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# Land Suitability Zoning for Ecotourism Planning and Development of Dikgatlhong Dam, Botswana

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### *Abstract*

The main objective of this paper was to discuss applications of GIS based multi-criteria decision analysis (GIS MCDA) and Analytical Hierarchy Process (AHP). These two techniques were applied in order to assist preparation of the Tourism Management Plan, depicting the most suitable zones for ecotourism development in Dikgathlong Dam Lease Area (DDLA) as one of the largest resources of potable water in Botswana. The MCDA was based on geo-morphometric, hydrologic, landscape and community indicators and criteria which emanated from expert's opinions, intensive field survey and literature review. In addition the AHP has helped to calculate individual criteria weights and to point the degree of suitability zones classified as highly suitable, moderately suitable, marginally suitable and not suitable for ecotourism. After performing both processes and establishing broad management zones it has been found that the Sustainable Development Scenario is the most appropriate option as the future ecotourism development proposal. This research provides new methodology that can be incorporated into future tourism policies and management strategies.

**Keywords:** GIS, multi-criteria decision analysis (MCDA), analytical hierarchy process (AHP), ecotourism, land suitability zoning.

## Introduction

The tourism sector is one of important drivers of Botswana's economic growth and over the years has contributed significantly to the country's economic output (accounting for almost 12% of GDP) (Saarinen et al., 2012; Statistics Botswana, 2015, GISPlan, BTO, 2016; 2017). The challenge however, is that even though Botswana is endowed with a wide range of tourism assets, and referent institutions has brought numerous tourism acts and strategies, which provide the basis for developing a much more diversified tourism product for the country, it is not all yet developed to fullest potential (Mbaiwa, 2005; Kaynak & Marandu, 2006; Basupi et al., 2017). In this way, niche tourism products and markets (such as Dam tourism) can be created and propagated in Botswana.

Ecotourism is the most recently used term for a sustainable form of tourism targeting preserved areas which need environmental conservation, visitors education, cultural preservation and experience, and economic benefits for local community (Cobbinah, 2016; Gigović et al., 2016; The International Ecotourism Society [TIES], 2015). It emerged in the 1990's as an alternative form in order to neutralize the disadvantages of conventional (mass) tourism, with respect to sustainable development (Bunruamkaew & Murayam, 2011). From socio-economic standpoint, ecotourism delivers a variety of economic benefits (Whelan, 1991; Cobbinah, 2016). Ideally, ecotourism should take care of conservation of biological, hydrological and cultural

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diversities (Ryngnga, 2008; Cobbinah, 2016; Gigović et al., 2016).

GIS and remote sensing tools are widely used for identifying location suitability and resource inventories according to environmental, socio-economic and spatial planning concerns (Jankowski & Richard, 1994; Malczewski, 2006, Charabi & Gastli, 2011; Gigović et al., 2016). GIS suitability mapping involves usage of a different data sources where weights are assigned to determine the importance of particular criteria (Janke, 2010; Bunruamkaew & Murayam, 2011; Al-Yahyai et al., 2012). In recent years, multicriteria decision analysis (MCDA) or multicriteria decision making approach (MCDMA) is widely exploited by many experts in order to holistically evaluate the suitability of particular land area for different purposes, e.g. flooding prevention (Fernández & Lutz, 2010), wildfire risk estimation (Kant Sharma et al., 2012), agricultural management (Mendas & Delali, 2012) or energy generation (Abudeif et al., 2015). A few efforts were done to analyze ecotourism potentials as well (Bunruamkaew & Murayam, 2011; Koschke et al., 2012; Gigović et al., 2016; Jeong et al., 2016; Fang, 2017; Çetinkaya et al., 2018).

One of the most widely used MCDA weight estimation and criteria correlation technique is the Analytical Hierarchy Process (AHP) (Mardani et al., 2015). This method provides a structural basis for quantifying the comparison of decision elements and criteria in a pair wise matrix (Saaty, 1980). Typically, the priority of each factor involved in the AHP analysis is determined based principally on the expert's opinions or information from various literature sources (Saaty, 2008; Alexander, 2012). This method has proven as beneficial decision-making tool for future planning of tourism facilities, ecotourism resource utilization and sustainable development (Zhang & Yang, 2009; Bunruamkaew & Murayam, 2011; Mohd & Ujang, 2016).

