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Impacts of dam construction on tree species diversity in semi-arid regions: The case of Ruti Dam in Zimbabwe

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Research Article

Impacts of dam construction on tree species diversity in semi-arid regions: the case of Ruti Dam in Zimbabwe

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ABSTRACT

The aim of the study was to assess the impacts of Ruti dam construction on tree species diversity. The study focused on a comparative impact assessment between two localities which are the upper catchment and the lower catchment. A total of 30 quadrats were sampled, 15 on each part of the catchment. Data on the tree species present and their relative abundance was collected from each quadrat. Next, we estimated tree species diversity by calculating the Shannon Weaver Index (H) for each quadrat. The Mann-Whitney U test was then used to test for significance in differences between tree species diversity in the two sections of the catchments. The results showed that tree species diversity, was significantly lower in most quadrats on the upper catchment as compared the downstream of the dam wall. This shows that dam construction despite its importance to agricultural production in semi arid regions can cause a decline in tree species diversity.

Keywords: biodiversity, dam construction, Shannon weaver index.

INTRODUCTION

Biodiversity is the variety of species, their genetic make-up and the natural communities in which they occur. It includes all the native plants and animals and the process that sustain life on earth (www.pabiodiversity.org). Put in other words, biodiversity refers to the encountered variety of living things on the planet. These living organisms, interacting among themselves and with the non-living environment, comprise the ecosystems of the world (www.unep.org). The importance of biodiversity to human society is hard to state or determine. An estimated 40% of the global economy is based on biological products and processes (www.unep.org). Human species depend on biological diversity products for their day -to -day survival (www.pabiodiversity.org). The invaluable importance of biodiversity led to the crafting and subsequent adoption of the Convention on Biological Diversity (CBD) on 29 December 1993 in Rio de Janeiro (www.cbd.int). The three main objectives of the CBD are: the conservation of biological diversity, the sustainable use of the components of biodiversity and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources (www.cbd.int).

A dam is a barrier built across a river or stream to confine and utilize the flow of water for human purposes such as irrigation and generation of hydroelectricity (www.arch.mcgill.com). While dam construction is done with positive intentions in mind, their adverse impacts on elements of biodiversity are threatening to outweigh the positive objectives for which they are built. Throughout the past few years, the negative impacts of dams have become well-documented that some countries have stopped building them altogether and are now forced to invest their money into fixing the problems created by existing dams (Manatunge et al., (undated), www.arch.mcgill.ca). Dammed rivers reduce flood rates, impacting badly on the flood plains that rely on seasonal variations of water (www.fauna-flora.org,). Starving flood plains of water negatively impacts on flood plain ecosystems, especially the breeding and reproduction cycles of certain species leading to their extinction. As an example, following the closure of the Kainji Dam in Nigeria, 50-70% of downstream area of flood recession crop was lost (www.wikipedia.org).

Although the negative biodiversity impacts of dams have been studied and documented, these have tended to be mainly concentrated on either the aquatic species such as fish (www.internationalrivers.org, www.wikipedia.org) or the downstream riverine vegetation. Very little has been done to document the impacts of dam construction on terrestrial flora such as trees (Harris et al., 1987). Knowledge of the impacts of dam construction on tree species diversity will help to craft measures to mitigate such impacts. Thus, this study aims at investigating the impacts of dam construction on tree species diversity in a semi-arid region.

MATERIALS AND METHODS

Study Area

The study was carried out around the Ruti dam figure1. The dam is in Buhera district of Zimbabwe. In the case of the dam under study (Ruti Dam), it was constructed in 1976 to serve the local communities and the Chisumbanje Irrigation Scheme in the southeast lowveld of Zimbabwe (www.tastecate.com). Due to the increased need for irrigation and the increased frequency of droughts, the capacity of Ruti dam was increased by 25% through the installation of hydroplus fusegates on the 284m spillway sill in the year 2000 (www.oxfamireland.org). The areas on the upper catchment are dominated red loam soils, while those on the lower catchment are dominated loose alluvial soils. The climate of this area is characterized by normal to below normal rainfall amounts during the rainy season. Thus, the dam acts as a reliable source of drinking water for livestock, as well as the source of irrigation water downstream. Ruti dam occupies the Save Catchment Area and Dewure sub-catchment area in particular. (www.waterpowermagazine.com).

