Potential for renewable use of biomass from reedbeds on the lower Prut, Danube and Dniester floodplains of Ukraine and Moldova

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SUMMARY

The first phase of the ReedBASE project commenced in September 2016 and ended in March 2018. It assessed the use of reed biomass as a source of sustainable energy and raw material for other products in parts of the floodplains of the Prut, Danube and Dniester Rivers in Ukraine and Moldova. It was estimated that the project study areas alone could sustainably generate some 100,000 tons of reed biomass per year. In energy terms, this is equivalent to almost 50,000 tons of coal or 39.5 million cubic metres of gas. Using reed biomass would not only provide a substantial amount of energy, but also avoid emitting some 79,000 tons of CO_2 from burning fossil fuels. Moreover, conservative estimates indicate that the organic soils in the project area contain around 850,000 tons of carbon, and this amount will increase as the organic matter accumulates over time. ReedBASE also established a cluster of interested organisations in order to enhance their collaboration.

KEY WORDS: ecosystem services, greenhouse gas, innovation cluster, ReedBASE, sustainable energy

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INTRODUCTION

The common reed *Phragmites australis* grows prolifically in the floodplains of the Prut, Danube and Dniester river basins in Ukraine, Moldova and Romania. Indeed, one of the largest expanses of reedbed in the world occurs in this region and they are of global significance for their biodiversity, hosting a wide range of threatened mammals, birds, fish and plants so that much of the area is covered by international conservation designations (Goriup *et al.* 2007). However, extensive modification of floodplains since the 1950s (for flood control, irrigation and fisheries) has had significant impacts on wetland habitats and biodiversity, as well as on wetland ecosystem services (Goriup & Goriup, 2015). In particular, long-standing monotonous reedbeds have become widespread, displacing species needing more dynamic habitats. In that, they counteract nature conservation targets as well as land use interests and are generally regarded as a nuisance. Careful harvesting of reedbeds and economic use of the biomass generated could be a sustainable way of reviving the more open and dynamic habitats.

Between September 2016 and March 2018, a project was conducted on the development of a cross-border innovation platform/cluster for using reed biomass as a source of sustainable energy in the lower floodplains of the Prut, Danube and Dniester Rivers in Ukraine, Moldova and, partially, in Romania (ReedBASE). Led by the Michael Succow Foundation, the ReedBASE project area covered four study sites in Ukraine and one in Moldova (Figure 1).

ReedBASE partners carried out a number of activities, including:

- a desk study concerning the former and current status of wetlands in the project area, and identifying strengths and weaknesses in existing reed harvesting and biomass processing and combustion technologies;
- compilation of a database of stakeholders and decision makers from different governmental and non-governmental organisations from national to local level, which are or should be involved in sustainable reed bed utilisation in the project area;
- undertaking two stakeholder consultation "roadshows" within the project area in order to identify and inform potential partners for promoting the sustainable use of reed biomass harvested in the project area; and
- convening a meeting of Parties in Odessa to conclude and sign the ReedBASE Cluster Memorandum of Understanding.