By using the aforementioned practices the main goal of this research was to identify and categorize locations suitable for ecotourism development in the wider Dikgatlhong Dam Lease Area (DDLA) in Botswana, based on the following:

1. Finding suitable criteria to be used in the analysis
2. Assigning criteria priority, weight and class weight (rating) to the parameters involve
3. Production of land suitability maps for ecotourism development potential
4. Zoning of ecotourism potential areas (Broad Management Zoning - BMZ).

## Study area

Dikgatlhong Dam is situated in the north-eastern part of Botswana about five kilometres upstream of the Botswana-Zimbabwe border at the confluence of Shashi and Tati River, and in close proximity to villages of Robelela to the South, Matopi to the North and Patayamatebele to the NW (Figure 1). The DDLA covers an area of 13,124.64 ha, while the Dam itself is a zoned earth fill structure, 41 metres high and 4.5 kilometres in length. Dikgatlhong Dam, as the largest dam in the country, has a total capacity of 400 million m³.

Border of the lease area was agreed by respecting several criteria, among which the most relevant were

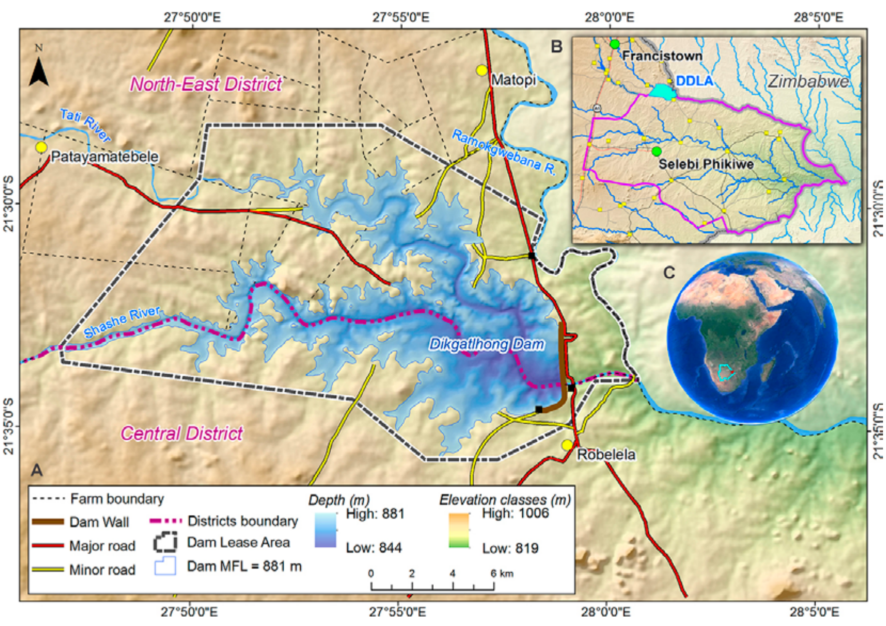


**Figure 1.** Study area

tribal regulation, govermental regulation, as well as general consensus with local community (GISPlan, BTO, 2016; 2017). As a result, the present border of the DDLA represents a compromise, still ongoing (Figure 1, A). The land tenure in the DDLA is all tribal land. However, Water Utilities Corporation (WUC) has leased a large area so far and there is a recent intention to make consensus with Botswana Tourism Organization (BTO) who will then be in a position to lease concession areas to prospective tourism operators. The Dam falls within the SPEDU (The Selebi Phikwe Diversification Unit Company) region, dedicated for diversified economic development (Figure 1, B) (GISPlan, BTO, 2016; 2017).

## Materials and methods

### *Data Sources*

During the planning process the five-step data collection approach encountered for the following: (i.) primary and secondary data collection; (ii.) development of GIS mapping models based on concepts, spatial/environmental logics and mathematical calculus; (iii.) GIS analysis and visualisation of criteria identified; (iv.) interpretation of analytical data and aerial zoning according to suitability; (v.) application of the results and stakeholders involvement.

The primary data from the field survey were collected through administration of interview questionnaires to the public. This helped to merge outcomes from field survey, literature findings, historical, statistical, GPS and drone record with GIS and environmental planning expert datasets. Additionally, some open data sources were also utilised including Statistics Botswana, Regional Center for Mapping of Resources for Development (RCMRD), and Earth Explorer.

