Chapter 21
Landscape Rehabilitation: The Old Drava Programme

Dénes Lóczy and József Dezső

Abstract Floodplains are highly sensitive to human pressure. The lower sections of the Hungarian catchment of the Drava River, particularly the Drava Plain, have suffered large-scale landscape degradation in recent decades. The negative influences affected both the physical and socio-economic environment. To counter negative impacts from upstream flow impoundment, bed material excavation and other kinds of human impact, a comprehensive government project of landscape rehabilitation, the Old Drava Programme, was launched in Hungary. In the core of the Programme, the water replenishment scheme focuses on the improvement of water availability of the floodplain through replenishment indirectly from the main river channel. The scheme is meant to take advantage of a network of abandoned drainage elements (oxbows, abandoned channels, levee crevasses, backswamps) in the floodplain. On this basis, an ambitious landscape management project is designed with the announced long-term objective of significantly improving economic (employment), social (integration of ethnicities), and cultural (preservation of cultural heritage and its utilization for increasing tourism potential conditions). Rehabilitation potential is used as a measure to express the extent to which the scope of ecosystem services/landscape functions can be broadened. Water availability and the ensuing landscape transformations are monitored with the purpose of assessing the efficiency of the core project of the Old Drava Programme (a water transfer scheme) in the test area of the Cún-Szaporca oxbow. Based on the findings of monitoring the short-term success of the first lake replenishment campaign is evaluated. Through the assessment of expected provision of ecosystem services, the long-term benefits and deficiencies of the scheme are highlighted.

Keywords Floodplain · Rehabilitation · Oxbows · Water replenishment
Groundwater · Socioeconomic setting · Ecosystem services

D. Lóczy (✉) · J. Dezső
Department of Physical and Environmental Geography, Institute of Geography and Earth Sciences, Faculty of Sciences, University of Pécs, Ifjúság útja 6, Pécs 7624, Hungary
e-mail: loczyd@gamma.ttk.pte.hu

J. Dezső
e-mail: dejozsi@gamma.ttk.pte.hu

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21.1 Introduction

For the remediation of rivers and their floodplains, i.e. the elimination of degraded conditions, several concepts are employed. River *recovery* is defined as a sequence of stages of geomorphic adjustment governed by the nature of the landscape and its sensitivity to floods following disturbance (Sparks et al. 1990; Fryirs and Brierley 2000; Brierley and Fryirs 2005). The often very limited space available for regulated rivers as geomorphic agents (Schiemer et al. 1999; Piégay et al. 2005), however, does not normally allow recovery.

River *restoration* is conceived as "the complete structural and functional return to a predisturbance state" (Cairns 1991, p. 187). In eastern Central Europe, this concept is formulated in the following way: River restoration improves river quality and allows the recovery of its previous functions (Macura and Izakovičová 2000; Eiseltová et al. 2007). The ecological concept of *resilience* (i.e. a system's potential to recover biophysical properties and processes following disturbance—Niemi et al. 1990) is central to holistic restoration schemes (e.g. along the Missouri—National Research Council 2002). Areas with high potential for ecological recovery and low socioeconomic constraints have the greatest potential for future restoration (Hulse and Gregory 2004). However, complete restoration is a goal not commonly achievable or even desirable (Downs and Thorne 2000).

The introduction of another term seems to be necessary. *Rehabilitation* means "the partial structural and functional return to a pre-disturbance state" (Cairns 1991, p. 187) or, in a holistic sense, "the return of an ecosystem to a close approximation of its condition prior to disturbance" and this can never be perfect (National Research Council 1992, p. 18).

For similar activities, *revitalization* is often the preferred term in Hungary (see Chap. 20 in this volume) and Croatia (e.g., Dragun et al. 2014). The emphasis here is on planning (landscape architecture) with the purpose of re-creating habitats for plants and animals. Wetland *mitigation* or compensatory mitigation, on the other hand, is a legal term, which refers to human interventions to compensate for wetland losses as prescribed by law, for instance, through the creation of constructed wetlands (Kentula 2000).

The concept of rehabilitation, as used in this chapter covers all measures towards improved ecological (environmental) functioning of the system (Lóczy 2013). Rehabilitation potential is central to any rehabilitation scheme as it is a tool to measure the realistic opportunities for re-establishing ecosystem services/landscape functions (Gren et al. 1995; Gilvear et al. 2013). In spite of rather similar formulations of concepts, in this respect, the target of rehabilitation (e.g., with view of future water availability or species composition) is markedly different from that of restoration defined in a strict sense (Jennings and Harman 1999; Lóczy et al. 2017). In addition, *stabilization* is also cited as another type of river remediation, which aims to exclude both aggrading and degrading conditions over time (Jennings and Harman 1999). Whatever approach of river and floodplain remediation is decided on, it is advisable to observe the first 'rule' stated by Leopold (1949): that at least the interventions should do no harm to the system. In addition, the scheme should be satisfactory in the light of social expectations and perception of the landscape (Dufour and Piégay 2009) or 'aspirations of the public' as it is stated in the European Landscape Convention (Council of Europe 2000).

21.2 The Fluvial Environment and Society

Changes in river mechanism, cutoffs and channel shifts, accumulation and degradation, channel broadening or narrowing had been parts of the pre-regulation fluvial systems. All over Europe dam construction and river channelization were major interventions into the life or rivers (Petts 1984), which significantly reduced the space available for river action (which is now restricted to the active floodplain). The geomorphic evolution of the 'protected floodplain' took a new path, instead of fluvial processes, it became governed mostly by the influences of human land use (cultivation—see Chap. 3 in this volume) and natural vegetation.

The 'natural' channel pattern of the Drava River was well-developed meandering and locally anastomosing accompanied by a broad convex floodplain with natural levees, abandoned channels and backswamps. Beginning with 1750, river channelization divided the area into active and 'protected' floodplain (see Chap. 8). Dyke construction ensured increasingly safe conditions for agricultural land use and settlement development even on lower-lying surfaces (Gyenizse and Lóczy 2010).

The environmental problems of the Drava channel and its floodplain are described from numerous aspects in the previous chapters of this book. The main statements are summarized here and some selected additional facts with socioeconomic as well as policy implications are cited.

Commercial *extraction* of sand and gravel are strictly restricted in all countries along the Drava. At Petrijevci, Croatia, some 30 km from the confluence with the Danube, however, Croatian water management authorities and private firms illegally excavated more than 3,000,000 m^3 of sand for motorway construction (Popovič and Mikuska 2010). As an example of conservative water management policy, a 56 km-long stretch of the Drava River is overregulated with some 112 different structures (Popovič and Mikuska 2010). At Osijek, a barrage and a 25-km-long reservoir were established for the purposes of electricity generation, flood protection, irrigation, navigation, tourism and recreation—but despite strong opposition from NGOs and without previous environmental impact assessment.

Flow regulation measures have been repeatedly implemented for the purposes of navigation. In principle, for barges of 400–600 Gross Registered Tonnage (GRT) the river is navigable downstream Barcs, but the actual volume of traffic is negligible. A significant development of navigation would require large-scale interventions which are environmentally not acceptable.

In the 20th century, 22 hydroelectric plants were built on the upper Drava sections, partly with peak-time operation, and caused a huge sediment deficit in the river (see Chap. 9). From this development, severe problems for wildlife, agriculture, forestry, groundwater levels and river stability resulted. The most recent and most downstream of the hydroelectric plants (at Dubrava, Croatia, 17 km upstream of the Hungarian border, completed in 1989) has a reservoir of 150,000,000 m^3 capacity (accommodating three days' mean discharge). A beneficial influence of damming is the mitigation of flood hazard. Floods became rarer and the average annual number of flood days dropped from 18 (before 1976) to 2 days (1989–2013).

The principal problems along the Hungarian Drava section are extreme daily *fluctuation of water level* (up to 1.5 on the uppermost Hungarian section), channel incision, and narrowing as well as intensive bank erosion (Kiss and Andrási 2011 and Chap. 11). Dropping water levels are recorded in groundwater observation wells even at 2–3 km distance from the channel. Natural channel development is not possible for most of the floodplain watercourses, 96% of them are in need of channel rehabilitation (AQUAPROFIT 2010).

