IJERD – International Journal of Environmental and Rural Development (2023) 14-1

Research article

National versus Local Climatic Variability and Implications for Communities in Protected Areas: The Case of Lake Malawi National Park

DICKSON M. MAZIBUKO
Graduate School of Agro-Environmental Science, Tokyo University of Agriculture, Japan
Faculty of Basic and Applied Sciences, University of Malawi, Zomba, Malawi

LAMECK FIWA
Faculty of Agriculture, Lilongwe University of Agriculture and Natural Resources, Malawi

MASKEY SARVESH
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan

HIROMU OKAZAWA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Japan
Email: h1okazaw@nodai.ac.jp

Received 22 May 2023 Accepted 20 June 2023 (*Corresponding Author)

Abstract Understanding the rainfall dynamics of a nation/region is key to decision-making, especially regarding agriculture within protected areas. This study focused on the area of Cape Maclear and the adjacent villages located within the Lake Malawi National Park (LMNP). By gaining insight into how communities whose agricultural activities interact with protected areas operate, we can gain insight into the long-term sustainability of the LMNP. This study aimed to assess the historical rainfall dynamics for Cape Maclear using 35-year annual rainfall and temperature data. Rainfall trends were established and compared with recorded events. The results indicated that Cape Maclear rainfall trends resonate with reported national drought events, though with variations. This provides a proxy possibility of making localized predictions of such events. Analysis of the return period shows annual rainfall of between 500-900 mm occurs every 2-3 years, indicating no significant shifts from what has been observed in the past. Due to the sensitivity and fragility of the LMNP ecosystem, there is a need to design local solutions for the communities living within the park to enable them to better prepare for future climatic shocks, especially rainfall inadequacies.

Keywords climate, community, drought, rainfall, protected area

INTRODUCTION

Protected areas face several challenges, and one emerging challenge is climate change. Global climatic change is receiving a lot of attention due to the diverse impacts currently felt and being projected. Besides broader climatic variabilities, local scale events have been observed. Ngongondo et al. (2021) assessed drought and floods in Malawi and found variations in the frequency and intensity of these events across all districts in Malawi, indicating that their occurrence is not nationally homogenous. It is predicted that climate change will lead to an altered frequency, intensity, and duration of localized climatic shocks such as droughts and temperature extremes (Chen et al., 2018), with diverse impacts. For communities living in protected areas, whose alternative livelihoods are sought from protected natural resources, such climatic shocks will impact ecosystems. Ecosystems impacts vary in their extent, however for communities embedded within protected areas, such impacts could be particularly pronounced for both people and the protected area itself. The existence of agriculture within protected areas is illegal in most countries (Tranquilli et al., 2014). For Lake Malawi National Park, however, there are settlements inside the National Park. This is because, at its founding in 1981, a presidential directive stopped the eviction of any persons that were already living in the park. The two key livelihood activities within the National Park are agriculture and harvesting of non-timber forest products (NTFP). Agriculture is thought of as a threat to park diversity due to people-nature conflicts that result as communities extract livelihoods from protected areas. These conflicts include deforestation for fuel needs, especially in tropical Africa (Wade et al., 2020), population growth leads to agricultural expansion at the expense of parkland (Sardjo et al., 2022; Joppa et al., 2009), agricultural inputs that negatively impact on diversity within protected areas, and other direct human-animal conflicts (Mohan, et al., 2020) due to proximity of existence. For the sustainability of agriculture within protected areas, there is a need for agriculture production approaches that minimally impact protected area diversity. In Italy, organic agriculture is a dominant agricultural practice within protected areas (Grandis and Triantafyllidis, 2010). The decision regarding what kind of agricultural practice to enact depends, to some large extent on the understanding of the climatic atmosphere of a given locality. In a predicted changing climate, and for protected areas supporting agriculture, an understanding of local climate dynamics is thus key in innovating ways to mitigate the impacts. Lake Malawi National Park provides fuelwood that is sold for income alongside other non-timber forest products that support livelihoods. For communities existing within protected areas, the need for fertile agricultural land can also lead to Park incursions. Such incursions could lead to park-community conflicts.

The Lake Malawi National Park (LMNP) was established in 1980 (Abbot and Mace, 1999) as the only protected area in Malawi with human settlements within its legal boundaries. A government order at the outset, stipulated that there should be no relocation of communities already living within the park. This scenario poses unique conservation and sustainability challenges. Key challenges include overexploitation of fisheries (Sato et al., 2008), deforestation, and climate change (Markham, 2018). Over time, agriculture is emerging as a challenge in part due to the growing human population that requires more land for food production. These challenges pose a threat to the biodiversity of LMNP.

