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The Human Ecology of Wetlands in Least Developed Countries in Time of Climate Change: Policy and Strategy Implications for Wise Use and Conservation of Wetlands

G. S.Ogato

Department of Rural Development and Agricultural Extension , Institute of Cooperatives and Development Studies, Ambo University, Ethiopia, Email: gemechushale2005@yahoo.com

This article is an outcome of the desk study on "The Human Ecology of Wetlands in Least Developed Countries (LDCs) in Time of Climate Chang: Policy Implications for Wise Use and Conservation of Wetlands." Wetlands are among the most important ecosystems on Earth because of their unique hydrologic conditions and their role as ecotones between terrestrial and aquatic systems. Although many uses and values of wetlands are evident, historically wetlands have been regarded as wastelands which if possible, should be turned into something else that would be more useful**.** As a result, wetlands have been drained, turned into agricultural land, and commercial and residential developments at an alarming rate. The general objective of the study is to evaluate the status of wetlands in LDCs in time of climate change and identify policy and strategy implications. The findings of the study confirm that mainstreaming climate change adaptation and mitigation into sustainable development and natural resources conservation efforts of least developed countries (LDCs) is of paramount importance for conservation and sustainable utilization of wetlands in time of climate change. In conclusion, this review confirmed that deep wetlands generally capture carbon dioxide from and release methane to the atmosphere and the combination of these two fluxes determines whether these countervailing processes make a wetland system an overall contributor to the greenhouse effect. Moreover, both natural processes and human activities are responsible for the predicted wetland losses in least developed countries. Least Developed Countries may benefit from sustainable utilization and conservation of wetlands by responding to implications like anticipatory and systematic 'Climate Change integrated Conservation Strategies' in time of climate change.

Key Words: Adaptation, climate change, conservation, least developed countries, mitigation, wise use

Introduction

A wetland is an area that is inundated or saturated by water at a frequency and for sufficient duration to support emergent plants adapted for life in saturated soil conditions. The Ramsar Convention also includes all open fresh waters (of unlimited depth) and marine waters ("up to a depth of six metres at low tide") in its "wetland" concept (Parish et al., 2008). They are both lentic (pond) and lotic (stream) habitats that are either permanent or temporary (Semlitsch & Bodie, 2003). Wetlands are areas of water saturated soil, and include small lakes, floodplains, and marshes (Silva et al., 2007). Wetlands only cover a small proportion of the earth's land surface (approximately between 2% and 6%, but contain a large proportion of the world's carbon (approximately 15×1014 kg) stored in terrestrial soil reservoirs (Kayranli et al., 2010). Wetland ecosystems (including lakes, rivers, marshes, and coastal regions to a depth of 6 meters at low tide) are estimated to cover more than 1,280 million hectares, an area 33% larger than the United States and 50% larger than Brazil (Millennium Ecosystem Assessment, 2005).

Wetlands certainly occupy the transitional zones between permanently wet and generally dry environments – they share characteristics of both environments yet cannot be classified unambiguously as either aquatic or terrestrial. The key is the presence of water for some significant period of time, which changes the soils, the microorganisms and the plant and animal communities, so that the land functions in a different way from either aquatic or dry.

Habitats (Barbier, 1997; Baker et al., 2006; SRCW & UNWTO, 2012). Wetlands are the integration of aquatic and terrestrial systems that vary across a hydrologic continuum and wetland biota are adapted to these hydrologic conditions and contribute to the ecological functioning of wetlands (Galbraith, et al., 2005; Baker et al., 2006; Ramsar Convention Secretariat, 2010). In other words, hydrology is considered the most important component for the establishment and persistence of wetlands (Hunt et al., 1999; Frenken & Mharapara, 2002; Tekaligne, 2003; Millennium Ecosystem Assessment, 2005; Mcinnes, 2010).

Wetlands are among the Earth's most productive ecosystems (Barbier, 1997; Galbraith, et al., 2005; SRCW & UNWTO, 2012). Barbier (1997) contends that the features of the system may be grouped into components, functions and attributes. The components of the system are the biotic and nonbiotic features which include the soil, water, plants and animals (Galbraith, et al., 2005; Baker et al., 2006). The interactions between the components express themselves as functions, including nutrient cycling and exchange of water between the surface and the groundwater and the surface and the atmosphere (Brix, 1994; Barbier,1997; Steinman et al., 2003; Galbraith, etal., 2005; Baker et al., 2006; Kayranli et al., 2010). The system also has attributes, such as the diversity of species (Barbier, 1997; Guizhu, 2001; Millennium Ecosystem Assessment, 2005; Baker et al., 2006; Mcinnes, 2010).

It is possible to identify five broad wetland systems (Barbier, 1997): estuaries – where rivers meet the sea and salinity is intermediate between salt and freshwater (e.g., deltas, mudflats, salt marshes); marine – not influenced by river flows (e.g., shorelines and coral reefs); riverine – land periodically inundated by river overtopping (e.g., water meadows, flooded forests, oxbow lakes); palustrine – where there is more or less permanent water (e.g., papyrus swamp, marshes, fen); and lacustrine – areas of permanent water with little flow (e.g., ponds, kettle lakes, volcanic crater lakes).