### *Multi-Criteria Evaluation (MCE) and Analytical Hierarchy Process (AHP)*

After goals setting, the combined MCA and AHP methodology was performed in five major steps specifying the hierarchical structure, determining the relative important weights of the criteria and sub-criteria, assigning preferred weights of each alternative,

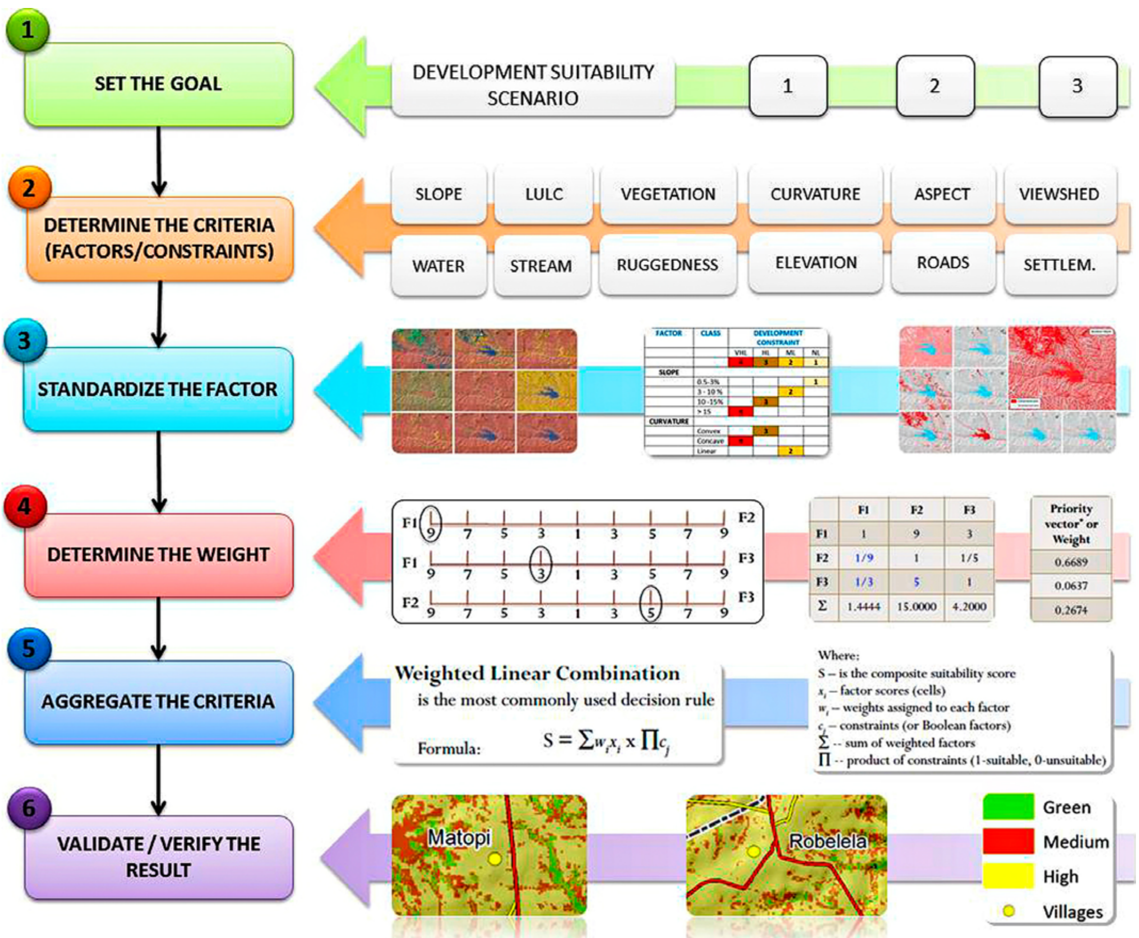


**Figure 2.** Phases of MCDA process (Source: GISPlan, BTO, 2017)

determining the final score, and, finally, validating achieved results/model (Figure 2).