OBJECTIVE

Climatic shocks such as droughts and their associated rainfall variability, could lead to additional direct and indirect impacts on the protected area. An understanding of historical climatic events could partially enable some preparedness. However, since the occurrence of such shocks is not nationally homogenous, this study sought to assess local rainfall dynamics in the LMNP within the national context. Specifically, this study sought to qualitatively assess how national drought events compare with localized rainfall trends. Secondly, to determine local rainfall dynamics during four known drought years in Malawi and LMNP, and finally to assess how rainfall during drought shocks relates to impact crop productivity, i.e., the onset of the growing season and overall crop water requirements.

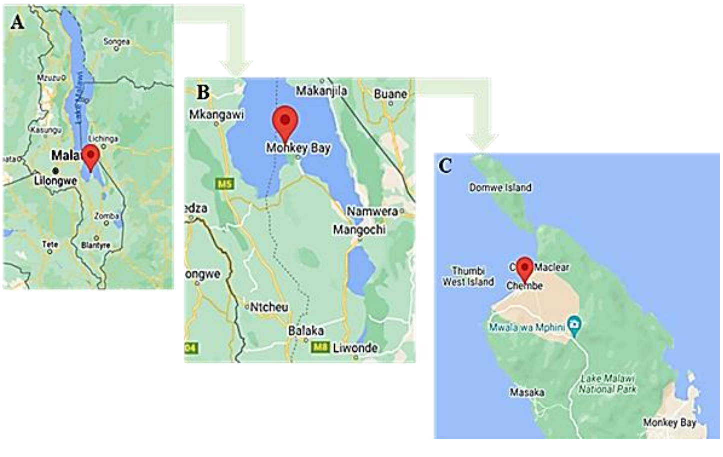

Fig. 1 The study site indicated in map of Malawi

(A) showing the relative position of the larger Chembe village community; Mangochi, (B) showing the wider Monkey Bay area and Chembe village community (within Cape Maclear), (C) and the surrounding Lake Malawi National Park

METHODOLOGY

The study area comprises five enclaved villages within LMNP; 14° 02'S by 34° 53'E (Fig. 1). The park is also a world heritage site. The climate is tropical with annual temperature ranging between 19.6 ºC to 21.4 ºC minimum and between 29 ºC to 30.7 ºC, maximum. Average annual rainfall ranges between 600 mm to 1600 mm with pronounced variations between seasons. This study used historical daily rainfall data for a period of 35 years (1st January 1979 to 31st December 2015) collected from the Department of Climate Change and Meteorological Services for Monkey Bay weather station, which is the closest to the study site. The rainfall dynamics of interest were documented drought and flooding events of 1985-1986; 1988-1989; 1991-1992; 1994-1995; 2001-2002; 2005-2006; and 2012-2013. This paper utilized the MarkSim DSSAT Weather Generator to obtain maps and a Microsoft Excel spreadsheet for computation and graphics.

RESULTS AND DISCUSSION

Reported and Local Rainfall Comparison

The study site generally showed reduced annual rainfall amounts in all the years with nationally reported drought and flooding events (Fig. 2); five droughts and 2 floods. During the 35 years, rainfall is observed to have been extremely variable with no clear trend in direction as indicated by the weak coefficient of determination (r^2 =0.003) as shown in Fig. 2. Overall, the data shows more drought than flooding. It can be noted however that annual rainfall values of above 1,200 mm and below 600 mm are associated with flooding and drought respectively. After 2015, Malawi experienced two serious flooding events; first, the 2015 La Niña driven flooding and the 2019 flooding caused by cyclone Idai (Ngongondo et al., 2021) mostly affecting the southern region of the country.