The ‘wise use’ of wetlands, at the centre of the Ramsar philosophy, may be defined as “the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development" (Ramsar Convention Secretariat, 2007). Wise use, therefore, has at its heart the conservation and sustainable use of wetlands and their resources for the benefit of humankind (Frenken and Mharapara, 2002; Mcinnes, 2010). A Ramsar Site, or Wetland of International Importance, is a wetland area designated under the Ramsar Convention by the national government of a Member State. Currently there are over 2,000 such sites covering over 192 million hectares: an impressive global network of wetlands that meet criteria related to their biodiversity and uniqueness (SRCW and UNWTO, 2012).

Climate change may refer to a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods (United Nations, 1992; IPCC, 2007). Threat of global climate change is one of the most significant scientific and political challenges of our time (Betsill and Bulkeley, 2006). Climate change is expected to increase the frequency and intensity of current hazards and the probability of extreme events, and also to spur the emergence of new hazards and new vulnerabilities with differential spatial and socioeconomic impacts (Mitsch & Gosselink, 2007; Revi, 2008).

As global climate change is unfolding, its effects are being felt disproportionately in the world’s poorest countries (Least Developed Countries) and among the groups of people least able to cope. As the world adapts to its evolving climate, more global attention is now being focused on adaptation to the effects of climate change (Kidanu et al., 2009). According to Schipper et al. (2010), numerous factors determine vulnerability to climate change in LDCs, including geographical location, gender, age, political affiliation, livelihood, access to resources and wealth (entitlements), etc**.** In other words, vulnerability to climate change is not uniform, but differs according to the socio-cultural axes of a society (Denton, 2002; Downing, et al., 2004; Aalst & Burton, 2008; Huxtable & Yen, 2009; Elasha, 2010; Nelson, 2011; Oates et al., 2011; Ogato, 2013).

Climate change poses a serious challenge to social and economic development (USAID, 2004). Least Developed Countries (LDCs) are particularly vulnerable because their economies are generally more dependent on climate-sensitive natural resources, and because they are less able to cope with the impacts of climate change. Moreover, the effects of climate change may be especially critical to the achievement of development objectives related to the most vulnerable groups and communities in these countries (Elasha, 2010; Nelson, 2011). Thus, the projected impact of climate change on access to natural resources, heat-related mortality and spread of vector-borne diseases such as malaria, for example, has direct implications for the achievement of several of the Millennium Development Goals (Pandey, et al., 2003; Gigli & Agrawala, 2007).

Wetlands are among the most important ecosystems on Earth because of their unique hydrologic conditions and their role as ecotones between terrestrial and aquatic systems. Although many uses and values of wetlands are evident, historically wetlands have been regarded as wastelands which if possible, should be turned into something else that would be more useful**.** As a result, wetlands have been drained, turned into agricultural land, and commercial and residential developments at an alarming rate (Brix, 1994; Hall et al., 2004; Millennium Ecosystem Assessment, 2005).

However, recently, the multiple functions and values of wetlands have been recognized not only by the scientists and managers working with wetlands, but also by the public**.** Wetland Wetlands are multi-functional resources. In other words, not only do they supply humans with a number of important resource outputs (e.g., fish, fuelwood, wildlife), but they also perform an unusually large number of ecological functions which support economic activity. However, many of these latter services are not marketed and they are not bought and sold because the support they provide to economic activity is indirect and therefore largely goes unrecognised. In the case of tropical wetlands of Least Developed Countries, many of the subsistence uses of wetland resources are also not marketed and are thus often ignored in development decisions (Barbier, 1997; Galbraith, etal., 2005; Mcinnes, 2010).

While the functional and economic values of wetlands are increasingly recognized, they are particularly susceptible to mis-allocation decisions because of the nature of the values associated with them and development projects continue to lead directly or indirectly to their loss in Least Developed Countries (Barbier, 1997; Hall etal., 2004; Mcinnes, 2010). For instance, irrigated agriculture has been destructive in the past, and has the potential to continue to do so in the future unless better management processes are established in the least developed (Hall et al., 2004; Galbraith, etal., 2005; Scholz et al., 2007; Parish et al., 2008).

Undervaluing of wetland resources and functions is a major reason why wetland systems are mis-allocated – often to conversion or exploitation activities yielding immediate commercial gains and revenues. Economic valuation may provide decision-makers with vital information on the costs and benefits of alternative wetland use options that would otherwise not be taken into account in development decisions (Barbier, 1997; Thiesing, 2001; Hall et al., 2004; Millennium Ecosystem Assessment, 2005; Parish et al., 2008).

Previous studies in the field confirmed that changes in land use due to global warming such as increased drainage of wetlands for agricultural purposes could potentially lead to large carbon dioxide and methane fluxes to the atmosphere, further accelerating climate change. Moreover, destruction of wetlands is also likely to lead to secondary water pollution from the release of nutrients during wetland degradation due to lower water levels (Millennium Ecosystem Assessment, 2005; Kayranli et al., 2010).

The impact of global warming on the economic exploitation of wetlands and on conservation policies is not well understood, and is therefore often not considered in global models of climate-change effects. Moreover, much of recent terrestrial ecosystem modelling is aimed at estimating ecosystem carbon budgets and their future trends under a changing climate. In addition, the current global financial crisis is likely to lead to reduced investment in wetland protection and conservation measures. The future of conservation wetlands should be secured by protecting their status (Millennium Ecosystem Assessment, 2005; Kayranli et al., 2010).

