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PREDICTING AND ASSESSING THE BIOPHYSICAL ENVIRONMENTAL IMPACTS OF A PROPOSED DAM PROJECT

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Abstract This paper demonstrates the application of Geographic Information System (GIS) and Remote sensing techniques in quantifying the biophysical impacts such as the actual area to be flooded by the dam, habitat loss and ecosystem productivity loss in terms of average biomass index and average diversity index during Environmental Impact Assessment (EIA). Quantifying biophysical attributes such as ecosystem productivity is critical considering the widespread concern about global warming and climate change which has led to an interest in reducing emissions. The major challenge in dam EIA is identifying and quantifying the ecological impacts of dam construction in cases where the proposed dam is to be situated in a forest which is a habitat for animals. In most cases the people carrying out EIA find it difficult to quantify ecological attributes such as the implications of vegetation clearance to ecosystem productivity and habitat loss. The major difficulty is to quantify and attach a value to each vegetation type that will be flooded by the proposed dam project. This study therefore presents how the spatial capabilities of GIS and remote sensing can be manipulated in order to quantify different ecological attributes such ecosystem productivity so as to determine the extent of the negative implications of the dam project. The paper also demonstrates the use of GIS operations such as the neighbourhood analysis in Integrated Land Water Information Systems (ILWIS) GIS to accurately estimate the area to be covered by water after the dam is constructed. Such knowledge is critical as it reveals the magnitude of the predicted impacts so as to develop appropriate mitigation strategies.

Key words: environmental impact assessment, dam construction, GIS, Remote Sensing

Introduction

Environmental impact assessment (EIA) refers to a systematic examination of the consequences of a project with a view of improving overall environmental quality by reducing or mitigating the negative consequences and capitalise on the positive impacts (UNEP). The purpose of an EIA is to ensure that development proposals are sustainable. In theory EIA should lead to cancellation of projects. However, projects are rarely abandoned because of an EIA. Instead, EIA recommends ways of managing the negative impacts as project is implemented (Mbengo, 2007). In Zimbabwe, EIA is mandatory. The Environmental Management Act 20:27 of Zimbabwe lists dam construction as one of the projects which require EIA before resuming. This is because dam construction project can have negative implications to both the biophysical environment if EIA is not done properly. After the dam has been constructed, it usually floods an area upstream of the dam wall. This implies that after construction of the dam, the water covers some sections which used to be dry land. It is therefore critical to assess both the biophysical and the socio economic implications of the proposed dam project so as to develop a mitigation plan before the dam is constructed. Biophysical impact prediction involves assessing the implications of the proposed dam project on the vegetation, wildlife, water resources, soil quality and air quality of the area. The greatest challenge in dam construction is coming up with accurate measurements of the total area that will be flooded by water after the dam is constructed. Without the figure for the total area that will be flooded by water after dam construction, it is difficult to accurately estimate the biophysical implications of the proposed dam project. The major challenge in dam EIA is identifying and quantifying the ecological impacts of dam construction in cases where the proposed dam is to be situated in a forest which is a habitat for animals. In most cases the people carrying out EIA find it difficult to quantify ecological attributes such as the implications of vegetation clearance to ecosystem productivity and habitat loss. The major difficulty is to quantify and attach a value to each vegetation type that will be flooded by the proposed dam project. This paper demonstrates the application of Geographic Information System (GIS) and Remote sensing techniques in quantifying the biophysical impacts such as the actual area to be flooded by the dam, habitat loss and ecosystem productivity loss in terms of average biomass index and average diversity index. Quantifying biophysical attributes such as ecosystem productivity is critical considering the widespread concern about global warming and climate change which has led to interest in reducing emissions (Gorte, 2009). The process of photosynthesis combines atmospheric carbon dioxide with water. A forest ecosystem captures and retains large volumes of carbon. As trees develop a large biomass and capture large amounts of carbon dioxide as they grow. Thus forests act as carbon sequesters (Sedjo, 2001). Destroying forests is major cause for concern as the process of decaying and decomposition of dead plant matter releases the carbon that the tree would have stored for decades into the atmosphere. Carbon dioxide concentration in the atmosphere has negative implications. This is because carbon dioxide is a green house gas which traps out going long wave radiation thereby causing a rise in global temperatures or global warming and climate change. Destroying forests without replacing them has negative implications as the forests sequester carbon lessening the atmospheric carbon dioxide.

