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THEMATIC ISSUE

Assessment of ecosystem services of the wetlands in the Ili River Delta, Kazakhstan

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Abstract Central Asia is the region with the worldwide highest number of endorheic or closed river basins. Many of those river basins are transboundary ones. Following the desiccation of the Aral Sea, Lake Balkhash has become the largest lake of Central Asia with an area of 17,000 km^2. The Ili Delta, in total 8000 km^2 large, is the largest natural delta and wetland complex of Central Asia. Seventy percent of the Ili River's runoff is generated in China. So, the Ili Delta is a showcase for a wetland complex lying downstream in a transboundary river basin. The objective of this paper is to assess the area and distribution of the wetlands and *Phragmites australis*-dominated reed vegetation as major natural ecosystems in the Ili Delta and their associated ecosystem services. An analysis of Rapid Eye satellite images revealed that there are wetlands and reed vegetation on a total area of 211,778 ha in the Ili Delta. A total of 85,400 ha are submerged reed beds with a total estimated biomass of 869,097 t. *P. australis* is used as fodder and raw material. Currently, there are about 100,000 livestock grazing in the delta. The submerged reed is planned to be used by a factory for chipboards and a paper factory. The wetlands are important spawning grounds for fish of Lake Balkhash. In 2014, almost 10,000 tourists visited the delta. Most of all tourists come from Almaty, followed by Russia, other regions of Kazakhstan, and Europe (outside Russia).

Keywords *Phragmites australis* · Biomass · Remote sensing · Livestock · Raw material · Tourism

Introduction

Central Asia, which stretches from the Caspian Sea into Mongolia, is largely dominated by dry lands and mountains (MEA 2005). Furthermore, Central Asia is the region with the worldwide highest number of endorheic or closed river basins, i.e. rivers that do not drain into the sea, but in an end-lake or inland delta. The most well-known end-lake was the Aral Sea (UNEP 2008). The major rivers in Central Asia have in common that they are transboundary rivers, along which there is an upstream–downstream conflict over water and competition for water between water users, like irrigated agriculture and natural ecosystems (CACILM and ADB 2010).

Following the desiccation of the Aral Sea, Lake Balkhash has become the largest lake of Central Asia with an area of 17,000 km^2 (UNEP 2014). 70–80% of the annual inflow into the Lake Balkhash is delivered by the Ili River. The Ili Delta, in total 8000 km^2 large, is the largest natural delta and wetland complex of Central Asia, which permanently receives water, and thus still remains in a rather undisturbed stage (Dostaj et al. 2006; Dostay et al. 2012). The Ili Delta therefore is of crucial significance for ecosystem services and the biodiversity of that region and

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is a showcase how deltas and wetlands in Central Asia could look like.

The Ili River is a transboundary river shared by Kazakhstan and China. The Ili River's two source rivers, i.e. Künez and Tekes, have their headwaters in the Tianshan Mountains in Xinjiang, China. The largest tributary to the Ili River, the Kash River, originates from China too. Thus, about two-thirds of the Ili runoff are generated in Xinjiang, China. Like other major wetlands of Central Asia, the Ili Delta is located in a downstream position. Upstream, in China and Kazakhstan, water is abstracted for irrigated agriculture and domestic water use. The water inflow into the Ili Delta furthermore is regulated by the operations of the Kapchagay Reservoir (Dostaj et al. 2006). Thus, the Ili Delta with its ecosystems and people competes for water with upstream water users, which makes it a representative example of a delta and wetland complex for the region Central Asia. This competition most likely will be aggravated in the course of climate change and melting glaciers due to reduced river discharge (Unger-Shayesteh et al. 2013). Still in the past two decades much research has been devoted to the Aral Sea and Amu Darya Delta (e.g. Kostianoy and Kosarev 2010; Breckle et al. 2012). Less research has been invested on the rather undegraded Ili Delta.

Against this background, in this study we assess the area and distribution of the wetlands and *Phragmites australis*-dominated reed vegetation as major natural ecosystems in the Ili Delta and their associated ecosystem services. Previous research has shown that the reed (*P. australis*) vegetation either submerged or non-submerged is by far the most productive vegetation, to which most ecosystem services of the delta can be attributed to (Table 1). Currently, the reed vegetation and water bodies in the delta provide the following ecosystem services (Jungius 2010; TEEB 2013; Hirschelmann 2014; Imentai et al. 2015; Piechottka 2015; Schäpe 2015; Röttgers 2016; Baranowski 2016):

- Provisioning
  - Fodder for livestock.
  - Fish as the Ili Delta serves as spawning place and thus provides a large share of the commercial fish catch of Lake Balkhash.
  - Biomass currently is used in small amounts. A factory that plans to produce reed chipboards opened in 2015. A paper factory is planned.
- Regulating
  - Carbon sequestration may play a role considering ongoing deposition of organic material in submerged reed beds, though this effect might be counterbalanced by methane emissions from those reed beds. Considering conservation of the carbon that is bound in organic deposits under submerged reed, reed beds play a role to retain sequestered carbon.
  - Regulating water quality plays a role as the Ili River carries a nutrient load from agriculture upstream, especially the rice fields in Bakanas and Bakbakty. Furthermore, reed beds purify the wastewater from the local population and tourism.
  - Regulating the local climate (cooling effect).
  - Flood control does not play a role with regard to the Ili Delta, because flood pulses from upstream are controlled by the Kapchagay Reservoir. Furthermore, there is only Lake Balkhash downstream of the delta, for which flood control is not essential.
- Cultural
  - Basis for recreation.