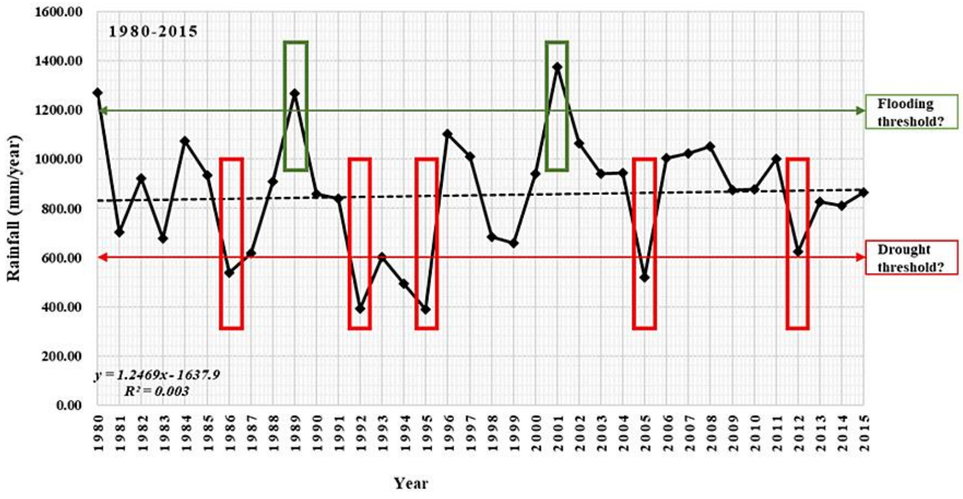

Fig. 2 Documented drought (Red) and flooding (Green) seasons/years between 1980 and 2015 in Malawi and LMNP

Regarding the prediction of localized climatic shocks from national data, this work provides some positive indications. The national drought records are in sync with local scale data (in terms of decreasing trends). This observation thus provides opportunities for the formulation of informed presumptions regarding possible future climatic shocks for climate modeling studies. While this is the case, the extent of such shocks, and associated adaptations, should be determined and understood in a local context.

Rainfall Dynamics

To assess the rainfall dynamics during these drought events, the overall distribution of rainfall was assessed (Fig. 3). The amounts of rainfall and its duration during the crop growing season in Malawi (October to April) were compared with an 1880-81 season as a reference.

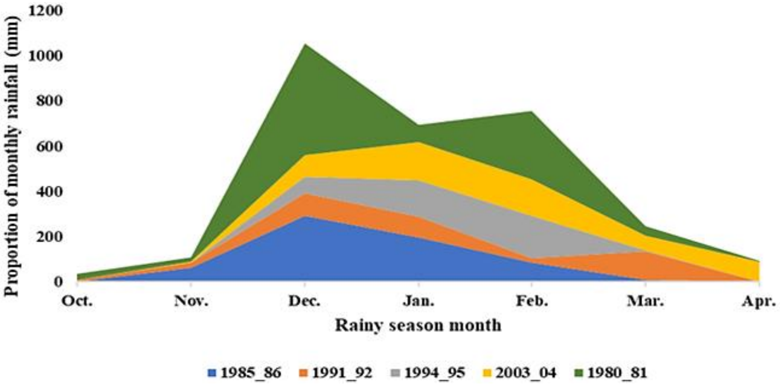

Fig. 3 Relative rainfall amounts across the six months growing season for four seasons
Including reference (Green); showing various skewness of precipitation amounts across the growing season

During the 1985-86 drought, adequate rainfall was available around December after which it steadily declined. In the 1991-92 season, inadequate rainfall was recorded early in the season and adequate rainfall amount fell after February when no cropping could be done. 1994-95 had less rainfall except only during January and February. For the 2003-04 season, there were some consistent medium rainfall amounts throughout the rainy season irrespective of the national drought.

Crop Productivity

First, the general requisite conditions for the onset of the growing season (GS) and the broader rainfall amount that support crop productivity were assessed. Fiwa et al. (2014) refer to the onset of GS as when 25 mm of rainfall is experienced in the first 10-day period from a given rainfall event, and at least some additional 20 mm within the next 20 days after the onset of GS. Based on Fiwas' determination, seasons 1991-92 and 2003-04 for the study site had adequate conditions for planting. However, Allen et al. (1998) consider an annual rainfall range of 500-700 mm as a minimum requirement for crop productivity in the case of maize. Maize has been chosen as an example as it is a staple crop for the country. From this criterion, the study site had adequate rainfall for two drought years/seasons (1985-86 and 2003-04).

Table 1 Cape Maclear rainfall dynamics during nationally reported drought events
The year/season 1980-81 is included as a reference. RE= Rainfall event; GS= growing season, and REF means reference (season)

Season	First rainfall event (amount; mm)	The onset of the growing season (Rainfall 1st 10 days) (mm)	Intervening RE (mm)	RE after the 10th day of GS onset (mm)	Annual precipitation (mm)
1985_86	10 Oct (0.1)	6 Nov (50.5)	0 (-)	6 RE (10.7)	538.8
1991_92	13 Oct (8.1)	10 Dec (76.3)	6 RE (25.8)	5 RE (21.1)	391.6
1994_95	15 Oct (0.9)	3 Dec (46.4)	0 (-)	1 RE (3.1)	388.6
200304	18 Nov (0.1)	12 Dec (71.6)	4 RE (6.9)	5 RE (20.4)	520.5
(REF)-1980_81	1 Oct (5.3)	30 Nov (185.0)	2 RE (26.4)	4 RE (42.8)	704.3

The season 1991-92 had satisfied requirements for the onset of the growing season but the annual rainfall was way below the minimum required to support crop production. The apparent discrepancy between the two crop-growing requirements necessitates that they be considered concurrently in determining optimal conditions for agricultural productivity. Another key observation during the four seasons is a lack of adequate rainfall during one or both key months of crop growth (Fig. 3). Issues of spatiotemporal rainfall distribution within the growing season are thus key in deciding what crops to grow.

