

## Chapter 23

# Wetlands Biodiversity, Livelihoods and Climate Change Implications in the Ruaha River Basin, Tanzania

Pantaleo K.T. Munishi, Halima Kilungu, Nice Wilfred, Bernadetha Munishi, and Stein R. Moe

**Abstract** Wetland ecosystems in Tanzania contribute significantly to livelihoods and biodiversity conservation. These ecosystems are vulnerable to both human and climate change induced impacts though the implication of climate change on these ecosystems is poorly known. We assessed a wide range of wetlands in the Ruaha River basin to quantify their biodiversity, livelihoods and potential climate change impacts. It was observed that biodiversity of wetlands is much higher than that in adjacent habitats. Wetlands are refuge for endangered plant species making them important in biodiversity conservation. Wetland cultivation and fisheries contributed over 40 % of the total household income and food. Over 90 % of the dry season agriculture is wetland dependent forming the major livelihood source for majority in the basin. The most visible climate change impacts on the wetlands of Ruaha are reduced water flows, drying of wetlands and degradation of their ecological functions. With climate change, water flows in the Ruaha have decreased by 10 % causing substantial reduction in extent of wetlands in the basin. Adapting the wetlands to climate change require evaluation of current and future climate vulnerability of

---

P.K.T. Munishi (✉)

Department of Forest Biology, Sokoine University of Agriculture, PO Box 3010, Morogoro, Tanzania

e-mail: [pmunishi2001@yahoo.com](mailto:pmunishi2001@yahoo.com)

H. Kilungu

Department of Tourism and Hospitality, Open University of Tanzania, PO Box 23409, Dar es Salaam, Tanzania

e-mail: [kilunguh@yahoo.com](mailto:kilunguh@yahoo.com)

N. Wilfred • B. Munishi

Ministry of Agriculture, Food Security and Cooperatives, PO Box 9192, Dar es Salaam, Tanzania

e-mail: [niceafb@yahoo.co.uk](mailto:niceafb@yahoo.co.uk); [benney\\_munishi@yahoo.com](mailto:benney_munishi@yahoo.com)

S.R. Moe

Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, Box 5003, 1432 Aås, Norway

e-mail: [stein.moe@nmbu.no](mailto:stein.moe@nmbu.no)

wetland ecosystems and related livelihoods. This information is important in informing policies, adaptation and mitigation strategies for wetland ecosystems.

**Keywords** Wetlands • Biodiversity • Livelihoods • Climate change

## Introduction

Wetlands are among the world's most biologically rich ecosystems with high species diversity (Mvena 1999; Yanda et al. 2005; Munishi 2006). Wetlands ecosystems are second only to the rain forests in the number of wildlife and plant species that depend on them for feeding and habitat. Historically, wetlands have been regarded as wastelands but they can also be viewed as being among the last truly wild and untouched places in the world (Maltby 1986) making them of high repository of biological diversity with most wetlands offering important habitats to a variety of fauna and flora.

For most African countries, wetlands have a considerable importance in provision of innumerable benefits like drinking water, transport, harvestable plants and animals and food production (Munishi et al. 2010). Though not well quantified, Tanzania's wetlands contribute in diverse ways to livelihoods of many millions and are chiefly utilized for crop and livestock production (Kashaigili 2006; Munishi et al. 2010). Wetlands provide income in both dry and wet years for fairly large number of people engaged in agriculture because of their available water and high soil fertility (Mkavidanda and Kaswamila 2001; Kashaigili et al. 2005; Munishi et al. 2010; Kilungu and Munishi 2009).

The 2025 Tanzania's vision overall goal specifically includes references to 'sustainable development endeavours, on intergeneration equity basis, such that the present generation derives benefits from the rational use of natural resources of the country without compromising the needs of future generations'. Further more the National Strategy for Growth and Reduction of Poverty (NSGRP) or MKUKUTA recognize poverty as largely a rural phenomenon and that the rural poor depend solely or to a greater extent on natural resources (Bagachwa 1994; DPG 2005; URT 2006). Consequently the national environmental policy of 1997 and all the natural resource policies emphasize the clear cause-and-effect relationship between poverty and environmental degradation, and because of this they stress on the need for sectoral policies to address poverty issues by taking into account the need for wise use and sustainable resource exploitation (MNRT 2003, 2004, 2009).

Wetlands are amongst the most productive ecosystem in Tanzania and have significant economic, social, cultural and biological values. Apart from agricultural use wetlands are considered useful as sources of a variety of natural resources of significance to human welfare. Tanzania is endowed with exceptional wetland resources in which 10 % of the country is covered by wetland ecosystems. These