Table 1 Ecosystem services and their significance to the local population in the Ili Delta

Ecosystem service	Significance for local population
Provisioning	
Fodder for livestock	Non-submerged reed vegetation is grazed or used for haymaking for livestock herding in the Ili Delta (Baranowski 2016)
Fish	Fishery is an important source of income for the villages close to the lake shore (Piechottka 2015)
Biomass	Harvest from submerged reed beds during winter, utilization as construction material for houses in the delta region (Hirschelmann 2014). Raw material for chipboards and paper according to planned factory operations (Schäpe 2015)
Regulating	
Regulate water quality	Important for tourism, which is an important source of income in the delta, important for Lake Balkhash, in order to ensure good quality of fish catch
Regulate local climate	Asset for tourism
Cultural	
Basis for recreation	Tourism is an important source of income from the delta (Roettgers 2016)
Identity	Core identity feature for population of Bakanas County and beyond

– Identity: the Ili Delta is a well-known place in Kazakhstan to which people attribute significance.

Study area

The study area is the Ili Delta between Bakanas in the east and the lake shore of Lake Balkhash in the west (Fig. 1). About 50 km west (downstream) of Bakanas, the Ili River branches off into the three major branches of the delta: Ir, Zhideli, and Ili. Therefore, the Zhideli, the middle branch, carries most of the runoff (Dostaj et al. 2006). The Ili Branch, in the south, is the smallest branch in the delta. These three branches carry water all year round up to the lake shore of Lake Balkhash. Highest runoffs and thus highest water levels in the delta occur in autumn and winter, when the Kapchagay Reservoir has been filled and thus water is released. Over summer, runoff and water levels drop by 0.5 m to 1 m with lowest runoffs and water levels in August/September, because during summer water is abstracted for irrigation along the Ili River (Imentai et al. 2015).

Administratively, the Ili Delta belongs to Bakanas County within Almaty Region in the south eastern part of Kazakhstan. There are 20 settlements, which belong to nine village governments in the Ili Delta. In total there is a population of 16,000 people (pers. comm. County Government Balkhash, 2015-07-24). The village Kuigan, as an example, had a population of altogether 1440 people in 2013, out of which 25% were less than 18 years old, 8% were above 65 years, and 78% were of age in between (Hirschelmann 2014). The Ili Delta is part of the Ile River Delta and South Lake Balkhash Ramsar Site. Within this Ramsar Site there are two Important Bird Areas (IBA) Ili Delta (574,300 ha) and Topar Lake System (32,530 ha), which are located in the Ili Delta (Ramsar Convention 2012).

The delta is a mosaic from perennial and seasonal river branches and lakes with reed beds (dominated by *P. australis*), riparian forests (Tugai), halophytic meadows, desert meadows, and shrub vegetation, according to the Russian vegetation classification (Ogar 2003; Sivanpillai et al. 2006; Ramsar Convention 2012). The reed beds are submerged at least during part of the year and are distributed along river branches and lakes. Next to *P. australis*, *Typha angustifolia* occupies part of those reed beds. The riparian forests are built by *Elaeagnus angustifolia*, *Populus pruinosa*, and *P. euphratica* as well as Salix species and thus are the only forests in the study region (Rachkovskaya et al. 2003). Halophytic meadows are formed by grass species, including *P. australis*, on sites which are not or seldom submerged, with groundwater levels of 1.5–2.5 m (Ogar 2003). Desert meadows are distributed on terraces along active river branches or on previous flood plains with