Method

Baseline survey of the biophysical environment

Baseline survey refers to the description of the current biophysical and socio economic status of the environment at the site where the dam will be constructed. According to Murwira and Murwira (2012), when a dam is constructed across a river in a valley, the area upstream of the dam wall will be flooded up to a certain level with water. Murwira and Murwira (2012) demonstrate how Geographic Information System (GIS) can be employed to explore the biophysical setting of the site of the proposed dam project.

Determining the site of the dam

Determining the dam site is a fundamental stage in baseline survey. Such information is critical as it is impossible to assess the biophysical or socio economic implications without the information on the exact position of the dam. The most critical baseline data used when determining the position of a dam project is the Digital Elevation Model (DEM) showing the relief or altitude of the terrain of the proposed dam site. This is because altitude is critical in deciding where to place the dam wall. Figure 1 depicts the altitude of the proposed dam site in metres. As shown in figure 1, the highest altitude at the site of the dam is 1438m. Figure 1 also shows that the lowest altitude in the area is 433m. This means that the dam wall will be sited where the altitude is lower as shown in figure 1.

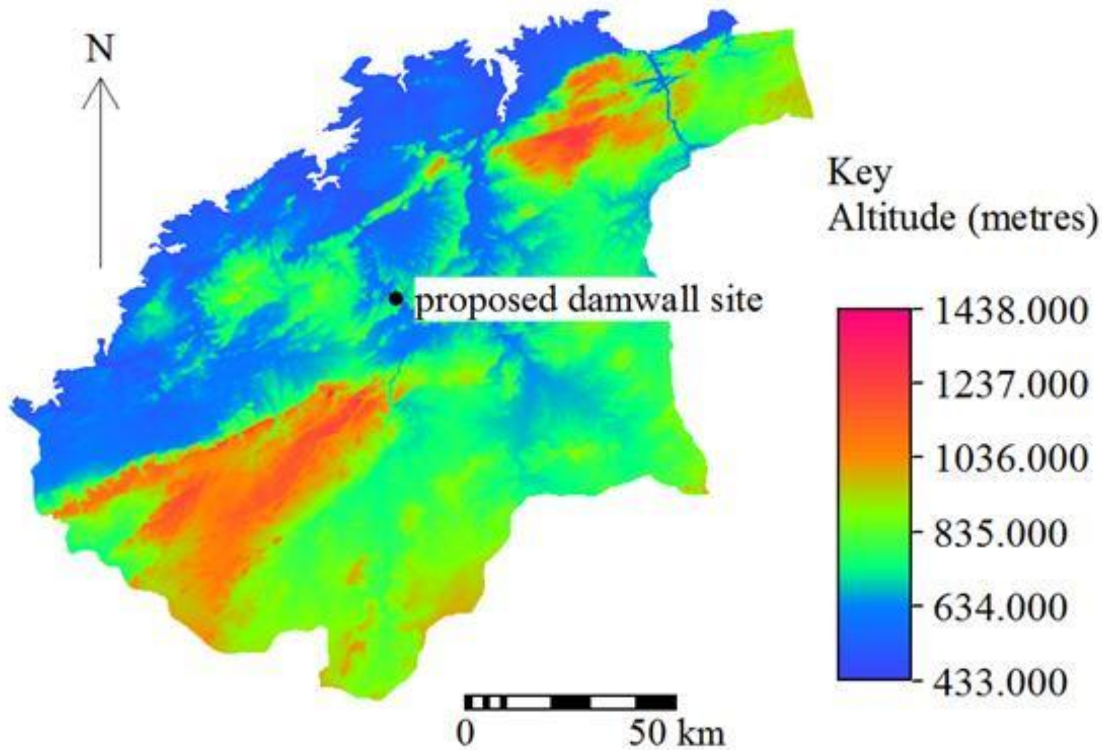

Figure 1: Digital Elevation Model (DEM) of the proposed dam site

Source (Murwira and Murwira, 2012)

Identifying the type of vegetation to be flooded by the dam

Before a dam is constructed, the baseline data should include the types of vegetation found in the study area.