### *Determination and Classification of Criteriae*

The following set of criteria as indicators of suitability within the land ecosystem of DDLA context were identified and analysed: geomorphometric (slope, aspect, ruggedness, land form, planar curvature), landscape (vegetation, land cover and land use), hydrology (rivers and lakes) and community features (settlement size and roads accessibility) (Table 1).

### Hydrology

Drainage density of DDLA is a sign of amount of streams and tributaries, leading to a relatively rapid hydrologic response to rainfall events, or having a slow hydrologic response in a poorly drained basins (Curry & Horn, 2009). In the context of future ecotourism development, the DDLA basin act as focus for potential ecotourism sites. Its surrounding tributaries and central water body are crucial for spatial organisation of tourism activities based on water carrying capacities.

**Table 1.** Criteriae used in the research

| Cluster | Factors | Unit | Source | Reference |
|---|---|---|---|---|
| Landscape | Land use/Land cover | class | RCMRD (2010); LANDSAT (2015) - 30 m | Bunruamkaw & Murayam, 2011; Gigović et al., 2016; Jeong et al., 2016; Fang, 2017; Çetinkaya et al., 2018 |
| | Vegetation | class | LANDSAT (2015) - 30 m; Terrain mapping | |
| Topography | Slope | degree | Topographic map (1:25.000); Terrain mapping | Zingg, 1940; Lee & Min, 2001; Saha et al., 2002; Fernández & Lutz, 2010; Jeong et al., 2016; Fang, 2017; Çetinkaya et al., 2018 |
| | Planar curvature | type | | Ayalew et. al., 2004; Milevski, 2008 |
| | Landform | type | | Blaszczynski, 1997 |
| | Aspect | side orientation | | Mitasova et al., 1996; Kumar et al., 1997; Fang, 2017; Çetinkaya et al., 2018 |
| | Ruggedness | type | | Sappington et al., 2007; Hochstetter et al., 2008 |
| Hydrology | Rivers and lakes | mask | National Data Infrastructure | Mahdavi & Niknejad, 2014; Gigović, 2016; Jeong et al., Fang, 2017; Çetinkaya et al., 2018 |
| Community | Settlement size | population size | Census 2001 | Bunruamkaew & Murayam, 2011; Jeong et al., 2016; Fang, 2017; Çetinkaya et al., 2018 |
| | Road network | mask | National Data Infrastructure | Gigović et al., 2011; Chandio & Matori, 2011; Fang, 2017; Çetinkaya et al., 2018 |

### Geomorphometric parameters

Terrain mapping was performed because the Dikgatlhong Dam was not built at the time when official DSM topographic maps were produced. A digital raster-based terrain model (DTM) of the DDLA was generated from contours after vectorization of topographic map (1:25.000). Elevation dataset was created using ANUDEM method as the most effective way for interpolating contours (Hutchinson, 1989). Suitable pixel size (spatial resolution) was set to 5 m, according to the Complexity of terrain method (Hengel, 2006, Šiljeg et al., 2018). Five geomorphometric parameters were identified as relevant for the purpose of this research, since literature review showed that they were already used in similar analysis: slope (Zingg, 1940; Lee & Min, 2001; Fernández & Lutz, 2010; Saha et al., 2002), planar curvature (Schmidt, 2003; Šiljeg et al., 2018; Ayalew et al., 2008), aspect (Mitasova et al., 1996; Kumar et al., 1997), ruggedness (Lozić, 1995; Sappington et al., 2007; Hoechstetter et al., 2008) and landforms (Swanson et al., 1988).

### Landscape parameters

Land Cover/Land Use (LCLU) – The DDLA land cover is dominated bylimited woodland facets, bush land, savannah, wooded and open grassland (Bunruamkaew & Murayam, 2011; Gigović et al., 2016). According to Land Cover/Land Use (LCLU) map, generated from the RCMRD (2010) and the United States Geological Survey (USGS) - Earth Explorer (2015) data bases (Fuzzy overlay), there were seven distinctive LCLU classes in DDLA planning area. Each class is importance for balancing bio-diversity and human activities in tune with nature.

### Vegetation

The DDLA vegetation classes are generated from the same data source by performing supervised classification of satellite images (USGS - Earth Explorer, 2015), as well as terrain mapping for model quality control. Similarly, to other important factors which could attract tourism and mitigate environment, different measures for further expansion of vegetation and related wildlife species are incorporated in criteria for generating suitability maps for the three planning scenarios (Bunruamkaew & Murayam, 2011; Gigović et al., 2016).