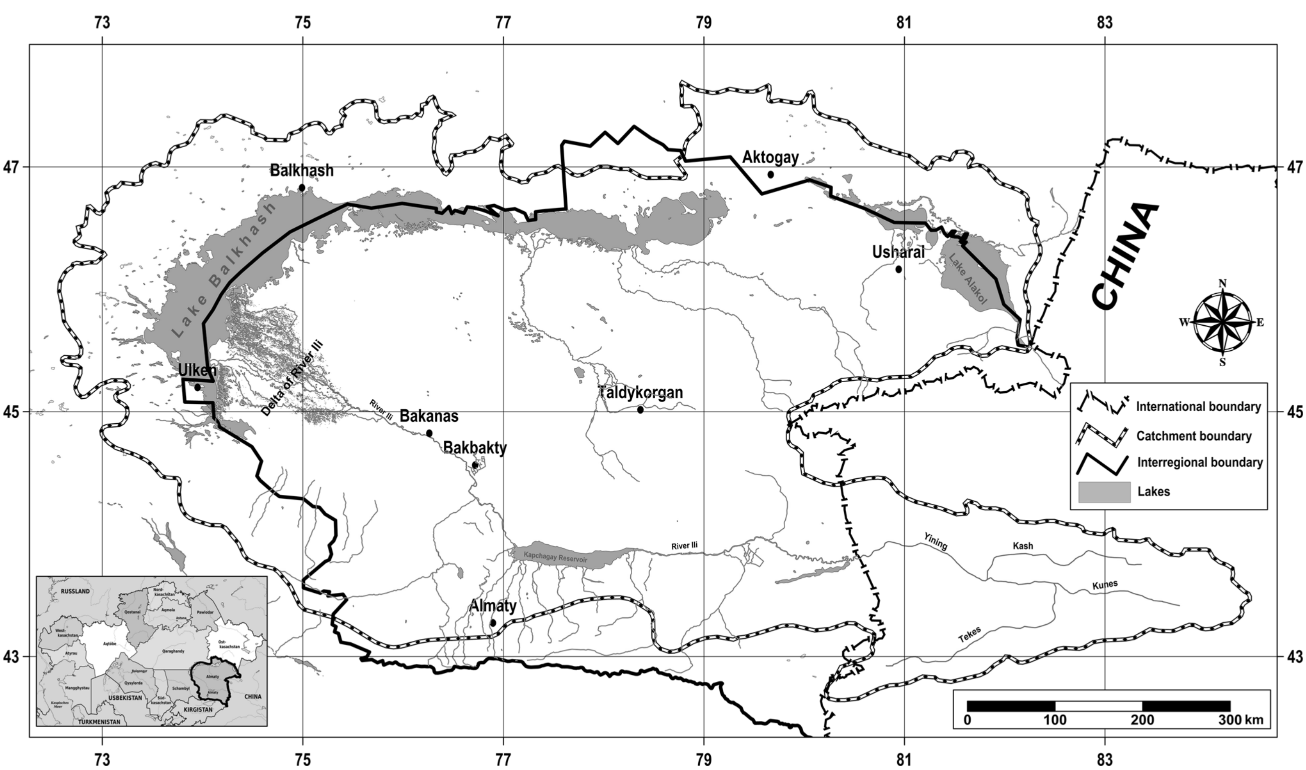

Fig. 1 Map of the Ili-Balkhash basin (Imentai et al. 2015)

groundwater levels deeper than 2.5 m. Desert meadows are formed by grasses, perennial herbs like *Alhagi pseudoalhagi* or *Glycyrrhiza uralensis*, and shrubs like *Halimodendron halodendron* or *Tamarix* species. Both meadow vegetation types are the most important land for grazing and haymaking, whereby *P. australis* by far is the most productive plant species. The shrub vegetation splits into *Tamarix*-dominated shrub vegetation, *Haloxylon aphyllum* vegetation, and shrub communities dominated by Halophytes (Ogar 2003). Such shrub vegetation is distributed on terraces or on previous flood plains and forms the boundary to the desert which surrounds the delta.

The climate is extremely continental and arid with an average January temperature of −7.1 °C, and average July temperature of 25.2 °C, and an annual precipitation of 240.2 mm (climate station Bakanas, www.weatherbase.com). Due to the arid climate, most plant species of the vegetation types listed above are so-called phreatophytes, i.e. they exploit the groundwater to cover their water demand. The groundwater is recharged by the Ili River and its branches.

Methods

In this study, the following research steps were undertaken: firstly, the wetland areas and areas with substantial reed vegetation were mapped through remote sensing with the help of Rapid Eye (see Table 2 for further details) and Landsat satellite images. Rapid Eye was chosen, in order to be able to include the red edge channel, while Landsat offered the short-wave infrared, which allows better mapping of water and soil moisture. Secondly, above ground and above water surface biomass of reed (*P. australis*) was measured on sites representing the whole range of wetlands and other *P. australis*-dominated reed vegetation. These biomass measurements were related to the Normalized Difference Vegetation Index (NDVI) of the Rapid Eye satellite images, in order to estimate the reed biomass of wetlands and other *P. australis*-dominated reed vegetation.

Table 2 Characteristics of Rapid Eye satellite. *Source*: https://resa.blackbridge.com/page/satellitenkonstellation

Spectral channels	Wavelength (nm)
Blue	440–510
Green	520–590
Red	630–685
Red edge	690–730
Near infrared	760–850
Spatial resolution	5 m
Time resolution	Daily (off-nadir)/5.5 days (at nadir)

Finally, the major ecosystem services of wetlands and other *P. australis*-dominated reed vegetation and their significance were assessed. Here, this study uses the results found by a series of Bachelor and Master theses, which had been carried out in the study region from 2013 to 2015 (Haeberlein and Kaiser 2014; Hirschelmann 2014; Hennlein 2015; Piechottka 2015; Schäpe 2015; Roettgers 2016; Baranowski 2016).

Rapid Eye satellite images, which covered the whole Ili Delta, were obtained from Blackbridge for April, June, July, and September 2014. As the object of this study was wetlands and other *P. australis*-dominated reed vegetation, the analysis of the satellite images aimed at the following land cover classes listed in Table 3. The thresholds of the total vegetation cover were adopted from the Land Cover Classification System by FAO (Di Gregorio and Jansen 1998).

