EIP-AGRI Focus Group

Nature-based Solutions for water management under climate change

Agricultural Nature-based Solutions as biodiversity hotspots for river ecosystems resilience

COORDINATOR: ADRIANO BATTILANI

CONTRIBUTOR: JEROEN DE WAEGEMAEKER

funded by European Commission

Table of contents

INTRODUCTION - MOTIVATION

What's the mini paper about?

In Mediterranean countries, Alpine areas and many other regions, watercourses are characterised by a strong seasonal variation in flow rate: dry or almost dry in summer, and torrential waters in autumn and winter.

Existing ecosystems, or those intended to be restored, have adapted to these seasonal variations of the watercourses. Since 2003, increasing variability in the flow rates of rain-fed rivers and watercourses is recorded: from seasonal variations in precipitation that result in small variations in flow rates of surface waters towards a regime of intermittent rain and prolonged droughts that result in ephemeral watercourses. Furthermore, rather than be oasis for biodiversity, large watercourses in the plains are often experiencing "out of season" water flows typical of the drier summer, due to prolonged drought spells in winter or springtime.

IPCC AR6 forecasts that these trends will worsen in the next decades and, as a result, we'll have to deal with rivers that are swollen with water during rainstorms and which risk to flood vast plains on the one hand, and that are dry during long-lasting droughts on the other hand. During the second hydrological regime, the watercourse is reduced to some permanent waterholes which act as refugia for the river's aquatic ecosystem.

Refugia or hotspots are localised, permanently-wet meso or microhabitats where organisms can survive or even thrive during the dry periods, waiting to recolonise the rivers in wet periods.

This strategy of refugia can be applied to control also other stressors that impact the river's ecosystem, aiming to create interruption to anthropic disturbances when the overall hydroclimatic condition are making them a threat for the ecosystems. As an example, refugia design is usually considering the need to regulate water temperature by means of vegetation shadowing the river bed, and the refuge's banks are often designed or re-shaped according green engineering criteria offering different water depth, areas with aquatic vegetation and supporting the whole food chain, a suitable environment to let biodiversity thrive.

Increasing the biodiversity and its resilience in highly modified river basins is also deemed as a crucial step forward towards a non-conflictual application of the ecological flow regime.

Why is this minipaper needed?

Although the IPCC AR6 forecasts that droughts and intermittent rain will worsen in the next decades, our efforts to create resilient aquatic ecosystems are predominantly based on our memories (how the river used to flow) and not on the basis of climate forecasts (how the river will flow). To increase and safeguard the rivers' ecosystems and their biodiversity we can resort to existing infrastructure must foresee new additions, e.g. permanent-wet hotspots interconnected with the river bed as well as proper connection along the river length.

STEP 1: During rivers' high flow water is stored in the hotspots moving also biodiversity in it.
STEP 2: Rivers low flow, water scarcity or drought are reducing biodiversity into river beds and riparian areas, while the permanently-wet hotspots meso and microhabitats survive or even thrive.
STEP 3: At the end of the dry periods, hotspots biodiversity will recolonise the riverine ecosystems, reducing the recovery time and thus increasing their resistance and resilience to extreme climate events.

NbS criteria and current experience applied to agricultural waterworks, for example, can add a novel function and purpose to them. There is a potential great interest in implementing NbS, also coupled with novel water governance criteria and soft/eco technologies, to improve aquatic ecosystems resilience.

Agricultural water boards are looking to NbS with modest interest, recognising as main barrier the availability to change and risk appetite of the final users: the farmers. As a matter of facts, farmers are called to undertake an action of individual responsibility or, through their Associations and the Agricultural water Boards they control,

funded by European Commission

to comply with their corporate responsibility towards the environment and the sustainable uses of natural resources. Nevertheless, rather than be a big investment and a further operational and management cost (OPEX), the use of existing infrastructures or the design of new ones according to these novel governance model, can reduce OPEX while creating business opportunities like recreative areas integrating agrotourism services, cycling routes supporting zero-kilometre agricultural market or farmers' hospitality, etc., hence increasing the resilience of the farming area/activity.

The present minipaper is intended to raise awareness among farmers about the possibility to stabilize or even to greatly increase watercourses' ecosystem services, including the artificial watercourses utilised for agricultural land drainage/irrigation, while reducing OPEX and creating business opportunities.