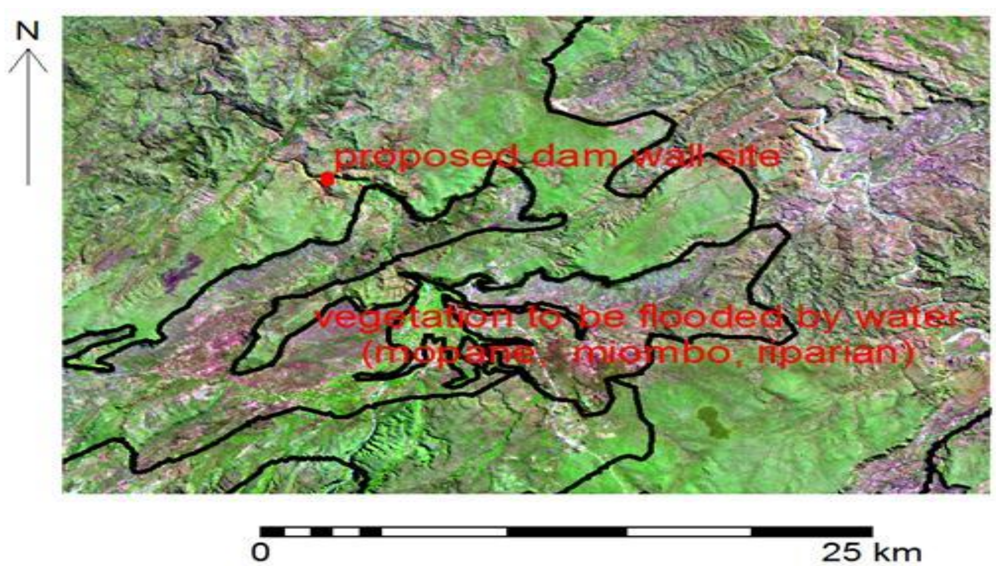

Figure 2 Vegetation type to be flooded by water

Source (Murwira and Murwira, 2012)

As shown in figure 2, the types to be flooded by water include miombo, mopane and riparian vegetation. Identifying the types of animals found in the area is crucial. It is also important to note whether the types of animal species to be affected are endangered or not. Such information will determine the mitigatory measures that will be implemented. Baseline survey in dam projects should take into cognicence the rivers which drain the area. At this stage the information on whether the rivers are perennial or ephemeral should be recorded. The geology of the area should be identified and assess whether the geology of the area supports dam construction or not.

Biophysical impact prediction

Biophysical impact prediction refers to the evaluation of the magnitude and spatial distribution of the impacts. As Murwira and Murwira (2012) suggest, biophysical impact prediction in dam construction involves determining the actual area which will be flooded after the dam has been constructed. This is done using the neighbourhood analysis function in ILWIS. The information which is used to calculate the area to be flooded includes the dam site, DEM of the dam, free board, water level.

Determining the area to be flooded by the dam

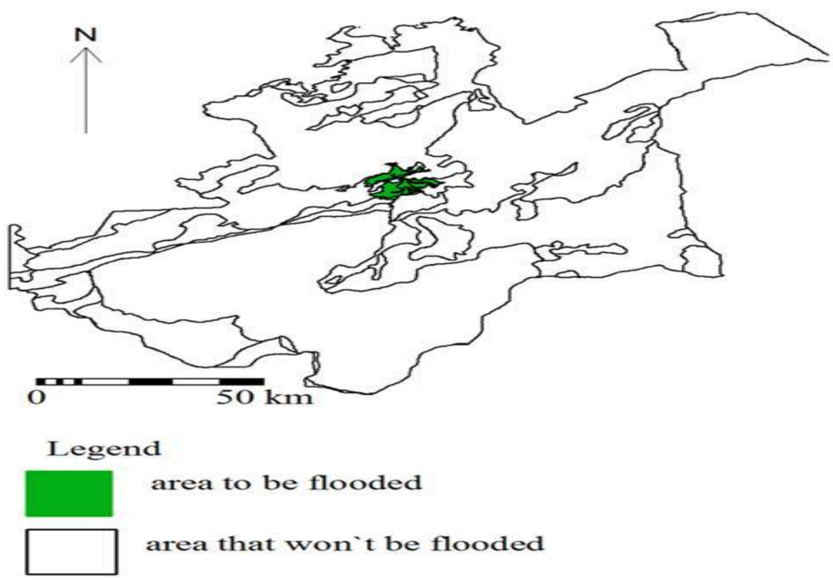

Figure 3 Total area to be flooded by water after dam construction

Source: (Murwira and Murwira, 2012)

Figure 3 illustrates the total area to be flooded by water after dam construction. As shown in figure 3, the total area to be flooded by water when the dam is constructed is 102.3km^2 . Such information is critical as it will give a guide when predicting the implications of the dam project from a biophysical perspective.

