a total length of 9.3 km, i.e. 6.3% of the length of the study reach. Most of them are located upstream, between kp 15.9 and 69. Thirty sections of the river are of particular interest in terms of restoring the erodible corridor (Figure 1). They represent a total length of 28.6 km, or 19.7% of the length of the study reach and are occupied by 11.3 km of bank protections, which corresponds to 39.3% of the total length of the 30 sections. Compared to the conservation sections, they are more evenly distributed along the study reach. However, they are mainly located upstream: 12 of the 30 restoration sections are located between kp 26.6 and 48.6, i.e. over 20 km (15.1% of the study reach length). Moreover, they represent 76.9% of the total length of the restoration sections.

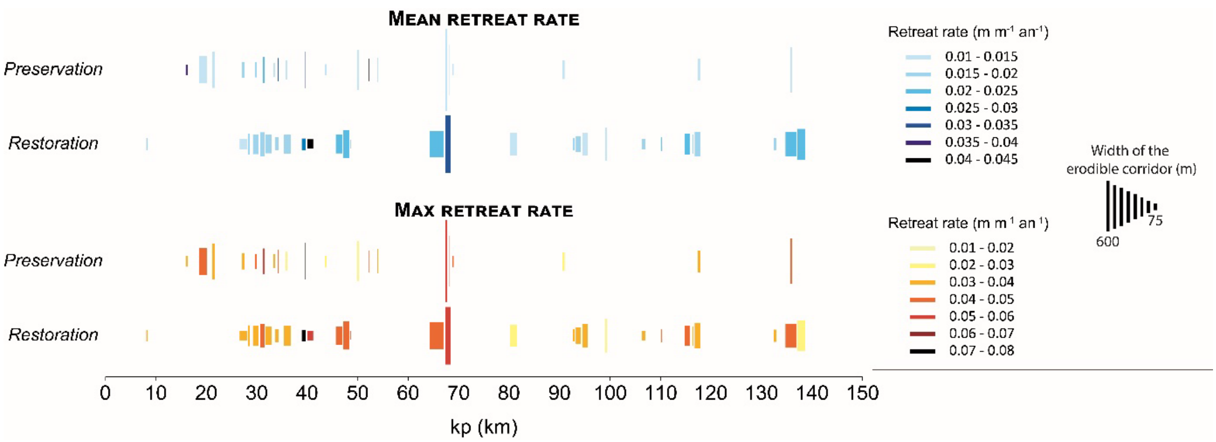

Figure 1 - Longitudinal pattern of priority reaches for preservation or restoration of lateral mobility.

5. DISCUSSION

5.1. Self-maintenance of river migration

We have here located and prioritized the reaches presenting a significant potential for preserving or restoring the erodible corridor. However, it does not provide information on the real capacity for self-maintenance of the lateral mobility of the Cher River. It is yet a condition to guarantee the success of the erodible corridor restoration. This capacity is mainly controlled by the availability of a sufficiently large load of mobile coarse sediments. It has indeed been shown that meandering rivers will be more laterally active the higher the sediment supply. If we consider that the longitudinal dichotomy in the density of geomorphic units reflects a marked difference in available bed-material load, and thus in bedload, and knowing that the specific stream power is not high downstream to the breakpoint, it follows then that the capacity for self-maintenance of lateral erosion processes should be much more limited along the downstream sub-reach. Such a hypothesis would tend to be confirmed by the fact that bank retreat rates from 1959 to 2016 were significantly higher upstream of kp 70. Data from several technical reports confirm the lower downstream availability of coarse sediments. It results from the longitudinal decrease in the size and volume of coarse particles. In the downstream sub-reach, this reduced stock would limit the reinjection of coarse sediments into the riverbed following bank erosion, with a consequent limited capacity for self-maintenance of lateral bed instability compared to the upstream sub-reach.

5.2. Improvement of the ecological status: what prospects?

Along the study reach, the ecological status of the river according to the WFD reference is considered as poor or moderate depending on the location. If we assume that the unsatisfactory ecological status of the Cher River is at least partly the result of the strong direct anthropogenic pressures exerted on the lateral mobility of the river, no improvement of the ecological status could be achieved without any restoration of the erodible corridor. However, such a restoration could only concern a relatively limited number of river sections. Furthermore, the low bedload velocities (30-300 m per decade) indicate that most of coarse sediments reinjected in the riverbed by lateral erosion would remain at close proximity of the eroded banks at a decadal scale. It implies that only a local increase in the heterogeneity of aquatic and riparian habitats could be achieved through such injection. The effects of restoration actions would thus be spatially limited. In view of these various elements, achieving good ecological status along the entire length of the river and over a short time scale (a few years to decades) should consider mechanical actions to reintroduce sediment rather than self-adjustment due to low energy conditions.