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management has not always been supported by market mechanisms that enhance better resource management and higher agricultural productivity. Yet, the commercialisation of smallholder production is part of the process of globalisation that is not going to stop. Unless there is greater guidance of the process by the government, the vision towards achieving higher agricultural productivity, higher income, reduction of poverty and improvement in environmental resources management is not likely to be realised. There is the need to guide the process of commercialisation and reduce the constraints it brings to smallholder producers. Enhancing smallholders' competitiveness in the market economy through better organisation should be encouraged. The government should take responsibility for ensuring fair trade that would benefit farmers and enhance their ability to undertake the sustainable management of agricultural resources.

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Using GIS for decision-making: the case of Kidunda dam in Morogoro, Tanzania

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Introduction

Dams are important water resource management systems. In many places, water is regulated by and stored in dams for various purposes, but most importantly to maintain a reliable supply of water. Currently 64% of the total population of Africa relies on water resources that are limited and highly variable (Smith 2004). The major source of water for Dar es Salaam is the Ruvu River. In the driest years, the mean flow for the Ruvu River is 1.25 $m^3 s^{-1}$ and water abstraction from the river at full capacity is 3.6 $m^3 s^{-1}$. The city water demand forecasted for the year 2030 is 27.7 $m^3 s^{-1}$ and for the year 2050, 62.0 $m^3 s^{-1}$. Little water storage capacity is available, and there are always water shortages when flows of the Ruvu are low.

The increase in the city water demand has necessitated the proposition to construct a dam to store water to meet the future water requirement for the city (Norconsult 2005). Based on the hydrology and geomorphology of the Ruvu River, the Kidunda area in Morogoro region has been identified as a suitable location for a dam (Figure 1). However, the area is environmentally and socio-economically sensitive. Of the 473 km^2 of land designated as dam area, 123 km^2 of this land comprises the Selous Game Reserve (a UNESCO World Heritage Site), 85 km^2 is the Mkulazi Forest Reserve, 25 km^2 is productive agricultural land and 8 km^2 is residential land. All these land resources are at risk of being inundated by the dam reservoir.

The dam location has been identified based on engineering and economic criteria for dam construction and operations. However, with a greater awareness of environmental concerns and social responsibilities, it is no longer acceptable to optimise dam operation on the basis of engineering and economical criteria alone (WCD 2000). For a more equitable distribution of benefits to be gained from dam construction,

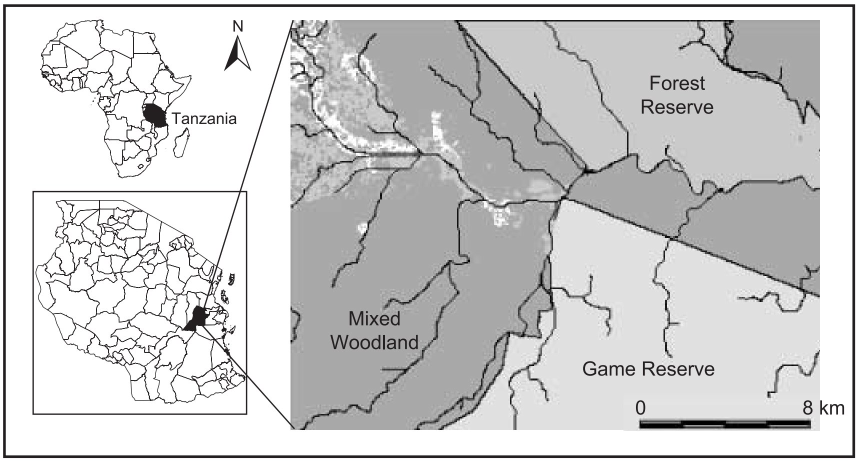

Figure 1 Kidunda area in Morogoro District, Tanzania

decisions made must now take into account all water users and give consideration to all economic, social, environmental and biophysical factors. In any specific situation, the relationships between these different elements are difficult to ascertain and this makes decisions on dam location and operations problematic. Although there are a number of reservoir planning and operation decision tools available, most of these focus primarily on the physical aspects of the system and frequently are based on simple engineering principles for dam operation (Murphy 1997). Few of these principles facilitate communication with people without technical abilities to enable them to be empowered to participate fully in the decision-making process.