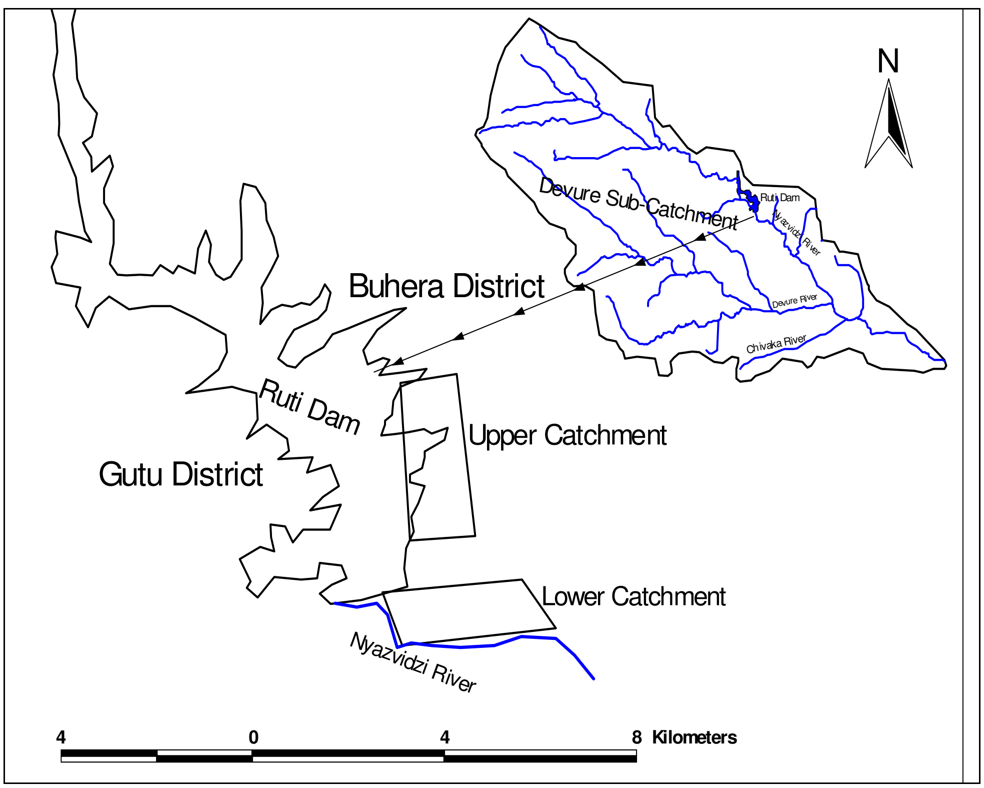

Figure 1: Study-area map

Materials

The materials used in the study include following:

1. A Geographical Information Systems
2. Landsat satellite images
3. GPS receivers
4. Tape measures

5. Data collection sheets
6. SPSS statistical package

Methods

1. Landsat images were imported in a GIS and then used to mark and digitise the boundaries of areas to be studied. This resulted in a base map of the study area.
2. The base maps established 3km*1km rectangular study areas on each of the sides of the dam wall (Upper and Lower Catchments) (figure 2). Rectangular study areas were adopted to minimize the edge effect, and have been proven to cover and contain more species for a given area than any other shape, and is also ideal for easy comparison purposes (Clapharm, 1992).
3. 30 random points were then generated randomly on the study areas, 15 on the upper catchment and the other 15 on the lower catchment. Hand held GPSs were then used to navigate to the random points chosen.
4. The 30 random points were then marked into 30m*30m quadrats as shown on figure2.

