# Global change constraints and opportunities for the restoration of large river floodplains

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**Abstract:** Global changes impose constraints but can be incorporated as opportunities for the ecological restoration of floodplains of large rivers. General reductions of water discharge and change of the discharge regime were observed in most European rivers. This impose a reduction of water and dynamics to recreate new sites in floodplains but offers the opportunity to recreate new sites and develop ecological restoration projects by re-connecting and establishing ecological corridors between the rivers and their floodplains. Decreased water quality is a global change affecting large rivers. The ecological restoration of floodplains is an opportunity to contribute to improve water quality by accumulating sediments and removing nutrients, particularly nitrogen. Extensive use of floodplain areas for agriculture lowered biodiversity at landscape scale. It can be an opportunity now to involve farmers and agricultural plans in new activities demanded by society, including reduction of flood risk. It can be also an opportunity to counteract impacts from invasive species while offering alternatives for the conservation of native biodiversity under stress in degraded channels of large rivers. Intensive use of floodplain areas by urban and industrial areas is the most difficult constraint to address as it requires revitalization of social activities for planning the change of land use cover and their restoration at ecosystem scale. Case studies in the Ebro River floodplains illustrate these strategies to plan and implement ecological restoration**.**

**Keywords:** Global, climate, change, large rivers, floodplains, Mediterranean, connectivity, water dynamics.

## Introduction

The present climate change is the consequence of global changes caused by human activities during the industrial era (IPCC 2007). These can be grouped in relation with fossil fuel extraction and burning, changes of the biogeochemical cycles, land use and land cover changes, and changes of biodiversity and they are related to each other (Vitousek *et al.* 1997). All these global changes are impacting large rivers and should be taken into account for their restoration, particularly for their floodplains. These global changes represent constraints for their restoration and are setting up difficult challenges to meet, particularly because of the uncertainties related to climate change impacts (Harris *et al.* 2006). However, these constraints can be considered also as opportunities for developing new pespectives for ecological restoration.

With respect to floodplains of large rivers, major constraints are related to reduction of water discharges, land use cover changes and biodivesity and water quality loss. Nevertheless, it is interesting to remark that impacts of global changes are predicted to show a wide spatial heterogeneity, which may also set up a variety of spatial targets according to the scale of the restoration objectives. In this paper we propose a framework of opportunities related to global change constraints for the ecological restoration of large rivers and their floodplains.

## Material and Methods

Global changes causing the present climate change are reviewed in relation with their impacts on large rivers and their floodplains following results reported in IPCC (2007). Impacts of global changes in the Ebro River (NE Spain) are used to illustrate constraints

and opportunities for its ecological restoration. A detailed description of the characteristics of this large river is presented in Cabezas *et al.* 2008).

**Results and Discussion**

*Global changes affecting large rivers and their floodplains*

Projections of climate change for the 21st century show a general trend of increasing the frequency of flood events in north latitudes and the frequency of dorught evnts in south latitudes which may be related to similar trends for annual runoff (Milly *et al.* 2005,). Restoration strategies and actions will need to be in agreement with this spatial heterogeneity of impacts. Otherwise, a single strategy and technique may not be appropiate for the restoration of the same type of ecosystem in different parts of the world. Consequently, in high latitudes it may be adequate to let the river flood large floodplains. However, in low latitudes reallocation of water uses and recovery of water discharges and water flow regime is a major objective to restore dynamic and sustainable river-floodplain systems. Alternatively, groudwater excavation may be used as an efficient tool to recover floodplain-river vertical and lateral connectivity as far as no other negative consequences arise.

Land use and land cover changes are mostly related to agriculture and urban development in floodplains (Tockner & Stanford 2002). The practice of initial agriculture to occupy fertile floodable soils near large rivers was not corrected after agricultura developen new fertilization and irrigation systems. So, instead of an adaptive strategy to use floodable areas, moren agriculture development used a defensive strategy constraining rivers within banks and dikes and channelizing rivers. As a consequence, restoration of floodplains transformed into agricultura zones requires space ("room for rivers", Rohde *et al.* 2006). Space for the flood to proceed in the floodplain and connect with remaining wetlands and other natural sites in the floodplain and space to recreate new ones. However, space is not enough as a dynamic system as the river-floodplain system is rquires energy and transformations during time. So, room is necessary but no sufficient as energy, rythm is also required.