ecosystems range from large lake systems to river floodplains, deltaic mangrove formations and associated catchments (Maltby 1986; Kamukara and Crafter 1993). Of the area covered by wetlands, 5.5 % is occupied by four Ramsar sites namely Malagarasi/Moyovosi (32,500 km<sup>2</sup>), Lake Natron Basin (2250 km<sup>2</sup>), Kilombero valley floodplains (7950 km<sup>2</sup>) and Rufiji-Mafia-Kilwa (5969.7 km<sup>2</sup>) (MNRT 2003). Broadly the country is divided into nine drainage (river) basins which include Lake Rukwa, Lake Victoria, Lake Tanganyika, Lake Nyasa, Rufiji River, Pangani River, Ruvuma River and Southern Coast, Wami-Ruvu River and Internal Drainage basin. Each of these basins includes a network of rivers and inland valley bottom wetlands scattered throughout the country. These vast biologically rich resources in Tanzania are unique in their biodiversity values as well as support to local livelihoods (MNRT 2003; Kilungu and Munishi 2009). The implications of climate change and human induced activities on the wetlands of the Great Ruaha River are diverse. Protection of the wetlands against biodiversity loss, while maintaining their socio-economic value under the wake of climate change does not however appear to be a serious alternative among majority of the society in Tanzania thus jeopardizing future sustainability of these wetlands.

This paper presents results of a study to assess the role of wetland ecosystems in conserving plant diversity, contribution to livelihood enhancement and implications of climate change in the Great Ruaha River basin Tanzania.

## Methodology

The Great Ruaha River is a river in south-central Tanzania that flows through the Usangu wetlands and the Ruaha National Park east into the Rufiji River. Its basin catchment area is 83,970 km<sup>-2</sup>. The population of the basin is mainly sustained by irrigation and water-related livelihoods such as fishing and livestock keeping. Great Ruaha is about 475 km long, its tributary basin has a catchment area of 68,000 km<sup>2</sup> and the mean annual discharge is 140 m<sup>3</sup>/s. The Great Ruaha River supplies 22 % of the total flow of the Rufiji catchment system. Thirty-eight species of fish have been identified in the Great Ruaha River. The river's headwaters are in the Kipengere Range. From there the Great Ruaha River descends to the Usangu plains, an important region for irrigated agriculture and livestock in Tanzania. The river eventually reaches the Mtera Dam and then flows south to the Kidatu Dam which generate about 50 % of the Tanzania's electricity. The river continues southwards and flows across the Selous Game Reserve before reaching the Rufiji River. The major rivers contributing to the Great Ruaha River are Lukosi, Yovi, Kitete, Sanje, Little Ruaha, Kisigo, Mbarali, Kimani and Chimala whereas the small ones include Umrobo, Mkoji, Lunwa, Mlomboji, Mpombochi, Ipatagwa, Mambi, Isimani stream, Idete River, Mkungwe, Kinoga d Mswiswi Rivers and associated swamps and streams (Fig. 23.1). The wetlands of Little Ruaha River start from Bumilayinga, Nyololo, Mafinga and Ihalimba wards (Fig. 23.1). The River further extends to Kilolo and Iringa Districts crossing the Ipogoro Bridge along the Dar es Salaam—Mbeya road before joining the Great Ruaha River at Mawande village. The entire



## Data Collection

### *Ecological Study*

For ecological study, sites were selected based the presence and extent of valley bottom wetlands within the sites. Three sites were selected for the ecological studies which include Uchindile with Mpombochi River and Isimani stream plus associated swamps, Idete with Idete River and associated swamps/streams and Mapanda with Mkungwe and Kinoga Rivers and associated swamps/streams (Fig. 23.1). Prior to field surveys, the areas were stratified into broad vegetation types using existing topographic/land cover maps and reconnaissance survey. This stratification gave several major vegetation types including woodlands, grasslands, valley bottom wetlands/swamps undisturbed natural vegetation and plantations of different types. These broad types were further sub divided into sub categories depending on field conditions such as wooded grasslands, natural grasslands, pine plantations and eucalyptus plantations.

Temporary nested sample plots measuring  $20 \times 20$  m were adopted and established systematically in clusters representing different vegetation types in each stratum on transect lines established along a predetermined compass direction. About 100 plots were established in each site based on area and an adopted minimum sampling intensity of 0.01 % ensuring a sufficient coverage and representation of each stratum. The location of each plot was recorded using Global Positioning System (GPS). At each quadrat all the plant species encountered were identified, recorded and percent cover determined. For species that were difficult to identify in the field voucher specimens were collected and identified at a herbarium.

### *Socio-economic Study*

For the social economic studies villages were selected based on their proximity to wetland ecosystems. Multistage sampling was used where two divisions within the upper catchment of the Little Ruaha sub catchment were selected randomly. Two wards were then selected randomly from each Division. For each ward two villages were selected randomly for the study. The selection of villages was based on close proximity to the wetlands with the assumption that the respective communities were more involved with wetlands cultivation as compared to other villages. In this case, Matanana village (Bumilayinga Ward) being in the upper catchment and Luganga village (Ifwagi Ward) on the lower catchment were sampled. Other villages included in the study are Nyololo Njiapanda (Nyololo Ward), Kisada (Bumilayinga Ward) Igowole and Nzivi (Igowole Ward) (Fig. 23.1). In each village the village register was used as a sampling frame, households were then randomly selected and a questionnaire administered to heads of the selected households. Households were taken as sampling units in this study and total of 93 households were sampled

(44 and 49 households from Luganga and Matanana respectively). The questionnaire sought to get information on whether the household is involved in any kind of wetland utilization, socio-economic activities undertaken in the wetlands, costs and revenues from wetland utilization. Further to questionnaire survey PRA techniques including Focus Group Discussions (FGD) were used as well as participant field observation to supplement information from household surveys.