DISSERTATION

Description of key issue(s)

Hotspots are based on diverse mechanism depending on the spatial and temporal attributes of the physical environment and of the stressors, and of the requirements of the target organisms. These factors need to be duly analysed and fully understood. The same uncertainty is affecting all the decision processes related to aquatic ecosystems preservation and restoration, as well as ecosystem services identification and quantitative assessment.

NbS Hotspots can help not only to support ecosystems resilience after recurrent drought spells, but they also offer a great opportunity to collect data and to fill the knowledge gaps, allowing to apply in targeted manner sophisticated eco-hydrologic models assessing water regimes impacts on the riverine biodiversity. The acquired knowledge, and the NbSs Hotspots themselves, will be also important to overcome the problem of temporary lack of connection between riffle and pool/glides habitats, or between river subsections.

Hotspots are often considered as natural refugia, therefore design criteria for artificial NbS Hotspots are lacking. Even a roughly standardised design methodology and economic assessment criteria would be of the utmost importance for the widespread implementation of these solutions.

NbS Hotspots can be combined with i.e. treated wastewater storage, thus adding value to the NbS itself and to the peri urban landscape and agricultural canal networks.

NbS Hotspots can be designed for multipurpose uses, supporting ecosystem production all over the year and integrating hydrological risk management and agricultural uses, benefiting more stakeholders and sectors thus reducing conflicts already arising.

Farmers must benefit of NbS Hotspots. Therefore, they must be designed to reduce OPEX and for compatible multiple uses. NbS Hotspot size, water residence time, flow velocity differentiated by zones, banks shape, riparian vegetation, and minimum permanent water level, must be harmonised with the original use of the drainage/irrigation canal. NbS Hotspots could also serve as water storage, i.e., when integrated in a water reuse system, coupling ecological and agricultural uses of the treated water.

There is also a need of social innovation for NbS Hotspots. The objective to develop a river ecosystem's resilience via NbS hotspots demands for an approach on the landscape scale, the watershed of the local watercourse to be precise. According to the geographical context the size of such watershed ranges from several hectares up to a county. Moreover, the size of a farm in Europe varies greatly: from 5 hectares to more than 100 hectares (EUROSTAT 2016). As a result, the construction of hot spots on the field requires in many cases the co-operation of many stakeholders including multiple farmers, water managers, and nature developers. As a consequence, NbS for river ecosystems resilience demands for social innovation, bringing astringed parties together. A model of long lasting and effective collective/cooperative management of water in agriculture is offered by Consorzi di Bonifica in Italy and Comunedades de Riegantes in Spain and Portugal. These institutions controlled by farmers have the capability to integrate NbS Hotspots in the agricultural water governance. Notwithstanding, there is a big need for further research an inspiring example on how diverse stakeholders can be brought together in countries were tradition of farmers cooperation in managing water resources is lacking.

State-of-the-art of research/practice

Starting from the extensive work done since 1988 on terrestrial Hotspots, the concept of highly biodiverse areas hosting and protecting a substantial fraction of the local biodiversity has been extended to marine and ultimately freshwater habitats.

The search of natural hotspots made evident that biodiversity is not evenly distributed on our planet, neither inside a defined ecosystem. Put another way, biodiversity is heavily concentrated in certain refugia with exceptionally high concentrations of endemic species. We must conserve these places which high levels of endemism are irreplaceable.

Refuges have the ability to facilitate survival of biota under adverse conditions, efforts must focus on ensuring a higher number of hotspots, because the unique species they contain cannot be saved elsewhere. To be effective a hotspot requires long-term persistence of the protected biodiversity, rather than simply protect existing natural hotspots systematic efforts to identify gaps in the riverine biodiversity continuum, caused by anthropic disturbances, will enable to strategically add new artificial NbS Hotspots. These artificial hotspots provide “stepping stones” to facilitate movement of species to new ranges, restoring biodiversity, or to re-colonise rivers after a long-lasting drought spell or a flood.