There are huge information and research gaps in Least Developed Countries as far as climate change and wetlands nexus is concerned. For instance, predicting how the carbon balance of wetlands will respond to anticipated climatic change requires a process level understanding of carbon cycles through wetlands. Furthermore, mapping of the spatial distribution of relevant wetland characteristics, and the ability to predict how climate change will impact on wetland hydrology and the depth of the water needs critical attention. In other words, more research is needed to better understand the impacts of wetland water level fluctuations on carbon fluxes under variable climatic regimes. Further wetland research case studies should also aim to differentiate between methane production and consumption processes, and evaluate their respective roles in carbon cycling and oxygen consumption both seasonally and during gradual system maturation (Kayranli et al., 2010).

Though the aforementioned research gaps require primary data and secondary data, the proposed review work mainly aims to evaluate the status of wetlands in Least Developed Countries in time of climate change and identify policy and strategy implications to contribute for filling the existing information gap. In other words, the review was guided by the following questions:

- What is the relationship between climate change and wetlands of Least Developed Countries in time of climate change?
- What are the drivers for degradation and loss of wetlands in Least Developed Countries in time of climate change?
- What are the ecosystem services and functions of wetlands in Least Developed Countries?
- What are the strengths, weaknesses, opportunities and threats of wetland policies and strategies in Least Developed Countries? and
- What are the policy and strategy implications for sustainable conservation of wetlands of Least Developed Countries in time of climate Change?

The review has both general objective and specific objectives. The general objective of the review is to evaluate the status of wetlands in LDCs in time of climate change and identify policy and strategy implications. The specific objectives of the study are:

- To assess the drivers for degradation and loss of wetlands in Least Developed Countries in time of climate change;
- To assess the ecosystem services and functions of wetlands in Least Developed Countries;
- To appraise policies and strategies of wetlands in Least Developed Countries;
- To explore best practices of conserving wetlands in time of climate; and
- To identify policy and strategy implications for sustainable conservation of wetlands in Least Developed Countries in time of climate change.

Research Methodology

The study adapts Human Ecological Approach. Human ecology generally refers to the study of the dynamic interrelationships between human population and the physical, cultural and social characteristics of the environment and biosphere (Lawrence, 2003). Human ecology is also the study of complex and varied systems of interaction between human species and their surrounding environment. It explores not only the influence of humans on their environment but also the influence of the environment on human behaviour, and their adaptive strategies. In other words, the core of human ecology is to understand the interrelationship and interactions between human beings and their environment, which solution targets and strives towards sustainable development. Human Ecology is described as an interdisciplinary applied field that uses a holistic eco-systems approach to help people solve problems and enhance human potential within their near environments – through family and community as social-cultural environment, and through material culture as human-built environment (University of Alberta, Undated).

This review focuses on the evaluation of the status of wetlands in Least Developed Countries in time of climate change. The secondary materials were chosen in order to best reach the objectives set out above. In other words, the author undertook a comprehensive literature search predominantly with the help of goggle scholar search engine and web of science. The review themes were: wetlands of Least Developed Countries in time of climate change; drivers for degradation and loss of wetlands in Least Developed Countries in time of climate change; ecosystem services and functions of wetlands in Least Developed Countries; policies and strategies for conservation and sustainable utilization of wetlands in Least Developed Countries; and the quest for wetland conservation and sustainable utilization policies in Least Developed Countries in time of climate change.

Discussion

This section analyses and discusses the review themes. The review themes analysed and discussed in this chapter are: Wetlands of Least Developed Countries in time of climate change; Drivers for degradation and loss of wetlands in Least Developed Countries in time of climate change; Ecosystem services and functions of wetlands in Least Developed Countries;

Policies and strategies for conservation and sustainable utilization of wetlands in Least Developed Countries; and The quest for wetland conservation and sustainable utilization policy and strategy in Least Developed Countries in time of climate change.

Wetlands of least developed countries in time of climate change: carbon sources or sinks?

Previous studies on wetlands of Least Developed Countries in time of climate change confirm that although not immediate, global warming threats to wetland ecosystems and aquatic biodiversity are serious indeed (Millennium Ecosystem Assessment, 2005). For instance, Shumway (1999) asserts that aquatic habitats will change more over the next 100 years than they have over the last 10,000 years.

Wetlands can absorb carbon dioxide from the atmosphere and capture it within the sediment, and may therefore be greenhouse gas sinks (Millennium Ecosystem Assessment, 2005). In other words, the high productivity, high water table, and low decomposition rate associated with wetlands lead to carbon storage within the soil, sediment, and detritus and the process of locking carbon dioxide away from the atmosphere is called carbon sequestration (Kayranli et al., 2010). Wetlands contain five main carbon reservoirs: plant biomass carbon, particulate organic carbon, dissolved organic carbon, microbial biomass (a significant carbon sink) carbon, and gaseous end products such as carbon dioxide and methane (Kayranli et al., 2010).

On the other hand, wetlands are considered to be greenhouse gas sources, particularly with respect to the emission of methane gas to the atmosphere. According to Kayranli et al. (2010), Methane has a much higher global warming potential than carbon dioxide, and contributes to the atmospheric absorption of infrared radiation and subsequent warming. Scientists in the field attest that minimizing methane fluxes from created and restored wetlands should therefore be a vital aim in combating climate change. Moreover, they contend that improved design, construction, and operation of wetlands used for treatment and conservation purposes should therefore help to mitigate global warming by reducing the release of greenhouse gases and enhancing carbon storage at the same time (Millennium Ecosystem Assessment, 2005; Kayranli et al., 2010).