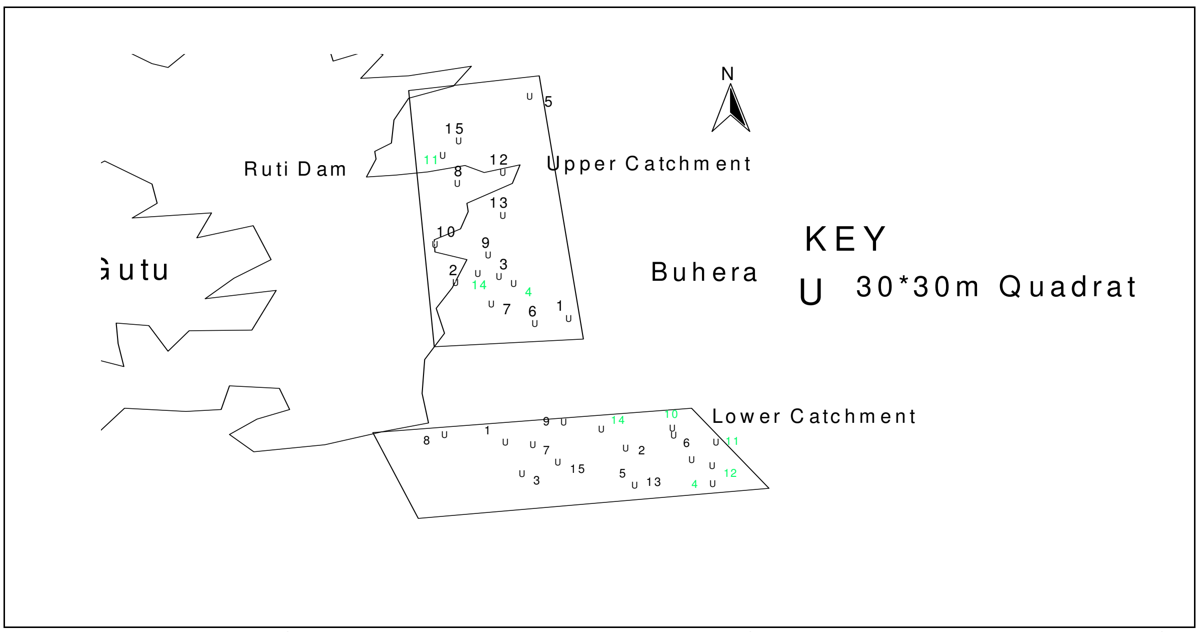

Figure 2: Demarcation of the study area, showing the location of the quadrats in the two sections of the catchment.

5. In each quadrat data on tree species present and relative abundance was then collected and entered onto a data sheet.
6. The data was then entered into an SPSS spreadsheet for statistical analysis. This included test for normality of data, randomness of the data and significance testing.
7. The Mann-Whitney U test was used to test for significance in differences between samples on the upper catchment and those on the lower catchment.
8. The Shannon weaver index (H) (1994) was then used as a quantitative measure of diversity. The index indicates species diversity of a community or area. According to Kent and Coker (1992), the Shannon-Weaver index is the most frequently used for the combination of species richness and relative abundance of vegetation. A value of the index of Shannon-Weaver (H) usually lies between 1.5 and 3.5; although in exceptional case, the value can exceed 4.5 (Pielou, 1969).

RESULTS

A Kolmogorov-Smirnov test of normality showed that the data was random; therefore non-parametric statistical tests had to be used. The Mann-Whitney Test U test showed that there were significant differences between biodiversity on the upper catchment and diversity on the lower catchment ($p = 0.00$, $\alpha = 0.05$).Figure3 shows that quadrats on the lower catchment have a higher mean value of H than those of the upper catchment. This means that the lower catchment is significantly more diverse than the lower catchment because the higher the value of H, the higher the diversity.

Figure3 shows that the mean diversity of quadrats on the lower catchment are way higher than the quadrats with the highest diversity on the upper catchment.