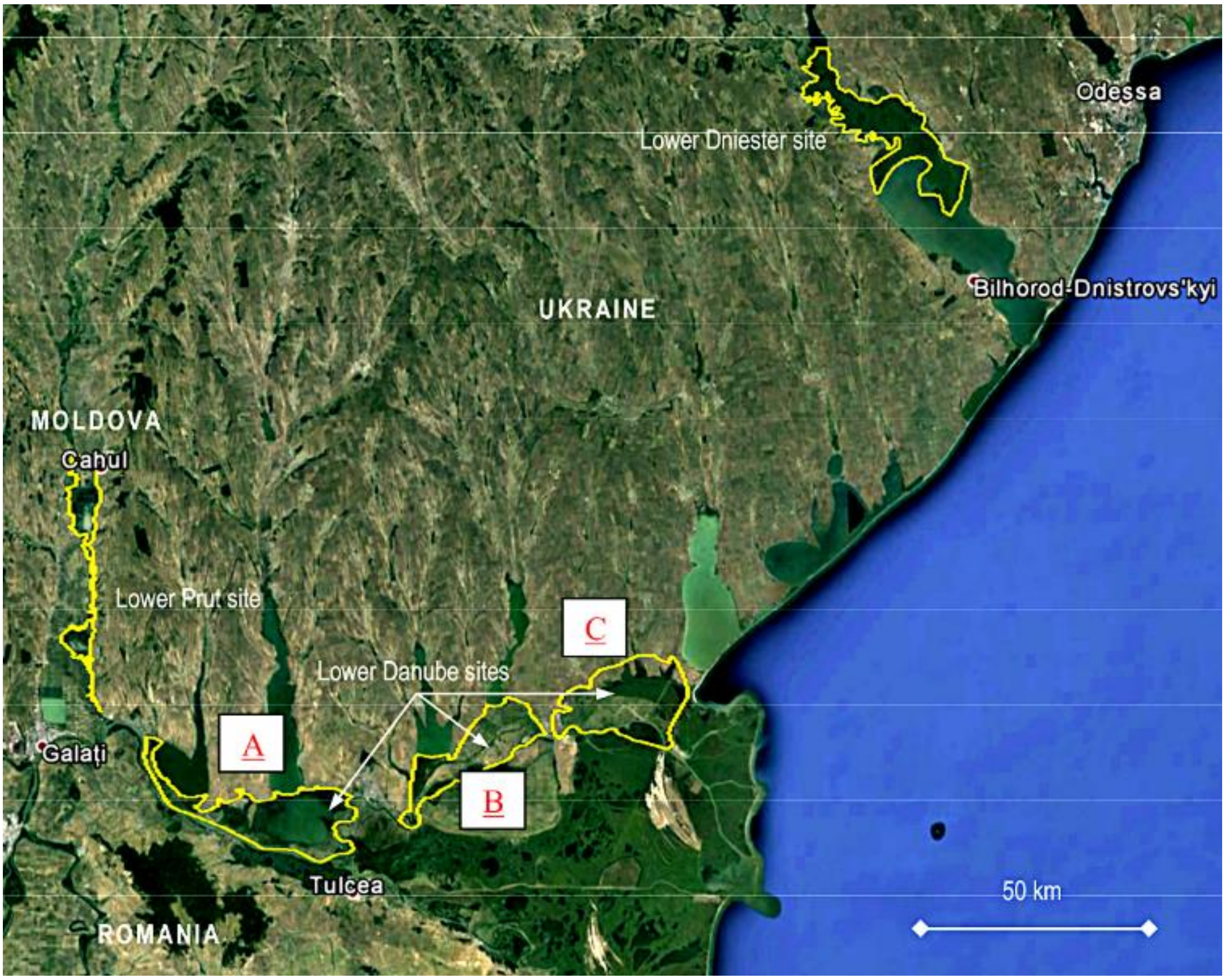

Figure 1. Location of the ReedBASE study sites: the Lower Prut floodplain in Moldova, from Cahul to Giurgiulesti (top left); three sections of the Lower Danube floodplain between Reni and Vylkove in Ukraine (A) from Reni to Izmail, (B) from Izmail to Kiliya and (C) from Kiliya to Vylkove and Primorsky; and the lower reaches of the Dniester/Turunchuk rivers in Ukraine, from the border with Moldova to their entry into the coastal Dniester Liman (top right). Source: ReedBASE project.

METHODS

Reed resource desk study

Based on existing knowledge, we selected five study sites (Figure 1) to represent floodplain areas where reed cover was (or had been) extensive, with a particular focus on establishing the occurrence of soils with high organic content that might be suitable for paludiculture (Wichtmann *et al*. 2016). In effect, this approach covered most of the floodplain areas with the exception of the Kiliya delta in Ukraine because this coastal zone has little peat formation and is part of the Danube Biosphere Reserve where reed utilisation is highly constrained. We mapped and analysed the study areas using ArcInfo Geographical Information System software. The main data sources produced by the ReedBASE project were:

1. Land cover / land-use maps

- High-resolution satellite imagery available via Google Earth, Bingmaps and Yandex map services. Access under links:
  https://www.google.com/earth
  https://www.bing.com/maps
  https://yandex.ua/maps
- Road network based on OSM data.
- Background: World Imagery ESRI layer.

2. Soil maps

- Bilanchyn *et al*. (2014).
- National geospatial data fund of Moldova. Soils. Access under link: http://geoportal.md
- Public Cadastre map of Ukraine. Access under link: http://map.land.gov.ua/kadastrova-karta

- National atlas of Ukraine. Soils. Access under link: http://wdc.org.ua/atlas
- Road network based on OSM data.
- Background: World Imagery ESRI layer.

3. Land ownership maps

- Public Cadastre map of Ukraine. Access under link: http://map.land.gov.ua/kadastrova-karta
- Informational portal of real estate cadastre of Moldova. Access under link: https://www.cadastru.md
- Road network based on OSM data.
- Background: World Imagery ESRI layer.

4. Protected areas

- The Ukrainian Scientific Center of Ecology of the Sea. Ecological network of Odesa oblast. Access under link: http://ims.sea.gov.ua:8081/econetwork/
- Official web-page of Danube biosphere reserve. Access under link: http://www.dbr.org.ua/search/label/maps_ua.
- Official web-page of Lower Dniester National Nature Park. Access under link: http://nnpp.org.ua/sample-page/
- Official web-page of Department of Ecology and Natural Resources of Odesa State Regional Administration. Access under link: http://ecology.odessa.gov.ua/regonalna-ekologchna-merezha-odesko-oblast-eskzna-kartoshema/
- Road network based on OSM data.
- Background: ESRI World Imagery layer.

Wetland biomass resource use

In order to assess the current situation regarding wetland biomass use in the study areas, we conducted reviews of:

- land cover and utilisation according to the CORINE classification (https://www.eea.europa.eu/publications/COR0-landcover);
- the distribution of river floodplain soils (focusing on the presence of peat or mineral soils);
- land ownership;
- extent of protected areas; and
- floodplain conditions and current hydrological infrastructure and alterations (inventory of drainage ditches and channels, pumping stations etc. and their condition).