### ***Hydrology and Climate***

The data on climate impacts was based on the changes observed in the flow of the Ruaha River at Msembe station 1KA59 using historical flow data for 46 years—four decades (1958–2004) (Fig. 23.1).

## **Data Analysis**

### ***Ecological Data***

All special features of interest in the area e.g. water sources, valley bottom wetlands, natural grassland ecosystem, miombo woodlands and wooded grasslands were identified and compiled into a list with a description of their species composition. The identified strata and field data were developed into tables showing a list of different vegetation types and their species composition, richness, abundance and dominance. The abundance and dominance of each species was determined from their percent cover estimates.

### ***Socio-economic Data***

Socio-economic data were analyzed and summarized into social economic activities undertaken by a household, agricultural utilization of wetlands and crops grown in dry/wet seasons and the proportional contribution of each wetland related socio-economic activities to household food security (food available for household consumption) and income. The economic benefits were assessed by using gross margin analysis, food available for consumption as indicator of food security was used to assess food security at household level; and the contingent valuation technique was applied to assess the value of wetlands services. The gross margin analysis was computed as:

$$GM = TR - TC$$

Where:

- GM Average gross margin (Tshs/kg) or (Tshs/month)  
TR Average total revenue (Tshs/kg) or (Tshs/month)  
TC Average total variable cost (Tshs/kg) or (Tshs/month)

The food available for consumption at household level was determined to be 300 kg of cereal/person/year. This figure was used to offset post harvest losses (storage loss and handling loss) (FAO 1985; Ishengoma 1998). Food available for consumption was obtained by subtracting the amount of food crop that was sold from the total food produced per person per year. Standardization of food available for consumption was done using adult equivalent scale considering age category (Ishengoma 1998). In this case where the adult above 15 years old has unit equivalent of 1, ages 11–15 will have unit equivalent of 0.75 while children with age equal or less than 10 years will have unit equivalent of 0.36 (Ishengoma 1998).

### ***Hydrology Data***

The hydrologic data were analyzed for trend to give information on what have been the changes in the flow of the river over time that may have influenced the wetland status. Further, the data were analyzed for periods of extreme low flows that would be a determining factor on wetland conditions.

## **Results**

### ***Vegetation Types and Plant Species Composition in the Great Ruaha Basin***

Several vegetation types were identified in the different sites. The major natural vegetation types identified included valley bottom wetlands, natural grasslands, wooded grasslands, and miombo woodlands. In addition planted exotic tree species formed specific vegetation types and included *Eucalyptus* and *Pine* plantations. There was a big variation in plant species composition and richness in all sites studied with the different vegetation types having different species composition and richness within sites. The variation in composition is a reflection of high diversity of plants in the areas. In all the three sites valley bottom wetlands ranked the highest in plant species richness when compared with other natural vegetation and combined natural vegetation and plantation of exotic species. This general trend shows that

valley bottom wetlands in the Ruaha River Basin will likely be the major repositories of biodiversity of plant species. By the fact that vegetation composition may be a reflection of other taxa in an ecosystem there is a high possibility that fauna diversity will follow the same trend. Because plants respond to multiple environmental factors both biotic and abiotic, this richness and diversity of species is a reflection of the heterogeneity of the areas, diverse vegetation types, habitats and landscapes that allow co-existence of species in heterogeneous landscape (Carson and Root 2000; Franzén 2004; Tetsuya and Kuniyasu 2005; Munishi et al. 2007; Tomáš and František 2008).