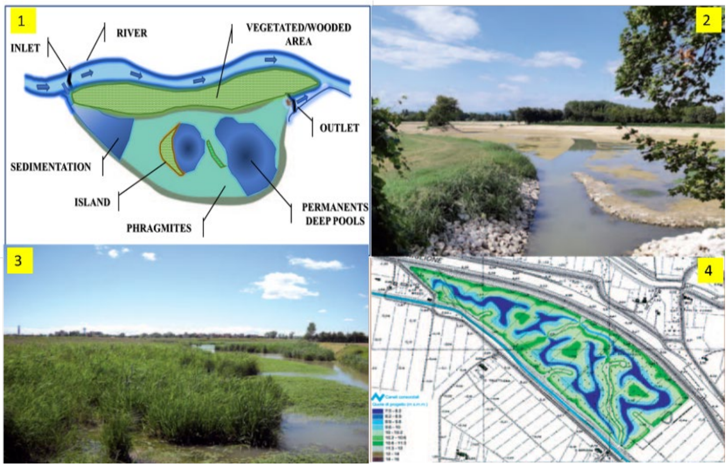
Methods of recognizing likely future refugia and approaches to assessing the vulnerability of freshwater biota to a warming and drying climate have been developed in Australia. These perennial waterbodies hotspots (both groundwater and surface water fed) support obligate aquatic organisms. These species will persist where suitable habitats are available and dispersal pathways are maintained.

Nevertheless, knowledge about freshwater systems remain sparse compared with information on terrestrial systems. This lack of knowledge is even more pronounced for freshwater ecosystems in arid and semiarid zones. These environments sustain water flows that can be perennial, with changes in their water level, as well as intermittent rivers under extreme conditions. Many areas in Europe are evolving as arid or semiarid ecosystems characterized by an almost total absence of rain even during the winter, causing the dry-up of rivers, while many rivers overflow every year as a result of heavy rains.
Global warming has brought focus on drylands rivers, as case studies for providing ecosystem services and supporting biodiversity although with channels remaining typically dry and only occasionally transporting water and sediments. The relevance for aquatic biodiversity of different types of refuges is increasingly recognised. Experiences are carried on in Costa Rica and Mexico and Peru. In South-America, wetlands, defined as areas covered or saturated with water, under a natural or artificial, permanent or temporary water regime, are housing a unique ensemble of biological communities. In Costa Rica drylands rivers, the biodiversity measured into river beds and neighbouring organic rice paddy fields was similar. In Australia has been found that in dryland rivers, the viability of fish populations depends on the availability of waterhole refuges for individuals to survive drought (resistance) and the ability of surviving fish to repopulate the rivers by recruitment and dispersal once flow returns (resilience).

The capability to consider the spatial arrangements of the most critical areas of a river ecosystem provides a means to systematically prioritize mitigation measures such as local management of natural key waterholes/refugia and the construction of artificial NbS Hotspots to increase drought and extreme events resistance.

funded by European Commission

NbS applied in North/Central Italy to restore aquatic ecosystems of agricultural/peri urban canals offer the ground for further increase NbS multifunctionality.



A general scheme of multifunctional artificial refuge area is shown in figure 1, this schema has been applied for NbS design in North/central Italy.

Figure 2 shows the artificial wetlands, in the photo at the ground levelling stage, built by the Consortium di Bonifica Acque Risorgive in the Scolo Orcone in Camposampiero/Santa Giustina in Colle (Padua). The aim was creating habitats to improve biodiversity by increasing the morphological and ecological evolutionary dynamics. The NbS is also increasing the water self-purification and reducing the risk of flooding.

With the same purposes have been realized the wetlands in the riverbed along the Fossa Pagana, Venice (Consorzio di Bonifica Acque Risorgive) (Fig. 3), and the humid area the Altipiano Channel - Ca 'di mezzo, Codevigo (Padua) (Consorzio di Bonifica Adige Euganeo) (Fig.4). The NbSs aiming to create habitats able to improve the state of wildlife and riverine communities; increasing ecological connectivity through the creation of ecological nodes; reducing the load of nutrients conveyed to the Venice Lagoon; decreasing the risk of flooding; creating conditions for the fruition of the area by local communities.

Existing best practices, tools, etc.