Both the climatic and energetic *agroecological potentials* of the arable land of the region (30–32 t ha^{-1} and 30.5–31.5 t ha^{-1} biomass production, resp.) are assessed as slightly above average on Fluvisols and Histosols (AQUAPROFIT 2007a). On the 1 to 100 scores range of the D-e-meter Land Evaluation system, the average score of the Drava Plain is 61.9 (Tóth et al. 2014), i.e. falls somewhat, but not significantly, below the average for the Great Hungarian Plain (63.4). Environmental sensitivity, however, is also above the national average. The overwhelming arable land use is interrupted in lower-lying backswamps occupied by grasslands and pastures with scattered fruit trees (open orchard meadows or in German: Streuobstwiesen), which are a particularly valuable type of seminatural habitat. In spite of the favorable natural conditions, stockbreeding (pigs, sheep, cows, poultry) is of subordinate importance, economically not viable and shows decline.

In Hungary the introduction of sustainable and environmentally acceptable *land use* is promoted by the National Agri-Environmental Programme (NAEP, 2000–2004; renewed for 2007–2013—Nemes and High 2011). The Programme is aimed at the conservation of natural resources, establishment of biotope network, rehabilitation of wetlands, management of derelict land. It was followed by the National Rural Development Plan (NRDP, 2004–2006, with emphasis on support for backward areas, afforestation of agricultural land), the New Hungary Rural Development Programme (NHRDP, 2007–2013, which covers watershed and flood risk management, habitat preservation in the practice of forestry and agriculture) (Gálosi-Kovács 2010) and the Darányi Ignác Plan (National Rural Development Strategy, 2012–2020, focusing on rural employment, preservation of water resources, support to local 'social economy'). The implementation of these programmes, however, progresses very slowly in this region with inadequate human resources.

Ethnically, the floodplain along the lower section of the Drava River, the Ormánság region is an area of mixed population (Hungarians, Romas, Croats) characterized by depopulation with outmigration being the prevalent demographic process (Reményi and Tóth 2009). A general lack of capital and human resources (unskilled labor) are typical. On the other hand, since the region benefited from missing industrial development, the environment is preserved in a healthy state, free of industrial pollution. Historically, the disadvantaged position of the regions springs from the dominance of small-sized, often dead-end, villages with single access roads of poor surfacing and peripheral location next to the Croatian border (Tésits 2012; Tésits and Alpek 2012, 2014). At present, however, economic activities are limited to community service programmes and investments by the government.

For cultural and *ecotourism* the Ormánság region has a wide range of attractions, including genuine curiosities such as the Reformed churches with painted wooden ceilings (their restoration is incorporated into the Old Drava Programme), vernacular traditions and crafts on the one hand and rich wildlife and undisturbed landscapes for hikers, cyclists and fans of water sports on the other. However, all previous development projects in tourism have failed and the opportunities could not be exploited until now (Csapó et al. 2011). To this day, the Ormánság region has remained one of the least developed, peripheral areas of Hungary (Gálosi-Kovács et al. 2011).

21.3 History of the Old Drava Programme

The interventions serving rehabilitation in the degraded landscape of the Drava Plain can be planned observing different (internationally or nationally formulated) requirements. Some important guidelines are presented below as background to action plans.

The Water Framework Directive of the European Union (European Commission 2000) describes tasks to improve aquatic and riparian environments. In addition to the reduction of pollutions of various kind and origin, the related Watershed Management Plan for the partial watershed of the Drava River (VKKI 2010) includes the following general targets:

- To make excess water storage facilities capable of retaining water and to reduce the nutrient load of recipient water bodies; the stored excess water made available for irrigation or induced infiltration; to find solutions for the compensation of land proprietors whose land was used for excess water storage;
- To ensure good fishing and angling practice (management of fish-ponds, dammed reservoirs and natural water bodies);
- To ensure the provision of ecosystem services and public functions of fish-ponds;
- To identify constraints for used thermal water inflow into surface waters;
- To improve the hydromorphological conditions of watercourses and lakes (reducing the impacts of previous regulation measures through channel restoration, slowing down riverbed incision, increasing sinuosity and bank diversity, maintaining seminatural conditions in oxbows enhancing connectivity, building

bottom weir, removing organic and inorganic mud fill from lakes, management of aquatic herbal vegetation etc.);

- To restore riparian vegetation (gallery forests) where sufficient space is available or to create an artificial riparian buffer zone (8–10 m wide if wooded with native trees or wider if bush and grass) along the Drava channel where this space is more limited, to protect riparian zones against the spreading of invasive plants;
- To rehabilitate active floodplains, rationalize their land use and make them suitable for accommodating rising flood discharges (identifying flood reservoirs [‘polders’], compensating land owners for losses, removing or shifting back flood-control dykes etc.);
- To preserve wetlands through the regulation (restriction) of surface and groundwater utilization and, if necessary, through water transfer;
- To supervise riverbed structures and operate them in a manner to allow longitudinal river connectivity;
- To design navigation routes in an ecologically acceptable manner (with minimum disturbance);
- To govern water resources economically (retention of floodwater, storage of excess water and use for irrigation in drought periods, additional purification of treated sewage in biological filter zones, prevention of pollutions resulting from accidents);
- To ensure environmental/ecological flow throughout the year (to devise appropriate methodology for identifying environmental flow, restriction of water intake, encouraging ethical water use, etc.).

Naturally, the Watershed Management Plan also identifies a series of legal and technical measures which are necessary to reach the above objectives.

In the international Drava Declaration (Department of Carinthia 2008) ten main tasks in the development of environmental conditions of the Drava region are enumerated. The items most closely related to floodplain functions are the following:

- To enhance flood control through water retention in the floodplain;
- To continue restoration activities in the channel of the Drava River and on its floodplain;
- To re-establish ecological connectivity of the Drava River for migratory fish;
- To create a transboundary recreation area;
- To achieve integrated river basin management;
- To promote further regional development in partnership with the resident human populations.

The changes of the fluvial system coupled with climate change reduced water supply and involved the frequent recurrence of droughts and economic decline in the Ormánság region, i.e. the lower Hungarian Drava floodplain. The Hungarian government recognized that to maintain natural conditions and agricultural activities in the future, water replenishment is indispensable. Therefore, water governance is placed in the centre of a comprehensive development project, called the

Old Drava Programme, which was first proposed in 2004 (AQUAPROFIT 2005) and approved by the Government of Hungary on 17 July 2012. The name itself hints at the reconstruction of old conditions (abandoned drainage network) along the Drava River.

The priorities of the Old Drava Programme (Márk et al. 2006; AQUAPROFIT 2010; Salamon 2014) are

- economic development (agriculture, irrigated horticulture and food industry);
- landscape management (afforestation, creation of water surfaces and grazing lands);
- tourism development (angling, rafting, hunting, horse riding, bicycling, built heritage, nature trails, gastronomy, etc.).

In the *first version* of the Old Drava Programme, a new water governance system is envisaged for the region, a combination of water replenishment ensured indirectly from the Drava River (12 $m^3 s^{-1}$), through gravitational water intake and pumping, distribution of water by a main gravitational canal (at 5–10 km distance from the Drava) using elements of the natural drainage network and floodwater retention in the floodplain (Fig. 21.1). According to the water management plan (AQUAPROFIT 2007a), water replenishment would allow the irrigation of 5,000 ha of agricultural area and the establishment of almost 700 ha total water surface in restored lakes and newly-created reservoirs. In modeling the system, maximum (peak-time) water demands were taken into consideration. The original scheme explicitly claimed that excellent water availability (comparable to the conditions typical before river channelization) can be re-created in the Drava Plain (AQUAPROFIT 2010).

Indirect benefits of the water governance system are envisioned to include improvements in economic structure, safety of harvest, providing touristic attractions, stability of ecosystems and subsistence level of population, leading to a higher carrying capacity of the landscape.

In the proposed land use of the floodplain (Table 21.1) traditional occupations (orchards, reed and willow craftsmanship), mostly strongly dependent on good water availability, are planned to be revived, the extension of forested areas is planned and, at the same time, the water demands of nature conservation and large-scale arable farming are intended to be satisfied simultaneously.