This paper demonstrates the use of a geographical information system (GIS) as a decision support tool for appropriate dam construction. It shows how stakeholders' interests are used in deciding the size of the dam. Since the dam's location is already decided, this paper provides scenarios of dams and their impact, and identifies a scenario that minimally impacts natural reserves, agricultural and residential land, while supplying sufficient water to Dar es Salaam City.

Methodology

Variables for deciding the size of the dam to be constructed were identified through a participatory rapid appraisal that involved discussion with villagers in the three villages to be affected by the construction of the dam, the Wami-Ruvu River Basin Authority, and the stakeholders in the game and forest reserves. Inventories of resources and important species were made to identify impacts of the dam in the area. The concerns identified by the stakeholders were developed into criteria for determining appropriate dam construction (Table 1).

Representative variables of the concerns were translated into mappable information. For example, to identify the magnitude of population displacement, residential areas were located from the 2005 SPOT 4 image and a map of residential areas made,

Table 1 Social economic and environmental concerns and their relative importance (weightings)

Concern addressed	Criteria	Weightings
1. Population displacement	Avoid residential areas as possible	0.4
2. Game habitat destruction	Avoid the Selous game reserve	0.4
3. Resources/species destruction	Avoid Mkulazi forest reserve	0.1
4. Rural economy disruption	Avoid high-grade agricultural land	0.1
5. Dar es Salaam City water demand	Sufficient volume of water to fulfill Dar es salaam water demand	Constraint

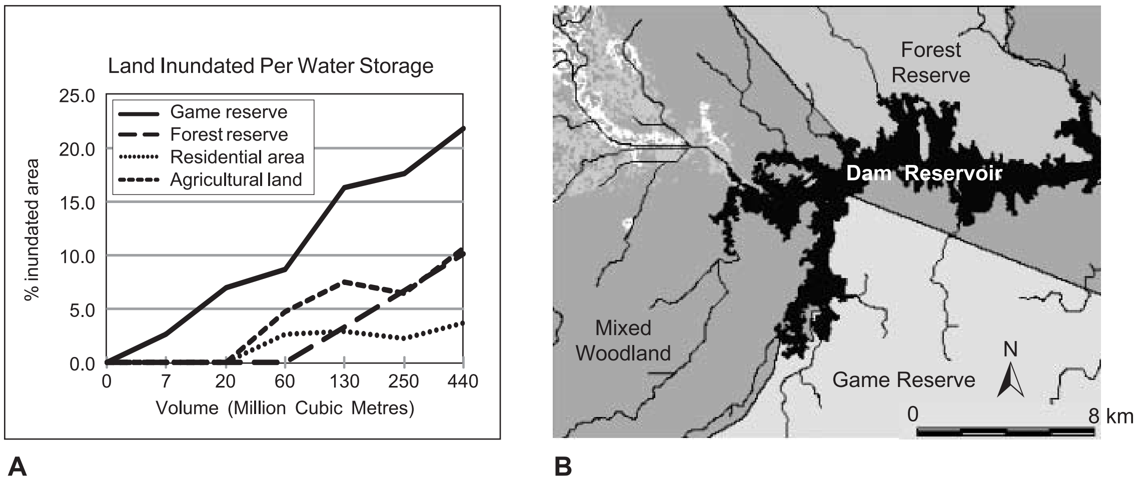

Figure 2 (A) Inundated land resources per reservoir volume; (B) spatial coverage of the 250 million m^3 dam reservoir

and each concern was translated onto a map. Each map was used as a criterion (basis of decision) and used as a variable for input in a GIS decision support system. Four maps (residential, game reserve, forest reserve and agricultural land maps) were developed. Each criterion was weighted according to perceived importance of the resource by stakeholders. Stakeholders were asked to rank the order of importance of the four criteria and a pairwise comparison method was used to determine their relative weightings. Each criterion map was scaled from 0 to 255. For example, high-quality agricultural land was given a value of 255 and poorer quality land progressively decreased in value down to 0 for non-agricultural land. The same scale was applied to residential, game and forest reserve criteria.