A decision tree was built, as shown in Fig. 2, in order to map the land cover classes listed in Table 3. This decision tree used the Normalized Difference Vegetation Index (NDVI) (Colwell 1974) calculated from the visible red (channel 3) and near infrared (channel 5) of the Rapid Eye satellite images from July 2014, in order to first map out dense reed. The dense reed was split into submerged dense reed and non-submerged dense reed through a threshold of the radiance (after http://landsat.usgs.gov/Landsat8_Using_Product.php) as shown in Fig. 2. After the dense reed pixels had been mapped out, water bodies were mapped out through a threshold of the Normalized Difference Water Index (NDWI) after Gao (1996) and Xu (2006). Finally, the remaining pixels were separated into open reed and shrub vegetation and other land covers through a threshold of the average of the red edge channel of all Rapid Eye images.

The thresholds applied in the decision tree classification were defined through two sets of groundtruth data. In June and July 2014, groundtruth data were taken on 630 points, in order to find the thresholds to map out dense reed and open reed and shrub vegetation. For each groundtruth point, the total vegetation cover and the vegetation cover of the dominant plant species were recorded. In May 2015, at 127 points it was recorded, whether that point was an inland water or reed. At points with reed, it was recorded if the reed was submerged or not.

At each of those groundtruth points, the pixel values were queried for the NDVIs and the five channels of the Rapid Eye satellite images from April, June, July, and September as well as the minimum, maximum, and average of NDVI and the Rapid Eye channels over 2014. Those channels with the largest differences were used to define the thresholds. Similarly, the pixel values of the NDWI and the SWIR I were queried and used to define the thresholds to map out waters and divide dense reed into submerged dense reed and non-submerged dense reed.

Table 3 Land cover classes relevant for assessment of ecosystem services and their definition

Land cover class	Definition
Water bodies in the delta	Open water with <4% vegetation cover
Submerged dense reed	Reed (*P. australis* dominated) vegetation with a total vegetation cover of 70% or more and submerged soil during most time of the year
Non-submerged dense reed	Reed (*P. australis* dominated) vegetation with a total vegetation cover of 70% or more non-submerged soil during most time of the year
Open reed and shrub vegetation	Reed (*P. australis* dominated) vegetation, partly interspersed by shrubs with a total vegetation cover of <70%, but at least 20%, and non-submerged soil during most time of the year

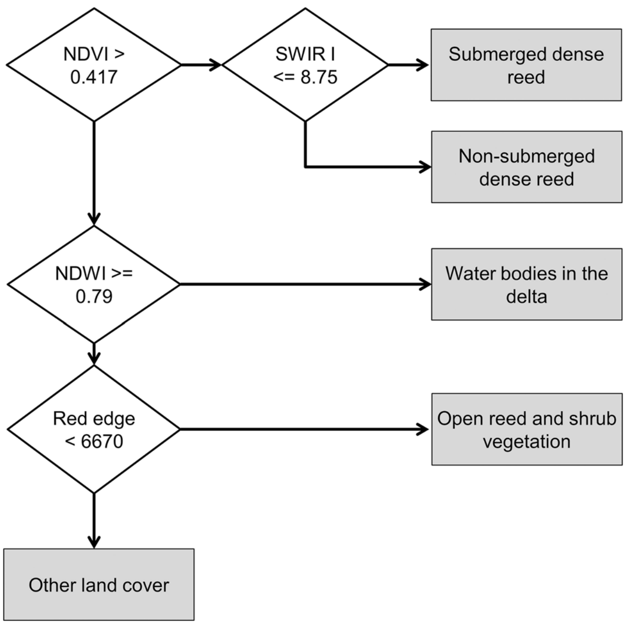

Fig. 2 Decision tree for mapping wetland and other Phragmites australis dominated reed vegetation. NDVI refers to NDVI from Rapid Eye from July 2014. SWIR I refers to radiance of the short wave infrared channel I of Landsat LC8 from 4th April 2015. NDWI refers to Normalized Water Index also from Landsat LC8 from 4th April 2015. Red edge is the average value of channel 4 (red edge) of Rapid Eye from April through September 2014

Reed biomass was measured on 17 sites, which spanned over the whole range of wetlands and other *P. australis*-dominated reed vegetation, after Thevs et al. (2007). Afterwards, the following formulae were fitted to calculate reed biomass:

$$\mathrm{Log}(\text{stem biomass}) = 3.4429 * \mathrm{NDVI}_{\mathrm{July}} - 1.009 \; R^2 = 0.69$$

$$\mathrm{Log}(\text{total biomass}) = 3.3283 * \mathrm{NDVI}_{\mathrm{July}} - 0.8145 \; R^2 = 0.7$$

The information on ecosystem services and the (economic) benefits were taken from the studies of Haeberlein and Kaiser (2014), Hirschelmann (2014), Hennlein (2015), Piechottka (2015), Schäpe (2015), Roettgers (2016), and Baranowski (2016). Information in those studies was gathered through household and expert interviews in the years 2013 and 2015 as well as from statistical data. As for the economic benefits, those theses provide data on the gross values or revenues and partly to income and net values from ecosystem services. Since information was not sufficient to calculate net values consistently, only gross values or revenues will be reported here. We are aware that this provides only a rough estimation of the social welfare generated by the ecosystem services of the Ili Delta. Monetary values were adjusted to 2014, as the map of wetlands and other *P. australis*-dominated reed vegetation reflects the reed distribution in 2014. Monetary figures given in Kazakh Tenge (KZT) were converted into USD after the average exchange rate of 1 USD: 177.086 KZT for 2014 (http://www.oanda.com/lang/de/currency/converter/). Monetary figures from 2015 to 2013 were converted into 2014 figures with a discounting rate of 5%. All interviews in 2015 took place before the devaluation of the KZT.