The success of river and floodplain rehabilitation efforts largely depends on reaching the water management targets formulated in the scheme (AQUAPROFIT 2007a), i.e. ensuring water availability for the floodplain and a stable water budget for oxbows. Floodwater storage largely depends on the geomorphology of the floodplain. A recent survey (Schwarz 2014) finds favorable conditions in the Drava floodplain and envisages up to 3,000 ha area with significant water retention potential proposed for floodplain restoration along the lowermost 25-km-long Hungarian section of the Drava River.

In the *new version* (Pécsi HIDROTERV Bt. 2015) the emphasis shifted towards environmentally more acceptable solutions, which promote water retention in the

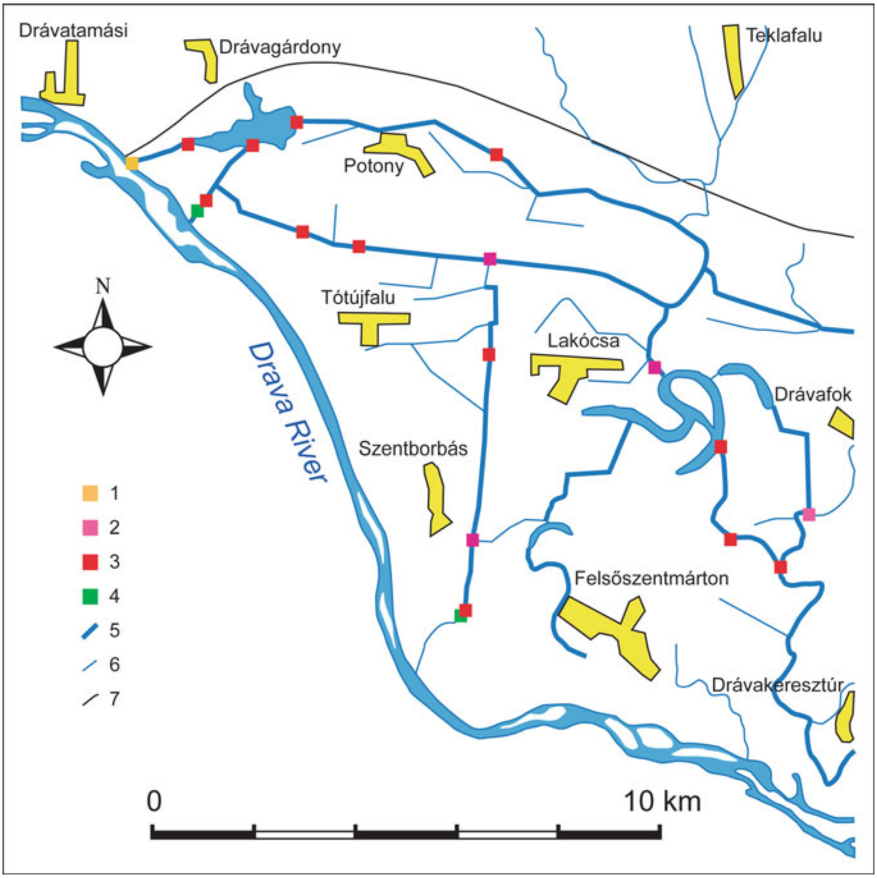

Fig. 21.1 Detail of the water recharge system of the original version of the Old Drava Programme (upper section). Water conducted from the Drava River into a reservoir and distributed through a canal network which partly utilizes abandoned channels. 1, water abstraction from the Drava; 2, distributory structures; 3, pumping station; 4, sluice, dam; 5, main canals; 6, secondary canals; 7, boundary of planning area. *Source* AQUAPROFIT (2007a)

floodplain, taking advantage of natural landforms. The provision of ecological water demands for the ecosystems of floodplain wetlands acquired primary importance. At the same time, the safe drainage of excess water and collection in recipient water bodies has to be ensured. Instead of calculating with maximum water needs, irrigation water demands were resurveyed and found to amount to about 2,767,000 m^3 y^{-1} (2,422 ha area to be irrigated) (Pécsi HIDROTERV Bt. 2015).

The new Old Drava Programme is more prepared to face extreme weather situations (i.e. years with too high or too low precipitation) to be expected under

Table 21.1 Land use proposals for landforms of different elevation (based on AQUAPROFIT 2007b)

Landforms	Elevation range (m)	Frequency of inundation	Proposed land use
Sand dunes	100–110	Flood-free, occasional excess water from precipitation	Built-up, arable, forest, grassland, orchard, hunting, gathering (mushrooms, forest fruits, etc.), apiculture, tourism
Natural levees	98–105	Rare and short-term inundation	Orchard, horticulture, forest, hunting, gathering (mushrooms, forest fruits etc.), apiculture, tourism
Low floodplain level	94–98	Regular (yearly or seasonal) inundation	Pasture, meadow, forest, fishing, growing swamp plants, hunting, gathering (medicinal plants, dried flowers, raw materials for crafts, etc.), apiculture, tourism
Backswamps and infilled abandoned channels	90–98	Waterlogged for most of the year	Fishing, reed-cutting, aquatic plants, waterfowl, hunting, gathering (medicinal plants, dried flowers, etc.), apiculture, water tourism

climate change. For agriculture (and locally forestry), the supply of irrigation water will be crucial in the future.

The pilot action of the Programme was the completion of a feeder canal (length: 1,360 m; capacity: 0.4 m^3 s^{-1}; elevation: 93.5 m above sea level; slope: 0.005) from the Fekete-víz Stream (mean discharge: 4.5 m^3 s^{-1}) to Lake Kisinc of the Cún-Szaporca oxbow in 2016. According to the water management plan (AQUAPROFIT 2007a), a single water replenishment intervention was conceived for March (when the average water flow of the Fekete-víz Stream is 6.379 m^3 s^{-1} and 90%-probability flow is 2.0 m^3 s^{-1}). Later, however, need for summer (June–July) feeding also arose (DDKÖVIZIG 2012). From the impounded Fekete-víz Stream replenishment will require 10–19 days in spring, at 0.4 m^3 s^{-1} (43,200 m^3 d^{-1}) rate, totaling 515,000 m^3 inflow, and 24–28 days in June at 0.33 m^3 s^{-1} (24,512 m^3 d^{-1}) rate, totaling 535,000 m^3 (DDKÖVÍZIG 2012).

The first replenishment campaign took place in spring 2016. Its goal was to fill up the oxbow to at least 91.3 m elevation and merge the individual lakes of into an open water surface of 20.7 ha area. (The actual areas with open water surface are the following: Lake Kisinc: 5.3 ha; Lake Szilihát: 2.7 ha; Lake Inner Hobogy 1.5 ha; Lake Lanka: 1.3 ha.)

21.4 Assessment of the Programme from Nature Conservation Aspect

In the Hungarian Drava Plain ca 25,000 invertebrate species are found. Oak forests with meadows and trees of variable ages show the highest biodiversity. Wetlands and dry grasslands show a somewhat lower diversity but also host rare species (leaches, snails, crayfish, beetles, butterflies, stinging insects etc.). In most habitats, water availability is crucial: amphibian larvae develop in water and desiccation is a major threat for them. Some mammals (such as otters, ermines) are also bound to water.

In general, the experts of the Danube-Drava National Park attribute positive impacts to the Old Drava Programme (Pécsi HIDROTERV Bt. 2015), primarily for the water retention objectives. The raising of groundwater levels (particularly in forests) is also considered a possible favorable outcome of the Programme. Direct flooding is feasible for abandoned channels and backswamps, but wet meadows should only be waterlogged in spring. For bogs, river water inflow may have a negative effect on vegetation. In reed and sedge beds water level raising by more than 20–30 cm could inhibit the nesting of herons. Much higher (50–60 cm) increase in water level is needed to save the desiccating alder groves—but it should be implemented over several years. The oxbow lakes of Bresztik, Old Drava and Lake Fekete (see Chap. 12) would benefit of even 1 m higher water level, while the lakes Verság and Piskó are more sensitive to this kind of change and cannot bear more than 25–30 cm rise.

