Spatial support tools for biodiversity management: a case study of Bojanala Platinum District Municipality, South Africa

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Abstract

It is a legal requirement in South Africa that development, spatial planning and land-use management decisions include the biodiversity of the area under consideration (National Environmental Management Act, 1998). Biodiversity refers to the full range of living organisms in terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part of. It encompasses the genes, species, ecosystems, land-or seascapes, as well as the ecological processes that enable these elements of biodiversity to exist over time. Geographical information systems (GIS) constitute a useful tool to convey and present geographical information by overlying geo-referenced biodiversity data. This will result in facilitating the assessment of biodiversity conservation.

This article discusses how GIS can be a useful tool in addressing biodiversity conservation at a municipal level and draws on the GIS component for the development of the 2012 Biodiversity Management Plan for the Bojanala Platinum District Municipality (BPDM). The BPDM Biodiversity Management Plan was developed based on the systematic biodiversity planning approach to prioritise biodiversity significant areas based on factors such as connectivity, fresh water ecosystem status, habitat condition and location of endemic vegetation types. This study did not aim to provide a comprehensive overview of all the biodiversity data available for the BPDM or to discuss the actual Biodiversity Management Plan; but rather to provide the user with informative spatial tools that could help identify biodiversity hot-spots, critically biodiversity areas and ecological support areas within the district based on those datasets which were made available. The results show that through the creation of the biodiversity maps, and the biodiversity spatial support tools, decision makers in BPDM can be better equipped for effective biodiversity conversation planning; however it is recommended that other supportive information be incorporated into the decision making process.

Keywords

biodiversity management plan, critical biodiversity areas, ecological support areas, biodiversity hot-spots

Introduction

Biological diversity, also known as biodiversity, is a term used to describe the array of life inhabiting a particular area and includes all bacteria, algae, fungi, plants and animals. The term biodiversity is also used to describe the variability among living organisms (at the community, species or genetic level), terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are a part of. Furthermore it is used as a measure of the health of ecosystems in a particular area. Since the health of an ecosystem is difficult to measure, biodiversity is commonly used as a surrogate. A loss of biodiversity will represent a decrease in the health of an ecosystem.

The biodiversity pattern and ecological processes are the two most important components of biodiversity [1] Biodiversity pattern refers to different vegetation types (e.g. grasslands, shrublands, forests) or habitats (e.g. rocky outcrops, wetlands, rivers) or specific features (e.g. populations of rare plants which grow in a specific area and nowhere else) in a given area. Ecological processes on the other hand are physical, chemical and biological actions or events that link organisms and their environment. They can occur at a micro-scale (e.g. decomposition, pollination, nutrient cycling) or at a mega-scale (e.g. fire, floods, migrations). While they have been discussed here as two separate components, they are in fact interdependent. For example, biodiversity patterns are maintained or altered by various ecological processes. Likewise, the functioning of ecological processes is determined by the health and integrity of biodiversity pattern.

Spatial biodiversity plans have evolved considerably in South Africa since 1990s and South Africa has emerged as a leader in producing spatial biodiversity plans [2]. Spatial biodiversity planning has supported the identification of Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs), which are both important for conserving a representative sample of ecosystems and species, for maintaining ecological processes. CBAs have been identified as areas which support features critical for the conservation of biodiversity and ecosystem function [3]. These include Special Habitats where species of special concern occur and areas that require the continued existence and functioning of species, ecosystems, and the delivery of ecosystem services. These areas should remain in a natural state to ensure that their biodiversity features remain intact for continued ecosystem function and services. The ESAs serve as supporting areas or buffers to prevent the degradation of these CBAs and Protected Areas (PAs). ESAs can sustain a greater degree of degradation or support more intensive or different types of development because, in many cases, the ecological processes can still continue when the biodiversity pattern has changed. For example, a wetland can still fulfil its role in flood attenuation even if the area is used for grazing and the natural vegetation composition and distribution has been consequently altered. Both CBAs and ESAs are important areas for biodiversity concerns and a biodiversity
spatial support tool is one of the proposed conservation tools that can ensure that ecological processes and patterns are safeguarded and maintained.

**Justification for a biodiversity spatial support tool**

It is a legal requirement in South Africa that development, spatial planning and land-use management decisions include the biodiversity of the area under consideration [4]. These national policies are guided by the principle of sustainable development which aims to ensure that all development serves both present and future generations. Humankind benefits from a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are known as ecosystem services and include products like clean air, clean drinking water and processes such as the filtering and decomposition of wastes and control of diseases and pests. As human population accelerates, so does the pressure for space and resources such as water and minerals. Unfortunately, these natural resources are not infinitely available and often not resilient enough to withstand anthropogenic change. The environmental impacts of human actions are becoming increasingly apparent and without a strategy for conservation and protection of what is currently remaining, the problem will continue to unfold.