Rainfall Return Period

An analysis of the return period shows that the highly expected annual rainfall ranges are between 500-900 mm/y during every 2-3 years. The Return period of 1000 mm/y of annual rainfall indicates 4 years in Fig. 4. From the analysis (and without absolutism), rainfall events above 1000mm (normally observed to be associated with floods) can be predicted to occur at least every 4-5 years. In a broader sense, the area is not particularly wet. From an agricultural perspective, it is prudent for farming communities to invest in crops with moderate to low water requirements.

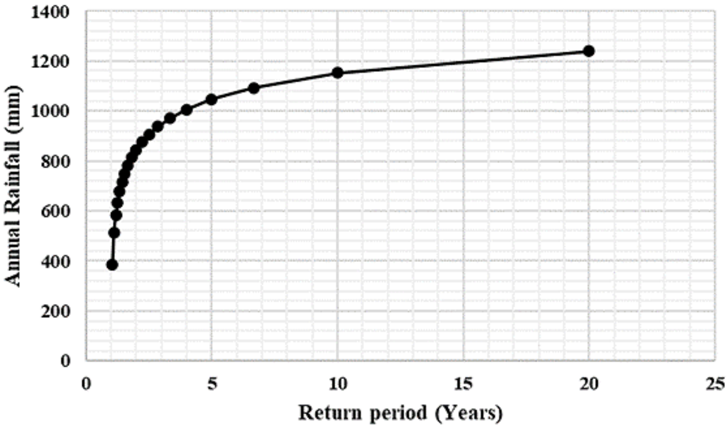

Fig. 4 Rainfall return period for Cape Maclear, Lake Malawi National Park

Implications for Park Enclave Communities

The current global climate change predictions point to an increase in the frequency of drought and flooding shocks (Zhao et al., 2020). Drought events limit crop productivity as moisture is a key determinant for plant growth. For rural communities, it entails a lack of income from Agri-based labor, general food insufficiency, and social instability. These pressures inadvertently lead to the use of other ecosystem services (specifically forests), leading to incursions into protected parkland. The desperate harvesting and overuse of NTFP and parkland incursions lead to the depreciation of protected forest resources. Ultimately, the park's long-term sustainability will be compromised. Conservation of agricultural approaches is one way to adapt to rainfall variability and droughts. Vegetables for example, due to their higher water demand than other crops (Manuel et al., 2017), might benefit from mulching technology or utilizing seasonal riverbanks with residual moisture. With the prevailing global change, climate-smart agriculture approaches must be promoted to ensure the sustainable utilization of resources from the National Park.

CONCLUSION

Understanding localized climate dynamics is key as it enables concerned stakeholders to make appropriate decisions during shock events. The rainfall trends for Cape Maclear resonate with national ones for drought years reported for Malawi. The association observed between national rainfall dynamics and those local to Cape Maclear signal the potential of using projected national future climatic events at a local level; especially where stochastic approaches are utilized. Such projection would ensure preparedness for various shocks, ensuring the preservation of the fragile protected area. Rainfall dynamics during drought years generally indicate amounts acceptable for crop production but with uneven seasonal distributions. These seasonal distributions are hard to predict, but the production of early maturing crops could be a good safety net. Overall, there exist differences in rainfall spread, amounts, and the onset of growing seasons. The main limitation of the study has been a focus on rainfall only and a lack of verification of the observed climate dynamics and actual productivity assessments. Future studies should focus on other climate variables such as temperature and how associated impacts on agricultural production.

ACKNOWLEDGEMENTS

The authors are particularly appreciative to Mr. John Matewere and Mr. Brighten Ndawala (the leaders of a community vegetable garden in Chembe Village, Cape Maclear, Mangochi, Malawi) for fruitful discussion and background information. This paper is based on a broader idea conceived during this discussion. We thank Prof. Tetsu Sato, the principal investigator of SATREPS, and all the members of the "Integrated Natural Resource Management System in Lake Malawi National Park (IntNRMS) Project" under the SATREPS program.

FUNDING

This study was funded by the "Integrated Natural Resource Management System in Lake Malawi National Park (IntNRMS) Project" under the SATREPS program provided by the JST and JICA (JPMJSA1903). This work was also supported by research programs of the Tokyo NODAI Research Institute, Tokyo University of Agriculture.

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