Scientists in the field also confirmed that water table level of wetlands not only influences the amount of methane emitted to the atmosphere, but also the removal of methane from the atmosphere. For instance, relatively high methane emissions could be observed when the groundwater table was high and soil temperatures were higher than 12°C (Kayranli et al., 2010).

The important greenhouse gases like carbon dioxide, methane, and nitrous oxide can be released from natural and constructed wetlands. In other words, processes such as denitrification and methane production are dependent on the oxygen status of soil and sediment. For instance, anoxic soils and sediments produce methane, while well-drained soils act as a sink for atmospheric methane due to methane oxidation (Millennium Ecosystem Assessment, 2005; Kayranli et al., 2010).

In short, previous studies in the field confirmed that deep wetlands generally capture carbon dioxide from and release methane to the atmosphere and the combination of these two fluxes determines whether these countervailing processes make a wetland system an overall contributor to the greenhouse effect. In other words, the ratio of methane release to carbon dioxide consumption determines the carbon exchange balance with the atmosphere for any wetland ecosystem (Millennium Ecosystem Assessment, 2005; Kayranli et al., 2010).

Drivers for degradation and loss of wetlands in least developed countries in time of climate change

The degradation and loss of wetlands in Least Developed Countries is more rapid than that of other ecosystems. In other words, the status of both freshwater and coastal wetland species is deteriorating faster than those of other ecosystems (Millennium Ecosystem Assessment, 2005). Previous studies undertaken by scientists in the field confirmed that both natural processes and human activities are responsible for the predicted wetland losses in least developed countries (Junk, 2002; Lemma;2003; Kingsford, 2000; Tiner, 2005; Colls, et al., 2009; Fennessy, et al., 2007; Gitay et al., 2011). Studies also confirmed that wetlands are dynamic systems, continually undergoing natural change due to subsidence, drought, sea-level rise, or infilling with sediment or organic material (Barbier, 1997; Junk, 2002; Millennium Ecosystem Assessment, 2005). For example, Barbier (1997) asserts that many wetlands are only temporary features of the landscape and will be expected to change and eventually disappear, whilst new wetlands are created elsewhere. The chief natural process is sea-level rise, which affects both estuarine and palustrine wetlands (Barbier, 1997; Millennium Ecosystem Assessment, 2005; Tiner, 2005; Nicholls, 2006).

According to Millennium Ecosystem Assessment (2005), direct and indirect human activity has considerably altered the rate of change of wetlands. In other words, the loss of wetlands has far outstripped the gains due to direct and indirect human activities in wetland ecosystems (Barbier, 1997; Guizhu, 2001; Boyer and Polasky, 2004; Millennium Ecosystem Assessment, 2005; Baker et al., 2006; Mcinnes, 2010; Crooks et al., 2011). The primary indirect drivers of degradation and loss of inland and coastal wetlands have been population growth and increasing economic development while the primary direct drivers of degradation and loss include infrastructure development, land conversion, water withdrawal, eutrophication and pollution, overharvesting and overexploitation, and the introduction of invasive alien species (Abebe, 2003; Sissay, 2003; Millennium Ecosystem Assessment, 2005; Nicholls, 2006; Silva et al., 2007; Senaratna et al., 2008).

Scientists in the field contend that global climate change is expected to exacerbate the loss and degradation of many wetlands and the loss or decline of their species and to increase the incidence of vector-borne and waterborne diseases in many regions (Millennium Ecosystem Assessment, 2005; Mitsch and Gosselink, 2007; Parish et al., 2008). Moreover, Shumway (1999) affirms that those ecosystems already stressed by human impacts are considered to be the most vulnerable to the negative impacts of climate change. In other words, wetlands are one of the most vulnerable ecosystems to global warming. For instance, a sea level rise of a few centimetres would flood huge areas of marshes and mudflats that are essential shorebird breeding grounds (Shumway, 1999; Barbier, 1997; Tiner, 2005).

Global mean sea level will continue to rise during the 21st century (IPCC,2013) and the main aspects of climate change that can be expected to have a negative impact are sea-level rise and changes in precipitation (Millennium Ecosystem Assessment, 2005; Nicholls, 2006; Erwin, 2009). For instance, plants of wetland ecosystems in Least Developed Countries like Mangroves are particularly vulnerable to sea level rise, as sea level position is central to their functional ecology. Moreover, different species of mangrove have different preferences of micro-elevation, which determines salinity and frequency of inundation (Martens et al., 1997; Shumway, 1999).

Many coastal wetlands will change as a consequence of projected sea level rise, increased storm and tidal surges, changes in storm intensity and frequency, and subsequent changes in river flow regimes and sediment transport (Millennium Ecosystem Assessment, 2005). Global mean sea level is projected to rise 0.09–0.88m from the 1990 level by 2100 (IPCC, 2001) and will considerably affect mangroves and coastal freshwater wetlands. By the 2080s, up to 22% of the world’s coastal wetlands could be lost. When combined with other losses due to direct human action, this number could rise to 70% (Junk, 2002). There will be adverse consequences for wetland species, especially those that cannot relocate to suitable habitats, as well as migratory species that rely on a variety of wetland types during their life cycle (Junk, 2002; Millennium Ecosystem Assessment, 2005).