### ***Plant Species Composition by Vegetation Types in Uchindile Landscapes***

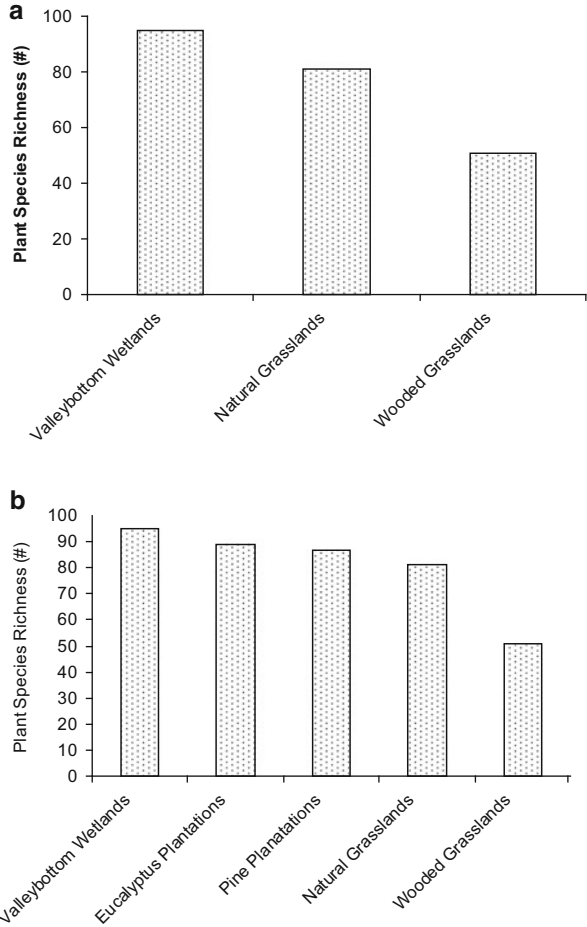
Three natural vegetation types were identified in Uchindile including (i) Valley bottom Wetlands/Riverine/Riparian, (ii) Natural Grasslands and (iii) Wooded Grasslands. In addition to the natural vegetation there were two types of plantations of exotic tree species which are among the major vegetation found on the landscape. These are (i) Pine plantations and (ii) Eucalyptus plantations. The number of plant species varied between vegetation types. In regards to the natural vegetation Valley bottom Wetlands have the highest number of species compared to all other vegetation types (Fig. 23.2a). Further when we consider all the vegetation types Valley bottom Wetlands still rank the highest in plant species richness (Fig. 23.2b). Previous studies have also shown the valley bottom/riverine/riparian vegetation to have higher species richness than the other types of vegetation (Munishi 2006, 2007).

### ***Plant Species Composition by Vegetation Types in Idete Landscapes***

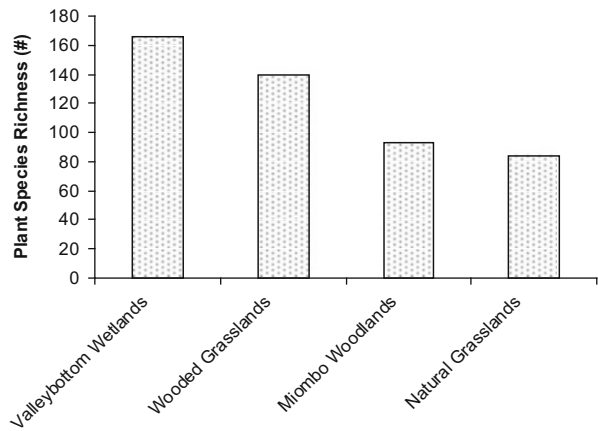
Four different natural vegetation types were identified in the Idete landscapes. These vegetation types include Valley bottom Wetlands/Riparian Areas, Natural Grasslands, Wooded Grasslands and Miombo Woodlands. Valley bottom Wetlands/riparian areas had the highest proportion of species compared to all other vegetation types followed by Wooded Grasslands. Miombo Woodlands and Natural Grasslands had almost the same species richness (Fig. 23.3). These findings indicate that the wetland ecosystems are the most diverse followed by wooded grasslands.



**Fig. 23.2** (a) Average number of plant species by natural vegetation types in Uchindile. (b) Plant species richness in all vegetation types in Uchindile



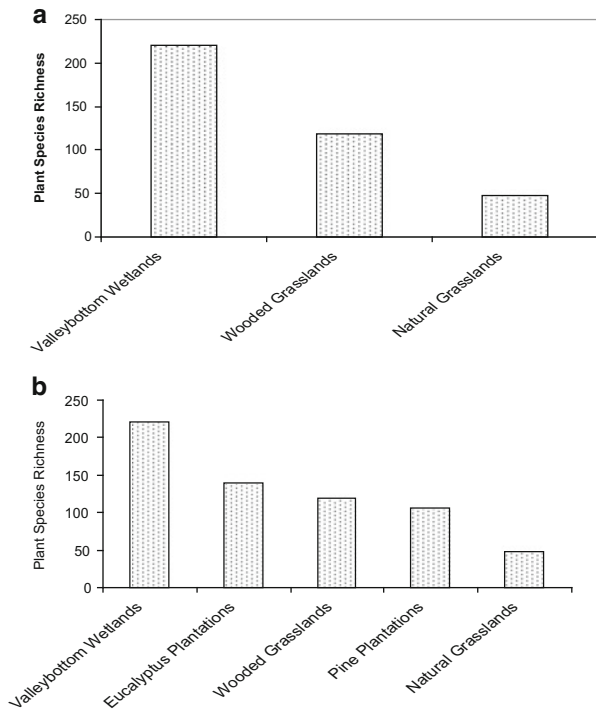
**Fig. 23.3** Plant species richness in different natural vegetation types of Idete Landscapes Iringa Tanzania



### ***Plant Species Composition by Vegetation Types in Mapanda Landscapes***

A total of 320 plant species belonging to 96 families were identified in the Mapanda landscapes which is a reflection of the heterogeneity of the landscape and habitats. Three natural vegetation types were identified in Mapanda which include Valley bottom Wetlands, Wooded Grasslands and Natural grasslands. In addition two vegetation types of planted exotic species were identified as among the major cover types in the landscape. These are *Eucalyptus* and *Pine* plantations. Among the natural vegetation types Valley bottom Wetlands had the highest plant species richness (Fig. 23.4a) followed by wooded grasslands. Of all vegetation types combined Valley bottom Wetlands still rank the highest in species richness (Fig. 23.4b), showing the value of wetland ecosystems as repositories of species in the landscape.

