Sustainable Use of Papyrus from Lake Victoria, Kenya

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Anne A. van Dam and Julius Kipkemboi

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Abstract

Cyperus papyrus-dominated wetlands in eastern and southern Africa are important for millions of people because of their provisioning ecosystem services (food, water, materials, medicines) but also because of regulating services (e.g., water and nutrient retention, climate regulation), cultural services (heritage of wetland communities, importance for science and tourism), and biodiversity. Papyrus wetlands are under pressure from agricultural and urban development. Freshwater and food production are important, but sustainable management strategies are needed to protect regulating services and biodiversity. This chapter summarizes current uses of papyrus wetlands in the East African region and identifies natural and human-induced factors affecting these. To achieve sustainable management,

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more awareness of regulating ecosystem services and more quantitative methods for assessing them are needed. This will allow better estimation of the value of papyrus ecosystem services and better evaluation of trade-offs with conversion to other uses.

Introduction

Wetland degradation poses a threat to biodiversity, ecosystem integrity, and human well-being. The important ecosystem functions of wetlands support not only the health and biodiversity of terrestrial and aquatic ecosystems but also the livelihoods of large numbers of people (Millennium Ecosystem Assessment 2005; Russi et al. 2013). The *Cyperus papyrus* (L.)-dominated wetlands in eastern and southern Africa, commonly referred to as papyrus marshes, are good examples of this. It is estimated that millions of people depend on these wetlands for diverse products such as food, water, medicine, handicrafts, utensils, building, and other materials (Gaudet 2014).

Despite the importance of these marsh systems, African wetland area and aquatic biodiversity are decreasing at alarming rates (Owino and Ryan 2007; Rebelo et al. 2010; Darwall et al. 2011). The average rate of loss of papyrus wetlands over the last 50 years was estimated at 3% per year (van Dam et al. 2014). In Africa, the rural communities living adjacent to wetlands depend heavily on their ecosystem services, so changes in the ecosystem can have direct implications for people's lives. Developing sustainable management strategies for papyrus wetlands is therefore important and urgent. This contribution provides an overview of the different uses of papyrus wetlands and discusses options for their sustainable use in the context of the ecosystem services framework.

Uses of Papyrus Wetlands: Ecosystem Services

Table 1 summarizes a number of uses of papyrus wetlands using the ecosystem services (ES) framework of "The Economics of Ecosystems and Biodiversity" study (TEEB 2010; Russi et al. 2013) with four ES categories: provisioning, regulating, cultural, and biodiversity/habitat services.

Provisioning Ecosystem Services

The most visible and direct use of papyrus wetlands is the harvesting of materials (food, fiber, minerals) from the natural wetland ecosystem (Fig. 1; Rongoei et al. 2013). Vegetation is harvested for many purposes (Fig. 2). Virtually every part of the papyrus plant, from rhizomes to umbel, can be utilized. The rhizomes and dry culms can be used as fuel. Culms are used for a wide variety of crafts, material for mat making and house construction (e.g., rope making and thatching), and fishing traps.

Table 1 Common uses of papyrus marshes in sub-Saharan Africa and link to ecosystem services (ES) category according to TEEB (Russi et al. 2013). Based on van Dam et al. 2014 and references therein