Results

Predicted impacts of the dam project on vegetation

This involves evaluation of the extent of the implications of the proposed dam project on different vegetation types found at the site where the dam will be constructed. To achieve this, the map containing the data of different species in the area is crossed with the map showing the area which will be flooded by the dam after construction. This is done in ILWIS GIS.

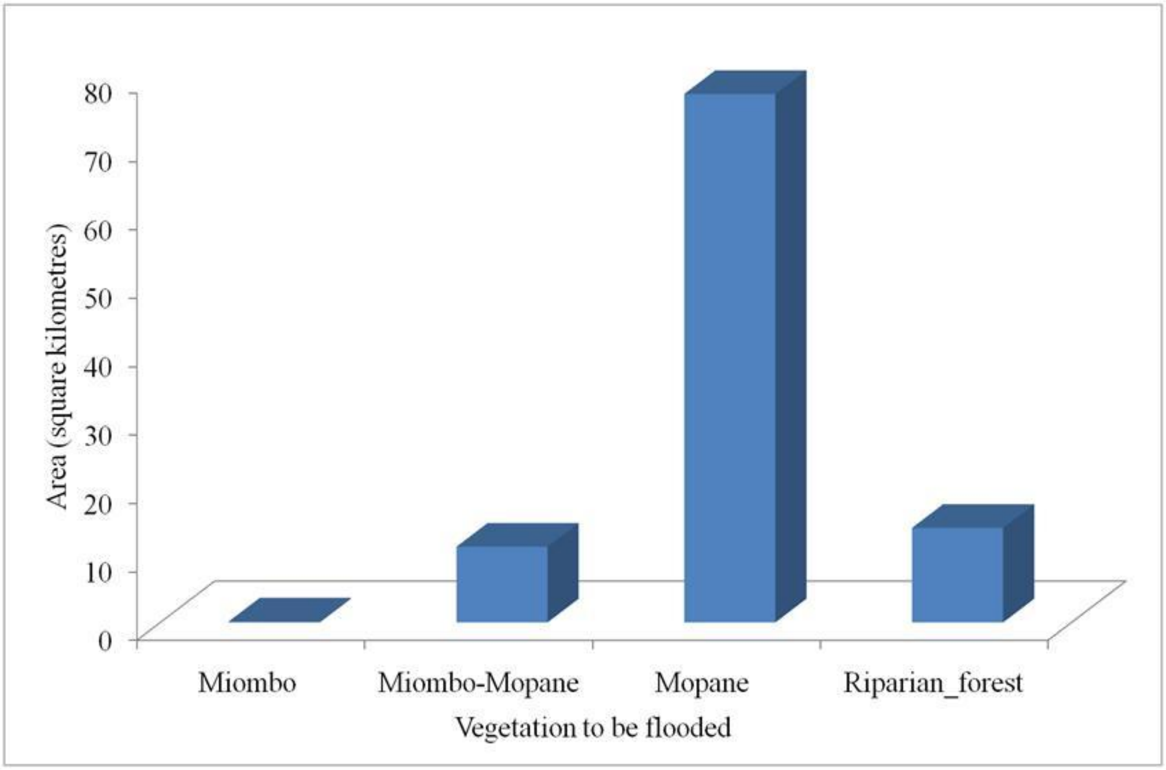

Figure 4 Predicted impacts of dam construction on vegetation

Figure 4 depicts that mopane has the highest area (77km^2) that will be covered by water, followed by riparian forest with (13.83km^2). About (11km^2) of Miombo- mopane will be covered by water. Miombo has the list figure that will be flooded with (0.12km^2).

Biophysical impact assessment

Rarity index

Biophysical impact prediction is an evaluation of the significance of the predicted impacts. Figure 5 shows the rarity index of vegetation that will be flooded by the proposed dam project. The impacts can be quantified if possible. The rarity index shows whether the vegetation to be affected by the dam project is rare or not. Rarity index indicate the type of vegetation which will be significantly reduced in size after the dam is constructed. The Rarity index is calculated in ILWIS GIS using the following formulae: Rarity=total area of vegetation type to be covered by water/total area of the vegetation type in the proposed dam site (Murwira and Murwira, 2012). As illustrated in figure 5, the dam project will significantly reduce the size of the riparian forest in the area. This also implies that miombo with a low rarity index will be less impacted by flooding compared to the vegetation type with a high rarity index which is the riparian forest. Hence the project proponent will have to take this into cognicence when developing mitigatory measures for the dam project.