While human influences are the main cause of desertification, global climate change is likely to accelerate both desertification and increased periods of drought in Least Developed Countries like sub-Saharan African countries (Martens et al., 1997; Shumway, 1999; Hannah *et al.*, 2002; Millennium Ecosystem Assessment, 2005). As a result, rivers are likely to experience reduced flow in areas with reduced precipitation or increased air temperatures. In other words, reduced habitat for fish and a reduction in the dilution of pollutants may threaten the biodiversity of rivers. In addition, some streams may become warmer, killing off species that can tolerate only a narrow temperature range. Lakes are also negatively affected by climate change. For instance, global warming models suggest increases of 2-4°C for African lake basins, based on a doubling of CO_2. In other words, the warmer water will mix less than current waters, and retain less oxygen in bottom layers. Moreover, lakes that weakly overturn or that already have low oxygen activity, such as Lake Victoria, could experience a massive dieoff of benthic organisms (Shumway, 1999; Hannah *et al.*, 2002; UNEP, 2006).

However, increases in temperature and atmospheric CO_2 in wetland ecosystem are expected to improve growth and litter production of mangroves which may be taken as positive impact of climate change (Shumway, 1999).

In a nutshell, the extent of future wetland losses in Least Developed Countries will depend on land-use policies, socioeconomic conditions, and vulnerability to climate change. The greatest impact to wetlands is from changes to hydrologic regimes. For instance, higher temperatures accompanied by either lower precipitation or greater precipitation that is not enough to compensate for increased evapotranspiration will change the hydrologic regime enough to damage wetland functions (Hartig et al., 1997; Millennium Ecosystem Assessment, 2005; UNEP, 2006).

Ecosystem services and functions of wetlands in least developed countries

An Ecosystem is the dynamic complex of plant, animal and micro-organism communities and the nonliving environment interacting as a functional unit. It assumes that people are an integral part of ecosystems (Millennium Ecosystem Assessment, 2005). Ecosystem Services are the benefits that people obtain from ecosystems. They can be described as provisioning services (e.g. food, water, timber); regulating services (e.g. regulation of climate, floods, disease, waste and water quality); cultural services (e.g. recreational, aesthetic and spiritual) and supporting services (e.g. soil formation, photosynthesis and nutrient cycling) (Millennium Ecosystem Assessment, 2005).

Wetlands provide many ecosystem services that contribute to human well-being and poverty alleviation (Boyer and Polasky, 2004; Silva et al., 2007; Millennium Ecosystem Assessment, 2005; Mcinnes, 2010; SRCW and UNWTO, 2012). Some of the ecosystem services wetlands provide include: Habitat for aquatic birds, other animals and plants, fish and shell fish production; biodiversity; food production; water storage, including mitigating the effects of floods and droughts; groundwater recharge; shoreline stabilization and storm protection; water purification; nutrient cycling; sediment retention and export; recreation and tourism; climate change mitigation; timber production; education and research; and aesthetic and cultural value (Ozesmi and Baur, 2002; Abunie, 2003; Galbraith, et al., 2005; Millennium Ecosystem Assessment, 2005; Wetlands International, 2010).

Scholars of wetlands contend that wetlands can be natural or artificial or mixtures of both. There is general agreement that the existence of wetlands is due to specific hydrology, soil type, and vegetation and animal communities, and that their functions depend on the context of their relative placement within the ecosystem (Galbraith, etal., 2005; Millennium Ecosystem Assessment, 2005; Mcinnes, 2010).

Wetlands serve many ecosystem functions, including the ability to sequester nutrients from the landscape. The ability to serve as nutrient sinks can be particularly valuable in agricultural landscapes, where nutrient loads are often high and threaten the integrity of downstream water bodies (Hartig et al., 1997; Steinman et al., 2003; Boyer and Polasky, 2004; Baker et al., 2006). In other words, the ability of wetlands to transform and store organic matter and nutrients has resulted in wetlands often being described as “the kidney of the landscape” (Brix, 1994; Abunie, 2003; Baker et al., 2006; Mcinnes, 2010). Wetlands also play an important role in carbon cycling because they represent 15% of the terrestrial organic matter losses to the oceans. In other words, among all terrestrial ecosystems, they have the highest carbon density. Furthermore, wetlands are a diffuse source of humic substances for some receiving freshwater systems (Kayranli et al., 2010).

Wetland systems directly support millions of people and provide goods and services to the world outside the wetland. People use wetland soils for agriculture, they catch wetland fish to eat, they cut wetland trees for timber and fuelwood and wetland reeds to make mats and to thatch roofs (Ozesmi and Baur, 2002; Frenken and Mharapara, 2002). Direct use may also take the form of recreation, such as bird watching or sailing, or scientific study. For example, peat soils have preserved ancient remains of people and trackways which are of great interest to archaeologists (Barbier, 1997).

Apart from using the wetlands directly, people benefit from wetland functions or services. As flood water flows out over a floodplain wetland, the water is temporarily stored; this reduces the peak river level and delays the time of the peak, which can be a benefit to riparian dwellers downstream. As mangrove wetlands reduce wave energy, they protect coastal communities, and as wetlands recycle nitrogen, they improve water quality downstream. By benefiting in this way, people are making indirect use of the wetland functions. These functions may be performed by engineering schemes such as dams, sea walls or water treatment plants, but such technological solutions are normally more expensive than when performed by wetlands (Barbier, 1997). In other words, wetlands can effectively minimize sediment loss, control runoff volume, purify surface water, and enhance aquifer recharge (Ozesmi and Baur, 2002; Frenken and Mharapara, 2002; Baker et al., 2006; Ramsar Convention Secretariat, 2010).