Use/activity	Examples of use
Provisioning services	
Vegetation harvesting	- Construction: house construction and thatching, boats and rafts/ floating islands - Crafts, tools, and utensil-making: chairs and other furniture, baskets, wall hangings and other decorations, ropes, brooms, mats, paper, fishing traps, and baskets - Fuel/energy: dry rhizomes and culms used as firewood; briquette production - Food: harvesting of wetland plants for edible roots and other plant parts; medicinal plants - Fodder: young papyrus umbels are consumed by livestock; wetland grasses and other vegetation serve as fodder
Clay and sand mining	- House walls smoothing; brick production; pottery
Hunting/fishing	- Fish: various wetland species - Game: swamp antelopes (lechwe, kobs), hippopotamus
Crop production	- Seasonal subsistence farming: fertile soils rich in organic matter used for production of rice, maize and other cereals, cocoyam, vegetables, and cotton; umbels used to shade vegetable seedings after transplanting - Commercial farming: rice, sugarcane, and other crops often following permanent conversion to cropland by drainage; construction of irrigation infrastructure
Water source	- Drinking water: shallow wells at wetland edges, particularly during the dry season; larger scale for drinking water production (e.g., Nabajjuzi wetland, Uganda); livestock watering - Irrigation: use of water for crop production
Regulating services	
Water quality improvement	- Natural wetlands: uptake of nutrients and other compounds by vegetation; binding to soil. Examples: Nakivubo and Namiiro wetlands (Uganda); Kahawa swamp (Nairobi, Kenya) - Constructed wetlands: wastewater treatment by papyrus vegetation
Water quantity regulation	- Water storage; groundwater recharge; evaporation
Climate regulation	- Evaporative cooling; carbon sequestration
Cultural services	
Culture and tradition of wetland people	- Use as sacred places for worship and as a source of myths and traditional wisdom (e.g., the Luo people in Uganda, Kenya, and Tanzania, and the Dinka and Nuer people in South Sudan). Clay is used in traditional ceremonies among the Luhya and Kalenjin communities in western Kenya
Scientific research and education	- Papyrus wetlands have been the subject of scientific research since the early 20th century leading to insights on wetland biogeochemistry, hydrology, ecology, and management. Papyrus wetlands are important for BSc and MSc programs in various universities in Africa and Europe

(*continued*)

Table 1 (continued)

Use/activity	Examples of use
Ecotourism	- Wildlife habitat, tourism, bird watching, and other wild game observation areas
Biodiversity and habitat services	
Biodiversity and habitat	- Habitat for various endemic fish and bird species, swamp antelopes, amphibians, aquatic invertebrates, reptiles, and hippopotamus. Several papyrus wetlands are Ramsar sites (e.g. the Sudd wetland in South Sudan, the Okavango delta in Botswana, and Lake Naivasha, Kenya) or Important Bird Areas. There is also some evidence for papyrus marshes playing important roles as repositories for cichlid biodiversity in Lake Victoria

Fig. 1 Vegetation harvesting in papyrus wetlands, with papyrus umbels for broom making (**a**) and papyrus culms (**b**) drying in the field after harvesting, a bundle of papyrus culms (**c**), and harvested grasses (**d**) (Photo credit (**a**): J. Kipkemboi © copyright remains with the author; Photo credit (**b-d**): A.A. van Dam © copyright remains with the author)

Young tender umbels form good fodder for livestock while mature umbels are used by some communities for making brooms. Besides papyrus, other wetland plant species are harvested for construction and craft making (e.g., *Phragmites* sp., *Eichhornia crassipes*, wetland grasses and trees), for human consumption (herbs and medicinal plants), for fuel/firewood, or as fodder for livestock kept in the homesteads.

Fig. 2 Papyrus products, with mats for sale along the roadside (**a**), example of artwork produced with papyrus (**b**), and brooms (**c**) and fish traps (**d**) made from papyrus fibres (Photo credit: A.A. van Dam © copyright remains with the author)

Besides harvesting of naturally produced vegetation, papyrus wetlands are also used for crop cultivation. Both small-scale, low-input, often seasonal agriculture and large-scale commercial agriculture can be found in papyrus wetlands (Fig. 3). During the dry season, dramatic changes to papyrus wetlands can be observed in floodplains with large areas of vegetation converted to sugar cane, maize, rice, and vegetable farms. With the conversion of natural wetlands for agricultural production come changes to the geomorphology and hydrology of the wetland, such as building dikes for flood protection, channelization for crop irrigation and for exclusion of wildlife which feed on crops (such as hippos), and soil desiccation through clearance of above-ground vegetation and cultivation. Burning of wetlands is also common in many areas to reduce the amount of senesced biomass and to allow fresh biomass to regenerate as pasture for livestock grazing, or to clear wetland margins for seasonal agriculture or drive out wild game during hunting.