We contacted and received information from relevant government bodies, non-government organisations, research institutes and private companies active in the sector. In addition, we mounted two stakeholder ‘roadshows’ in June and October 2017. These comprised tours in each of the study sites where members of the project team carried out field visits to enterprises and projects, and held a local workshop about the ReedBASE project and its findings in the main towns concerned (Cahul, Reni, Izmail, Vylkove and Mayaki) with representatives from local public authorities, research institutions, businesses and civil society organisations.

ReedBASE Cluster formation

The ‘roadshow’ workshops mentioned above also served to gauge local interest in forming an interest group or cluster that would identify, develop and implement innovative approaches for wetland biomass management and utilisation within and beyond the study sites. To assist this process, we circulated and discussed a draft ReedBASE Memorandum of Understanding with stakeholders during the second stakeholder ‘roadshow’.

RESULTS

Reed resource desk study

Land cover

The land cover analysis (Table 1) showed that the total extent of the study sites amounted to 117,920 ha. The most widespread land cover types were low-lying arable land (36,802 ha or 31 %) and pure reedbeds (35,760 ha or 30 %). A further 9,974 ha (8 %) comprised reed mixed with other vegetation types (grassland, woodland or shrubs). The remaining area was largely represented by open water (23,139 ha or 20 %).

Soils

Maps of soils were available for 92,092 ha (78 %) of the study site area (Table 2). In the Prut floodplain, soils are almost equally divided between dry to wet mineral alluvial soils and alluvial swamp organic soils. The Danube floodplain soils are dominated by moist to wet alluvial types. They are almost entirely mineral in the western part (Reni–Izmail), with increasing amounts of more organic peat-forming soils in the central and eastern parts. The western and central parts include a large area of drained wetlands currently used for rice and other cereal production. The soils of the Lower Dniester wetlands are predominantly moist or wet alluvial soils, including a significant area (up to 19,700 ha) of peat-forming soils.

Table 1: Land cover (CORINE classification) in the project area (figures in ha, rounded). Source: ReedBASE project.

Land cover category, level 1	Land cover category, level 2	Lower Prut	Lower Danube (A)	Lower Danube (B)	Lower Danube (C)	Lower Dniester	Total
Agricultural areas	Arable land	2,319	7,514	13,305	13,271	394	36,802
	Heterogeneous agricultural areas	99	1,447	202	739		2,487
	Pastures	30	92	54	84		260
	Permanent crops	2		131			133
Artificial surfaces	Green urban areas		61	45	359	62	526
	Industrial units	2	29	147	336	3	516
	Transport units		24		3		26
	Industrial & transport units			22			22
Forest & shrubs		1,099	1,166	1,543	418	2,709	6,935
Herbaceous vegetation	Natural grassland	108	58	12	44	107	328
	Natural grassland & moors	47					47
	Natural grassland & shrubs	31	148	73			252
	Natural grassland, moors, shrubs	181					181
Open spaces with little or no vegetation	Sparsely vegetated areas	14	24		3		41
Water bodies	Estuary					2,209	2,209
	Lakes	2,364	9,582	1,868	2,904	968	17,686
	Artificial	2					2
	Fish ponds	1,327		188	260	814	2,588
	Ponds	1					1
	River					654	654
Wetlands	Grassland				177		177
	Grassland & shrubs	165	147				312
	Reedbeds	1,744	2,106	2,941	9,187	19,781	35,760
	Reedbeds & fish ponds		524				524
	Reedbeds & forests	692					692
	Reedbeds & arable land				61		61
	Reedbeds & grassland			114	15		129
	Reedbeds & shrubs	56		56			112
	Reedbeds, grassland & shrubs				154		154
	Reedbeds, forest & shrubs	433					433
	Water & moors	3					3
	Water bodies & reedbeds	279	6,517	72	889		7,757
	Water bodies, reedbeds & shrubs				110		110
							Total area: 117,920

Land ownership

The registered ownership of land in the study sites according to the national land cadastres is provided in Table 3. These data indicate that the whole of the Lower Prut area has been cadestrated, with 74 % of the area in state ownership and much of that under protection. In Ukraine, on the other hand, some 68,297 ha (36 %) of land in the sites remains unregistered. However, this land is predominantly covered by reedbeds and water bodies that are constitutionally under state ownership (including large portions of the Danube Biosphere Reserve and Dniester National Park). Of the 38,627 ha of registered land in Ukraine, the majority (24,529 ha or 63.5 %) is privately owned, almost entirely as household, family or market farming land.

Protected areas

A relatively high proportion of the land in the project area, totalling 22,580 ha (19 %), is designated for nature protection, attesting to the outstanding biodiversity value of the region (Table 4). However, the Lower Danube (A) site (Reni to Izmail) has no protected areas at present.

Floodplain conditions, current hydrological infrastructure and impact on fisheries

The five study sites in present-day Ukraine and Moldova were incorporated into the Soviet Union in 1944. As border areas, they were heavily guarded and movement in and out of them was strictly controlled. Subsequent intensive land use development had far-reaching consequences for the former steppe and wetland areas. From the early 1960s, various small-scale irrigation systems were introduced to improve cereal production. These initiatives gathered pace and by 1966 work had started on a grand scheme for a Danube-Dniester irrigation system which consisted of canals and storage reservoirs intended to turn the drought-prone area between the two rivers into arable

Table 2. Extent of soil types in the ReedBASE study sites (figures in ha, rounded). Source: ReedBASE project.