The concept of constructed wetlands applied for the purification of wastewaters has received growing interest because most of these systems are easy to use, require only little maintenance and have low construction costs (Kayranli et al., 2010). Dissolved organic matter is a very important water quality parameter associated with the performance of treatment wetland systems. Some microorganisms including bacteria use dissolved organic matter as an energy source for processes such as denitrification. However, too high levels of dissolved organic matter can prevent light penetration within the water column. In other words, the treatment efficiencies of wetlands vary depending on climate, vegetation, microorganism communities, and type of wetland system (Kayranli et al., 2010).

Wetlands provide important natural and socio-economic functions that should be fully taken into account when envisaging any intervention in such areas (Frenken and Mharapara, 2002; Junk, 2002). Wetlands have been described both as "the kidneys of the landscape", because of the functions they can perform in the hydrological and chemical cycles (Brix, 1994; Barbier, 1997), and as "biological supermarkets" (Barbier, 1997) because of the extensive food webs and rich biodiversity they support.

In a nutshell, the natural functions of wetlands include (Frenken and Mharapara, 2002): Sponge function-absorbing temporary large quantities of water to release slowly. As a consequence, groundwater tables around the area are recharged and natural springs will continue to flow over longer periods and provide water for humans, livestock and wildlife; As a result of the significant lower water flow velocities in wetlands, eroded materials will deposit during the stay of the water in the wetland area, resulting in improved soil quality and fertility in the swamps itself, while less deposits downstream prevents siltation of rivers and reservoirs; Because of the high water table and their relatively inaccessibility, wetland areas provide the habitat for a variety of plants and animals (including migratory birds) that depend on the wetland for their survival. On the other hand, the socio-economic functions of wetlands include: Production of materials traditionally used for different purposes such as handicraft and building materials; Gathering of plants and fruits, fishing and hunting; Cattle grazing, in particular in dry season; Filtration of nutrients and other chemicals from river water; Peat extraction for fuel or clay for brick making; and Tourism (Frenken and Mharapara, 2002).

Policies and strategies for conservation and sustainable utilization of wetlands in least developed countries

The convention on wetlands of international importance especially as Waterfowl Habitat– commonly referred to as the Ramsar Convention from its place of adoption in Iran in 1971 –was the first of the modern global intergovernmental treaties on conservation and wise use of natural resources (Barbier, 1997; Ramsar Convention Secretariat, 2007). The mission of the Ramsar Convention is "the conservation and wise use of wetlands by national action and international cooperation as a means to achieving sustainable development throughout the world" (Barbier, 1997; Ramsar Convention Secretariat, 2007**;** Mcinnes, 2010**;** SRCW and UNWTO, 2012).

The Convention provides a framework for international cooperation and was established following concern in the 1960s about the serious decline in populations of waterfowl (mainly ducks). It came into force in 1975 and contracting Parties, are obliged to undertake the following four main activities (Barbier, 1997; Ramsar Convention Secretariat, 2007; Mcinnes, 2010): To designate wetlands for inclusion in the 'List of Wetlands of International Importance' and to maintain their ecological character; to develop national wetland policies, to include wetland conservation considerations within their national land-use planning, to develop integrated catchment management plans and, in particular, to adopt and apply the guidelines for implementation of the "Wise Use Concept", which is the sustainable utilisation of wetlands for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem; to promote the conservation of wetlands in their territory through establishment of nature reserves and to promote training in wetland research, and management; and to consult with other contracting Parties about transfrontier wetlands, shared water systems, shared species and development aid for wetland projects**.**

According to Millennium Ecosystem Assessment (2005), the projected continued loss and degradation of wetlands will reduce the capacity of wetlands to mitigate impacts and result in further reduction in human well-being (including an increase in the prevalence of disease), especially for poorer people in Least Developed Countries, where technological solutions are not as readily available. At the same time, demand for many of these services (such as denitrification and flood and storm protection) is claimed to increase.

When wetland conservation policies are established it is expected that they provide guidelines, and a conducive environment and support for the implementers and communities to operate effectively. It is also expected that, once policies are passed, they would be appropriately translated, implemented or enforced by the responsible authorities (Frenken & Mharapara, 2002; SRCW & UNWTO, 2012). Moreover, the Ramsar Convention offers a framework for international co-operation and encourages the establishment of National Ramsar (or wetland) Committees which should include representatives from other government sectors, NGOs and local communities (Tiega, 2001).

Wetlands are, undoubtedly, an integral component of the production base for rural communities in Least Developed Countries, and in that respect contribute significantly to their livelihoods. They are important in that they provide water for domestic use and animal watering, crop and fodder production, and habitats for a variety of flora and fauna that are valuable to communities. Moreover, they are a vital part in the hydrological continuum of the catchment-drainage system (Frenken and Mharapara, 2002; Millennium Ecosystem Assessment, 2005). However, the management of the natural resources, and wetlands in particular, has been largely ignored, and where this is attended to, conservation without utilization is considered the panacea. Unfortunately, this approach lacks the participation of the resident communities who are, in essence, the custodians and beneficiaries of the resources (Frenken and Mharapara, 2002; Millennium Ecosystem Assessment, 2005).

Despite the global importance of wetlands, these ecosystems are sometimes perceived as wastelands by decision-makers in many Least Developed Countries. For instance, some water users consider wetlands as competitors for water. To overcome this challenge Tiega (2001) contends that the conservation and wise use of wetland biodiversity need to be addressed through the wider perspective of the sustainable use and management of both land and water resources. Moreover, despite the vital ecosystem services and functions of wetlands in Least Developed Countries, the previous and ongoing conservation policies and strategies are not successful in promoting sustainable development. In other words, wetlands in Least Developed Countries have been continuously degraded and lost despite the efforts of governmental and non-governmental organizations to conserve them. The analysed strengths, weaknesses, opportunities, and threats of previous and ongoing policies and strategies of conserving wetlands in Least Developed Countries are summarized hereunder.