The non-merging of the quartiles of the two catchments clearly proves that there is a significant difference between these catchments' mean diversity. Put under the Mann-Whitney Test U, the mean ranks of these two catchments are 20-73 for the lower catchment and 10-27 for the upper catchment respectively.

In both catchments, most of the quadrats have diversity that is higher than their means as shown by figure3 that shows the means to be close to the upper quarter. The lower catchment specifically shows that the distribution of bio diversity within quadrats is more or less even from the lower quarter to the upper but those with higher diversity showing more dispersion from the mean. On the other hand, on the upper catchment, it is the lower quarter quadrats that show more dispersion from the mean in a magnitude that is more pronounced than on the lower catchment.

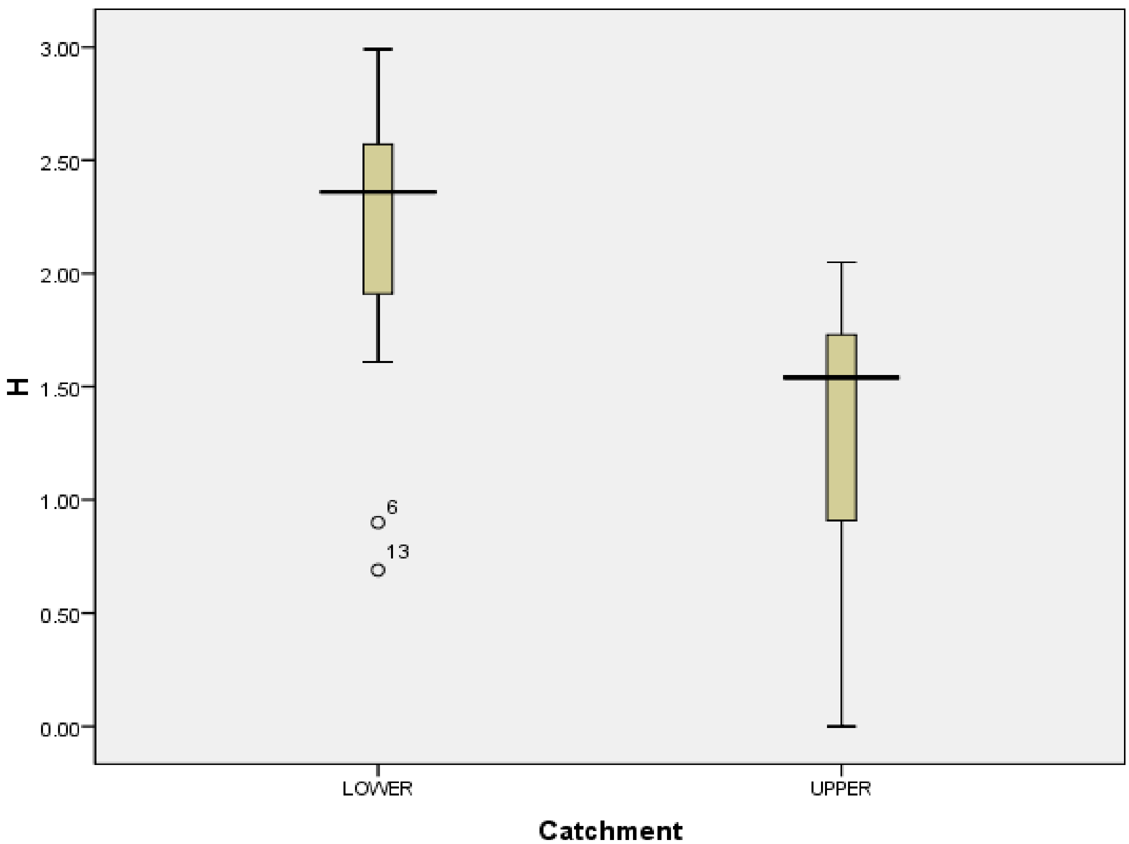

Figure 3: Comparison of the Biodiversity in Upper and Lower Catchments

DISCUSSION

The results show that dam construction results in biodiversity loss. Dam construction is very important in areas that are semi arid like in the study area as they provide a reliable source of water to communities were rainfall is erratic and unreliable. Important as they are, the construction of dams also contributes to the problem of biodiversity loss.
Future dam constructions lined up in Zimbabwe like the Tokwe-Mukorsi and Gwayi-Shangani dams' constructions need to take note of their possible impact on biodiversity and the take measures to reduce these possible losses.
The differences in diversity between the upper and the lower catchment could be attributed to a reliable source of water for the vegetation down-stream following the establishment of a water reservoir. The river now has a constant discharge and supply of water to the lower catchment vegetation through capillary action, construction of dams can

cause changes in groundwater flow lines downstream of the dam which then leads to saturation of the rooting zone and raising the water levels of shallow, unconfined aquifers of the lower catchment forest.

The fact that the lower Ruti dam catchment has higher biodiversity than the upper catchment is in sharp contrast with what other researcher concluded elsewhere. The researchers have described the decline in biodiversity of riparian forests downstream from dams (e.g. Reily and Johnson, 1982; Harris et al., 1987; Bren, 1988; Rood and Heinze-Milne, 1989; Rood and Mahoney, 1990). They attribute the decline to the altered seasonal stream flow patterns (high- and low-flow regimes), changes in channel morphology and pattern, and the retention of suspended silt, sediment, and nutrients behind the dam wall.

Furthermore, the development of a general model for predicting the impacts of dams on downstream riparian forests has proved elusive owing to the differences in species composition, geomorphic setting and hydrologic setting from site to site (Kondolf et al., 1987), as well as the dynamic response of vegetation to natural and artificial events such as droughts and dam releases.