**Fig. 23.4** (a) Plant species richness in different natural vegetation types of Mapanda Landscapes Iringa Tanzania. (b) Plant Species Richness in all Vegetation Types of Mapanda Landscapes Iringa Tanzania



### ***Socio-economic Values of Valley Bottom Wetlands in the Little Ruaha River***

Tanzania's wetlands contribute in diverse ways to livelihoods of many millions and wetlands are chiefly utilized for crop production and livestock. An assessment of wetland contribution to livelihoods in six villages of the Little Ruaha sub catchment of the Great Ruaha River showed that the total use value of productive activities carried out in upland and valley bottom wetlands was Tanzanian Shillings (Tshs) 3,415,458 (US\$2732) per year per household in which 31 % of the total economic benefits accrued from utilization of Valley bottom Wetlands. Wetland based socio-economic activities included agricultural production practiced by over 98 % of the population followed by livestock grazing and fishing. Wetland based socio-economic activities carried out in valley bottoms commonly known by local people as *vinzungu* contribute about 15 of household food and 55–95 % of household income annually, equivalent to Tshs 3,234,721 (US\$2588). In this respect valley bottom wetlands contribute significantly to household economy and food security. Planning for wetland friendly agricultural activities is pertinent in order to ensure wetlands conservation and sustainable contribution to household economy and food security without impairing the ecological integrity of the wetland ecosystems.

### ***Climate Change Impacts on the Hydrology and Wetlands of the Great Ruaha River***

There has been an appreciable decrease in water flows in the Ruaha River over time. An analysis of flows in the great Ruaha over 46 years period shows a decrease from an average of over  $85 \text{ m}^3 \text{ s}^{-1}$  to below  $70 \text{ m}^3 \text{ s}^{-1}$  (Fig. 23.5). This change is associated with rainfall variability in the basin, increased evapo-transpiration resulting from increasing temperatures as well as human induced impacts.

### **Extreme Low Flows**

Zero flows were not experienced before 1990s in the great Ruaha River. Over time the flow has been decreasing and zero flows started to be experienced starting December 1990s. The low flows have been persistent since then and their duration have prolonged extending back to September. Occasionally zero flows are observed in January, a period that would be rain season in the region (Fig. 23.6). This situation marks extended periods of drying of the Ruaha River with consequences on resident biodiversity and socio-economic activities especially those which are water dependent.

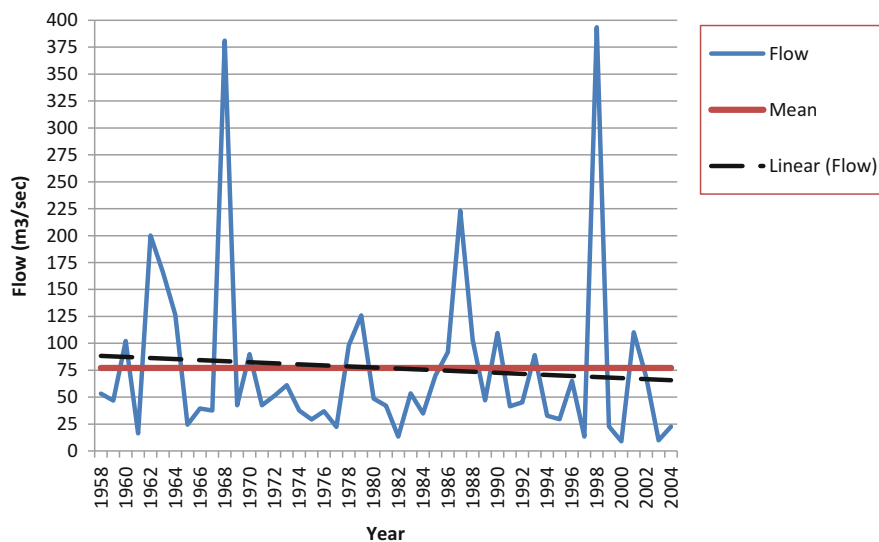


Fig. 23.5 Trends in the hydrology of the Great Ruaha River Tanzania 1953–2003 (40 years)

## Discussion

The significance of valley bottom wetlands in acting as refuge for many species becomes more apparent during the peak of the dry season in which there would definitely be higher species richness for both flora and fauna in valley bottoms because of the wetter and favourable conditions compared to the other more terrestrial habitats. Most grassland ecosystems for example would have higher number of short-lived plant growth forms (annuals) during the rainy season which disappear during the dry season. However valley bottoms remain relatively wet and fertile during dry conditions making them potential sites for species assemblages and growth.

According to Dykema et al. (2014), with increase of temperature in the temperate regions, species diversity will decrease as cold water species are out competed by better adapted warm water species. Further, optimum habitat for most species will shift. This leads to disruption in food webs and upsets the balance of the ecosystem. Species with high water flow and flood tolerance may out-compete others that could previously exist prior to climate change. With a change in biodiversity, many rivers may lose some of their economic value. With climate change affecting temperatures all over the world, states could face less income generated by fewer cold water species.