The strengths of previous and ongoing policies and strategies of conserving wetlands in Least Developed Countries include (Gichuki et al., 2001; Tiega, 2001; Frenken and Mharapara, 2002; Junk, 2002; Abebe, 2003; Millennium Ecosystem Assessment, 2005; Ramsar Convention Secretariat, 2010; SRCW and UNWTO, 2012): wetland mainstreamed water resource conservation policies and strategies; and mounting evidences on the economic, ecological and social importance of wetlands**.** The weaknesses of previous and ongoing policies and strategies of conserving wetlands in Least Developed Countries include: poor consultation and participation of stakeholders in wetland policies and strategies development process; low consciousness amongst policy makers on the quest for wise utilization and conservation of wetlands; absence of effective national, regional, and local wetland conservation policies and strategies; presence of ambiguous environmental conservation policies; continuous degradation and loss of wetlands due to economic growth; absence of specific and contextual wetland management plans; limited information about the status, ecological functioning, and values (such as hydrologic or economic value) of wetlands; absence of efficient incentives which serve to maintain and improve the livelihood of local people dependent on wetland areas; inadequate quantification of wetlands' conversion rates and the economic value of wetlands; poor understanding on the economic, social and ecological costs and benefits of wetland conversion; absence of suitable legislative frameworks; low public awareness on values, use, and threats of wetlands; limited education, and skills for undertaking quantitative research on wetlands; poor coordination among numerous national institutions and interest groups dealing with land use and water issues at local, national and international level; poor understanding on possible solutions to soil and wetland degradation; and absence of unique or "stand alone" wetland policy statement and/or strategy (Gichuki et al., 2001; Tiega, 2001; Frenken and Mharapara, 2002; Junk, 2002; Abebe, 2003; Millennium Ecosystem Assessment, 2005; SRCW and UNWTO, 2012).

The opportunities for wetlands' conservation policies and strategies in Least Developed Countries include: presence of international conventions for wise utilization and conservation of wetland resources and biodiversity; presence of international financial supports; presence of international and non-governmental organizations providing technical support for research and development on wetlands of Least Developed Countries; presence of natural wetland resources; and presence of indigenous knowledge and local innovations on conservation of natural wetlands (Tiega, 2001; Frenken & Mharapara, 2002; Junk, 2002; Abebe, 2003; Millennium Ecosystem Assessment, 2005; SRCW & UNWTO, 2012). The threats of previous and ongoing policies and strategies of conserving wetlands in Least Developed Countries include: climate change, insufficient political conviction or 'will' to formalise wetland conservation; land use which does not take wetlands and water resources conservation objectives into account; the pursuit of economic growth at the expense of sustainable development; presence of political instability and armed conflicts; and competing national development interests and programmes (Tiega, 2001; Frenken & Mharapara, 2002; Junk, 2002; Abebe, 2003; Millennium Ecosystem Assessment, 2005; SRCW & UNWTO, 2012).

The quest for wetland conservation and sustainable utilization policy and strategy in least developed countries in time of climate change

The Ramsar Convention and its Partners Organisations (BirdLife International, IUCN, Wetlands International and WWF), are being instrumental in urging Least Developed Countries to work towards the conservation of wetland ecosystems in LDCs. This is directed to a focus on economic valuation of wetlands; development of incentives to foster public and decision makers; awareness; training; environmental education and communication in order to raise the profile of wetland issues among young people; water or wetland policies; legislation and regulation; community empowerment; community capacity building -to promote an enabling environment; pollution control; initiatives related to climate change; invasive alien species control; threatened species conservation; and programs on adaptive management of ecosystems in response to a changing environment (Tiega, 2001; Millennium Ecosystem Assessment, 2005; Ramsar Convention Secretariat, 2007**;** Mcinnes, 2010).

According to Ramsar Convention Secretariat (2010), the disruption of wetland functions has a high cost — economically, socially and ecologically. In other words, the disturbance of their natural balance can destroy critical gene pools required for medical and agricultural purposes, it can affect their ability to naturally improve water quality and it can ruin their use for educational and recreational purposes. Moreover, the disruption of valuable wetlands must cease, the diversity of remaining wetlands must be retained, and where possible rehabilitation, restoration and re-creation of wetlands must be attempted (Ramsar Convention Secretariat,2010; SRCW and UNWTO, 2012).

Ramsar Convention Secretariat (2010) contends that contracting parties of the convention should consider formulation of national policies that promote wetland conservation. However, in a number of national examples completed to date in LDCs, this has been observed to sometimes involve a lengthy and complex process. Moreover, political, interjurisdictional, institutional, legal and financial constraints were identified to affect the formulation of such policies, in addition to social and economic factors that continue to contribute to wetland loss (Swart et al., 2003; Ramsar Convention Secretariat, 2010).

It is important that existing wetlands, and especially those of importance for nature conservation or the provision of existing ecosystem services, are protected. This is essential, and infinitely preferential, to creating new wetlands as components of integrated water management infrastructure than to negatively impact existing wetlands (Frenken & Mharapara, 2002; Boyer & Polasky, 2004; Mcinnes, 2010).