Results

In its delta, the Ili River sustained wetlands and reed vegetation on a total area of 211,778 ha (Table 4). Therefore, the wetlands, i.e. the land cover classes dense submerged reed (Fig. 3) and inland waters, were concentrated towards the downstream part of the delta, along the lake shore, and in the north-eastern part of the delta. Non-submerged dense reed (Fig. 4) occupied the areas adjacent to the wetlands and was largely located along the Zhideli River, which is the middle river branch in the delta. The Ili Branch, i.e. the southern branch, was not accompanied by reed vegetation. Only near to its mouth into Lake Balkhash there were larger areas of reed vegetation and wetlands. Open reed and shrub vegetation (Fig. 5) often formed a transition zone between the non-submerged dense reed and the desert that surrounds the delta. In the upstream part, the open reed and shrub vegetation partly resembled the courses of small periodical or previous river branches (Fig. 6).

The best user's accuracy was found for open waters, followed by the two dense reed land cover classes. Therefore, most of the misclassified pixels of the dense reed land cover classes were classified as open reed and shrub vegetation.

Table 4 Land cover classes relevant for assessment of ecosystem services with their areas and user's accuracies

Land cover class	Area (ha)	User's accuracy (%)
Water bodies in the delta	100,208	90
Submerged dense reed	85,400	77
Non-submerged dense reed	126,378	78
Open reed and shrub vegetation	138,400	67

The standing total biomass above water surface of reed growing on submerged sites ranged from 5.5 to 58.6 t/ha, both measured in 2014. Most sites showed a standing total biomass of more than 20 t/ha. The biomass values measured in 2015 roughly followed the values from 2014 (Table 5). The *P. australis* stands with the groundwater level near the soil surface showed biomasses in the same range as the submerged sites. *P. australis* on sites that were not submerged attained total biomasses of 10.1 t/ha and less. The values of 2014 and 2015 for no. 13 in Table 5 differ obviously, as the total biomass in 2014 was 10.1 t/ha, while it only was 5.6 t/ha in 2015.

The stem and the total biomass (i.e. including leafs) for the area under submerged dense reed was estimated with 869,097 and 1,178,975 t, respectively. The stem and total biomass of the whole area classified as dense reed was estimated with 2,322,976 and 3,142,044 t, respectively. Therefore, these biomass values referred to the biomass above the water or soil surface.

The non-submerged dense reed and open reed and shrub vegetation were grazed with a total amount of 101,767 livestock (Table 6), which was about 20% of the amount of livestock in the whole delta during Soviet Union times (Jungius 2010). About two-thirds of the livestock were kept by commercial farms, which rented large tracks of land in the central part of the delta, while the remaining animals were kept by households in and near the villages at the margin of the delta. Milk was only produced for household consumption. Currently, two farms for intensive cattle breading have been under construction, which aim at 10,000 cattle each.

Next to fodder, another provisioning ecosystem service was winter-harvested *P. australis* biomass as raw material. The biomass relevant as current and potential raw material source is the stem biomass of the submerged dense reed, i.e. 869,097 t, because leafs largely fall off until harvest time in winter. Thus, the average yield of harvested reed was 10.2 t/ha over the whole area of 85,400 ha of dense submerged reed. One factory for reed products started operating in autumn 2015 in Karoy in the northern part of the Ili Delta. This factory produces fodder from a mixture of *P. australis* hay, wheat, and corn. Furthermore, this factory planned to produce chipboards from *P. australis* biomass. Therefore, winter-harvested biomass from submerged dense reed will be the source for biomass (Schäpe 2015). A standard chipboard of 2 by 3 m, 8 mm thick, is produced from 33 kg *P. australis* biomass, being

Fig. 3 Submerged dense reed, Basa Delta, 45.73°N 74.43°E, photograph 21 June 2014

Fig. 4 Non-submerged dense reed, 45.72°N 74.48°E, photograph 22 June 2014

Fig. 5 Open reed and shrub vegetation, 45.65°N 74.47°E, photograph 22 June 2014

equivalent to 181 m^2 of chipboard that can be produced from 1 t of *P. australis* biomass. This factory plans to use 6000 t of reed biomass annually. In Zhideli at the Ili Branch (southern part of the delta), a paper factory plans to open. That factory is planned to use 60,000 t reed biomass annually, when operating at full scale. The current market