Anglers (in the Baranya County Association of Angling Clubs) welcome the plans for the establishment of new open water surfaces, replacing some swamps or extending existing lakes (e.g. at Sellye). The sedimentation of oxbow lakes (at Majáthpuszta, Zaláta, Hótedra, Bresztik) endangers their water storage capacity and fish habitats. Deposition is also rapid in the old bed of the Fekete-víz Stream, which used to be an excellent spawning site. Rehabilitation could reverse unfavorable tendencies also here.

21.5 Alternative Approaches to the Environmental Assessment of the Programme

For any river restoration scheme, short and long-term impacts should be evaluated separately. Experience gathered from monitoring and the first replenishment campaign allows us to summarize short-term effects (Dezső et al. 2017).

One option to assess the long-term consequences of water management interventions within the Old Drava Programme was a comprehensive evaluation of floodplain functioning by ecological indicators (Palmer et al. 2005). It can be based on the collection of both archive and actual data and the findings of environmental monitoring (Woolsey et al. 2007; Morandi et al. 2014). Several alternative ways for such an evaluation have been suggested: environmental flow specification (Arthington et al. 2006, 2009), the Floodplain Evaluation Matrix (FEM—Habersack et al. 2015) and analyses following different checklists of ecosystem services (Heal 2000; Ramsar Convention Secretariat 2010).

Kentula (2000) distinguishes between compliance, functional and landscape success of rehabilitation projects. Only the latter ensures the integrity of the region from an environmental aspect. The real challenge is to find an all-embracing set of reliable indicators for judging the success of landscape-scale rehabilitation.

21.5.1 The First Replenishment Campaign

An assessment of empirical data from monitoring may also give an idea of the achievements of water replenishment. Based on modeling seepage from the oxbow lake (see Chap. 14), hydrological scenarios were proposed for both replenishment rate and duration of water retention. In accordance with the water management plan of the Old Drava Programme (DDKÖVÍZIG 2012), the first scenario set the replenishment rate at a 30,000 m^3 d^{-1}, with a water level rise from 90.5 to 91.5 m above sea level.

Our model (for details see Dezső et al. 2017) shows that on day 25 of the replenishment water level reaches an elevation of 91.3 m and this water level remains relatively stable for a long time (Fig. 21.2). However, occasionally, during exceptionally rainy periods, replenishment is capable to raise water level to 91.5 m (DD-KVTF 2013). The rising water level in the oxbow considerably elevates the hydraulic pressure head above the adjacent areas. With the increasing volume in the oxbow, the potential contact surface (from where seepage is possible) also increases.

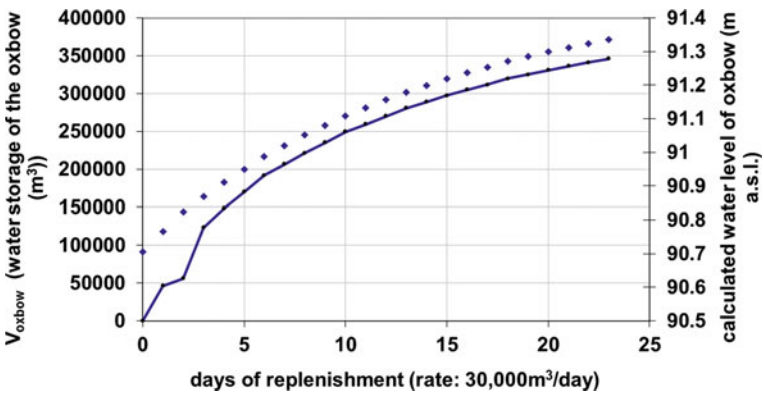

Fig. 21.2 Modelled relationship between water storage (V_{oxbow}) and relative water level (h_{oxbow}) during water replenishment to the oxbow (by József Dezső)

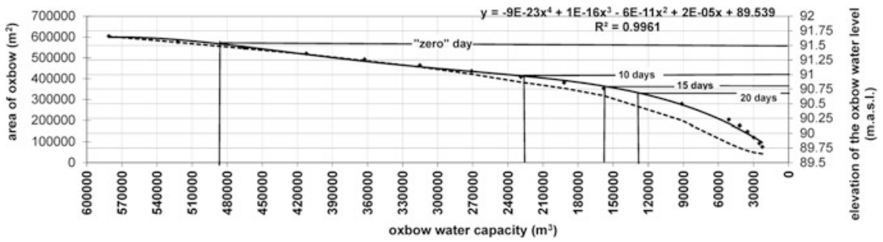

Fig. 21.3 Change of water surface area as a function of volume of water stored in the oxbow at 91.5-m replenished water level (by J. Dezső)

The second scenario was intended to estimate seepage rate from the oxbow and, thus, water retention there. On day 20 of the replenishment water level drops by 70 cm compared to the initial water elevation, while both the volume of the water stored and the area of the water surface shrink to about one third of the initial value (Fig. 21.3). Due to the high seepage rate from the oxbow, the replenishment would last too long, more than 25 days, and thus require improportionately greater amounts of water.

21.5.2 Ecological Indicators

The assessment of the long-term impacts of water recharge requires more comprehensive (but less quantitative) approaches. Palmer et al. (2005) propose five criteria for the ecological assessment of river restoration projects:

1. a guiding image (reference sites, called traditionally in German: Leitbild—Kern 1994), i.e. a more dynamic, healthy river of commeasurable dimensions should be specified;
2. measurable improvements in environmental (hydrogeomorphological and ecological) conditions have to be targeted and achieved;
3. the system has to be turned self-sustaining and resilient to external perturbations with minimal need for follow-up maintenance;
4. during the construction phase, no lasting harm should be inflicted on the ecosystem;
5. both pre- and post-project appraisal has to be completed (Downs and Kondolf 2002) and made available for the public.

In accordance with the above criteria a list of suitable indicators were suggested (Table 21.2), partly based on easily measurable parameters and partly checked on yes-or-no basis. The complete list is assumed capable to demonstrate the environmental success of the project.

Connectivity issues and landscape pattern should enjoy priority in such projects. The restoration of meandering reaches of abandoned river reaches would slow

Table 21.2 Indicators (modified after Palmer et al. 2005) for the ecological evaluation of the river and floodplain rehabilitation scheme

Wetland functions	Weight (w)	Present ESs provision	Exploitation level of potential: rating (s_p)	Planned ESs provision	Rating (s_f)
Hydrological functions					
Short-term storage of surface water	**1.00**	**Flood waves conducted downstream as rapidly as possible, floodwater storage only in side arms of the active floodplain**	**Insufficient: 3**	**Floodwater retention in oxbows and backswamps (ca 10 million m^3 = ca 1 day of absolute maximum discharge**	**5**
Long-term storage of surface water	0.75	Storage in oxbows with appropriate conductivity with the main channel	Insufficient: 2	Storage in better connected oxbows, but significant water losses	3
Storage of subsurface water, moderation of groundwater flow	0.75	Limited infiltration and seepage from oxbows; drawdown by the Drava; dropping groundwater table, low soil moisture content in growing season	Insufficient: 2	Moderate improvement in soil moisture conditions	3
Dissipation of energy at the land/water interface	0.50	Bank erosion precluded by riparian vegetation	Good: 4	No major change expected	4
Biogeochemical functions					
Removal of nutrients and contaminants	0.75	Average primary production, low levels of contaminant loading	Low: 2	Some increase in primary production	3
Retention of particulates	0.75	Sediment load of the Drava only reaches the side-arms	Low: 2	Sedimentation in re-connected oxbows	3
Export of organic carbon	0.25	Carbon storage for floodplain forests along the Danube: 450–500 t ha^{-1}	Medium: 3	Slight increase due to afforestation of some poor-quality arable land	4
Habitat functions					
Maintenance of plant and animal communities	0.25	Many aquatic and riparian habitats, majority of them Community Importance (Natura 2000); riparian forests mostly of native	Medium: 3	Better water provision helps to sustain, even improve the state of aquatic and riparian communities and habitats; some extension of native tree	4

(continued)

Table 21.2 (continued)

Wetland functions	Weight (w)	Present ESs provision	Exploitation level of potential: rating (s_p)	Planned ESs provision	Rating (s_f)
		species, but spreading invasive species		species; raising groundwater table creates wetter habitat types, e.g. sedge beds	
Landscape pattern	0.10	Overwhelming agricultural land use, few ecological corridors, oxbows are valuable refugia	Insufficient: 2	Through conversion of arable land more corridors are created	3

down current velocity and improve groundwater replenishment. Connectivity could also be promoted by grading, breaching dykes, or widening the active floodplain (Palmer et al. 2005). In the case of the Drava such profound interventions are not envisaged. The dredging of oxbow lakes is equally costly and regarded ecologically ineffective on the grounds of the disturbance caused and the need for associated constant maintenance. (However, it is unavoidable in lakes where angling is envisioned as a recreational activity.)