Soil type	Lower Prut	Lower Danube (A)	Lower Danube (B)	Lower Danube (C)	Lower Dniester	Total area
Swamp organic soils	0	0	0	0	19,699	**19,699**
Alluvial swamp organic soils	3,873	0	0	0	767	**4,639**
Alluvial mixed organic & mineral soils	0	17,199	15,608	7,337	0	**40,145**
Alluvial mixed organic & mineral soils within reedbeds	1,664	55	3,105	8,564	1,469	**14,857**
Alluvial mineral soils	1,673	0	0	0	1,119	**2,792**
Non-alluvial mineral soils within reedbeds	0	0	0	842	0	**842**
Non-alluvial mineral soils	11	0	0	9,107	0	**9,118**
Total mapped						**92,092**

Table 3. Land ownership in the ReedBASE study sites (areas in ha, rounded). Source: ReedBASE project.

Ownership	Lower Prut		Lower Danube (A)		Lower Danube (B)		Lower Danube (C)		Lower Dniester	
	ha	%	ha	%	ha	%	ha	%	ha	%
Private	2,863	26	3,327	51	10,275	85	10,922	71	5	0
State	8,133	74	3,083	47	1,820	15	4,296	28	4,538	99
Municipal	0	0	65	1	0	0	67	0	25	1
Undefined	0	0	82	1	0	0	128	1	0	0
	10,997		6,800		12,094		15,413		4,568	

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farmland (Marples 1985). The work undertaken as part of this project included the 1974 construction of a huge canal from the Danube, across the Stentsovsko-Zhebryanski marshes north of the Danube delta, to Sasyk Liman. The plan was to introduce fresh water to an erstwhile coastal lagoon by damming the connection with the sea.

Unfortunately the work not only destroyed a huge area of natural wetland and meadow, but also failed agriculturally because soils in the region are highly vulnerable to degradation after drainage. Oxygen penetrates drained peat soils and accelerates mineralisation rates leading to high emissions of CO_2 and severe changes in soil structure. In addition, the high evaporation rates in the steppe zone lead to topsoil salination and both processes severely reduce productivity. By the late 1970s, cereal production on irrigated land had started to fall behind that on non-irrigated land and the scheme was abandoned in the mid-1980s (Marples 1985).

After the dissolution of the USSR in 1991, farmland in Ukraine and Moldova, which was still organised as communal "kholkoses", was returned to private ownership and leased to management companies. However, these companies generally could not pay for agrichemicals, electricity for pumping water, new equipment or maintenance. As farm activity decreased, ongoing chemical pollution of soils and water declined and some fields in the floodplains were abandoned. Plans to extend irrigation systems and further intensify agriculture were stopped. Since then most of the dams, polders, pumping stations, weirs, sluices, power lines, aqueducts and canals have deteriorated and often been vandalised, leaving a legacy system which is barely operational. Nowadays, floodplain works are carried out principally to repair key infrastructure such as flood control dykes and canals that maintain water levels in the floodplain lakes mainly in order to preserve fisheries.

The hydrological infrastructure is not working properly today, but the continued existence of the embankments means that the floodplain lakes (Kagul, Kartal, Yalpug, Kugurlui, Katlabugh and Kitai) still lack the alluvial dynamics of Danube River floods that alter vegetation, deposit and remove sediments, and control water flow and quality. As a result, all the floodplain lakes suffer from heavy sedimentation, reed encroachment, evaporative mineralisation, and nutrient inflow from adjacent arable land.

Although not specifically covered by the ReedBASE project, it is worth mentioning here the dramatic effects of these changes on fisheries in the floodplain lakes since the mid-1950s as they graphically illustrate the ecological changes that were brought about. Before the 1960s, the aquatic ecosystems of the lakes were typically "clear water systems" with low nutrient loads and transparent water (Moss *et al*. 1996). The diverse wetlands provided ideal spawning conditions for native Common Carp *Cyprinus carpio* (the dominant fish species) as well as Pike *Esox lusius*, Rudd *Scardinus*

Table 4. Protected areas in the ReedBASE study sites (figures in ha, rounded). Source: ReedBASE project.

Status	Designation	Name	Study site	PA area (ha)	Study site area (ha)	% cover
National	Scientific Reserve	Lower Prut	Lower Prut	1,691	10,997	15
National	National Nature Park	Lower Dniester	Lower Dniester	15,502	27,700	56
National	Protected Site (within NP)	Dniester reedbed	Lower Dniester	-7,620	27,700	28
National	Biosphere Reserve	Danube	Lower Danube (C)	10,821	29,013	37
Local	Regional Landscape Park	Izmail Islands	Lower Danube (B)	1,366	20,773	7
Local	Regional Landscape Park	Lake Lung	Lower Danube (B)	799	20,773	4
Local	Regional Landscape Park	Wet Oak Forest	Lower Dniester	21	27,700	0
Total area protected				22,580		

erythropthalmus, Tench *T. tinca*, Bream *Abramis brama* and Roach *R. rutilus* which formed the basis for an economically important fishery. The lakes also supported large populations of Crayfish *Astacus astacus*, which reached a considerable size and offered a significant fishery in their own right.