The upper catchment has lower floral diversity because it has suffered a reduction in the population of tree species that favour dry conditions like the acacia species. This occurrence has also been noted to be causing the decline and disappearance of cycad forests on the upper catchment of the dammed Mpanga river in Uganda (www.cycadsg.org). The cycad tree does not require a lot of water and so, following the construction of the dam close to this forest, the species suffered from water logging and ultimately dried up. The waterlogged soil becomes anoxic and this leads to oxygen stress and eventual elimination of the primary root system (Nilsson and Berggren, 2000).

The species composition of the upper catchment might have to change in order to suit water logging and submersion following the damming and this might have reduced its diversity than the lower catchment. This is also affirmed by Decamps et al., (1988) who says that the forest species composition on the upper catchments will have to change the ones more characteristic of flooded upland areas when damming occurs. Also many upper catchment species are normally excluded from growing in and near free flowing river channels because of intolerance to sedimentation, erosion, submersion, physical damage, and low soil fertility. Lower catchment flora are, on the other hand, usually pioneer species, are adapted to or need such processes; they have easily dispersed seeds, rapid germination, and rapid root and height growth (Johnson, 1994).

The construction of Ruti dam has also led to the production of a micro climate with the lower catchment by virtue of being on the windward side of mountains, receives micro level relief rainfall with the moisture originating from the dam. This might have led to locally more rainfall for lower catchment and increased capacity to support more floral species than the upper catchment. Soil compaction on the upper catchment owing to heavy machinery used during construction of the dam is also hypothesized to thwart easy tree recruitment. Furthermore, there are very little nutrients left behind as the much fertile top soil is ferried away by the machines to the dam wall. This might be a factor explaining lower biodiversity on the upper catchment than the lower catchment.

CONCLUSIONS

Dam construction has been shown to cause loss of tree tress species biodiversity. This has been shown by the significant differences in biodiversity between the lower catchment which was more diverse than the upper catchment. Since dam construction causes biodiversity loss, the factor of concern with regards to proposed dam projects in Zimbabwe is that much of the remaining forests are preserved on the steep sides of valleys, which are also suitable sites for dam construction.

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