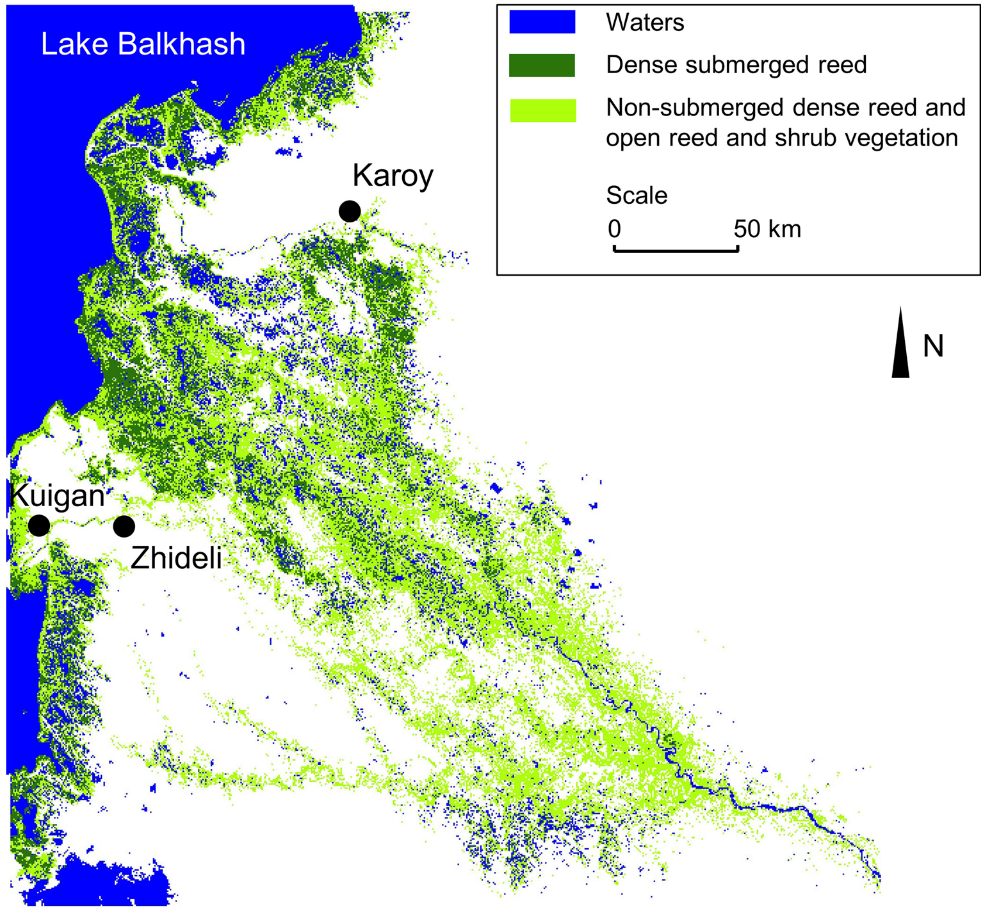

Fig. 6 Map with land cover classes relevant for ecosystem service assessment

price for harvested reed biomass was 7000 KZT/t in 2014 (39.50 USD/t) (Schäpe 2015).

The third obvious provisioning ecosystem service is that the dense submerged reed beds as well as inland water bodies of the delta serve as major spawning ground for the whole commercial fish catch of Lake Balkhash and the fish that are caught by tourists. The average annual fish catch from Lake Balkhash was about 10,000 t over the past few decades with an average selling price of 150 KZT/kg in 2013 (Piechottka 2015), about 0.89 USD/kg adjusted to 2014.

With respect to the regulating ecosystem service carbon sequestration it is questionable, how far reed vegetation sequesters carbon. For the wetlands there is the question, how far submerged reed vegetation is a net source or sink of greenhouse gases (Brix et al. 2001). Secondly, under the conditions that reed is either harvested (submerged sites) or grazed (non-submerged) sites, only a limited amount of biomass is left over that can be accumulated and store carbon. But, below water and below surface there is carbon stored in the sediments, which will be emitted, if those sediments are exposed to the air under decreasing water levels of the Ili River and Lake Balkhash.

The major cultural ecosystem service was that the Ili Delta served as basis for tourism and recreation. In 2014 there were 9370 tourists who visited the 13 tourist bases in the delta for two to seven days each. A total of 8610 tourists came for sport fishing, while 760 came for hunting as their main activity. In addition, there were about 5000 sport fishers that used their own tents throughout the delta. Most of all tourists come from Almaty, followed by Russia, other regions of Kazakhstan, and Europe (outside Russia). The accumulated willingness to pay for travel costs and services was estimated with 9.2 million USD (Roettgers 2016).

Apart from those three categories of ecosystem services, the Ili Delta is a hotspot of biodiversity (Tsytsenko 1988; Kipshakbaev and Abdrasilov 1994), with 25 fish, 284 bird, and 39 mammal species (Imentai et al. 2015). Eight bird species have more than 1% of their global population living in the Ili Delta and adjacent lake shore (Ramsar Convention 2012). Therefore, the reed areas play the most significant role as habitat for bird species (Hennlein 2015).