Land cover change in the watershed is a key factor regulating river dynamics and water quality as suspended and dissolved materials and water flows in the rivers are tightly linked to the characteristics of their watersheds. The restoration of a river and its floodplain should be approached at watershed scale (Jensen *et al.* 2006) addressing integratively a number of processes (erosion related runoff, landscape fragmentation, transport of solotes and dissolved compounds) which affect the role of natural systems in the watersheds and in the rivers to buffer impacts and their auto-depurative capacity.

One of the most global water uses afecting restoration potencial of large river floodplains is damming (WCD 2000, Nilsson *et al.* 2005). Dams change alters the water flow and quality, change land cover of the flooded zones, river dynamics upstream and dwonstream the dam, and water quality and biodiversity. Dam re-operation is an opportunity for partial restoration of rivers and their floodplains. Dam re-operation can be useful to re-establish river flows and floods. And also to re-create lost and damaged river and floodplain habitats (Richter & Thomas 2007).

Biological invasions of rivers are one of the most widespread global changes. Invasive species are prevailing in rivers at continental scale favoured for watershed and river degradation related habitat destruction (Crowl *et al.* 2008).

*Case Study: The Ebro River floodplains.+*
Opportunities for restoration of floodplains in the Ebro river include those related to increasing lateral connectivity in floodplains intensively transformed by agricultural and urban uses (Fig. 1). Removing dikes and banks and let floods to proceed while recovering floodplain functions, including buffering flood events, but integrated with a renewed creative capacity of floodplain habitats an socio-economic agreement with landowners are required to achieve an effective restoration and ensuring services provided by floodplains.

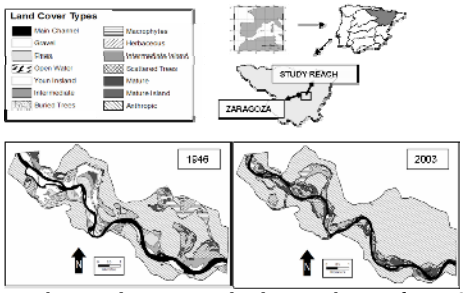


*Fig. 1* Study area above and contrasting land cover changes from 1946 to 2003.

This would let flooding floodplain zones close to the major river channel by just adjusting dams operation to water demand for human uses combined with riparian forest demand for sediment and seed dispersal.

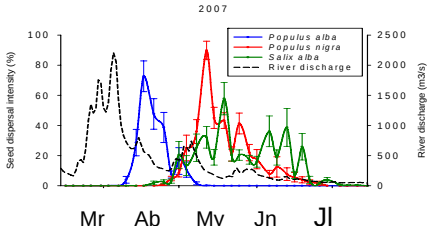


*Fig. 2.* Timing of seed dispersal for riparian trees related to the river flow in the Middle Ebro floodplain.

In the Ebro river, increasing lateral hydrologic connectivity of floodplains with the main river channel through groundwater has been and adequate approach to improve river-floodplain connectivity in zones with technical or social constraints for surface connectivity.
Buffering impacts of runoff from eroded sites in the watershed and from agricultural zones exporting high amounts of nitrogen can be accomplished by restoring and creating wetlands in the watershed and in the river margins and floodplains. This is a

major opportunity to integrate productive activities with ecosystems services while establishing ecological corridors and habitats favourable for native species.

**Conclusions**

Global changes impose severe constraints to the ecology of large river flooplains. Opportunities for their restoration depend on river flow and regime recovery, including dam re-operation, recovery of surface and groundwater connectivity. It should include an integrative approach for social agreements to recover ecosystem services linked to ecological corridors, habitat recreation and improved water quality.

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