21.5.3 Environmental (Ecological) Flow

Applying the checklist by Palmer et al. (2005), it is a challenge to translate 'natural flow regime' into quantitative environmental flow prescriptions for individual river reaches (Arthington et al. 2006). Hungarian ecologists claim that the ecological water demands of habitats have not yet been specified (Völgyesi 2009). For the water uptake of plants groundwater table depth is of primary significance, but its dependence on instream flow is difficult to establish. River rehabilitation is ineffective ecologically if it focuses exclusively on maintaining minimum instream flow, but fails to re-establish an approximately natural annual surface and subsurface flow regime for the entire riparian zone (Palmer et al. 2005). Our monitoring also proved the view by Sanford (2002) that the groundwater-recharge efficiency of infiltration is highly variable.

A recently elaborated approach for the estimation of 'low-water reserves' of river catchments in Hungary (Szalay 2009) can be helpful since it differentiates water bodies identified in the WFD (European Commission 2000). Low-water reserves are, however, to be distinguished from both environmental and ecological flow. The proposed flow values do not satisfy the criteria of ecological flow as defined in the Hungarian act on nature conservation. Also it does not say anything about the required frequency of medium and high flows—although these could only be vital for the survival of aquatic biota. Therefore, the environmental flow approach has not been considered as a real alternative for floodplain rehabilitation appraisal.

21.5.4 Floodplain Evaluation Matrix (FEM)

Recently three new approaches have been elaborated for integrated flood management in Austria (Habersack et al. 2010):

- The *Floodplain Evaluation Matrix (FEM)* serves the assessment of floodplains along individual river reaches from hydrological/hydraulic, ecological, and sociological viewpoints (Chovanec et al. 2005; Habersack et al. 2010, 2015; Schwarz 2014).
- The indicator *Minimum River Morphological Space Demand* (abbreviated from German as *FMRB*) is defined, based on flood analysis, as three to sevenfold the existing riverbed width, where no construction or cultivation should be allowed.
- The *Spatially Variable Vegetation Management (VeMaFLOOD)* method identifies dynamic, transition and sensitive zones of vegetation.

The FEM method (Chovanec et al. 2005) classifies the oxbows of the Hungarian Drava floodplain mostly to class H2 (water body with limited connectivity to the main river channel). The method includes hydrological (flood peak reduction, flood wave propagation, floodwater retention: floodplain width, slope and roughness, flood risk/inundation depth), hydraulic (water stages, current velocity, specific runoff), ecological (landscape pattern, water regime, connectivity, biodiversity and its conservation) as well as societal factors (land use classes, flow of communication). We perfomed a qualitative FEM analysis separately for the three flood embayments (Ormánság, Kémes-Drávaszabolcs and Old—see Fig. 21.4) of the Drava Plain (Table 21.3).

It is clear from the table that the upper and middle floodplain segments will be significantly affected by the Old Drava Programme and the impacts will be positive, while in the lower segment, which is outside the range of the Programme, no significant change is expected.

21.5.5 Ecosystem Services Approaches

Although any classification system of ecosystem processes and services is laden with redundancy (Wallace 2008), it is useful to compare the present degree of fulfillment of services with that to be attained through the implementation of the Old Drava Programme (Table 21.4). The range of attainable benefits characterizes

Table 21.3 Assessment of the conditions before and after the implementation of the Old Drava Programme using the Floodplain Evaluation Matrix (modified after Habersack et al. 2012) for the flood embayments of the lower Hungarian Drava floodplain (scale: 5, highest priority, 1, lowest priority)

Factors	Assessment of baseline situation in the flood embayments			Assessment of the rehabilitated flood embayments		
	Ormánság	Kémes-Drávaszabolcs	Old	Ormánság	Kémes-Drávaszabolcs	Old
Hydrological						
Flood peak reduction	4	3	3	5	4	3
Flood peak propagation	3	3	3	4	4	3
Floodwater retention	4	4	4	5	5	4
Flood risk/inundation depth	4	4	4	5	5	3
Hydraulic						
Water stages	4	4	4	5	5	4
Current velocity	3	3	3	4	4	3
Specific runoff	2	2	3	3	3	3
Ecological						
Landscape pattern	3	2	2	4	3	2
Water regime	2	2	2	3	3	2
Connectivity	1	1	1	2	2	1
Biodiversity	3	3	2	4	4	2
Conservation	3	3	3	3	3	3
Societal						
Land use classes	3	3	3	4	4	3
Flow of communication	2	2	2	4	4	3
Total	2.9	2.7	2.7	3.9	3.7	2.7

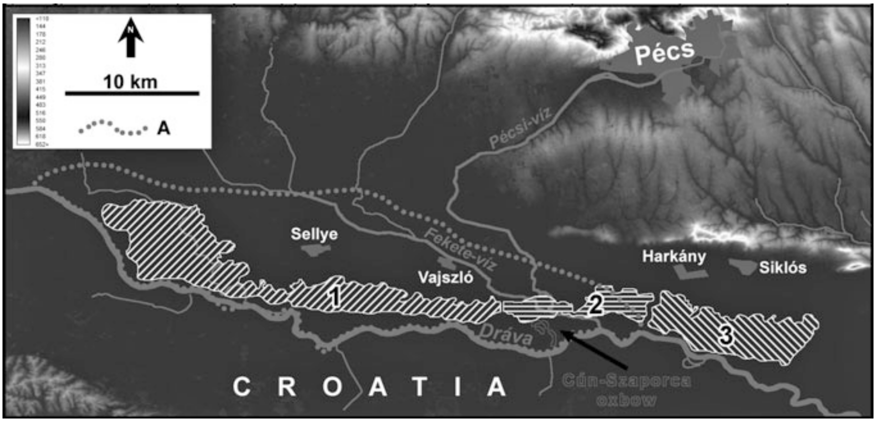

Fig. 21.4 Flood embayments along the lower Drava section. A, boundary of the Old Drava Programme planning area; 1, Ormánság embayment; 2, Kémes-Drávaszabolcs embayment; 3, Old embayment

the dimensions of rehabilitation potential. In landscape ecology, 'active' and 'passive' landscape functions (Konkoly-Gyuró 2011)—interpreted in a broader sense than ecosystem services—are also suggested as a basis for evaluation. Active functions are services provided by human activities, while passive functions are regulating and subsistence functions of the natural systems (environmental regulation, habitat protection, biomass generation, and production, etc.). This approach allows the better consideration of benefits originated from human activities along with natural landscape functions (WWF 2002).

Table 21.4 shows that six items in the Ramsar Convention list show significant growth in services. The predicted improvements are most striking in water-related regulatory (flood control, flood storage, local climate regulation) and cultural services (water sports).

An alternative list was compiled by the United States Army Corps of Engineers (after Brinson et al. 1995). It focuses on water-related ecosystem functions, where new water governance promises remarkable improvements (Table 21.5).