The fifth concern, a sufficient volume of water behind a dam, was developed from a digital elevation model (DEM) generated from the Shuttle Radar Topography Mission (SRTM) 30 m resolution. The DEM was used to demarcate a land area that would store sufficient volumes of water. Several scenarios of reservoir water storage volumes were produced at an interval of 2 m from 84 m (lowest river level) to 96 m (highest dam axis level). Water volume storage scenarios were estimated as the cumulative mean areas (areas below a specified elevation) between two successive areas multiplied by the interval. The volume criterion was formulated into a constraint variable, i.e. the limiting factor of the reservoir area per volume of water.

Weightings that represent the relative importance of concerns were developed for criteria 1–4, while the sufficient volume of water criterion was used to serve as a limiting factor. The natural resources, that is, the forest and game reserve concerns, were given the least weights of 0.10 each. Displacement of people is of high concern, compared with the loss of natural resources, thus the avoidance of settlements and agricultural land were given relatively higher weights of 0.4 each. The criteria, the limiting factors and their respective weightings were then inputted into the Idrisi Kilimanjaro Multi-Criteria Evaluation (MCE) decision support tool. Using this tool, the target land for dam reservoir per volume of water, and the respective impacts on game reserves, forest reserves, agricultural land and residential areas were identified. From these scenarios, the reservoir that fulfilled all five criteria was selected as an optimal solution. The reservoir water storage scenario, the respective impacts on resources expressed as a percentage of land inundated, and the reservoir with the least impact are presented in Figure 2.

Results and discussion

Areas suitable for the dam reservoir are shown in Figure 2A. The 7–130 million m^3 dams do not satisfy the 2030 projected water demand for Dar es Salaam City water. These reservoirs would have minimum impact on resources but are not suitable because of insufficient water storage. The 250 and 440 million m^3 dams are the ones that have storage capacities that are beyond the projected water demand. However, the 250 million m^3 dam reservoir would have a very low impact on residential (2.3% inundated) and agricultural land (6.5% inundated) compared with the 130 and 440 million m^3 dams. The 130 million m^3 reservoir would inundate 3.0 and 7.5% of residential and agricultural land, respectively, which is more impact than the 250 million m^3 dam. Therefore, the 250 million m^3

dam would have minimal impact on land resources and would fulfil the projected water demand. This dam is the optimal dam size for the area. However, the 250 million m^3 dam would inundate relatively more of the game (17%) and forest (6.7%) reserves. Much of the game reserve was sacrificed at the expense of residential and agricultural uses because it was not perceived as great a concern by stakeholders, as it was given only a 0.1 weighting of importance compared with 0.4 for the residential and the agricultural categories. If the volume of water storage is increased to meet a future water demand beyond the year 2030, much of the land would be inundated. About 10% of agricultural land and forest reserve would be sacrificed, 21% of the game reserve would be inundated, but only 3.6% of the residential area would be inundated by the 440 million m^3 dam. The 440 million m^3 water storage dam would claim almost equal agricultural and forest reserve land, although agricultural land has a higher order of importance compared with the forest. This is because much of the agricultural land is in the river flood plains and is likely to be sacrificed when the dam size is increased.

Conclusions

This paper shows that GIS can be an important tool in effecting resource allocation decisions. Concerns of stakeholders were used in the decision to determine the dam size for water supply. This paper shows that by using social and environmental concerns for all stakeholders, it is possible to produce an optimal solution where all criteria are fulfilled. Six dam scenarios, from 7 to 440 million m^3, were produced and it was found that the 250 million m^3 dam would have the least impact on agriculture, residential, game and forest reserves, while maintaining the water demand requirement. Much of the agricultural land and residential land would be spared because these were the resources considered most valuable in the area. Impacts on residential areas would be low, even beyond the projected requirement for the year 2030. When the volume of water storage was increased to 440 million m^3 the game reserve land was found to be the most impacted (21% of the area considered would be inundated), and the land of lowest impact was the residential land (only 4% inundated for the year 2050 demand).

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Perception and conceptualisation of urban environmental change: Dar es Salaam City

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Introduction

Although Dar es Salaam was elevated to a city status in 1961, the City Council was subsequently dissolved in 1972, following a government decision to abolish all local governments in Tanzania in favour of a decentralised system, which put more emphasis on rural local authorities. Consequently, urban areas throughout the country deteriorated. To address this problem, the urban local authorities were reinstated in 1978, but the urban areas continued to deteriorate. In 1992, a Commission of Enquiry was set up to investigate why the Dar es Salaam City Council was not delivering services as