A biodiversity spatial support tool is aimed at providing planners with a tool containing the most relevant and most recent biodiversity-related spatial information, which should be used during land-use planning and conservation allocation processes. The approach used to develop the proposed biodiversity spatial support tool is called systematic biodiversity planning, which is the most well developed conservation planning approach in South Africa and the most recognised method internationally [5]. Systematic biodiversity planning involves mapping a wide range of information about biodiversity features and patterns of land and resource use, as well as setting conservation targets. The systematic approach avoids the pitfalls of the ad hoc conservation approach whereby areas are conserved without due consideration to: connectivity with other conservation or important biodiversity areas; representativeness of the area (in terms of the level of biodiversity); as well as local context (for example, it should be compatible with other land uses and preferably generate its own income). An advantage of the systematic approach is that there is a clear methodology which can be repeated in other locations. The biodiversity spatial support tool will allow for the identification of areas where further loss of natural habitat should be avoided (CBAs) and aims to prevent the degradation of ESAs, while encouraging sustainable development and integrated land use in other natural areas.

**Case study: Bojanala Platinum District Municipality Biodiversity Spatial Support Tools**

The Bojanala Platinum District Municipality (BPDM) is located in the north eastern portion of the North West Province and encompasses five local municipalities, namely Kgetlengrivier, Madibeng, Moretele, Moses Kotane and Rustenburg. Fig. 1 shows the localities of these local municipalities.

The dominant land uses in the BPDM are agriculture, mining, conservation, industrial, commercial, recreational and residential/urban [6, 7]. Mining is one of the key land uses in the area and is historically the driver for much of the urban and transport network development in the area. There are several conservation areas, with the Pilanesberg being the most notable for its conservation of an endemic vegetation type. The BPDM encompasses a great diversity of terrestrial and aquatic ecosystems.

![Locality Map](image)
Methodology

The development of the biodiversity spatial support tools involved four steps. Firstly, stakeholder engagement meetings were held within the municipality to identify areas of importance and to source additional information. Secondly, a GIS gap analysis was carried out to identify the quality and usefulness of the datasets for a biodiversity spatial support tool. Thirdly an in-depth specialist workshop was held to classify and rank the selected biodiversity GIS layers. Fourthly a GIS overlay analysis using, ArcGIS 9.3, was done to create the Terrestrial CBA, Aquatic CBA and the two proposed biodiversity spatial support tools.

Biodiversity input layers

Table 1 summarises the input datasets, description sources:

<table>
<thead>
<tr>
<th>Data set</th>
<th>Layers</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation types</td>
<td>Vegetation types</td>
<td>The provincial vegetation map was created by incorporating the following layers: The national VEGMAP ((SANBI), Unpublished 2003; 1:250 000 scale); land type information; geology; climate information (rainfall zones) [8]</td>
<td>North West Province Biodiversity Conservation Assessment (2009)</td>
</tr>
<tr>
<td>Aquatic features</td>
<td>Rivers, wetlands, freshwater Ecosystem Priority Areas (FEPAs).</td>
<td>The National Freshwater Ecosystems Priority Area (NFEPA) project aim was to identify Freshwater Ecosystem Priority Areas (referred to as “FEPAs”) in order to meet national biodiversity goals for freshwater ecosystems, and to develop a basis for enabling effective implementation of measures to protect FEPAs, including free-flowing rivers. [9]</td>
<td>Atlas of Freshwater Ecosystem Priority Areas for South Africa (Nel et al 2011); available on <a href="http://bgis.sanbi.org">http://bgis.sanbi.org</a></td>
</tr>
<tr>
<td>Special habitats</td>
<td>Plant species</td>
<td>This dataset highlighted farm portions which contained important plant species. The SEF specialists ranked these species according to the IUCN relevance of importance – critically endangered, endangered, threatened, near threatened, rare.</td>
<td>NW DACE 2009</td>
</tr>
<tr>
<td></td>
<td>Dolerite areas</td>
<td>Dolerite areas are important biodiversity features because they create mosaic habitats which usually have a high degree of biodiversity and endemicity[7]</td>
<td>NW DACE 2009</td>
</tr>
<tr>
<td></td>
<td>Important bird areas</td>
<td>Important Bird Areas (IBA) are identified on the basis of the bird numbers and species’ complements that they hold, and are selected such that, taken together they form a network throughout the species’ biogeographic distributions [10]</td>
<td>IBA, 2012</td>
</tr>
<tr>
<td></td>
<td>Ecological corridors</td>
<td>Area of habitat connecting wildlife populations separated by human activities or structures. Corridors may help facilitate the re-establishment of populations that have been reduced or eliminated</td>
<td>NW DACE 2009</td>
</tr>
<tr>
<td></td>
<td>Hills and ridges</td>
<td></td>
<td>NW DACE 2009</td>
</tr>
<tr>
<td>Transform ed areas</td>
<td>Road buffers</td>
<td>A multi buffer analysis was conducted on the various roads in the area</td>
<td>CDSM 2009</td>
</tr>
<tr>
<td></td>
<td>Gully erosion</td>
<td>Gully eroded areas</td>
<td>ARC, 2011</td>
</tr>
<tr>
<td></td>
<td>Landcover degraded sites</td>
<td>Selected degraded features within the land cover dataset used.</td>
<td>NationalLandover, 2009</td>
</tr>
<tr>
<td></td>
<td>Formal protected area</td>
<td>Protected areas includes special nature reserves, national parks and provincial and local nature reserves; protected environments; world heritage sites; marine protected areas; specially protected forest areas; and mountain catchment area.</td>
<td>DEA 2010</td>
</tr>
<tr>
<td></td>
<td>Conservancies</td>
<td>Informally protected areas</td>
<td>NW DACE 2009</td>
</tr>
<tr>
<td></td>
<td>National Protected Area Expansion Strategy (NPAES)</td>
<td>Focus areas for land-based protected area expansion are large, relatively intact (in terms of natural vegetation cover) and unfragmented areas of high biodiversity importance, suitable for the creation or expansion of large protected areas, identified in the National Protected Area Expansion Strategy [11]</td>
<td>GSA 2010</td>
</tr>
</tbody>
</table>

Table 1: Biodiversity input layers.
Development of the Critical Biodiversity Area Maps

Fig. 2, summarises the input layers and the GIS data manipulation required to create the Terrestrial and Aquatic Critical Biodiversity Maps.

<table>
<thead>
<tr>
<th>GIS Methodology</th>
<th>Context Layers</th>
<th>Terrestrial CBA 1</th>
<th>Terrestrial CBA 2</th>
<th>Terrestrial ESA</th>
<th>Aquatic CBA 1</th>
<th>Aquatic ESA</th>
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<tbody>
<tr>
<td>CDGM Roads</td>
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<td>Gully Areas</td>
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<td>Landcover 2000</td>
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<td>NPAES</td>
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<td>Veg Type</td>
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<td>Ecological Corridors</td>
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<td>Special Plant Species</td>
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<td>IBA</td>
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<td>Hills and Ridges</td>
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<td>Dolomite Area</td>
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<td>Protected Area</td>
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<td>NEPDA Layers</td>
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<tr>
<td>RSA Rivers/ Water Bodies</td>
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</tbody>
</table>

Fig. 2: GIS flow diagram.

The Terrestrial CBA Map, Fig. 3, was developed using the union and buffer analysis tools. Below summaries what each terrestrial CBA layer consisted of:

- **Terrestrial CBA 1**
  - National Protected Area Expansion Strategy (NPAES) focus areas
  - Locally endemic vegetation types (1)
  - Endangered vegetation types that are along an ecological corridor
  - Special plant species that are listed as endangered according to IUCN

- **Terrestrial CBA 2**
  - Endangered vegetation types that are outside of corridor linkages
  - Degraded NPAES focus areas
  - Regionally endemic vegetation types (3)
  - Important bird areas
  - Hills and ridges

- **Terrestrial Ecological Support (ESA)**
  - 1 km formal protected area buffer
  - Dolerite areas
The Aquatic CBA map, Fig. 4, displays the relevant aquatic biodiversity areas. This map was created by incorporating specialist’s guidelines extracted from the NFEPA report [12]. The buffer analysis tool was used to generate a majority of the layers needed for the aquatic CBAs. Below lists how the layers were classified:

- **Aquatics CBA 1:**
  - 1,1 km buffer around all rivers (perennial and non-perennial) in FEPA catchments
  - 1,1 km buffer around NFEPA wetlands
  - 1,1 km buffer around NFEPA wetland cluster
  - 100 m buffer around rivers in upstream categories, Fish FSA and Fish corridors (none in Bojanala)

- **Aquatic Ecological Support Area (ESA):**
  - All other rivers (perennial and non-perennial) and water bodies which did not fall within the above buffers were then buffered by 100 m.
Development of the Biodiversity Spatial Support Tools

The biodiversity spatial support tools proposed are a simple biodiversity look-up table and a biodiversity hot-spot map, both developed as a combination of the terrestrial and aquatic CBAs.