NbS applied in North/Central Italy to restore aquatic ecosystems of agricultural/peri urban canals offer the ground for further increase NbS multifunctionality. Notwithstanding, best practices for artificial NbS Hotspots are still lacking. NbS Hotspots design and maintenance criteria must be based on green engineering criteria.

funded by European Commission

CONCLUSIONS

Summary: lessons learnt on the key issue

Scholars report that a change towards hot and arid climate will likely reduce aquatic ecosystems richness in temperate regions and worsen the situation in southern Europe. In recent years, even central and east Europe have been not spared by drought spells and floods. Drought as ranged so far North than Sweden. Climate change induced aridity, high water temperatures, high conductivity and intermittent flow, reduced water quantity and quality could further threaten riverine biodiversity. A loss of family richness could lead to negative impacts on nature's contribution to human well-being. Artificial NbS Hotspots could limit species loss driven by climate change and in parallel increase resilience of ecosystems to extreme events and anthropic pressures. To reach their full ecological and socio-economic potential, increasing the resilience of the basin, NbS hotspots should be designed in combination with other conservation, restoration and management measures.

RESEARCH NEEDS

Knowledge gaps to be cover by Research

The main knowledge gaps to be covered are artificial NbS Hotspots design criteria, eco-hydrological processes modelling, impact on ecosystem resilience indexes, NbS Hotspots capability to act as "biodiversity incubators", economic assessment and trade-off, production of ecosystem services for the local farmers, ecological and socio-economic drawbacks and risks.

Research needs from practice

Researches are needed to define and codifying methods to upgrade existing NbS or agricultural infrastructures to act as Hotspots.
Novel governance criteria must be developed to govern water in artificial canals aiming to preserve NbS Hotspots during drought spells.
Methods, tools and reference data sets are needed to monitoring and bio-monitoring NbS hotspots and to assess their effectiveness, impacts and performances. Specific key performance indicators should be developed to drive continue improvement.
In parallel, indexes to evaluate ecosystems resilience need to be developed and accepted by the scientific community and tested and validated on the field. The main challenge is to keep the monitoring activities as much simple as possible allowing the higher number of observation and measurement frequency.
Procedures for inter-farm and cross-sector cooperation, as well as establishment of Incentives for Ecosystem Services (through CAP or market tools).

funded by European Commission

IDEAS FOR INNOVATIONS

Ideas for innovative projects /solutions

Innovative projects and solutions can focus on the following topics:

- Anthropic disturbance interruption applying artificial NbS (involving single or multiple biotic or abiotic stressors).
- Definition of ecosystem's resilience indexes and assessment tools.
- Tools for policy/decision maker enabling evaluation of drawbacks and trade-offs of artificial NbS Hotspots according to the ecosystem's resilience indexes.
- Assessment criteria end quantification of artificial NBS Hotspots ecosystem services (ecologic, social, economic) and of their adaptive capability to fast changing boundary conditions.
- Artificial NbS Hotspots design and management criteria and tools for farmers and agricultural water manager.
- Easy to use, accessible datasets of macrobenthos, fishes, plants, etc. for field/labs test of biodiversity and resilience indexes, artificial NbS Hotspots' performance assessment (i.e., multi-barcode species catalogs).

Potential EIP-AGRI Operational Groups

EIP-AGRI Operational Group could cover the following themes:

- Agricultural water networks for Ecosystem protection and restoration - Interconnection with rivers/streams
- Joint irrigated agriculture management and artificial NbS Hotspots.
- Urban agglomerations interconnection with peri urban agriculture, treated water storage, recreative areas and its potential to incorporate artificial NbS Hotspots
- Farmers direct and indirect benefits and trade off: implementing artificial NbS Hotspots as a way out from water conflicts

Agricultural water networks for Ecosystem protection and restoration - Interconnection with rivers/streams			
Problems to be tackled	OG's activities/tasks	Results for Farmers & Advisors	OG's Potential Partners
NbS Hotspots are far more effective when correctly distributed along the river according with its hydromorphological characteristics and biota/bioma distribution, or when interconnected in the river's plains. To match the best placement to protect and enhance riverine biodiversity with the proximity to cropped fields, while interconnecting NbS forming corridors and	- Gather the needed competences and draft a first plan. - Design of the single NbS hotspot and of the network. - Facilitate adhesion to the overall plan by farmers, training for advisors, capacity building for decision makers. - Socio economic assessment and identification of trade-offs. - Improvement of the overall plan and carry out the (pilot) projects.	For Farmers: ecosystem services; sustainability of water uses (certification standards, branding, marketing, access to markets); access to water; better water quality; shallow water table recharge; agritourism and related activities; standard design criteria; financing schemas; collective/cooperative management. For Advisors: planning; training; capacity buildings; financing	Local Decision Makers and Authorities. Farmers (individuals) or Farmers' Associations. Local Agricultural Water Boards. Fund raising companies, Investment Banks, etc. NGOs. Academy (Agricultural Eng., Biology, Eco-Hydrology, Economics, Communication, Humanities, etc)

funded by European Commission

networks, it requires accurate planning.	- Engage existing water management bodies or promote and set up a new legal entity responsible of the management of the NbS Hotspots.	schemas; collective/cooperative management; stakeholders engagement.	