Table 21.4 Evaluation of the Old Drava Programme in the light of production and environment-related ecosystem services as identified by Ramsar Convention Secretariat (2010)

Ecosystem services	Weight (w)	Present-day provision	Exploitation level of potential: rating (s_p)	Expected provision	Rating (s_f)
3.5 Vegetational productivity (S)	0.25	Average primary production: 4.62 t ha^{-1}	Medium: 3	Wetland habitats extended—ca 10–15% increase in primary production	4
4.4 Groundwater replenishment (R)	0.75	Limited infiltration and seepage from oxbows; >1 m drawdown by the Drava River in ca 100 m (max. 300 m) wide zone	Inadequate: 2	Increased groundwater recharge from tributary streams	3
4.6 Food for human consumption (P)	0.10	Food production in ca 39,000 ha of arable land (total area: 54,026 ha), mostly large-scale farming (wheat, sunflower, maize)	Good: 5	To be reduced by ca 26,000 ha through land conversion to pasture, meadow and forest, increased landscape-level diversity, small-scale farming	4
4.7 Food for livestock (P)	0.10	Fodder (legumes, turnips, maize, grass) produced in 5,000 ha of arable land, meadow and pasture	Low: 3	Expansion of meadows and wooded pastures over 10,100 ha area	3
4.8 Wood, reed, fiber and peat (P)	0.10	1,420 ha forest area in previously defined project area	Resources in poor condition: 3	Moderate growth in forest areas	4
4.9 Medicinal products (P)	**0.10**	**Small-scale gathering of medicinal plants (chamomille, lime leaves, nettle, hawthorn, rosehip, etc.), some cultivation (poppyseed)**	**Low: 2**	**120–130 species to be collected or grown on organic farms at commercial scale**	**5**
4.11 Other products and resources, including genetic material (P)	**0.10**	**Organic farming by the Danube-Drava National Park; water melon, pumpkin (oil) production;**	**Insufficient: 3**	**Traditional fruit varieties reintroduced in 295 ha of (apple, pear, plum etc.) orchards, marketing**	**5**

(continued)

Table 21.4 (continued)

Ecosystem services	Weight (w)	Present-day provision	Exploitation level of potential: rating (s_p)	Expected provision	Rating (s_f)
		basket weaving; floodplain orchard gene bank of 400 fruit trees; cattle, sheep, pig, poultry and goat keeping (partly native Hungarian breeds: grey Hungarian cattle, 'racka' and 'cikta' sheep)		**frozen, canned and dried vegetables and fruits, jams, syrups, brandies, candies, honey; development of rabbit, goat and sheep husbandry at household scale keeping of native breeds in the Szaporca Visitor Centre**	
4.12 Flood control, flood storage (R)	**1.00**	**Flood waves conducted downstream as rapidly as possible, floodwater storage only in side arms**	**Insufficient: 3**	**Floodwater retention in oxbows (820 ha area, ca 10 million m^3)**	**5**
4.13 Soil, sediment and nutrient retention (R)	0.75	500,000 tonnes of sand and gravel dredged from the Drava River until now	Low: 2	Sedimentation in re-connected oxbows	3
4.15 Other hydrological services (R)	0.50	Neglected network of drainage ditches (total length: ca 200 km; longest: 28 km)	Resources in poor condition: 2	New facilities to collect and store excess water	3
4.16 Local climate regulation/ buffering of the change (R)	**0.50**	**Actual permanent water surfaces of 605 ha area + 1,500 ha area with forest microclimate, desiccating arable land and meadows**	**Low: 2**	**Additional water surfaces of 449 ha total area; annual evaporation of 458,000 m^3 to increase air humidity**	**4**
4.17 Carbon storage/ sequestration (R)	0.25	Carbon storage for floodplain forests along the Danube: 450–500 t ha^{-1}	Medium: 3	Slight increase due to afforestation of some arable land	4
4.18 Recreational hunting and fishing (C)	0.10	Boar, deer and hare hunting; waterfowl; 11 water bodies available for angling	Medium: 3	Further angling facilities to be established on the new water surfaces	4

Table 21.5 Assessment of the predictable achievements of the Old Drava Programme in the system proposed by the United States Army Corps of Engineers (after Brinson et al. 1995)

Wetland functions	Weight (w)	Present ESs provision	Exploitation level of potential: rating (s_p)	Planned ESs provision	Rating (s_f)
Hydrological functions					
Short-term storage of surface water	**1.00**	**Flood waves conducted downstream as rapidly as possible, floodwater storage only in side arms**	**Insufficient: 3**	**Floodwater retention in oxbows and backswamps (820 ha area, ca 10 million m^3)**	**5**
Long-term storage of surface water	0.75	Storage in oxbows with appropriate conductivity with the main channel	Insufficient: 2	Storage in better connected oxbows, but significant water losses	3
Storage of subsurface water, moderation of groundwater flow	0.75	Limited infiltration and seepage from oxbows; drawdown by the Drava; dropping groundwater table, low soil moisture content in growing season	Insufficient: 2	Moderate improvement in soil moisture conditions	3
Dissipation of energy at the land/water interface	0.50	Bank erosion precluded by riparian vegetation	Good: 4	No major change expected	4
Biogeochemical functions					
Removal of nutrients and contaminants	0.75	Average primary production, low levels of contaminant loading	Low: 2	Some increase in primary production	3
Retention of particulates	0.75	Sediment load of the Drava only reaches the side-arms	Low: 2	Sedimentation in re-connected oxbows	3
Export of organic carbon	0.25	Carbon storage for floodplain forests along the Danube: 450–500 t ha^{-1}	Medium: 3	Slight increase due to afforestation of some arable land	4
Habitat functions					
Maintenance of plant and animal communities	0.25	Many aquatic and riparian habitats, majority of them Community	Medium: 3	Better water provision helps to sustain, even improve the state	4

(continued)

Table 21.5 (continued)

Wetland functions	Weight (w)	Present ESs provision	Exploitation level of potential: rating (s_p)	Planned ESs provision	Rating (s_f)
		Importance (NATURA 2000); riparian forests mostly of native species, but spreading invasive species		of aquatic and riparian communities and habitats; some extension of native tree species	
Landscape pattern	0.10	Overwhelming agricultural land use, few ecological corridors, oxbows are important refugia	Insufficient: 2	Moderate afforestation, conversion of arable land; raising groundwater table creates wetter habitat types, e.g. sedge beds	3

21.6 Conclusions

At present, the Old Drava Programme is the largest-scale landscape rehabilitation project in Hungary. Floodplain rehabilitation should be viewed as a landscape ecological issue. Similarly to most European floodplains, along the Drava River flow regulation disrupted communication between the new straightened river channels and the cutoff oxbows. The latter are doomed to disappear within centuries, while no new meanders develop on the floodplain. Although their natural lifespan is naturally short, from the viewpoint of nature conservation the preservation of existing oxbow lakes as valuable geomorphosites and wetlands through active rehabilitation measures is certainly justified (cf. Tockner et al. 1998).

The environmental benefits of the Programme can be judged in the short-term (for instance, from experience with water replenishment to Lake Kisinc in the Cún-Szaporca oxbow) or in the longer perspective, how the new water governance will promote higher natural potentials.

The evaluation of rehabilitation potential based on ecosystem services/landscape functions, however, does not show a clear picture. Key functions, such as water storage, sustained biodiversity, and land use are explicitly included in the Old Drava Programme, while others, like landscape connectivity are only implicitly or not at all treated. For the efficient protection of wetlands, not only their water supply has to be ensured, but also strictly defined buffer zones have to be established or restored around them. The intensity of land use has to be reduced in areas with low productivity and arable land has to be replaced by a landscape mosaic of woodlands, pastures and open orchard meadows, a centuries-old traditional form of agriculture in the region.

We attempted to approach the problem using several assessment techniques. Although all of them are qualitative, they are partly based on measurable parameters. The outcome of the assessment, however, is jeopardized by the reliability of the available data, which is, unfortunately, still very low.