While annual fish catches increased and fisheries prospered during the 1950s (Figure 2) the progressive transformation of the river floodplain dynamics and intensification of farming reduced productivity of the native fish species by cutting migratory routes for reproduction and causing water quality and spawning grounds to deteriorate. To compensate for the declining productivity of native species, from the late 1960s fisheries started to stock the lakes with native Golden Carp *Carassius auratus* and domesticated common carp. Then, as clear water environments became increasingly scarce in the 1970s, authorities introduced the Grass Carp *Ctenopharyngodon idella* (which tolerates turbid water) and finally the Silver Carp *Hypothalmichthys molitrix*, a large fish from Asian rivers that feeds on algae and tolerates highly eutrophic waters (which Grass Carp does not). During the 1980s these highly invasive species replaced native species almost completely and finally led to complete collapse of the region's freshwater ecosystem. The consequent economic losses, combined with increased operating costs after 1991, led to a reduced level of stocking for Silver Carp. Today, fisheries in the lakes remain barely economic.

Wetland biomass resource use

Within the ReedBASE project area, the main species of interest for sustainable production of biomass raw material are common reed (including the highly productive octoploid genotype *Phragmites australis giganteum*) and willows (mainly *Salix alba*) because of their wide distribution, abundance and high biomass concentration. Alder *Alnus glutinosa* also has high potential for production of both high-quality construction timber and fuel wood.

In Moldova, the reed resource is rather limited; in the study site it amounted to just 1,744 ha. However, willow grown on a short rotation or pollarded for biomass production is being introduced as a suitable approach to wetland use. In Ukraine, reed is a substantial resource. Unfortunately, instead of using it, local people often simply set alight large areas of reed in situ, either by accident or in the hope of clearing ground for grazing or market gardening.

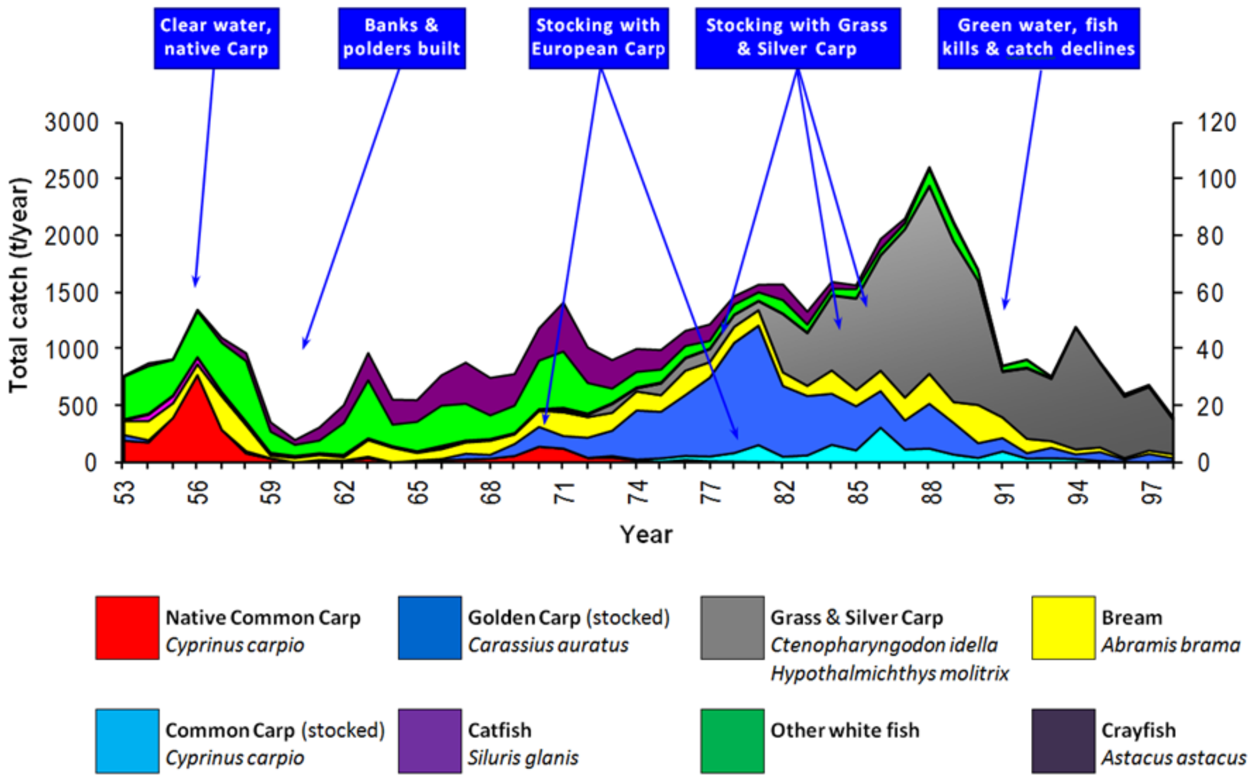

Figure 2: Composition of total fish catches and yield in Lakes Yalpug, Kugurlui and Katlabugh from 1953 to 1997, related to main impacts and development of stocking. Adapted from Goriup & Goriup (2015) based on data from Odessa Fisheries Protection Department in de Graaf *et al*. (2002).