Wetlands make appreciable contribution to rural livelihoods in terms of direct cash income and contribution to food security (Mkavidanda and Kaswamila 2001; Kilungu and Munishi 2009; Munishi et al. 2012), and many households that live close to wetland ecosystems in Tanzania and elsewhere utilize wetlands in



coping strategies during times of drought and food scarcity. Differences in environmental and socio-economic conditions however result into significant variation in patterns of use between one area and another. The significance of wetlands in agricultural production, poverty reduction and contribution to rural livelihoods have variously been emphasized (Mkavidanda and Kaswamila 2001; Ngailo et al. 2002; Kilungu and Munishi 2009). The wide range of economic benefits accrued from wetland ecosystems in Tanzania has been iterated (Yanda et al. 2008). It is argued that often overlooked, unappreciated, taken for granted and therefore unmanaged the ecosystem services provided by wetlands in Tanzania include hydro-power production in which 95 % of the hydropower production is from wetland related flows. Further 95 % of domestic, irrigation, industrial and livestock water is from wetlands, 80 % of traditional irrigation schemes depend on wetlands, 95 % of rice and vegetable production depends on wetlands, about 850,000 ha of wetlands have potential for future irrigation, 95 % of wildlife and wildlife corridors/game migration routes depend on wetlands, 66 % of rural animal protein is derived from livestock grazing, game meat or fisheries, 95 % of the 25 million livestock is maintained through dry season pastoralism in wetlands, 95 % of coastal and wildlife tourism depends wetlands and 33 % of the country's GDP depends on wildlife and wetland tourism. Other studies have shown that cultivation of paddy rice in wetlands of Bahi Tanzania contributed significantly to household food security generating 65.4 % of total household food crop production compared to other crops grown in drier areas adjacent to the swamp (Munishi et al. 2010). Fishing in this case played a substantial contribution to household food security through household consumption of 10 % of fish caught. For household income, sales of paddy rice from the swamp contributed 59.6 % while fish sales contributed 36 % of the total annual household income. Multiplier activities emerging during fishing season facilitate income to a wider group of communities and on average, 56.2 % of the population depend on the Bahi swamp for daily socio-economic activities associated with generation of household food and income. The Bahi swamp and related products therefore play a significant role in enhancing local livelihoods for the adjacent communities. Planning for wise use of the swamp in respect of the dominant socio-economic activities was seen as a means to improve its contribution to livelihoods.

Among the major impacts of climate change on river systems globally are decrease in flows and drying of associated wetlands. Further it will alter the ecological function of the river systems and the way the society interact with them (Swan River Trust 2014). The low flows in the Great Ruaha River have been persistent since 1990s and their duration have prolonged extending back to September. This situation marks extended periods of drying of the Ruaha River with consequences on resident biodiversity and socio-economic activities especially those which are water dependent. According to Walsh (2012) the Great Ruaha River upstream of Mtera Dam stopped flowing for the first time in living memory in December 1993. This became a matter of national concern in 1995 when electricity shortages and rationing in the country were blamed by the national power supply company (TANESCO) on the continuing drying-up of the Great Ruaha. Since then different institutions and interest groups have sought to explain

the river's increasing seasonality, focusing on resource use in and around its immediate source, the Usangu wetland, and laying the blame on different groups of resource users. Increasing government concern over power shortages culminated in the mass expulsion in 2006–2007 of livestock keepers from Usangu Wetlands a situation that has affected pastoralists' livelihood strategies in the Ruaha wetlands.

Munishi and Temu (1993) associated the drying of the Ruaha River with changing patterns of rainfall and anthropogenic activities in its upper catchment. Kashaigili (2006) observed that the frequency of occurrence of low flow events in the Great Ruaha River has increased over time. Between 1958 and 1973 there was not a single day with zero flow and the return period of a minimum 1-day duration flow of  $0.84 \text{ m}^3 \text{ s}^{-1}$  was approximately 30 years. Between 1974 and 1985 short periods of zero flow occurred and a zero flow of 1-day duration had a return period of approximately 4 years. Post-1985, zero flows of 1-day duration occurred in all years and zero flow for durations of 60 days and greater were common. According to Mwakalila (2011a), the irrigated agriculture is most important as a user of water and impacts most heavily on wetlands. Abstraction of water for agriculture is leading to dried up rivers, falling ground water tables, increase in soil salinity and polluted waterways.

It has been shown that the rainfall in both the upper and lower catchments of the basin is quite variable. According to Mwakalila (2011b) rainfall in the basin varies from 250 to 2000 mm per annum and falls mainly from November to May. Rainfall amounts vary from year to year and in most of the basin the annual rainfall is much less compared to potential evapo-transpiration, indicating a negative balance (i.e. moisture deficit). Such situation may be worsened by climate change. Climate change and increasing water demand resulting from population growth has been earmarked as causing major degradation of water resources in the Sub-Saharan Africa (Ngigi 2009). The availability of water is affected in many ways by climate change. For example, changes in the quantity, timing, intensity and duration of rainfall as a result of climate change will contribute to greater water stress in the basin intensifying climate change impacts on wetlands. Decrease in water levels in the river will have diverse and negative impacts on wetland status especially biodiversity as well the potential of the wetlands to support socio-economic activities such as fishing, crop production among others. Flows in the river have constantly been below the long term average from the 1980s.