### Community

*Settlement size*

Settlement and population zones were excluded as potential ecotourism areas, due to fact that their existence is opposed to the main principles of sustainable tourism (Bunruamkaew & Murayam, 2011). According to the Population Census (2011), the largest of all settlements surrounding the Dam is Mmadinare, with a total population of 11,672. It is followed by Matsiloje (2,380), Tshokwe (1,070), Robelela (829) and Patayamatebele (349).

*Road network*

The accessibility of the ecotourism site is largely affected by current road network which needs upgrades and improvements in order to enables the development of DDLA tourist destination and brand (Chandio et al., 2014).

### *Determination of Weight Values and Standardzation of Criteria*

After relevant criteria were studied and combined, the process of weight value estimation and standardization commenced. Two different approach were used in this regard: (i.) boolean mask (constraints) and (ii.) continuous surface method with analytical hierarchy process. Range of class values was from 0 (not suitable) to 1 (highly suitable), with only 0 and 1 in the case of Boolean approach, and with intermediate values in the case of continuous surfaces.

The AHP method was applied by using Microsoft Excel and ArcGIS to determine the relative importance of all selected factors. The total suitability score for each land unit (i.e. each raster map cell/pixel) was calculated applying linear combination of individual suitability scores for each criterion. For MCDA method, the assigned weights were summed up to 1 for each category/subcategory, and then each criterion in the last layer was grouped into 4-5 suitability classes with their appended scores ranging from 0 to 1. The total suitability score for each criterion was accumulated in order to produce contextual maps for conservation, sustainable and intensive ecotourism development.

To ensure the credibility and relative results significance, the AHP has also provided mathematical judgement and determined inconsistency. According to references from literature (which point on ratios between 0.04-0.10), the attained Consistency Ratio Index (CRI) of 0.04, was acceptable for the DDLA suitability analysis and establishment of the four (S1-S4) development suitability classes:

- S1 Class: Minor or no suitability limitations (no development restrictions).
- S2 Class: Moderate limitation (moderate development)
- S3 Class: High suitability limitation (low development)
- S4 Class: Very high limitations (low or no development)

### *Broad management zoning*

DDLA was delineated into broad management zones, with three alternatives presented for evaluation and consideration, where ad what kinds of land use zones/activities shall be best located in the DDLA. These zones have been established to serve as management units, within which prospective tour operators/concessionaires shall (through open tenders) be granted rights to carry on prescribed or recommended tourism activities for each zone.

The zonation is based on the outcomes of previously described spatial and suitability analysis, which considered all aforementioned factors and parameters for ecotourism development inclusive of bio-physical characteristics, resources and site location, vis-a-vis the whole DDLA, and related tourism and recreational attractions/opportunities. The management zones, thus aim at classifying land development uses within zones according to the levels of sensitivity and suitability of each zone. Management zones are to a large extent aligned with the zoning requirements in terms of activity types (land and water based). It is envisaged that specific land use/tourism activities will be assigned to each zone, Based on the zone type it is believed that tourism activities and facilities presented in Table 2 would be in line with the tourism development vision for Dikgatlhong Dam eco-tourism areas.

## Results and discussion

### *Site suitability analysis planning scenarios recommendations*

#### Conservation Development – Suitability Scenario I

This scenario was proposed in order to guide DDLA development zones with ecological and resource significance and thus important for their protection and conservation. In summary its aim is to support conservation of ecologically fragile transects which include riparian vegetation and flooding zones presented in Figure 3.

As can be gleaned from the map 3, there are four suitability classes assigned to this scenario. The largest is land protection area measuring 8,872.89 ha or 43,49% of the total land mass. It is followed by water protection area (the dam) with the same regime of excluded development accounting for 7,474.14 ha or 36.64 %. The low density type of development is allowed on 3,591.82 ha or 17.60%, thus placing the focus on conservation development and green urbanism types. The smallest land chunk belongs to fully restricted area on hilly sides with 462 ha or 2.27% respectively.