This leads to a large uncontrolled release of carbon gas and particles, collateral fires and smoke along roadsides, and deposition of ash which can affect cars, paintwork and drying laundry.

At present, reed is rarely used for heating in either Moldova or Ukraine because a specification for the full cycle of logistics and processing of reeds has not been developed. Instead, reed is most often harvested in the form of bundles for export to the Netherlands, Germany and Denmark for making thatched roofs as well as mats for insulation panels, shade screens or fencing and even some handicrafts. Harvesting is prevalent in the lower Dniester between Mayaki and Belyaivka, and in the lower Danube around Vylkove. The annual dry matter harvest in Vylkove amounts to about 13,500 t/year of which some 2,000–4,000 t/year is discarded during bundle-making and would be available for alternative uses (Zhmud *et al*. 2012). According to information provided to the project by the reed harvesting companies Dnestroviez and Ecodnestr in Mayaky, the annual dry matter harvest of reed in the Lower Dniester is about 12,000 t/year, with 1,500–3,000 t/year of waste reed.

Three enterprises (two in Vylkove and one in Mayaki) absorb some of the waste reed by operating reed briquetting lines to make boiler fuel, although the lines do not run well because their technical components are not adapted for reed properties (high silica content) and suffer from infrastructural flaws (in power supply or long transport distance for biomass). Moreover, demand for the consequently high-priced fuel briquettes is low, frustrating economic profits. Another enterprise in Reni produces pellets from reeds on a pilot basis and plans to increase production in future.

Stakeholder consultation ‘roadshows’

During the preparatory phase, ReedBASE conducted a survey of organisations that are or might be interested in the sustainable use of biomass from reed beds within the study sites. As a result, 118 organisations were identified, comprising research institutions, businesses, public authorities and civil society organisations (Table 5). The database was used to organise workshops within the study sites to discuss the use of wetland biomass. Overall, 33 people attended the meetings and shared information about reed harvesting; reed processing for thatch, mats, briquettes and pellets; and willow production for furniture, fuel and fodder. Most of the participants expressed interest in the formation of a ReedBASE cluster, provided that it would be active and generate initiatives that would benefit the local communities where wetland biomass occurs.

Table 5. Organisations related to wetland biomass utilisation in the ReedBASE study sites. Source: ReedBASE project.

Sector	No. in Ukraine	No. in Moldova	Total
Research / education	19	5	24
Industry	19	17	36
Government / PAs / IGOs*	32	7	39
Civil society	12	7	19
Totals	82	36	118

*Includes protected area administrations and inter-governmental organisations

DISCUSSION

The results from the ReedBASE project demonstrate that the wetland biomass resources (mainly reedbeds), as well as the organic soils, of the lower Prut, Danube and Dniester rivers are economically and environmentally significant in their own right. Further research, development and investment would allow these resources to be better managed and utilised while at the same time maintaining their ecological sustainability.

Potential biomass utilisation

Given its wide occurrence and abundance, reed biomass has the highest potential for sustainable utilisation in the project area in the short term. Moreover, reeds mostly grow on land that is too wet or marginal for conventional agricultural production and thus represent a substantial source of biomass without involving additional production inputs or competing with food production.

Reeds are currently harvested mostly for construction materials but can also be used as a source of organic chemicals and for energy by combustion or digestion for biogas. Indeed, since as much as 30 % of the reed harvested for thatch is discarded during processing, ‘waste reed’ amounts to several thousand tons a year. Seeking additional uses for this by-product would mitigate uncontrolled illegal dumping and burning and increase economic efficiency.

Recent research (Wichmann & Köbbing, 2015) shows that Europe is the largest market for thatching material worldwide, with a total annual consumption of some 29,400 tons of reed. However, it is notable that imports from China increased significantly from about 2007, for reasons of price and durability. Several of the stakeholders involved in the project were concerned that the export and domestic demand for reed will be further replaced by imports from China, and steps are needed to improve competitiveness and quality in Europe. Developing alternative uses for reed such as renewable energy would also be a way to reduce the risk of a loss of market share in thatching.

Unfortunately, a large gap remains between the current reality and the potential for new uses of reed biomass. This is due not only to the infrastructure and framework deficiencies described above, but also to low awareness of the benefits of switching from drainage based utilisation of marginal sites to wet reedbed management. While there are significant benefits to be gained, there are also significant obstacles to the implemention of even relatively simple reed processing plants, and achieving economic viability for small-scale initiatives is difficult. To address the obstacles, it will be necessary to draw together the various actors (government, research bodies, businesses and civil society) in a way that allows them to collaborate on innovative approaches for using wetland biomass.