Discussion

The *P. australis* biomass found for the submerged sites is in the same range as the *Phragmites* biomass measured in Lake Burullus in Egypt, 54 t/ha, by Eid et al. (2010) or

Table 5 Biomass, stem length, and basal stem diameter of *P. australis* in the Ili Delta

No.	Year	Water level	Stem length (m)	Stem diameter (mm)	Stem biomass (t/ha)	Leaf biomass (t/ha)	Total biomass (t/ha)
1	2014	Submerged	2.24	5.6	31.8	11.0	42.8
	2015		2.01	4.9	30.3	10.7	41.0
2	2014	Submerged	2.05	6.0	16.2	7.5	23.7
	2015		2.14	5.4	19.4	8.7	28.1
3	2014	Submerged	2.76	7.5	24.6	9.0	33.6
	2015		2.26	5.9	17.5	7.8	25.3
4	2014	Submerged	3.44	9.5	47.9	10.7	58.6
	2015		3.93	8.9	40.8	11.0	51.8
5	2014	Submerged	1.55	4.1	5.1	2.0	7.1
6	2014	Submerged	3.01	11.8	28.4	7.9	36.3
7	2014	Submerged	1.02	3.2	4.3	1.2	5.5
8	2014	Submerged	1.84	7.7	15.2	4.1	19.4
9	2014	Submerged	2.40	6.6	19.0	5.1	24.1
10	2014	GW 10 cm below surface	2.16	7.1	13.2	4.7	17.9
11	2014	GW 10 cm below surface	1.49	5.1	45.0	12.2	57.2
12	2014	GW 50 cm below surface	2.50	7.4	14.3	3.9	18.2
13	2014	Not submerged	1.32	4.8	7.9	2.1	10.1
	2015		1.20	3.2	4.1	1.5	5.6
14	2014	Not submerged	0.55	3.1	1.0	0.4	1.4
15	2014	Not submerged	1.20	4.5	5.0	1.4	6.4
16	2015		0.79	2.9	2.0	1.1	3.1
17	2015		0.88	2.7	4.9	2.4	7.2

Table 6 Livestock numbers in the Ili Delta (Veterinary Department of Bakanas County, pers. comm. 2015-07-24) and selling prices 2015, adjusted to 2014 prices (Baranowski 2016)

Livestock	Number	Selling price per head of livestock, adjusted to USD in 2014
Cattle	39,067	753
Sheep	22,977	161
Goats	28,726	67
Horses	10,997	1345
Total	101,767	

other authors, who report biomass of submerged reed beds, compiled by Thevs et al. (2007). Biomass values for non-submerged *P. australis* sites of this study were in the same range as Thevs et al. (2007) and further authors there.

With a total area of 211,778 ha (Table 4), the Ili Delta is one of the largest reed areas worldwide, having, e.g., a similar area as the Danube Delta (Köbbing et al. 2013 and further literature there), but being larger than the Liaohe Delta or Yellow River Delta in China (Poeyry et al. 2006b; Man and Croon 2007). The average yield of harvested reed biomass of 10.2 t/ha is in the range of wetlands of many provinces in China, including Xinjiang with its similar climate (Poeyry 2006a).

The biomass that can be harvested annually from the submerged reed as raw material is substantially higher than from tree plantations or forests, e.g. *Populus* and *Picea schrenkiana*, which are the most important timber and fuel wood species from the Ili river basin. Shatalov (1973) reports a volume stock of 465 m^3/ha for a 30-year-old *Populus nigra* stand in the steppe zone of Kazakhstan. This corresponds to an average annual growth of 5.47 t/ha (considering a wood density of 0.353 g/cm^3 after Chave et al. 2009). For a 60-year-old *P. schrenkiana* stand, Kozlovskii and Pavlov (1967) listed a volume stock of 374 m^3/ha. This corresponds to an average annual increment of 2.26 t/ha [wood density of 0.362 g/cm^3 (Chave et al. 2009)]. Therefore, an increased harvest and utilization of reed biomass, e.g. for chipboards, which are widely used in Central Asia for house construction, could either substantially reduce imports of wood or reduce pressure from forests. Therefore, particularly *P. schrenkiana* forests are important, as they are located in the mountains as the head waters of the Ili River and fulfil important ecosystem services there, like runoff regulation and combating soil erosion.

The current and potential revenues from the provisioning ecosystem services and tourism (ecosystem service basis for recreation) are as follows: under the assumption that 30% of the livestock listed in Table 6 were sold at the prices given in Table 6, the total annual revenue would sum up to 12.9 USD. The total revenues from a fish catch of 10,000 t annually from Lake Balkhash would amount to 8.9 million USD. Therefore, only a part can be attributed to the wetlands of the Ili Delta, because not all fish of Lake Balkhash spawn and grow up in the Ili Delta. Once the two factories in the Ili Delta operated at their planned scale, they would take in 66,000 t reed biomass annually. For reed harvesters this would sum up to an annual revenue of 0.26 million USD. From this revenue or gross value perspective, the ecosystem service of providing fodder is most significant followed by the ecosystem service recreation. The number of livestock will be increased as ongoing projects indicate so that the significance of the ecosystem service of providing fodder will further increase too.