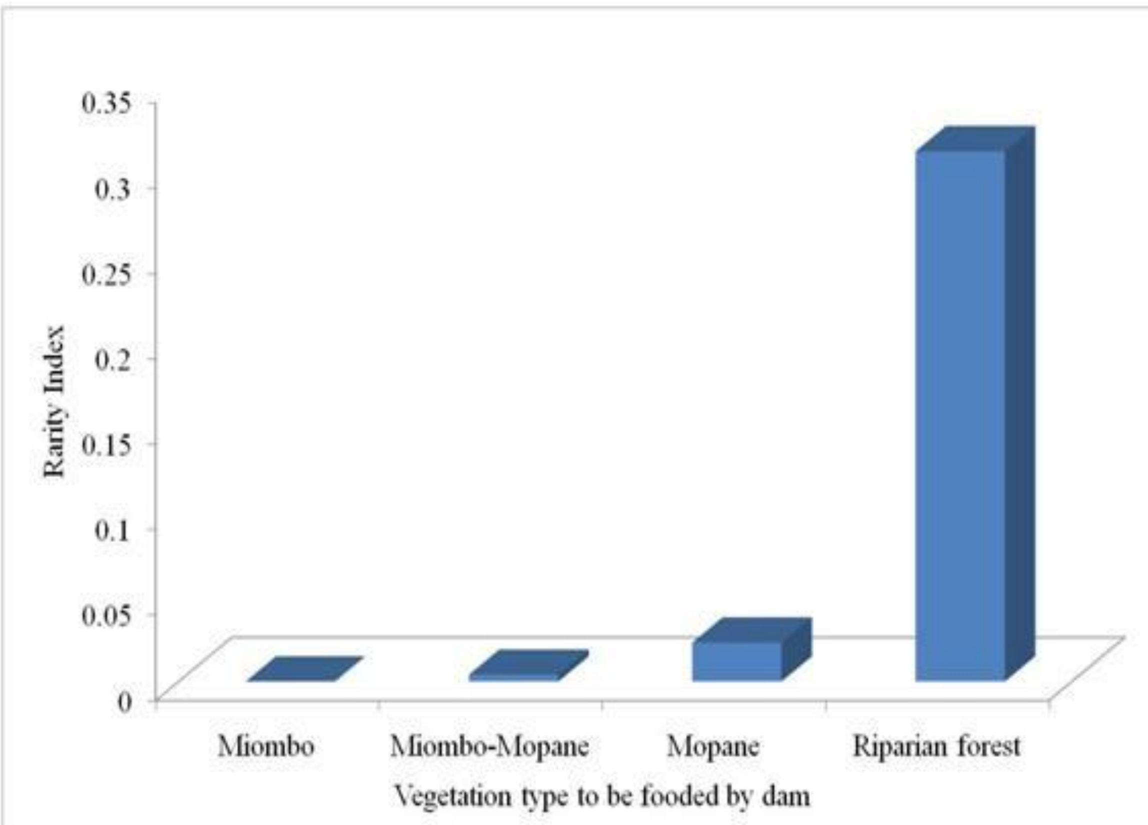

Figure 5 Rarity index of vegetation types in the study area

Effects of the proposed dam project on ecosystem productivity

Ecosystem productivity is determined by measuring diversity index and biomass index of vegetation. Estimating ecosystem productivity loss per vegetation type is critical as the proportion of carbon that will be released into the atmosphere if the vegetation is removed during dam construction varies significantly with average biomass and diversity indices of a species.

Average biomass index for each vegetation type to be flooded by the dam:

Biomass index is obtained by crossing the map of species which will be flooded by the dam after construction with the biomass map for the dam site in ILWIS GIS. The aggregation operations is then used to calculate the average biomass index for each of the species (figure 6) which will be flooded by water after the proposed dam project is complete.