As strongly contended by Shumway (1999) there is an urgent need for mitigation and adaptation plans in Least Developed Countries although local stresses are of greater threat for wetlands. In other words, given the importance of sustainable ecosystem services and functions of wetlands in LDCs, it is imperative to mainstream climate change mitigation and adaptation into conservation efforts of wetlands (Hall et al., 2004; Roberts, 2008). Moreover, global warming mitigation is becoming increasingly important as the negative impacts of climate change on wetland ecosystems are becoming apparent around the world. In other words, wetland protection and restoration measures are confirmed to improve the carbon sequestration potential of wetlands (Roberts, 2008). However, it takes several decades for the carbon sequestration ability of restored wetlands to reach levels comparable to those of natural wetlands such as peatlands and forested wetlands (Kayranli et al., 2010).

In response to the convention on wetlands of international importance(the Ramsar Convention) and based on the analysis of strengths, weaknesses, opportunities and threats of previous and ongoing conservation policies and strategies of wetlands in Least Developed Countries, the following policy and strategy implications are identified to promote conservation and sustainable utilization of wetlands in Least Developed Countries (Hartig et al., 1997; Guizhu, 2001; Hannah et al., 2002; Junk, 2002; Frenken & Mharapara, 2002; Lemma,2003; Tekaligne,2003; Millennium Ecosystem Assessment, 2005; Mitsch and Gosselink, 2007; Parish et al., 2008; Erwin, 2009; Colls, et al., 2009; Mcinnes, 2010; Mitsch & Gosselink, 2007; Wetlands International, 2010; Crooks et al., 2011; Joosten et al., 2012):

- Anticipatory and systematic ‘Climate Change integrated Conservation Strategies’ (CCS) should be promoted in Least Developed Countries since there are mounting evidences for global climate change and its negative impacts on wetland resources;
- Policies and strategies that promote protection of wetlands and establishment of buffer zones beyond the delineated boundaries of wetlands should be developed and properly implemented as appropriate preparatory measures for projected climate change;
- Policies and strategies of wise utilization and conservation of wetlands in Least Developed Countries should be based on the principles of integrated water resources management(IWRM) since IWRM recognises the need to manage water resources at different scales, from local to basin, to ensure that local needs can be sustainably met;
- Sustainable wetland/peatland conservation and restoration policies and strategies should be integrated with sustainable development and poverty alleviation policies and strategies since environmentally sound economic development is the basis for sustainable development that creates livelihood options and employment opportunities for current as well as future generations;
- Bilateral and multilateral cooperation between rich temperate and poor tropical countries in research projects and the training of local scientists should be intensified as gobalization will favour scientific cooperation and the large

scientific associations will become increasingly involved in initiating cooperation;

- Policies and strategies on wise utilization and conservation of wetlands in Least Developed Countries should promote economic valuation of wetlands as economic valuation provides an argument and a tool for promoting wise use approaches;
- Traditional management practices need to be studied, adapted and integrated into development plans, to satisfy the requirements of a rapidly growing population and changing economic conditions.
- Least Developed Countries should develop a "stand-alone" or unique wetland policy as unique wetland policy draws considerable attention to wetland issues particularly by legislators and the public. Moreover, it promote cooperation and action at many levels;
- Least Developed Countries should intensify south-south cooperation with respect to the use and improvement of low-cost and low-impact wetlands management methods;
- Wise use and conservation policies of wetlands in Least Developed Countries should promote ecosystem-based adaptation (EBA) since EBA integrates the use of biodiversity and ecosystem services into an overall strategy to help people adapt to the adverse impacts of climate change. It is also recognized by many Least Developed Countries as a cost-effective, accessible way of reducing poverty and climate risk;
- Least Developed Countries should encourage Environmental Impact Assessments (EIAs) are always undertaken before major development activities occur in order to realise the benefits that can be derived from wetlands, and to avoid, mitigate or compensate adverse impacts upon them;
- Wise use and conservation policies of wetlands in Least Developed Countries should promote wetland restoration since wetland restoration measure may restore and enhance wetland benefits by re-establishing natural ecological processes;
- Wise use and conservation policies of wetlands in Least Developed Countries should promote systems of protected areas since protected area networks at all levels, including the designation and management of Ramsar sites, play an important role, given the fact that individual sites are often functionally interconnected by reason of shared hydrology, migratory species, and so on;
- Wise use and conservation policies of wetlands in Least Developed Countries should promote Enhancement in wetland monitoring like developing automatic monitoring systems for wetland environment and resources and use of remote sensing and GIS techniques for setting up an information system on wetland resources and environment;
- There is also an urgent need to develop information management systems that would allow the sharing of existing and new information, and the skills and technologies that enhance the management of wetlands by regions;
- Correction of market failures and internalization of environmental externalities that lead to the degradation of ecosystem services; and
- Increased transparency and accountability of government and private-sector performance in decisions that affect wetlands, including through greater involvement of concerned stakeholders in decision-making.

Conclusion

In conclusion, this review confirmed that deep wetlands generally capture carbon dioxide from and release methane to the atmosphere and the combination of these two fluxes determines whether these countervailing processes make a wetland system an overall contributor to the greenhouse effect. Moreover, both natural processes and human activities are responsible for the predicted wetland losses in least developed countries. Least Developed Countries may benefit from sustainable utilization and conservation of wetlands by responding to implications like anticipatory and systematic 'Climate Change integrated Conservation Strategies' in time of climate change.

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