Carbon budget

Although assessing the carbon stocks and budget within the project area was not a focus of ReedBASE, this aspect is worthy of preliminary consideration here. Assuming that about 70 % of the reedbed area is accessible (excluding areas under strict protection or unsuitable for harvest), that a two-year harvest rotation is used, and that an average yield of 8 tons of dry reed per hectare is obtained, it is estimated that (in its current state of management) the project area could in time sustainably generate some 100,000 tons of dry reed biomass per year. In energy terms, this is equivalent to almost 50,000 tons of coal or 39.5 million cubic metres of gas. Thus, using reed biomass would not only provide a substantial amount of energy, but also avoid emitting the equivalent of some 79,000 tons of CO_2 from burning fossil fuels.

In addition, organic soils - which are particularly suitable for paludiculture as well as carbon accumulation and storage - cover significant areas in the Prut (3,873 ha) and lower Dniester (20,466 ha) study sites. Although further research is needed on the thickness, bulk density and carbon content of the organic layer, assuming modest estimates of 10 cm average thickness and carbon density 35 kg m^{-3} according to Lindsay (2010), the organic soils in the study areas would contain in the order of 850,000 tons of carbon. Preservation of this carbon stock by preventing further drainage, if not actually increasing it by rewetting drained areas, would be an important issue for management of the region’s carbon budget.

ReedBASE cluster formation

Triple Helix Approach

Innovation for efficient and sustainable use of renewable resources is gaining global importance and needs transboundary efforts for optimisation. In the “Triple Helix” approach, the potential for innovation and economic development is enhanced by close mutual interaction between government, research bodies and industry. For example, in 2008 the EU adopted Regulation (EC) No 294/2008 to establish the European Institute for Innovation and Technology (EIT, https://eit.europa.eu/) to connect and stimulate cooperation between top-level academic and industrial research and development institutions. EIT currently administers five so-called Knowledge and Innovation Communities (KICs) from their headquarters in Budapest, Hungary.

Forming a Triple Helix cluster is the best way to promote innovation for sustainable use of wetland biomass, and obtain the inherent ecosystem benefits this approach entails. Such a ReedBASE cluster could cooperate to develop initiatives and address obstacles that impede ecologically and economically sustainable use of the considerable existing and potential wetland biomass resources available in the lower Prut, Danube and Dniester river floodplains. The combination of environmental research, engineering and practical implementation of sustainable wetland management and paludiculture will lead to innovations that contribute to:

- restoration of ecosystem services including habitat improvement for migratory birds and waterfowl and the mitigation of greenhouse gas (GHG) emissions;
- nutrient retention and water purification in reedbeds and, therefore, improvement of water quality in the Black Sea;
- development of climate change adapted land management schemes;
- provision of renewable biomass for energy production and use as a raw material;
- reduction of regional energy imports;
- support of regional economies and increase of local employment; and
- establishment of showcase paludiculture-based enterprises.

Memorandum of Understanding

The final action of the ReedBASE project was to convene a meeting of parties in Odessa on 25 October 2017 in order to sign a Memorandum of Understanding which formally established the ReedBASE Innovation Cluster for cooperation in the field of innovative utilisation of renewable biomass from ecologically sustainable reedbed management. The founding parties of the MoU were: the Institute of Market Problems and Economic-Ecological Research, National Academy of Science of Ukraine (MoU leader); Michael Succow Foundation, Greifswald, Germany; Cross-Border Cooperation and European Integration Agency, Cahul, Moldova; Agricola NGO, Odesa, Ukraine; Agency of European Innovation, Lviv, Ukraine; Danube Region Centre for Sustainable Development and Ecological Research, Kiliya, Ukraine; and BioTop (a private company), Reni, Ukraine. The MoU remains open to signature by other interested organisations from European countries.

Clearing-house role

The central role of the ReedBASE cluster is to act as clearing house, facilitating contacts and information sharing amongst its members. It would identify opportunities to strengthen its membership base and promote good practice for reedbed management throughout Europe. In particular, ReedBASE could undertake activities such as:

- screening eligibility for relevant project grants e.g. EU Transnational Danube Programme, EU Horizon 2020, EU Neighbourhood Programme, EIT and other national and bilateral schemes;
- forming consortia of members to bid for grants for research and development projects;
- joining the Triple Helix Association (https://www.triplehelixassociation.org/about-tha); and
- seeking collaboration with the European Institute of Innovation and Technology and relevant Knowledge and Innovation Communities.

Policy development

The government sector has a major role to play in facilitating the use of wetland biomass as a renewable source of energy, within its green energy policy. Topics to be addressed include:

- enforcement of water protection zone management and rewetting floodplain areas where appropriate;
- promotion of short-rotation coppice for materials and energy;
- designating reed as a recognised energy and agricultural crop;
- incentive schemes for research and business creation at local level to initiate economic development based on short carbon cycles;
- certification of product quality (thatch, briquettes and pellets) according to European standards; and
- delivering necessary infrastructure such as electricity supply, communications and transport.

Research needs

Universities and research institutes in the region should engage with international networks and organisations, and on the other hand strengthen their investigations of, and train local expertise in, aspects such as:

- long-term monitoring of effects on habitat diversity and quality;
- assessment of carbon stocks in wetland biomass and organic soils;
- wetland management, especially for carbon sequestration;
- evaluation of improvements in ecosystem services delivery achieved by wetland restoration and wise management;
- paludiculture opportunities on peat soils;
- designing optimal biomass harvesting regimes to avoid soil compaction and reed die-back;
- innovative construction materials from wetland biomass; and
- economics of wetland biomass utilisation.