Zones of valuable natural vegetation and ecological sensitivity, which should be protected and conserved, while not being suitable for intensive development are more suited for recreational uses and wildlife habitats. Conservation efforts should therefore be focused on preservation/regeneration of natural vegetation cover, due to its role in wildlife support, water regime regulation, soil improvements and recreational opportunities.

#### Sustainable Development – Suitability Scenario II

The suitability analysis in this scenario has sought to establish the planning framework for controlled eco-tourism developments where transition between no-development and moderate developments should be highly visible (Figure 3). Based on principles of smart growth, resilient and sustainable development this scenario shows more flexibility. It has aimed to secure balance between "the design with nature" and concentrated developments based on use of sustainable building technologies and improved water and energy use.

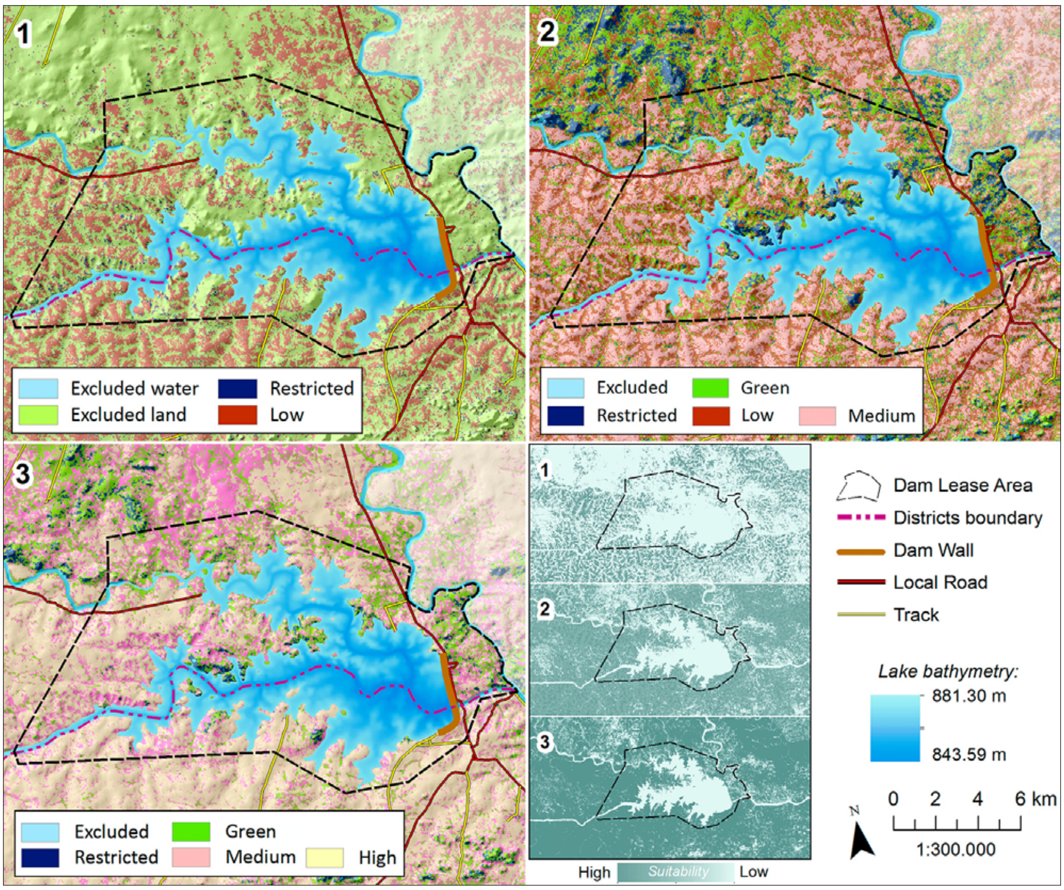


**Figure 3.** MCDA classification for 3 scenarios: 1) Conservation Development, 2) Sustainable Development and 3) Intensive Development

The largest portion is still under protective regime which includes 7,501.06 ha or 36.64% of the Dam water surface. Conservation sites cater for 1,504.89 ha or 7.38% and they are all restricted for development. Different forms of green urbanism are permitted to take place at the bottom of hilly sides on 3,936.47 ha or 14.39% of land, under condition of application of adequate engineering and environmental protection techniques. Low density development is approved in an area of 4,515.21 or 22.13%, while the medium density development can be implemented on 3,945.04 ha or 19.34% of total DDLA.