According to the Union of Concerned Scientists (2014) climate change is already beginning to affect plants and animals that live in freshwater lakes and rivers, altering their habitat and bringing life-threatening stress and disease. As air temperatures rise, water temperatures do also, particularly in shallow stretches of rivers and surface waters of lakes and streams and lakes may become unsuitable for cold-water fish but support species that thrive in warmer waters.

## Adapting Wetlands to Climate Change

Among the major effective climate change response and adaptation to drying of wetlands is to sustain and restore wetlands and their functions. Other adaptation and mitigation measures that will especially adapt wetland livelihoods to climate change include irrigation development, strengthening integrated water resources management, development of both surface and subsurface water reservoirs, promotion of community based catchment conservation and management and promotion of new water serving technologies in irrigation. A more pragmatic approach to adapting the river basin and associated wetlands to climate change would be an evaluation of current and future climate vulnerability of wetland ecosystems and related livelihoods, formulation of scenarios for the future of wetlands under climate change impacts, identification of potential adaptation measures, capacity building for wetlands management, and implementation of adaptation measures on a pilot scale. This would then be followed by operationalization of the adaptations measures which consist of assessing the success of the measure, institutionalization, promotion and development of agreements and recommendations on how to sustain the promising adaptation measures. This will then be followed by programs and policy developments that ensure sustainable wetlands management at different levels of government. Furthermore, management practices in the river basin catchment will need to accommodate understanding of climate change impacts throughout the area. According to the Swan River Trust (2014) understanding the impacts of climate change on rivers is important information for mitigation measures. It is also important to improve local authority's understanding of the problems of degradation occurring as a result of anthropogenic activities in the river basin.

## Conclusions

The most visible climate change impacts on the wetlands of Ruaha are reduced water flows, drying of wetlands and degradation of their ecological and socio-economic functions. With climate change, water flows in the Ruaha will decrease by 10 % causing substantial reduction in the extent of wetlands in the basin. Low flows have persisted since 1990s, with zero flows becoming more frequent and prolonged. A more pragmatic approach to adapting wetlands to climate change would be an evaluation of current and future climate vulnerability of wetland ecosystems and related livelihoods, formulation of scenarios for the future of wetlands under climate change impacts, identification of potential adaptation measures, capacity building for wetlands management, and implementation of adaptation measures on a pilot scale followed by operationalization of the adaptations measures. This information is important in informing policies, adaptation and mitigation strategies for wetlands.



**Acknowledgements** We acknowledge financial support from the Royal Norwegian Government through the Project NUFU-TZ 2007/10229 without which this study would have been impossible. Thanks to Sokoine University of Agriculture for institutional support in undertaking the NUFU Project and this study.

## References

- Bagachwa MSD (1994) Poverty alleviation in Tanzania: recent research issues. Dar es Salaam University Press, Dar es Salaam
- Carson WP, Root RB (2000) Herbivory and plant species coexistence: community regulation by an out breaking phytophagous insect. *Ecol Monogr* 70:73–99
- Development Partners Group (DPG) (2005) Brief on issues pertaining to tourist hunting. Development Partners Group, Dar es Salaam
- Dykema J, Kriegel N, Jimenez A, Kahn C, Johnson J (2014) The effects of climate change on rivers. Macalester College, St. Paul, [Macalester.edu/academics/environmentalstudies](http://Macalester.edu/academics/environmentalstudies). (Last visited November 2015)
- Food and Agriculture Organisation (FAO) (1985) Energy and protein requirements. Report of a joint FAO/WHO/UNU ad hoc Expert Consultation. Geneva, pp 724
- Franzén D (2004) Plant species coexistence and dispersion of seed traits in a grassland. *Ecography* 27(2):218–224
- Ishengoma C (1998) The role of women in household food security in Morogoro Rural and Kilosa District. Unpublished Ph.D. Thesis. Sokoine University of Agriculture, Morogoro, Tanzania, pp 337
- Kamukara GL, Crafter SA (Eds) (1993) Wetlands of Tanzania. In: Proceedings of a seminar on wetlands of Tanzania, Morogoro, Tanzania 27–29 Nov 1991. IUCN Gland, Switzerland, p 179
- Kashaigili JJ (2006) Effects of land use/cover changes on flow regime of the Usangu wetland and the Great Ruaha River in Tanzania. <http://www.waternetonline.ihe.nl/downloads/uploads/symposium/zambia-2007>
- Kashaigili JJ, Kadigi RMJ, Lankford BA, Mahoo HF, Mashauri DA (2005) Environmental flows allocation in river basins: exploring allocation challenges and options in the Great Ruaha Basin, Tanzania. *J Phys Chem Earth* 30(11–16):689–697
- Kilungu H, Munishi PKT (2009) Contribution of wetlands to household income and food security and livelihoods; a case of ‘Nyumba ya Mungu’ wetlands system in Northern Tanzania. *Tanzania J Forest Nat Conservat* 79(2):99–108
- Maltby E (1986) Water logged wealth, why waste the world’s wet places? International Institute for Environment and Development, London, p 19
- Ministry of Natural Resources and Tourism (MNRT) (2003) Assessment needs for wetlands inventory and tools for assessing, mapping wetland types and their distribution. Report, Prepared by Institute of Resource Assessment, University of Dar es Salaam, p 41
- Ministry of Natural Resources and Tourism (MNRT) (2004) An issue paper for the formulation of the national wetland strategy. Wildlife Division, Ministry of Natural Resources and Tourism, Dar es Salaam, p 98
- Ministry of Natural Resources and Tourism (MNRT) (2009) Wildlife, wetlands and climate change in Tanzania. Wildlife Division, p 7
- Mkavidanda TAJ, Kaswamila AL (2001) The role of traditional irrigation systems in alleviating poverty in Iringa Rural District, Tanzania. REPOA Research Paper No 01.2. Mkuki na Nyota Publishers, Dar es Salaam, p 36
- Munishi PKT (2006) Ecological survey in the Kilombero forest project at Uchindile Kilombero District, Tanzania, p 87