References

AQUAPROFIT (2005) Az Ormánság komplex rehabilitációja és térségfejlesztése. Ős-Dráva Program (Complex rehabilitation and regional development in Ormánság. Old Drava Programme). AQUAPROFIT, Budapest. 516 pp (in Hungarian)

AQUAPROFIT (2007a) Ős-Dráva Program. Vízügyi műszaki terv (Old Drava Programme: Technical plan of water management). AQUAPROFIT, Budapest – DDKÖVÍZIG, Pécs. 172 pp (in Hungarian)

AQUAPROFIT (2007b) Ős-Dráva Program Tájgazdálkodási Programterv (Old Drava Programme: Landscape management draft plan). AQUAPROFIT, Budapest (in Hungarian) http://www.osdrava.hu/download/tajgazdalkodasi.pdf. Accessed on 11.10.2013

AQUAPROFIT (2010) Ős-Dráva Program – Összefogással az Ormánság fellendítéséért. Vezetői összefoglaló (Old Drava Programme – Cooperation for the Progress of Ormánság: Executive summary). AQUAPROFIT, Budapest. 29 pp (in Hungarian)

Arthington AH, Bunn SE, Poff NL, Naiman RJ (2006) The challenge of providing environmental flow rules to sustain river ecosystems. Ecol Appl 16(4):1311–1318. https://doi.org/10.1890/1051-0761(2006)016[1311:tcopef]2.0.CO;2

Arthington AH, Naiman RJ, McClain ME, Nilsson C (2009) Preserving the biodiversity and ecological services of rivers: new challenges and research opportunities. Freshwater Biol 55 (1):1–16. https://doi.org/10.1111/j.1365-2427.2009.02340.x

Brierley GJ, Fryirs KA (2005) Geomorphology and river management. Applications of the river styles framework. Blackwell Publishing, Carlton, Victoria, 398 pp

Brinson MM, Hauer ER, Lee LC, Nutter WL, Rheinhardt RD, Smith RD, Whigham DE (1995) Guidebook for Application of Hydrogeomorphic Assessements to Riverine Wetlands. Army Corps of Engineers, Waterways Experimental Station, Vicksburg, MS. Technical Report TR-WRP-DE-11

Cairns J (1991) The status of the theoretical and applied science of restoration ecology. Environ Professional 13:186–194

Chovanec A, Waringer J, Straif M, Graf W, Reckendorfer W, Waringer-Löschenkohl A, Waidbacher H, Schultz H (2005) The Floodplain Index—a new approach for assessing the ecological status of river/floodplain-systems according to the EU Water Framework Directive. Archiv für Hydrobiologie Supplement 155:425–442

Council of Europe (2000) European Landscape Convention. Council of Europe, Florence. 9 pp (European Treaty Series No 176). http://conventions.coe.int/Treaty/en/Treaties/Html/176.htm. Accessed on 21.10.2014

Csapó J, Marton G, Aubert A (2011) The aspects of tourism development in the Ormánság (Hungary) with a special attention on the possibilities of internal integration. In: Dombay Ş, Magyari-Sáska Zs (eds) The role of tourism in territorial development. 4th international conference, 7–8 October 2011, Gheorgheni, Romania, vol 4, pp 40–49

DDKÖVÍZIG (2012) Revitalization of the Cún-Szaporca oxbow system. Final Master Plan. South-Transdanubian Environment and Water Directorate, Pécs. 100 pp

DD-KVTF (2013) Jegyzőkönyv közmeghallgatásról: a Dél-dunántúli Vízügyi Igazgatóság „A Cún –Szaporcai holtág vízpótlása az Ős-Dráva Program keretén belül” projekt környezeti hatásvizsgálati eljárása (Protocol of the Public Hearing on the EIS procedure of the project “Water replenishment of the Cún-Szaporca oxbow within the Old Drava Programme” by the

South Transdanubian Water Management Directorate). South Transdanubian Inspectorate for Environmental Protection, Natural Protection and Water Management, Pécs. 3 pp (in Hungarian)

Department of Carinthia (2008) Is the drava river basin management sustainable and well on the way? International Symposium “Drava River Vision”, 23–25 September 2008, Maribor, Slovenia. Department of Carinthia, Department of Water Management, Klagenfurt, Austria. 59 p

Dezső J, Halász A, Czigány Sz, Tóth G, Lóczy D (2017) Estimating seepage loss during water replenishment to a floodplain oxbow: a case study from the Drava Plain. Geografia Física e Dinamica Quaternaria 40:61–75. https://doi.org/10.4461/gfdq2017.40.6

Downs PW, Kondolf GM (2002) Post-project appraisals in adaptive management of river channel restoration. Environ Manag 29:477–496. https://doi.org/10.1007/s00267-001-0035-x

Downs PW, Thorne CR (2000) Rehabilitation of a lowland river: reconciling flood defence with habitat diversity and geomorphological sustainability. J Environ Manag 58:249–268. https://doi.org/10.1006/jema.2000.0327

Dragun D, Gavran A, Car V (2014) Hydrographic survey of the River Drava branches in the process of revitalization, flood control and morphological monitoring. In: FIG Congress 2014 Engaging the Challenges – Enhancing the Relevance, Kuala Lumpur, Malaysia 16–21 June 2014. 10 pp. https://www.fig.net/resources/proceedings/fig_proceedings/fig2014/papers/ts06j/TS06J_dragun_gavran_6869.pdf

Dufour S, Piégay H (2009) From the myth of a lost paradise to targeted river restoration: forget natural references and focus on human benefits. River Res Appl 24:1–14

Eiseltová M, Pokorný J, Ripl W, Bodlák L, Pechar L, Pecharová E, Kučera Z (2007) Restoration of water and matter retention functions of a floodplain: ecology and economics. In: Trémolieres M, Schnitzler A (eds) Floodplain protection, restoration, management. why and how. Lavoisier SAS, Paris, pp 190–199

European Commission (2000) Directive 2000/60/EEC. Establishing a framework for community action in the field of water policy. Official Journal of the European Communities, Luxemburg. L327. 1–71

Fryirs KA, Brierley GJ (2000) A geomorphic approach for identification of river recovery potential. Phys Geogr 21(3):244–277

Gálosi-Kovács B (2010) Környezetfejlesztés a kistérségekben (Environmental development in the microregions). Publikon Kiadó, Pécs. 247 pp (in Hungarian)

Gálosi-Kovács B, M Császár Zs, Pap N, Reményi P, Elekes T (2011) Social problems of the most disadvantaged Southern Transdanubian micro-regions in Hungary. Roman Rev Reg Stud 7 (2):41–50

Gilvear DJ, Spray CJ, Casas-Mulet R (2013) River rehabilitation for the delivery of multiple ecosystem services at the river network scale. J Environ Manag 126:30–43. https://doi.org/10.1016/j.jenvman.2013.03.026

Gren IM, Groth KH, Sylvén M (1995) Economic values of Danube floodplains. J Environ Manag 45:333–345

Gyenizse P, Lóczy D (2010) The impact of microtopography and drainage on land use and settlement development in the Hungarian Drava Plain. Hrvatski Geografski Glasnik 72(1):5–20

Habersack H, Schober B, Krapesch G, Jäger E, Muhar S, Poppe M, Preis S, Weiss M, Hauer C (2010) Neue Ansätze im integrierten Hochwassermanagement: Floodplain Evaluation Matrix (FEM), flussmorphologischer Raumbedarf (FMRB) und räumlich differenziertes Vegetationsmanagement (VeMaFLOOD). Österreichische Wasser- und Abfallwirtschaft 62 (1–2):15–21. https://doi.org/10.1007/s00506-009-0153-x

Habersack H, Schober B, Hauer C (2015) Floodplain evaluation matrix (FEM): An interdisciplinary method for evaluating river floodplains in the context of integrated flood risk management. Natural Hazards 75(Supplement 1):5–32. https://doi.org/10.1007/s11069-013-0842-4

Heal G (2000) Valuing ecosystem services. Ecosystems 3(1):24–30

Hulse D, Gregory S (2004) Integrating resilience into floodplain restoration. Urban Ecosyst 7 (3):295–314. https://doi.org/10.1023/b:ueco.0000044041.94705.52

Jennings GD, Harman WA (1999) Stream restoration lessons learned in North Carolina, USA. In: Rutherfurd I, Bartley R (eds) Proceedings, Second Australian Stream Management Conference, Adelaide, vol 1, pp 359–364

Kentula M (2000) Perspectives on setting success criteria for wetland restoration. Ecol Eng 15:199–209

Kern K (1994) Grundlagen naturnahen Gewässergestaltung. Geomorphologische Entwicklung von Fließgewässern. Springer Verlag, Berlin – Heidelberg – New York. 256 pp