### Intensive Development – Suitability Scenario III

The third scenario is in favour of mass tourism and limits the extent of environmental protection and conservation. It allows introduction of more intensive forms of development spreading over larger portions of land. If not controlled, this type of development could compromise the basic function of the Dam as a water resource of national importance. Also, other valuable ecological elements (e.g. natural habitats, stream channels, quantity/quality of water, landforms), protected in previous two scenarios could be endangered and basic tourism attractions can fade away. This model opens the room for built-environment growth and intensive change of land use and land cover.

According to this planning framework one third of the area is still dominated by the Dam water body (Figure 3). Conservation area is highly limited absorbing only 363.70 ha or 1.78%. On the other hand, this model captures more than 10,000 ha or 51.06% to be designated for different forms of medium and high density development. More sustainable development forms prescribed in Scenarios I and II are foreseen around hilly sides occupying 2,131.08 ha or 10.45%.

### *Recommended Planning Scenario – Proposed Tourism Management Plan*

Based on planning team work, public and clients inputs, and the MCDA results scrutiny, it was concluded that the best performance for ecotourism development may occur under Sustainable Development Scenario. Conservation Development Scenario doesn't leave much potential for economic development, while Intensive Development Scenario marginalizes some of the natural values of the area.

The proposed scenario depicts the sensitivity and suitability of the DLLA sites vis-a-vis the possible tourism activities/land uses, providing a wider range of tourism products that will appeal to various market segments. At the same time strives to strike a balance in terms of ensuring the sustainability of the ecosystems, biodiversity and acceptable change of DLLA carrying capacities without exceeding.

Eleven zones of sustainable development were established in this proposal and shown on Figure 4. Nature based activity use zone (land) covers an area of 5,265.77 ha (dry land area and inundation area) or 32.60% of the total DDLA and nature based activ-