- Munishi PKT (2007) Ecological survey in the Uchindile and Mapanda forest projects of Green Resources (Ltd), Tanzania, p 48
- Munishi PKT, Temu RPC (1993) The natural forests and environmental conservation in the Southern Highlands of Tanzania. In: Ekpere JA, Rees DJ, Mbwire KP, Lyimo NG (eds) Proceedings of an international workshop on agricultural research, training and technology transfer in the Southern Highlands of Tanzania: past achievements and future prospects. Uyolet Agricultural Centre, Mbeya, pp 405–412
- Munishi PKT, Shear TH, Wentworth T, Temu RPC (2007) Compositional gradients in plant communities in submontane rain forests of eastern Tanzania. *J Trop For Sci* 19(1):35–45
- Munishi PKT, Shirima D, Jackson H, Kilungu H (2010) Analysis of climate change and its impacts on productive sectors, particularly agriculture in Tanzania. A Study for United Republic of Tanzania Ministry of Finance and Economic Affairs, p 105
- Munishi PKT, Renatus R, Kideghesho JR, Kilungu H (2012) The role of Bahi swamp wetlands in enhancing household food security and income of adjacent communities. *Tanzania J Forest Nat Conservat* 82(2):120–137
- Mvena ZSK (1999) The past, present and future of urban agriculture in Tanzania. *J Agric Econ Dev* 3:71–77
- Mwakalila S (2011a) Assessing the hydrological conditions of the Usangu wetlands in Tanzania. *J Water Resour Prot* 3:876–882
- Mwakalila S (2011b) Vulnerability of people's livelihoods to water resources availability in semi arid areas of Tanzania. *J Water Resour Prot* 3(9):8
- Ngailo JA, Kaswamila AL, Senkoro CJ (2002) Rice farming system of the Wasukuma and its contribution to poverty alleviation. In: Presented at the 5th REPOA workshops, Dar es Salaam, 21–22 Mar 2002, p 23
- Ngigi N (2009) Climate change adaptation strategies. Water resources management options for smallholder farming systems in Sub-Saharan Africa. Earth Institute, MDG Center, East and Southern Africa, New York, 189p. ISBN 9789290592648
- Swan River Trust (2014) Annual report 2013–2014. <http://www.swanrivertrust.wa.gov.au/home>, p 107
- Tetsuya S, Kuniyasu M (2005) Organic matter dynamics control plant species coexistence in a tropical peat swamp forest. *Proc Biol Sci* 272(1571):1503–1510
- Tomáš H, František K (2008) Mechanisms of species coexistence in semi natural meadow communities; importance of species traits. <http://botanika.bf.jcu.cz/suspa/ohrazeni/>
- Union of Concerned Scientists (2014) Climate hot map. Global warming effects around the world. <http://www.climatehotmap.org/global-warmingeffects/lakes-and-rivers.html>
- United Republic of Tanzania (URT) (2006) Poverty reduction strategy paper (PRSP). IMF Country Report No. 06/142. International Monetary Fund, p 119
- Walsh M (2012) The not-so-Great Ruaha and hidden histories of an environmental panic in Tanzania. *J East Afr Stud* 6(2):303–335
- Yanda PZ, Majule AE, Mwakaje AG (2005) Wetland utilization, poverty alleviation and environmental conservation in semi-arid areas of Tanzania, the Case of Singida Region, Tanzania. In: Proceedings of East Africa integrated river basin management conference held on 7th–9th 2005 at ICE Hall, Sokoine University of Agriculture, Morogoro
- Yanda PZ, Olson J, Moshy P (2008) Climate change vulnerability impacts and adaptation in Tanzania. CLIP Working Paper. Institute of Resource Assessment, University of Dar es Salaam, Dar es Salaam