Compared to other wetlands worldwide, the number of tourists visiting the Ili Delta is very low (van der Duim and Henkens 2007). Also when comparing the inland wetlands assessed by Ramsar Convention on Wetlands and UNWTO (2012), which are Lake Nukuru in Kenya, Ibera Marshes in Argentina, the Danube Delta in Rumania, and Soomaa in Estonia with a number of annual visitors of 250,000, 17,000, 50,000, and 45,000, respectively, the Ili Delta only receives a small number of tourists.

Thus, the ecosystem service recreation has substantial potential to be increased.

The current fish catch is stated to be unsustainably high (Piechottka 2015 and further literature there). Therefore, fish catches most likely will drop either through regulations or simply through over-fishing so that the significance of the Ili Delta as spawning ground will decrease in this revenue perspective. Over-fishing also impacts on tourism, though the potential loss of sport fishing opportunity might be balanced through other upcoming recreation activities.

The current plans foresee an annual harvest of 66,000 t reed biomass. This is less than 10% of the estimated stem biomass from dense submerged reed. Thus, there is still room for more biomass harvest so that the significance of the ecosystem service providing raw material may increase in the future without compromising biodiversity. Since reed as raw material is harvested during winter, it offers nesting space in summer. Additionally, most birds migrate from the delta over winter (Sultanova et al. 2012). Still buffer zones around waters must be kept without or with limited harvest, in order to provide habitat for mammals and birds that start nesting early, i.e. before reed has grown to a substantial height and in order to maintain landscape beauty for tourism throughout the year.

Many wetlands of Central Asia have been degraded due to reduced runoff of the particular rivers that used to provide water to the wetlands. The reduced runoff results from increased water diversion further upstream, e.g. Aral Sea and the Amu Darya Delta (UNEP 2008). So far the Ili Delta still is in good condition and receives sufficient water (Imentai et al. 2015), but the runoff of the Ili River would decrease in the future, if land use and water diversion along its upstream increased. Furthermore, climate change and in its course glacier melt most likely will result in reduced discharge into the Ili River. Against this background, the question arises what will be at stake in the Ili Delta, if the discharge into the delta drops.

Along with a decreasing discharge into the Ili Delta, it is to expect that water levels of the water bodies in the delta will drop. Furthermore, periodically submerged areas of the delta will become non-submerged throughout the year. Along with those changes in water levels and duration of being submerged, groundwater levels will drop too, as has been reported by Treshkin (2001) and Geldyeva et al. (2012) for the Amu Darya Delta in the course of vanishing of the Aral Sea. Along with those changes of the water resources, the following ecosystem changes can be expected (cf. Ogar 2003; Thevs et al. 2008).

Part of the submerged dense reed turns into non-submerged dense reed. Thus, livestock herders gain land for grazing and haymaking. Spawning space and space for young fish to grow up as well as potential area for biomass harvest will be reduced. Part of today's non-submerged dense reed will turn into open reed and shrub vegetation, which offers less fodder for livestock. Open reed and shrub vegetation will turn into shrub vegetation, which again offers less fodder for livestock. In total, the land suitable for grazing and haymaking will be shifted from today's non-submerged dense reed and open reed and shrub vegetation towards today's submerged dense reed. Vegetation that provides the ecosystem service provisioning of fodder is shifted form the delta margins towards the central part of the delta. As the villages are located at the delta margin the households loose the grazing and haymaking land in their neighbourhood so that livestock keeping becomes more difficult for households. Most likely this shift will be coupled with an overall loss of land that provides fodder and a reduced productivity of that land, as was reported during the time when the discharge into the delta shrunk as the Kapchagay Reservoir was filled (Petr 1992; Kipshakbaev and Abdrasilov 1994). Current tourism will be impacted to a minor extent. The large and expensive tourist bases are located at the major water bodies, which will carry water even if the discharge drops. Smaller tourist bases at the margin of the delta will lose customers when the nearby water bodies fall dry. The potential for further tourism development will be compromised too.

Finally, habitats for the numerous bird and mammal species will shrink so that the conservation purpose of the Ramsar Site will be compromised.

Under the conditions of decreasing runoff into the Ili Delta, a wide range of ecosystem services and income opportunities of the communities in the delta region are at stake. Applying the Constant Natural Capital Rule as a precondition for strong sustainability (Daly 1996; Neumayer 2004; Ott and Döring 2008; Ziegler and Ott 2011) and the concept of land degradation neutrality as stated in SDG 15.3 (https://sustainabledevelopment.un.org/sdg15) the conservation of this delta region is imperative. Beyond the use values attached to the ecosystem services assessed in this paper, the Ili Delta deserves conservation for the sake of its biodiversity as acknowledged by recognizing it as a Ramsar Site. Being a Ramsar Site, there is an international obligation to protect this delta region from degradation. Furthermore, this delta must be protected due to its uniqueness (cf. argumentation of Ott et al. (2016) regarding water allocation along the Heihe River in China's arid north-west). The core condition for the protection of the Ili Delta is to ensure sufficient runoff into the delta, i.e. in a magnitude of today's inflow. This implies that there must be limits for future development of agriculture and other water abstraction along the whole Ili River in Kazakhstan and China.

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