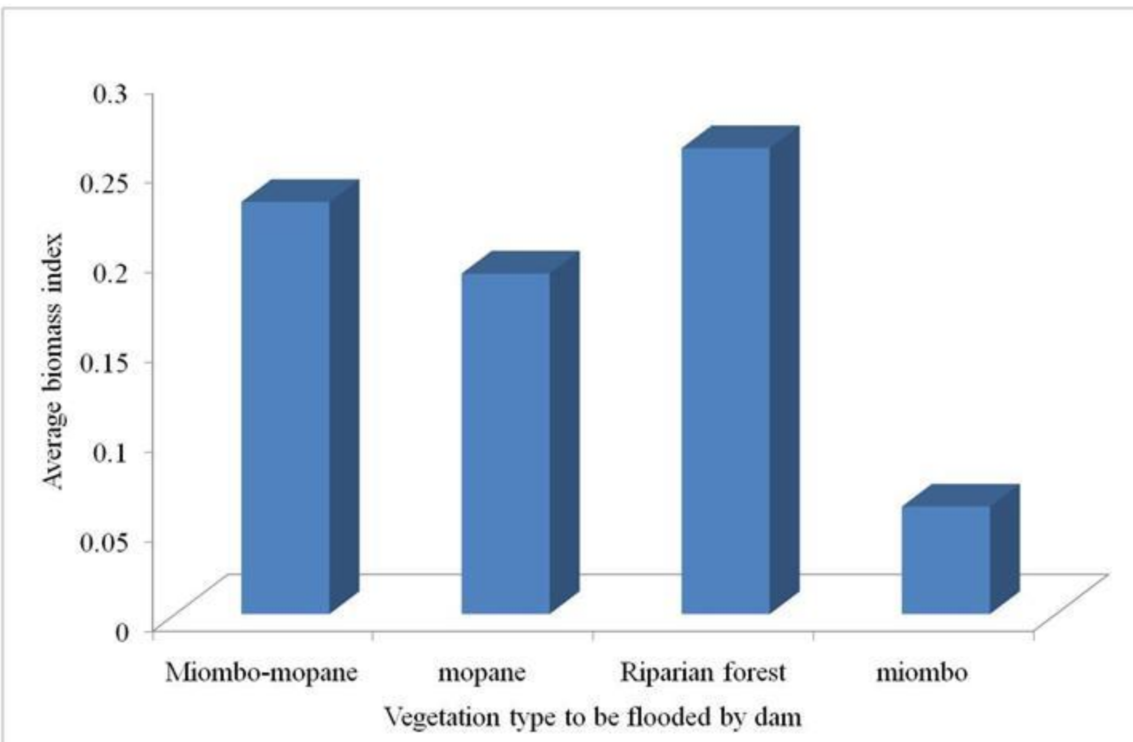

Figure 6 Average biomass index of vegetation to be flooded

The vegetation type with a low average biomass index will have a low impact on ecosystem productivity while vegetation with a high average biomass index will have a significant impact on the productivity of the ecosystem if flooded by the proposed dam project. In this case flooding the riparian vegetation with a high average biomass index of 0.26 will significantly affect the productivity of the ecosystem. Flooding the miombo forest will not have a significant effect on the productivity of the ecosystem since the average biomass index of the miombo forest is low (0.06).

Average diversity index of the ecosystem/ vegetation type to be flooded by the dam

Average diversity index for each of the species to flood by the proposed dam project is obtained by crossing the map for each of the species that will be flooded with water with the diversity map for the dam site.