Wetland fauna is also harvested as a source of protein. Papyrus wetlands are important for fish production in two ways: directly, by providing habitat for fish species that are caught in the wetland using a variety of fishing gears (Fig. 4); and indirectly, by providing a breeding environment and shelter for fish that subsequently recruit to adjacent river and lake fisheries. Generally speaking, fish catches

Fig. 3 Agriculture in papyrus wetlands, with livestock grazing in Nyando wetland, Kenya (**a**); tractors plowing a papyrus wetland in Bugesera, Rwanda (**b**); commercial rice cultivation in Namatala wetland, Uganda (**c**); and small-scale agriculture in Nyando wetland, Kenya (**d**) (Photo credit (**a**-**c**): A.A. van Dam © copyright remains with the author; Photo credit (**d**): M.M Rahman © copyright remains with the author)

from papyrus wetlands are poorly documented and it is hard to estimate fish production. A variety of fishing techniques is used, ranging from gill nets and small basket traps to elaborate structures to capture fish (Fig. 4c). Some research has been done to enhance fish production using seasonal fishponds ("fingerponds"). Despite the high potential demonstrated from this research, wider adoption of this practice is still limited (Kipkemboi et al. 2010). Besides fish, other animals that are harvested include marsh antelopes, hippos and insects.

Another important provisioning service of papyrus wetlands is water for drinking and for irrigation. Shallow wells at the edge of the permanent wetland are important for wetland communities, particularly in the dry season. In some places, papyrus wetlands are the source for production of municipal drinking water (e.g., in Nabajjuzi wetland near Masaka, Uganda).

Regulating, Cultural and Habitat Ecosystem Services

Besides the provisioning of food and materials, the importance of papyrus wetlands for their regulating services is increasingly recognized. The high growth rate and

Fig. 4 Fishing in papyrus wetlands, with a fisherman showing a lungfish (*Protopterus aethiopicus*) in Nyando wetland, Kenya (**a**); hook-and-line fishing with a papyrus culm as float in Namatala wetland, Uganda (**b**); and a fish trap in Nyando wetland, Kenya (**c**) (Photo credit: A.A. van Dam © copyright remains with the author)

biomass of papyrus ensure rapid uptake and storage of nutrients. Nitrogen, phosphorus, and other nutrients are taken up by plants and stored in their biomass (Muthuri and Jones 1997). Phosphorus is also bound to the sediment (Kelderman et al. 2007). Sediments from rivers are deposited in the wetland, and papyrus fringe vegetation reduces the entry of sediment particles into the adjoining water bodies (Boar and Harper 2002; Cohen et al. 2006). However, nutrient retention is probably strongly dependent on water flows between rivers/lakes and wetlands, with flushing of dissolved and particulate nutrients into the lake during high flow events. Papyrus wetlands are probably a source of DOC for Lake Victoria (Mwanuzi et al. 2003; Loiselle et al. 2008).

Nitrogen retention was estimated in model studies at around 22 g/m^2/yr (Hes et al. 2014). The nutrient uptake and storage capacity of papyrus can be utilized in constructed wetlands for wastewater treatment. Nutrient removal from wastewater by papyrus wetlands can be up to 70–80% for ammonium and orthophosphate (Chale 1985, Kansiime and Nalubega 1999).

Carbon storage in papyrus wetlands was estimated at over 700 tonnes of C per ha, mostly in the peat layer beneath the surface. In this sense, papyrus wetlands may be a significant carbon sink, but one that is vulnerable to hydrological drawdown and human activities (Saunders et al. 2014).

Papyrus wetlands also play a role in moisture circulation, influencing local and regional climate. Daily vapor flux through the canopy of a papyrus wetland at the Lake Victoria shoreline was found to be approximately 4.75 kg of water per m^2 per day, about 25% higher than water loss through evaporation from open water (Saunders et al. 2007). Estimates of annual evaporation from the Sudd wetland range from 1460 to 2100 mm (Sutcliffe and Parks 1989; Mohamed 2005). Although from the point of view of downstream water users evaporation is often considered a loss, papyrus wetlands contribute positively to local and regional precipitation (Zaroug et al. 2012).

With respect to cultural ecosystem services, papyrus wetlands play an important role in the history and culture of wetland communities like the Luo people in southern Uganda and western Kenya and Tanzania, and the Nuer and Dinka people in South Sudan. Traditionally, many papyrus wetlands harbored sacred places, although this practice is gradually disappearing (Kibwage et al. 2008). Some papyrus wetlands are important recreational and (eco)tourism destinations, particularly due their role as Important Bird Areas (IBAs). Papyrus wetlands form useful research and education objects, and some wetlands have been studied extensively by universities, government departments and NGOs (van Dam et al. 2014).