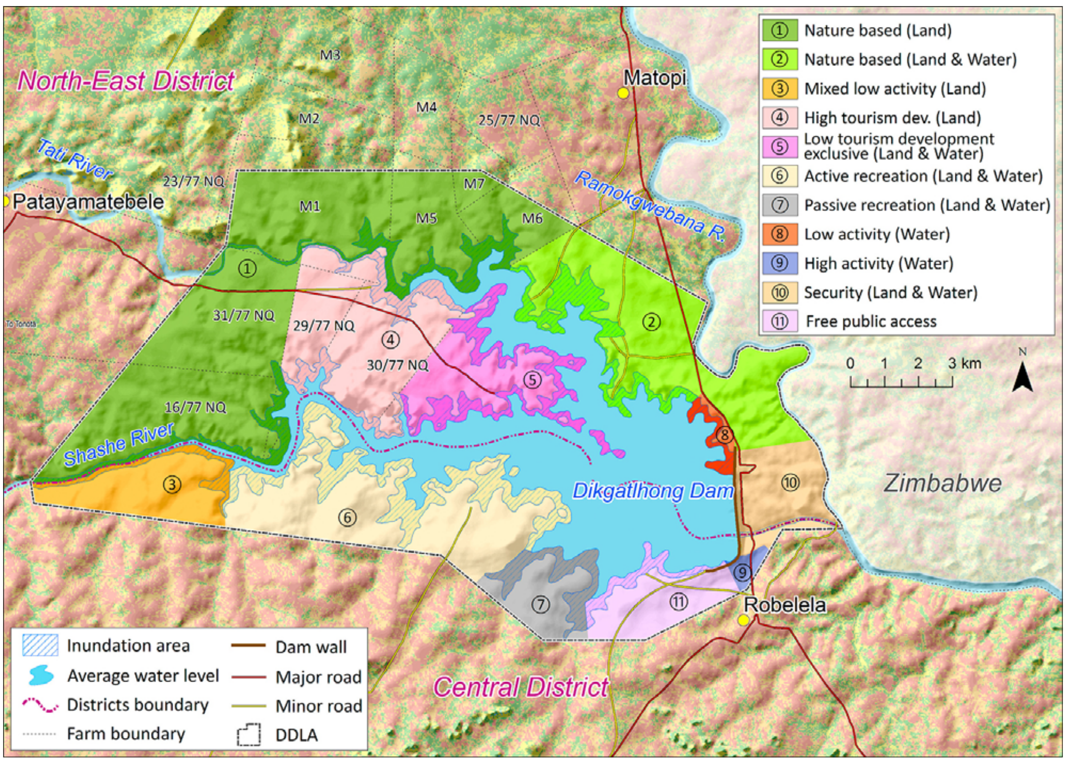


**Figure 4.** Sustainable development zoning proposal

**Table 2.** Sustainable Development Zoning - Possible Land Uses and Activities

| Broad Zones | Possible Uses/Activities |
|---|---|
| Nature Based Use Zone (Land) | Game Park, Game viewing Drives, Guided walking Trails, Bird watching, Photographic safaris |
| Nature Based Use (Land & Water) | Camping sites, walking Trails, Bird watching, sport fishing |
| Mixed Low Activity Use Zone (Land) | Horse Riding, Curio/Coffee shops, Art Gallery & Exhibitions |
| High Tourism Development Use Zone (Land) | Lodges, Conference facilities, Hotel staff accommodation, corporate events |
| Low Tourism Development Use Zone (Land) | Holiday Homes/Apartments, Exclusive Lodge Resort, Corporate Retreat centre, Boat cruises, sport fishing, Bird Watching |
| Active Recreational Use Zone (Land & Water) | Theme/Amusement park, Roller Coaster, Jumping Castles, Hot air Balloon over the Dam, Water slides, viewing Platforms, Vending stalls |
| Passive Recreational Use Zone (Land & Water) | Picnic sites, viewing platforms, Bird watching, vending stalls, curio and craft shops, coffee shops & Restaurant, Braai Areas |
| Low Activity Use Zone (Water) | Sport fishing, Boat sailing, House Boat cruising, canoeing, low speed Boat cruises, Dam Aquarium |
| High Activity Use Zone (Water) | Speed Boat Racing, Canoe paddling/rowing races and competitions, Water sports, water aerobics |

*(Source: GISPlan, BTO, 2017)*

ity use zone (land and water) covers a total area of 2,295.83 or 14.22% of the total DDLA. High tourism development use zone (land) covers a total area of 1,801.26 or 11.15% of the total DDLA, while on the other hand, the low tourism development exclusive use zone (land and water) covers a total area of 1,133.83 ha or 7.02% of the total DDLA. The smallest zones, under this proposal, in terms of size are low activity (water) and high activity (water) use zones occupies 143.10 ha and 86.10 ha respectively.

## Conclusion

Sustainable planning and management of DDLA aimed to conserve and maintain the biodiversity of the area, as well as to support economic diversification of surrounding communities. In this respect, MCDA and numerous spatial analyses and evaluation of individual and group of parameters applied in this research are all regarded as an important tool for application of sustainability, smart growth, and green planning principles for tourism master planning in a protected area. The outcomes of the DDLA's spatial and suitability analysis has enabled a clearer understanding of the characteristics of the area as a spatial entity; a bio-physical environment; and its inherent development opportunities as a tourism destination.

MCDA based scenarios showed variations in the term of sustainability analysed through the three different scenario models: conservation, sustainable and intensive. Accordingly, and in the light of ecotourism and its key objectives, the most relevant scenario for further planning and management of land use zones was sustainable development. Zoning proposals of this scenario are good example of how should spatial planning be performed using modern techniques in the region where local communities are willing to attract investments for the development of ecotourism establishments.Therefore, a more "practical" policies and related strategies, that consists of specific problem-solving methods and management directions, should be developed in the future.

The flexibility in the use of MCDA and AHC techniques presents a promising new approach to improve interdisciplinary research as exemplified in this article. The analysis results give comfort in the rightful decision making by local and central government authorities, investors, developers and communities. The fact that every square meter is evaluated from different aspects confers the highest level of objectivity in making decision "where, how and when" to allocate planned developments within the perimeter of land zones with different suitability constraints and opportunities. In that regards the MCDA and AHC applied for the case of Dikgathlong Dam open a new chapter in Botswana tourism research and development planning practice. The intention of authors in further research is to apply similar methodology on different study areas in order to evaluate the performance of suggested concept as a basis for ecotourism development.

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