Joint irrigated agriculture management and artificial NBS Hotspots			
Problems to be tackled	OG's activities/tasks	Results for Farmers & Advisors	OG's Potential Partners
Conflicts could arise from multipurpose management during serious and long-lasting drought spells. A strong commitment, based on mutual understanding and cooperation, it is necessary to allocate quotas for both environmental and agricultural uses.	- Gather the needed competences and draft a first management plan. - Create consensus on shared goals. - Draft multipurpose management plans and governance rules. - Prevent and manage present and future possible conflicts	For Farmers: water governance; sustainability of water uses (certification standards, branding, marketing, access to markets); access to water; collective/cooperative management; conflict prevention and management; integration in a local virtuous water management; reputational rewards. For Advisors: management schemas; training; capacity buildings; financing schemas; collective/cooperative management; stakeholders engagement; conflict prevention and management.	Local Decision Makers and Authorities. Farmers (individuals) or Farmers' Associations. Local Agricultural Water Boards. NGOs. Accademy (Agricultural Eng., Biology, Eco-Hydrology, Economics, Communication, Humanities, etc)

funded by European Commission

Urban agglomerations interconnection with peri urban agriculture, treated water storage, recreative areas and its potential to incorporate artificial NbS Hotspots			
Problems to be tackled	OG's activities/tasks	Results for Farmers & Advisors	OG's Potential Partners
NbS Hotspots can be combined with treated wastewater storage, thus adding value to the NBS itself and to the peri urban landscape and agricultural canal networks. NbS Hotspots in peri-urban areas should also retain water for a longer time in the landscape before reach rivers and streams. This is particularly important to avoid flash floods, damaging crop fields, urban infrastructures and houses, riverine biota. When inserted in a NbS Hotspots network they can also supply water, continuously produced by the wastewater treatment plant, to other NbS Hotspots. When coupled with innovative on spot treatment technologies they can also significantly contribute to improve water quality.	- Integration with Wastewater Treatment Plants. - Planning and design of water reuse schemas (as for REG. 741/2020/EU) involving NbS Hotspots as additional barriers. - Assessment of water quality improvements standards, KPI and benchmarks set up. - Integration with novel on spot water treatment technologies (microfluidics, compact nano filters, regenerable disinfection/filtration devices, etc..). - Integration of continuous fluxes in water networks characterised by intermittent uses	For Farmers: ecosystem services; sustainability of water uses (certification standards, branding, marketing, access to markets); access to water; collective/cooperative management; performance assessment and benchmarking; innovative technologies; integration in a local virtuous water management; reputational rewards. For Advisors: novel technologies; training; capacity buildings; financing schemas; collective/cooperative management; stakeholders engagement; key performance indicators and benchmarking.	Local Decision Makers and Authorities. Farmers (individuals) or Farmers' Associations. Local Agricultural Water Boards. Water boards and Agencies (urban). Wastewater treatment plant managers. NGOs. Consumers' associations Civil society/citizens representatives Academy (Agricultural Eng., Biology, Eco-Hydrology, Economics, Communication, Humanities, etc)

Farmers direct and indirect benefits and trade off: implementing artificial NbS Hotspots as a way out from water conflicts			
Problems to be tackled	OG's activities/tasks	Results for Farmers & Advisors	OG's Potential Partners
Overall NbS direct and indirect benefits are still unclear. When implementing NbS Hotspots, having higher degree of multifunctionality and involving limitations of agricultural uses an accurate analysis of economic advantages, drawbacks and trade-offs	- Standards/guidelines for Cost/Benefit Analysis (CBA) - Standards/guidelines for ecosystem services socio-economic assessment. - Identification of drawbacks, according to each of the NbS Hotspot purposes.	For Farmers: CBA assessment; socio-economic assessment; OPEX and CAPEX evaluation; Return of Investments and overall business plans; conflict management rules. For Advisors: socio-economic assessment; training; capacity	Local Decision Makers and Authorities. Farmers (individuals) or Farmers' Associations. Local Agricultural Water Boards. Water boards and Agencies (urban). Wastewater treatment plant managers. NGOs.