Business investment

The private sector is the main driver for the development and marketing of new products resulting from appropriate wetland biomass policies and incorporating research results. There are opportunities at many points along the biomass energy supply chain, including:

- development and sale/lease of biomass harvesting equipment;
- development and sale/lease of biomass processing equipment;
- development and sale/lease of end-use equipment (boilers and CHP units);
- repair/servicing of biomass-related equipment; and
- sale of products, including exports.

Social engagement

Civilian organisations, although not a formal part of the Triple Helix system, can still play an important role by promoting awareness, increasing acceptance of and raising demand for wetland biomass products:

- creating awareness of wetland biomass value as a natural capital asset;
- promoting consumption of locally produced wetland biomass products;

- discouraging ad hoc burning of reedbeds as anti-social behaviour and wasting resources; and
- promoting the role and value of wetland/peatland ecosystem services, especially in the context of climate change.

Potential collaborative wetland biomass projects

As a starting point after analysis of the project results, eight potential site-based projects were identified for development by the new ReedBASE cluster. In addition, a thematic project to improve biomass harvesting, processing and marketing was identified for research and development. All of these projects require collaboration and innovation among various stakeholders in order to succeed, and incorporate potential for cross-border cooperation.

Prut floodplain

The River Prut floodplain between Cahul and Colibași is well placed to serve local markets for construction materials and renewable energy produced from willows (at Manta) and reeds (from Vadul lui Isac to Colibași). The fact that this part of the Prut and its floodplain forms the border with Romania means that projects could be developed and implemented as transboundary and twinning initiatives, combining sustainable use of plant biomass with restoration of floodplain dynamics for improvement of water quality and fish production.

Danube floodplain between Reni and Orlivka

The small area of reedbed southeast of Reni (at Kirgani) is currently partially harvested for the production of biomass pellets (about 100 tons year^{-1}) that are sold to local businesses. This operation is in a pilot development stage and expected to increase in volume over the coming years. An area of ~15 ha in the floodplain south of Orlivka is currently used for growing and pollarding willow trees. The municipality of Orlivka recently received a biomass boiler to heat its community hall, funded by an EU project on adaptation to climate change.

Both types of biomass use could be expanded to provide sources of renewable energy for local heating purposes. For reeds, this could be done by rewetting and managing floodplain areas that are not used for agriculture (about 760 ha), which would also restore natural ecosystem services such as flood alleviation, water quality improvement (removing sediments and organic pollution) and fish spawning areas. In this way the smallest of the floodplain lakes, Lake Kartal, could be developed into a showcase for ecological floodplain restoration in the region. Willow production could be extended along the canals linking Lakes Kagul and Kartal. As this part of the Danube floodplain is adjacent or close to the borders with Moldova and Romania, the projects could be developed and implemented as transboundary and twinning initiatives.

Danube floodplain around Leski and Vylkove

Several thousand tons of waste reed are generated each year from reed harvesting for thatch. This waste reed should be disposed of in an environmentally neutral way (e.g. not by dumping or uncontrolled in-situ burning). Efforts to make briquettes have met with various obstacles (unreliable power supply, limited market demand). At the same time, the town of Vylkove suffers from shortages of power and energy for heating. A possible alternative use of waste reed is as a bulk feed (in bales) for a combined heat and power (CHP) unit. Small-scale CHP units are increasingly available and gaining in efficiency; a feasibility project for Vylkove could be undertaken.

In addition, the floodplain around Lesky was converted to rice paddy during the Soviet period. However, rice production is losing viability in the face of competition from imports and due to the cost of maintaining the water level infrastructure. There is potential for investigating the feasibility of reinstating the natural floodplain water regime on some polders. This would generate reedbeds that are easy to harvest as well as restore ecosystem services such as flood alleviation, water quality improvement (removing sediments and organic pollution) and fish spawning areas.

As this part of the Danube and its floodplain lies opposite to Romania, projects could be developed and implemented as transboundary and twinning initiatives.

Dniester Delta

The Dniester delta comprises the largest contiguous area of organic soils in Odessa oblast. Much of the area lies within the Dniester National Nature Park, where some of the reed biomass is harvested. However, fires often occur here which can impede the further development of peaty soils. There is potential for conducting research on peat formation, fire impact and carbon sequestration across the whole area. If carbon loss from drained peat soils due to peatland fires and continuous mineralisation can be quantified, it is possible that carbon credits from peatland rewetting projects outside the National Park area could be sold on voluntary carbon markets, provided that certification is envisaged under the Verified Carbon Standard and the VCS peatland methodology is strictly followed for project planning (Emmer & Couwenberg 2017).

It appears that some of the adjacent floodplain area, which should be in the water protection zone, is currently managed for arable production. Such areas, especially those where access is more difficult, might be better used for willow production. A project could be developed to investigate this alternative, which would also restore ecosystem services such as water quality improvement (removing sediments and organic pollution) and fish spawning areas.

As the delta lies along the border with Moldova, projects could be developed and implemented as transboundary and twinning initiatives.

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