The biodiversity and habitat ecosystem services of papyrus wetlands are also significant, with several species of endemic birds, marsh antelopes and hippopotamus (see "Papyrus Wetlands" by Kipkemboi and van Dam, Vol. 4 for a more detailed description).

Factors Affecting Human Use of Papyrus Wetlands

Changes in the status and area of papyrus wetlands are influenced directly by two strongly interrelated factors: water and human activity. Seasonal weather dynamics (one or two rainy seasons) produce distinct permanent and seasonally inundated zones, leading to zonation in soil moisture and vegetation. In the permanently flooded zone, papyrus is extremely productive and can outcompete most other aquatic plant species, resulting in almost monotypic stands of *C. papyrus*. In the seasonally flooded zone, the papyrus competes with plant species that are more adapted to dry conditions (Rongoei et al. 2014). In the longer term, hydrological change can lead to the more or less permanent disappearance or creation of wetlands. For example, many fringing wetlands of Lake Victoria were drowned during the Uhuru rains in the early 1960s when the lake water level rose by about 2 m. New papyrus wetlands were formed in the newly flooded zones (Thompson 1976).

Seasonal hydrological dynamics have strong impact on human activities in the wetland. Flooding and waterlogging excludes most human activities in the wetlands. However, dry conditions make wetlands vulnerable to human activities, including livestock grazing. In wetlands with seasonal agriculture, vegetation can be removed and crops planted as soon as the flood has retreated. Vegetation harvesting is also affected by flooding, as flooding restricts access to harvestable stands. Sometimes, harvesting is done by boat. Harvesting frequency in papyrus stands determines the regeneration potential and consequently biomass production (Osumba et al. 2010). Water depths of more than 20–30 cm also impede livestock herding. By contrast, fishing is enhanced during the rainy season.

Indirectly, human population growth and economic development, climate change as well as formal and informal institutions and policy interventions are important determinants of wetland use. In East Africa, high population density combined with limited employment opportunities result in low incomes from non-wetland activities. Recent changes in weather patterns, leading to prolonged dry spells, can influence the vulnerability of the wetland to livelihood activities. Changes in rainfall patterns can cause crop failure in traditional rain-fed upland agriculture and lead to migration towards wetlands, where seasonal agriculture and livestock herding remain possible. Traditionally, there were many informal institutions (traditions, customary land tenure arrangements) that regulated wetland resource use. In some areas, these traditions are now changing. Formal institutions and instruments (e.g., regulatory agencies and wetland policies) are being established and developed in many countries, but implementation and enforcement of sustainable management practices remain a challenge (Kibwage et al. 2008).

Sustainability and Future Challenges

The declining trend in wetland area and biodiversity raise concerns about the sustainability of current wetland management practices. The legitimate need for economic growth and food security of African nations will lead to further degradation and loss of wetlands through agricultural and urban development. Sustainability is defined in terms of the wise use of wetlands as “the maintenance of their ecological character, ...within the context of sustainable development” (Finlayson 2012). With increasing numbers of people relying on the productivity of papyrus wetlands, intensity of use has been increasing leading to permanent changes to the papyrus ecosystem and its ecological character.

More intense use comes with changes in water supply and drainage of the wetlands. Upstream water abstraction and damming of rivers leads to reduced surface or groundwater flows to papyrus wetlands. Removal of papyrus rhizomes and construction of drainage channels prevent recovery of the papyrus vegetation during the rainy season. The ensuing drying and mineralization of the underlying peat layer and release of the stored nutrients (including carbon) create conditions for plant species that are more adapted to dry conditions. More intense tillage increases sediment erosion. With time, the lower natural accretion of sediment and nutrients requires the import of nutrients in the form of fertilizers to maintain crop productivity, which increases nutrient discharge to downstream areas. Application of chemicals to control pests and diseases in arable crops introduced to wetlands through agricultural practices may affect biodiversity. Burning may become more frequent, disrupting the papyrus climax community and providing opportunity for invasive species (Terer et al. 2012). Urbanization also leads to permanent changes in papyrus wetlands due to conversion, water abstraction and pollution. The results of these changes are increasingly observed, for example, in a decline in papyrus surface area as well as in bird populations (Maclean et al. 2014).