Kiss T, Andrási G (2011) A horvátországi duzzasztógátak hatása a Dráva vízjárására és a fenékhordalék szemcseösszetételének alakulására (Impact of dams in Croatia on the water regime and bedload grain size of the Drava River). Hidrológiai Közlöny 91(5):17–23 (in Hungarian)

Konkoly-Gyuró É (2011) A tájfunkció elemzés koncepciójának kibontakozása (Evolution of the concept of the landscape function analysis). Workshop on Ecosystem Services, Corvinus University, Budapest, 24 November 2009. http://www.mta-taki.hu/hu/node/385 Accessed on 10.10.2014 (in Hungarian)

Leopold A (1949) A sand county almanac. Oxford University Press, Oxford, 266 pp

Lóczy D (2013) Hydromorphological-geoecological foundations of floodplain management: case study from Hungary. Lambert Academic Publishing, Saarbrücken. 382 p

Lóczy D, Dezső J, Czigány Sz, Prokos H, Tóth G (2017) An environmental assessment of water replenishment to a floodplain lake. J Environ Manag 202(2):337–347. https://doi.org/10.1016/j.jenvman.2017.01.020

Macura V, Izakovičová Z (2000) Krajinnoekologické aspekty revitalizácie tokov (Landscape ecological aspects of the revitalization of rivers). Slovakian Technical University, Bratislava. 262 pp (in Slovakian)

Márk L, Sindler Cs, Tálos A (2006) Ős-Dráva Program – Víz az Ormánság fellendítésért (Old Drava Programme – Water for progress in Ormánság region). 24th National Meeting of the Hungarian Hydrological Society, Pécs, 5–6 July 2006 vol II. http://www.tankonyvtar.hu/hu/tartalom/arcanum2/HidrologiaiTarsasagVandorgyulesei_2006_024_2/adatok.html Accessed 20.12.2014 (in Hungarian)

Morandi B, Piégay H, Lamouroux N, Vaudor L (2014) How is success or failure in river restoration projects evaluated? Feedback from French restoration projects. J Environ Manag 137:178–188. https://doi.org/10.1016/j.jenvman.2014.02.010

National Research Council (1992) Restoration of aquatic ecosystems: science, technology and public policy. The National Academies Press, Washington, DC, 576 pp

National Research Council (2002) The Missouri River Ecosystem: Exploring the Prospects for Recovery. The National Academies Press, Washington, DC, 175 pp

Nemes G, High C (2011) Implementation of agri-environmental programme in Hungary. Regional studies association annual international conference, 17–20 April 2011. Newcastle-upon-Tyne, UK. http://www.regionalstudies.org/uploads/conferences/presentations/international-conference-2011/nemes.pdf

Niemi GJ, DeVore P, Detenbeck N, Taylor D, Lima A, Pastor J, Yount JD, Naiman RJ (1990) Overview of case studies on recovery of aquatic systems from disturbance. Environ Manag 14 (5):571–597

Palmer MA, Bernhardt ES, Allan JD, Lake PS, Alexander G, Brooks S, Carr J, Clayton S, Dahm CN, Follstad Shah J, Galat DL, Loss SG, Goodwin P, Hart DD, Hassett B, Jenkinson R, Kondolf GM, Lave R, Meyer JL, O'Donnell TK, Pagano L, Sudduth E (2005) Standards for ecologically successful river restoration. J Appl Ecol 42:208–217. https://doi.org/10.1111/j.1365-2664.2005.01004.x

Pécsi HIDROTERV Bt. (2015) Ős-Dráva Program. Aktualizált Területi Vízgazdálkodási Tanulmányterv (Old Drava Programme: Actualized Regional Water Management Plan). Pécsi HYDROTERV Bt., Pécs. 180 pp

Petts GE (1984) Impounded rivers: perspectives for ecological management. John Wiley and Sons, Chichester, 326 pp

Piégay H, Darby SE, Mosselmann E, Surian N (2005) A review of the techniques available for delimiting the erodible river corridor: a sustainable approach to managing bank erosion. River Res Appl 21:773–789. https://doi.org/10.1002/rra.881

Popovič I, Mikuska T (2010) The Drava river – a flowing controversy. Danube Watch 1/2010. http://www.icpdr.org/main/publications/drava-river-flowing-controversy

Ramsar Convention Secretariat (2010) Managing wetlands: frameworks for managing Wetlands of International Importance and other wetland sites. Ramsar handbooks for the wise use of wetlands, 4th edn, vol 18. Ramsar Convention Secretariat, Gland, Switzerland. 96 pp

Rményi P, Tóth J (eds) (2009) Az Ormánság helye és lehetőségei (Position and opportunities of the Ormánság region). IDResearch Kft, Pécs. 56–58:302–355 (in Hungarian)

Salamon B (2014) With collaboration for the advancement of Ormánság. Old-Drava Programme Office, Kémes. 20 pp

Sanford W (2002) Recharge and groundwater models: an overview. Hydrogeol J 10:110–120. https://doi.org/10.1007/s10040-001-0173-5

Schiemer F, Baumgartner C, Tockner K (1999) Restoration of floodplain rivers: The Danube restoration project. Regul Rivers Res Manag 15:231–244

Schwarz U (2014) Restoration potential for floodplains in the Danube River Basin. Presentation at the 1st Danube Regional Workshop on Natural Water Retention Measures, Szentendre, Hungary, 28–29 January 2014

Sparks RE, Bayley PB, Kohler SL, Osborne LL (1990) Disturbance and recovery of large floodplain rivers. Environ Manag 14(5):699–709

Szalay M (2009) A felszíni vizek mennyiségi jellemzése. Kisvízi készlet (Quantitative description of surface waters: low-water reserves). Manuscript report. Öko Zrt., Pécs. 18 pp (in Hungarian)

Tésits R (2012) The nonprofit sector and employment expansion in the rural areas of Hungary. Eastern European Countryside 18(1):125–147. https://doi.org/10.2478/v10130-012-0007-6

Tésits R, Alpek BL (2012) Labour market needs assessment of the Hungarian-Croatian border region. South-Transdanubian Regional Resource Center, Pécs. 106 pp

Tésits R, Alpek BL (2014) Appearance of European employment policy in the rural areas of Hungarian-Croatian border region. Eastern European Countryside 20(1):55–71. https://doi.org/10.2478/eec-2014-0003

Tockner K, Schiemer F, Ward JV (1998) Conservation by restoration: the management concept for river floodplain system on the Danube River in Austria. Aquatic Conservation: Marine and Freshwater Ecosystem 8:71–86. https://doi.org/10.1002/(sici)1099-0755(199801/02)8:1<71:aid-aqc265>3.0.CO;2-d

Tóth G, Rajkai K, Bódis K, Máté F (2014) Magyarországi kistájak földminősége a D-e-meter szántó minősítési eljárás szerint. Tájökológiai Lapok 12(1):183–195 (in Hungarian)

VKKI (2010) Vízgyűjtő-gazdálkodási terv. Dráva részvízgyűjtő (Watershed Management Plan: Drava Partial Watershed). Vízügyi és Környezetvédelmi Központi Igazgatóság (Central Directorate for Water Management and Environmental Protection), Budapest. 162 p (in Hungarian)

Völgyesi I (2009) Ökológiai vízigény vagy megfelelő talajvízszintek? (Ecological water demand or proper groundwater levels). Hidrológiai Közlöny 89(5):53–56 (in Hungarian)

Wallace K (2008) Ecosystem services: multiple classifications or confusion? Biol Conserv 141 (2):353–354. https://doi.org/10.1016/j.biocon.2007.12.014

Woolsey S, Capelli F, Gonser TOM, Hoehn E, Hostmann M, Junker B, Paetzold A, Roulier C, Schweizer S, Tiegs SD, Tockner K, Weber C, Peter A (2007) A strategy to assess river restoration success. Freshwater Biol 52:752–769. https://doi.org/10.1111/j.1365-2427.2007.01740.x

WWF (2002) Áttekintés a Dráva alsó vízgyűjtőjének tájhasználatáról (An overview of land use in the Lower Drava River catchment). Report for the Worldwide Fund for Nature Hungary, Budapest. 142 pp (in Hungarian)