funded by European Commission

is essential. Agreed methodologies to calculate and benchmarking economic performances, or even costs, of NbS Hotspots are lacking. Thereby, criteria, tools and recognised standards to assess performances, as for all the diverse impacts directly and indirectly generated, are of the utmost importance.	- Standards/guidelines for trade-offs economic assessment. - Guidelines for conflict prevention and management, rules for conflict resolution.	buildings; financing schemas; business plans; stakeholders engagement; conflict management rules.	Academy (socioeconomy, conflict management specialists)

REFERENCES

Davis, J., Pavlova, A., Thompson, R., and Sunnucks, P. (2013). Evolutionary Refugia and Ecological Refuges: Key Concepts for Conserving Australian Arid Zone Freshwater Biodiversity under Climate Change. Glob. Change Biol. 19 (7), 1970–1984. doi:10.1111/gcb.12203

Eken G, et.al. (2004) Key biodiversity areas as site conservation targets. Bioscience 54:1110–1118

EUROSTAT 2016. Farms_and_farmland_in_the_European_Union – The evolution of farms and farmland from 2005 to 2016. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_ farmland_in_the _European_Union_-_statistics#The_evolution_of_farms_and_farmland_from _2005_to_2016.

López-López E. (2021) Editorial: Freshwater Ecosystems in Arid and Semiarid Zones Facing Multiple Stressors: Human Disturbances, Climate Change, and Dryland River Conservation. Front. Environ. Sci. 9:814225. doi: 10.3389/fenvs.2021.814225

Manuale per la gestione ambientale dei corsi d'acqua. Seconda edizione. L'esperienza dei Consorzi di Bonifica, Veneto Agricoltura, 2020. ISBN 9788863372595

Marshall JC, Lobegeiger JS and Starkey A (2021) Risks to Fish Populations in Dryland Rivers From the Combined Threats of Drought and Instream Barriers. Front. Environ. Sci. 9:671556. doi: 10.3389/fenvs.2021.671556

MINAM (2019). Mapa Nacional de Ecosistemas del Perú: Memoria descriptiva. Ministerio del Ambiente. Available at: https://sinia.minam.gob.pe/mapas/mapa-nacional-ecosistemas-peru

Myers N (1988) Threatened biotas: "hotspots" in tropical forests. Environmentalist 1988:187–208

Myers N (1990) The biodiversity challenge: expanded hot-spots analysis. Environmentalist 10:243–256

Myers N (2003) Biodiversity hotspots revisited. Bioscience 53:916–917

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858

Mittermeier, R. A., Turner, W. R., Larsen, F. W., Brooks, T. M., and Gascon, C. (2011). "Global Biodiversity Conservation: The Critical Role of Hotspots," in Biodiversity Hotspots. Editors F. Zachos, and J. Habel (Berlin/Heidelberg, Germany: Springer), 3–22. doi:10.1007/978-3-642-20992-5_1

Sheldon, F., Bunn, S. E., Hughes, J. M., Arthington, A. H., Balcombe, S. R., and Fellows, C. S. (2010). Ecological Roles and Threats to Aquatic Refugia in Arid Landscapes: Dryland River Waterholes. Mar. Freshw. Res. 61, 885–895. doi:10.1071/mf09239

Sedeño-Díaz JE and López-López E. (2021) The Influence of Climate Change on River Corridors in Drylands: The Case of the Tehuacán-Cuicatlán Biosphere Reserve. Front. Environ. Sci. 9:681703. doi: 10.3389/fenvs.2021.681703

Tooth, S. (2000). Process, Form and Change in Dryland Rivers: A Review of Recent Research. Earth-Science Rev. 51, 67–107. doi:10.1016/S0012-8252(00)00014-3

Tooth, S. (2013). "9.31 Dryland Fluvial Environments: Assessing Distinctiveness and Diversity from a Global Perspective," in Treatise on Geomorphology. Editor J. F. Shroeder (San Diego, CA: Elsevier. EUA.), 9, 612–644. doi:10.1016/b978-0-12-374739-6.00257-8

funded by European Commission