Conversion of papyrus wetlands to crop production enhances provisioning services, but the implications for regulating, cultural and habitat services are often not considered. This is partly due to the difficulty of quantifying these other ecosystem services, both in terms of material processes and economic value. A trade-off analysis as part of a management strategy is therefore not made (Zsuffa et al. 2014). As a result, African countries are losing the benefits and values of these important ecosystems. This also has implications for the equity of economic development, as poorer members of wetland communities depend particularly on highly diverse wetland livelihood activities whereas benefits from converted wetlands often accrue to fewer individuals or corporations. If sustainability is defined as "the long-term use of one or several of the wetland's ecosystem services without degrading or losing other ecosystem services" (van Dam et al. 2014), agriculture and other wetland uses should be developed in such a way that water quality functions and biodiversity values are taken into account and protected as much as possible.

To increase awareness of the importance of sustainable management of their papyrus wetlands, countries containing these systems need to assess the areal extent of land occupied by *C. papyrus* and the ecosystem services they provide, as a basis for monitoring change and identifying causes of degradation. There is a need to allocate adequate resources towards the implementation of wetland policies, where they exist, or to fast-tracking policy development where they do not exist. Management plans should be aimed at a better balance between agricultural and urban development and the maintenance of a wider suite of beneficial ecosystem services.

Research is required to provide better estimates of the value of regulating and cultural ecosystem services, and to develop methods for sustainable resource harvesting and crop and fish production that do not endanger the nutrient and water regulation functions of these wetlands. Experiences with attempts to improve wetland management in Africa have shown that stakeholder participation and capacity development are vital for the success of sustainable wetland management.

References

Boar RR, Harper DM. Magnetic susceptibilities of lake sediment and soils on the shoreline of Lake Naivasha, Kenya. Hydrobiologia. 2002;488:81–8.

Chale FMM. Effects of *Cyperus papyrus* L. swamp on domestic wastewater. Aquat Bot. 1985;23:185–9.

Cohen MJ, Brown MT, Shepherd KD. Estimating the environmental costs of soil erosion at multiple scales in Kenya using emergy synthesis. Agric Ecosyst Environ. 2006;114:249–69.

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (eds.) (2011). The diversity of life in African freshwaters: under water, under threat. An analysis of the status and distribution of freshwater species throughout mainland Africa. Cambridge, UK/Gland: iIUCN.

Finlayson CM. Forty years of wetland conservation and wise use. Aquat Conserv Mar Freshwat Ecosyst. 2012;22:139–43.

Gaudet JJ. Papyrus – the plant that changed the world – from ancient Egypt to today's water wars. New York: Pegasus Books; 2014. 300pp.

Hes EMA, Niu R, Van Dam AA. A simulation model for nitrogen cycling in natural rooted papyrus wetlands in East Africa. Wetl Ecol Manag 2014; 22:157–176.

Kansiime F, Nalubega M. Wastewater treatment by a natural wetland: the Nakivubo Swamp Uganda: processes and implications. PhD-thesis. Delft: IHE-Delft/Delft University of Technology; 1999.

Kelderman P, Kansiime F, Tola MA, van Dam AA. The role of sediments for phosphorous retention in the Kirinya wetland (Uganda). Wetl Ecol Manag. 2007;15:481–8.

Kibwage JK, Onyango PO, Bakamwesiga H. Local institutions for sustaining wetland resources and community livelihoods in the Lake Victoria basin. Afr J Environ Sci Technol. 2008;2:97–106.

Kipkemboi J, Kilonzi CM, van Dam AA, Kitaka N, Mathooko JM, Denny P. Enhancing the fish production potential of Lake Victoria papyrus wetlands, Kenya, using seasonal flood-dependent ponds. Wetl Ecol Manag. 2010;18(4):471–83. https://doi.org/10.1007/s11273-010-9180-4.

Loiselle SA, Azza N, Cozar A, Bracchini L, Tognazzi A, Dattilo A, Rossi C. Variabillity in factors causing light attenuation in Lake Victoria. Freshwat Biol. 2008;53:535–45.

Maclean IMD, Bird JP, Hassall M. Papyrus swamp drainage and the conservation status of their avifauna. Wetl Ecol Manag. 2014;22:115–27. https://doi.org/10.1007/s11273-013-9292-8.