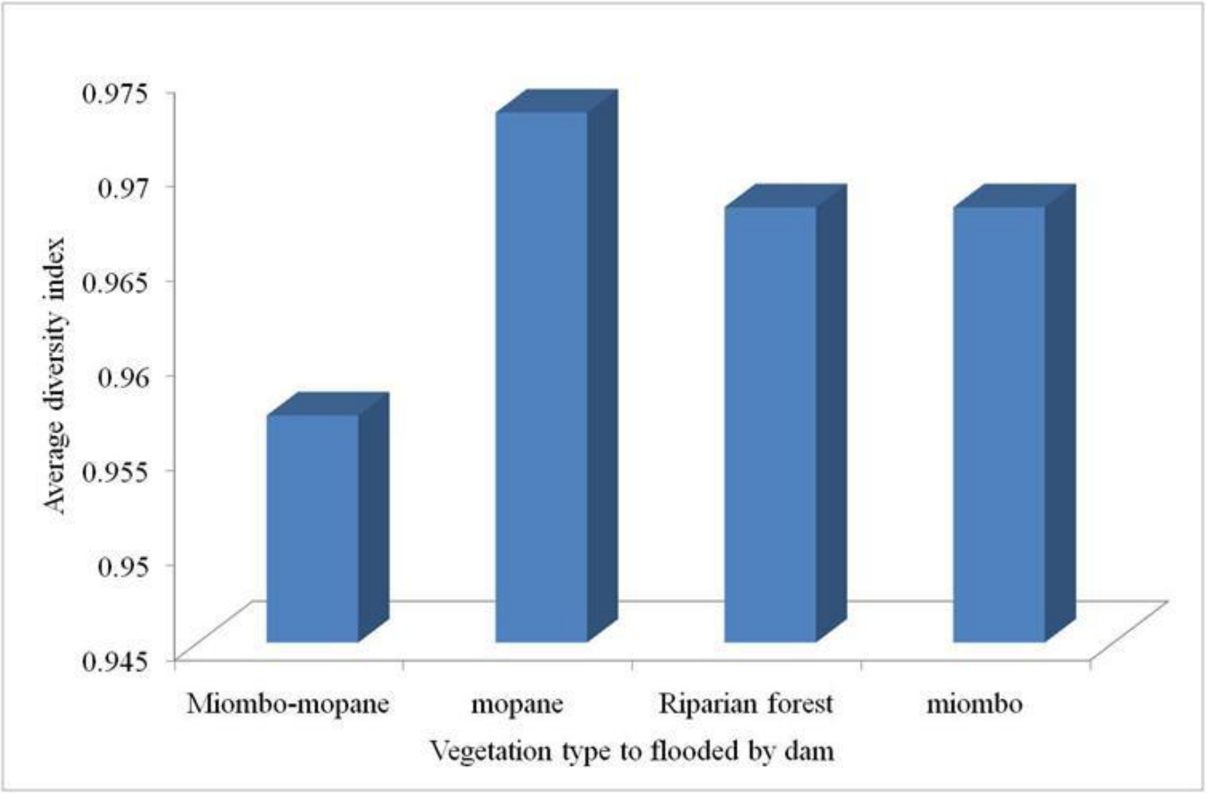

Figure 7 Average diversity index of vegetation to be flooded

Figure 7 shows that the flooding of a vegetation type with a low average diversity index will have less impact on overall productivity. This implies that the flooding of the miombo-mopane forest with a low average diversity index of 0.957 will not significantly affect the productivity of the ecosystem in the area. However, flooding the mopane forest with a high average diversity index of 0.973 will significantly affect the productivity of the ecosystem in the area.

Impacts of the proposed dam project on elephant habitat

Assessing the impacts of proposed projects on endangered animal species is critical if the site for the proposed dam is an elephant sanctuary. This involves determining the number elephants that will lose their habitat due to the flooding of each vegetation type at the dam site. To achieve this, the map showing the elephant density per square kilometre is crossed with the map for the vegetation types that will be flooded by the dam. This method can apply to other wildlife species besides elephants.