Millennium Ecosystem Assessment. Ecosystems and human well-being: wetlands and water synthesis. Washington, DC: World Resources Institute; 2005.

Mohamed YA. The Nile hydroclimatology: impact of the Sudd wetland. PhD thesis, UNESCO-IHE Institute for water Education/Delft University of Technology; 2005, 129pp.

Muthuri FM, Jones MB. Nutrient distribution in a papyrus swamp, Lake Naivasha, Kenya. Aquat Bot. 1997;56:35–50.

Mwanuzi F, Aalderink H, Mdamo L. Simulation of pollution buffering capacity of wetlands fringing the Lake Victoria. Environ Int. 2003;29:95–103.

Osumba JJL, Okeyo-Owuor JB, Raburu PO. Effect of harvesting on temporal papyrus (Cyperus papyrus) biomass regeneration potential among swamps in Winam Gulf wetlands of Lake Victoria Basin, Kenya. Wetl Ecol Manag. 2010;18(3):333–41.

Owino AO, Ryan PG. Recent papyrus swamp habitat loss and conservation implications in western Kenya. Wetl Ecol Manag. 2007;15:1–12.

Rebelo LM, McCartney MP, Finlayson CM. Wetlands of Sub-Saharan Africa: distribution and contribution of agriculture to livelihoods. Wetl Ecol Manag. 2010;18:557–72.

Rongoei PJK, Kipkemboi J, Okeyo-Owuor JB, van Dam AA. Ecosystem services and drivers of change in Nyando floodplain wetland, Kenya. Afr J Environ Sci Technol. 2013;7:274–91.

Rongoei PJK, Kipkemboi J, Kariuki ST, van Dam AA. Effects of water depth and livelihoodactivities on plant species composition and diversity in Nyando floodplain wetland, Kenya. Wetl Ecol Manag. 2014;22:177–89. https://doi.org/10.1007/s11273-013-9313-7.

Russi D, ten Brink P, Farmer A, Badura T, Coates D, Förster J, Kumar R, Davidson N. The economics of ecosystems and biodiversity for water and wetlands. London/Brussels/Gland: IEEP/Ramsar Secretariat; 2013.

Saunders MJ, Jones MB, Kansiime F. Carbon and water cycles in tropical papyrus wetlands. Wetl Ecol Manag. 2007;15:489–98. https://doi.org/10.1007/s11273-007-9051-9.

Saunders MJ, Kansiime F, Jones MB. Reviewing the carbon cycle dynamics and carbon sequestration potential of *Cyperus papyrus* L. wetlands in tropical Africa. Wetl Ecol Manag. 2014;22:143–55. https://doi.org/10.1007/s11273-013-9314-6.

Sutcliffe JV, Parks YP. Comparative water balances of selected African Wetlands. J Hydrol Sci. 1989;34(1,2):49–62.

TEEB. The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB. Nairobi: United Nations Environment Program. 2010. http://www.teebweb.org. Accessed 29 Sept 2014.

Terer T, Triest L, Muthama MA. Effects of harvesting *Cyperus papyrus* in undisturbed wetland, Lake Naivasha, Kenya. Hydrobiologia. 2012;680(1):135–48.

Thompson K. Swamp development in the headwaters of the White Nile. In: Rzoska J, editor. The Nile, biology of an ancient river, Monographiae biologicae, vol. 29. The Hague: Dr. W. Junk; 1976. p. 177–96.

van Dam AA, Kipkemboi J, Mazvimavi D, Irvine K. A synthesis of past, current and future research for protection and management of papyrus (*Cyperus papyrus* L.) wetlands in Africa. Wetl Ecol Manag. 2014. https://doi.org/10.1007/s11273-013-9335-1.

Zaroug MAH, Sylla MB, Giorgi F, Eltahir EAB, Aggarwal PK. A sensitivity study on the role of the swamps of southern Sudan in the summer climate of North Africa using a regional climate model. Theor Appl Climatol. 2012. https://doi.org/10.1007/s00704-012-0751-6.

Zsuffa I, van Dam AA, Kaggwa RC, Namaalwa S, Mahieu M, Cools J, Johnston R. Towards decision support-based integrated management planning of papyrus wetlands: a case study from Uganda. Wetl Ecol Manag. 2014;22:199–213. https://doi.org/10.1007/s11273-013-9329-z.