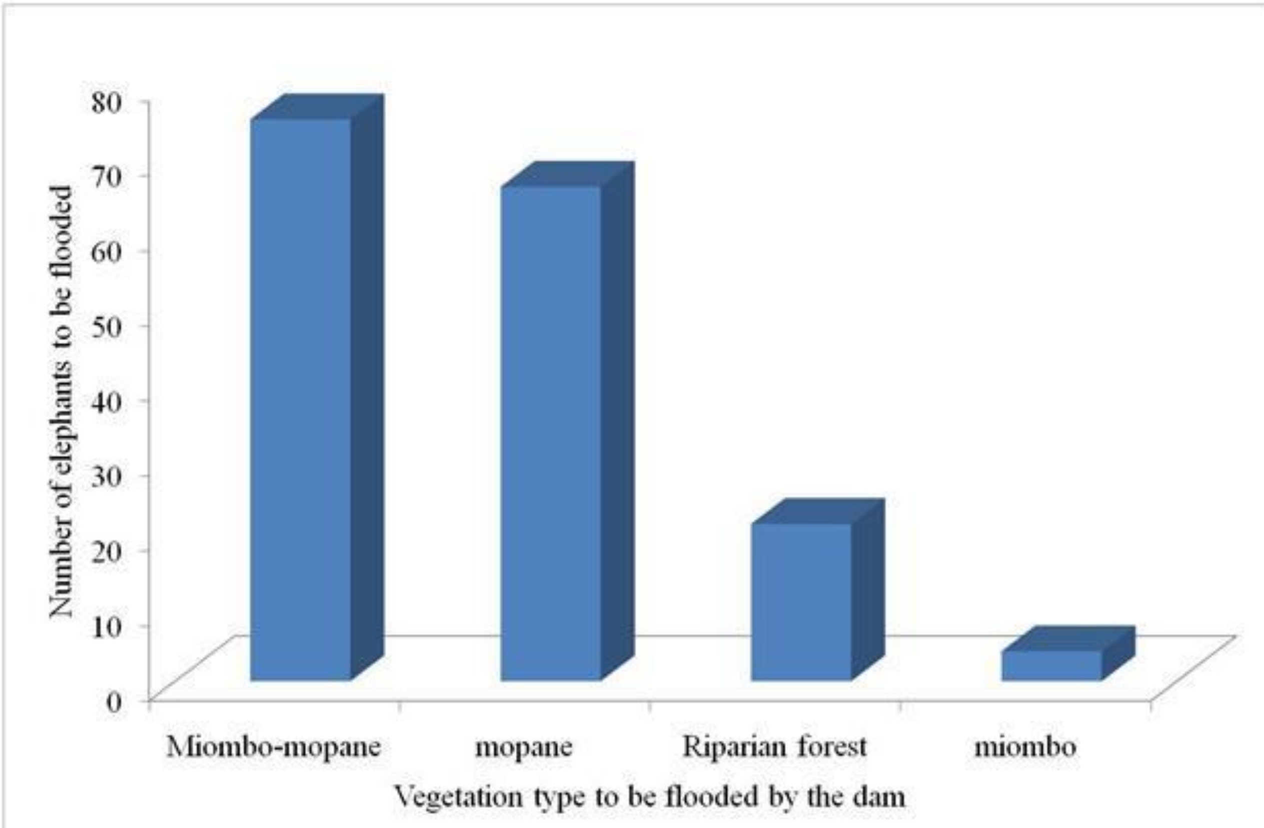

Figure 8 Number of elephants to be flooded per habitat/vegetation type

Figure 8 indicate that flooding the miombo-mopane forest will have a significant impact as this will imply that a total number of 75 elephants will lose their habitat. Only 4 elephants will lose their habitat if the miombo forest is flooded by water after dam construction. This implies that flooding the miombo forest will not have a significant impact on elephant habitat as the miombo forest is not used by elephants for habitat.

Mitigation measures that may minimise the negative biophysical impacts of the dam project.

Table 1 mitigation measures for the significant impacts of the proposed dam project

Significant impact	Mitigation plan
Rarity index (Riparian forest, 0.31)	reforestation
Biomass index (Riparian forest, 0.26)	reforestation
Diversity index (Mopane, 0.973)	reforestation
Habitat loss (Miombo-mopane, 75)	Relocate the elephants to a nearby park

As shown in table 1, the proposed project will have a significant impact on the productivity of the ecosystem of different vegetation types. The riparian forest will be significantly affected as depicted by the high biomass index and rarity index figures which are 0.26 and 0.31 respectively. Table 1 also indicates that flooding of the mopane forest will have a significant impact on the diversity of the ecosystem as the mopane forest has the highest diversity index (0.973) among all the vegetation types at the site of the proposed dam project.

As indicated in table 1, the proposed mitigation plan to address the significant implications of the dam project on ecosystem productivity is reforestation. This is because destroying forests significantly alters the carbon cycle as forests act as sequesters of the atmospheric carbon dioxide which is linked to climate change. Land use changes such as dam construction alter vegetation on a site, affecting carbon storage and release by changing the biomass levels. The decomposition which occurs when the vegetation is destroyed releases large amounts of carbon back into the atmosphere (Gorte, 2009).

Table 1 also illustrates that flooding of the miombo-mopane forest after the dam is completed will have a significant impact as 75 elephants will lose their habitat. In this case the best mitigation plan is to drive away the elephants to a near elephant conservation area before the dam project start. This is because flooding and killing elephants is not acceptable form a conservationist perspective as CITES regard elephants as endangered species which requires conservation to prevent extinction.

Recommendations

This discussion suggests that, when carrying out EIA for dam projects to be sited in areas with a large forest, there is need for the EIA team include a GIS and Remote sensing expert so that the impacts of proposed project on ecological attributes such as ecosystem rarity and productivity are quantified. Quantifying the amount of loss of diversity and biomass of the ecosystem to proposed dam projects is critical as this determines whether the impacts will be significant or not. Such knowledge is crucial as it provides appropriate management and mitigatory measures which ensures that the project goes ahead without compromising the ecological processes at the site.

References

- Gorte, R.W. (2009) Forest carbon sequestration: Some issues for forest investments. Discussion paper 01-34 Research for future, Washington D.C
- Sedjo, R.A. (2001) Carbon sequestration in forests CRS Report for Congress
- Murwira, K.S (2012) Biophysical Impact Prediction Geo-Information and Remote Sensing Institute, SIRDC (unpublished)
- Murwira, A. (2012) Biophysical Impact Prediction Department of Geography and Environmental Science, University of Zimbabwe (unpublished)