The look-up table was developed to offer the user the ability to quickly and easily identify biodiversity significance of a site. The table was created by combining the Terrestrial and the Aquatic CBA layers which allowed for a more realistic view of the CBA distribution in BPDM. A GIS overlay analysis was carried out and areas ranked in CBA 1 took preference over areas in CBA 2. Fig. 5 shows this map created as a result of the CBA combination.

![Fig. 5: Combined Critical Biodiversity Area Map.](image)

The table was designed to allow quick and easy understanding of the over-all plan and give a reasonably robust feature list for a site as well as quick management guidelines for decision makers. The attribute behind the biodiversity management tool includes the following fields:

- **CBA category (Field = CBA):** This gives the CBA category for the polygon. It indicates whether the polygon is a formal Protected Area, a CBA or an ESA.
- **Terrestrial CBA1 (Terr_CBA1):** Describes the features used to classify a certain polygon as CBA 1.
- **Terrestrial CBA2 (Terr_CBA2):** Describes the features used to classify a certain polygon as CBA2.
- **Hydrological (Hydro):** Critical areas (CBA) and important supporting areas (ESA) for maintaining hydrological processes. These are areas where developments should be carefully screened to ensure no major impact on the rivers and their riparian corridors, wetlands and their buffers, or estuaries and their buffers are likely.
- **Dolerite Sites (Litho):** If dolerite is present
- **Protected Area Buffer (ESA):** Describes the ecological support area based on distance from a protected area.
- **Protected Area (Reservename):** If a site is formally protected
- **Management Guideline (Manage_G):** This field outlines the management objective for the land parcel. This relates to either maintaining ecological patterns or ecological processes.

Although the look-up table shows why an area is classified as a particular biodiversity category and gives some guidelines, it does not allow a decision maker to identify which areas within the BPDM need greater conservation efforts. As can be seen in Fig. 5 the combined CBA map shows a significant portion of the BPDM which falls within the very high category. A hot-spot analysis was done, showing the greatest value in biodiversity. Conservation action in these areas is therefore needed.

Identification of biodiversity hot-spots was carried out using an ArcMap 9.3 raster overlay function. This function allowed for the identification of areas where numerous CBA and ESA layers overlapped. The first step involved converting the above CBA and ESA layers from a vector format to a raster format of equal pixel size. This allowed for compatibility of the layers for the overlay analysis. An additional field called SUM was then added to each layer for reclassification purposes. To this field the following values were inserted for each layer:
- CBA 1 layers = 20
- CBA 2 layers = 10
- Ecological support layers = 5
- Protected areas = 2000

The rationale behind the above values was that protected areas needed to be masked out and CBA 1 needed to be given maximum priority for conservation. Hence both these layers were given high values which could be easily identified during a reclassification. These layers were then inserted into the weighted sum overlay function which produced a raster that summed all the layers. The output raster now had values ranging from 5 to +2000. The output weighted sum raster was then reclassified using a manual threshold technique which could visually map the following classes successfully:

- Protected area
- Biodiversity hot-spot
- High
- Medium
- Low
- No significance

The area of main concern here is the biodiversity hot-spot class and to better represent this class, 10 cluster zones were highlighted as areas of conservation concern. These are the areas circled in purple in the Biodiversity Hot-spot Map. The purpose of highlighting clusters was to investigate areas that were more or less contiguous, making them more suitable for formal protection.

![Biodiversity Hot-spot Map](image)

**Fig. 6: Biodiversity Hot-spot Map.**

The largest clusters, namely 8 and 9 are also in areas which are highly transformed and which have the highest densities of the alien invasive plant species. These areas may be too fragmented and/or disturbed to be effectively conserved. Ground-truthing would be required to determine whether the transformed areas are permanently transformed e.g. converted to urban areas, roads and intensive mining or partially transformed e.g. grazing land, agriculture with pockets of natural vegetation and/or areas where disturbance is limited. Cluster 3, 5, 6 and 7 are found alongside protected areas which makes it easy and relatively cost effective to incorporate into protected areas should this be deemed a suitable solution to protection. However, it also means that the characteristics that make up the hot-spot may be included in the area currently under protection and as such may be ranked as lower priority for conservation than areas which are more unique. This would need to be determined through groundtruthing of the hot-spots as well as the adjacent protected areas. Clusters 1, 2 and 8 probably show the most potential for conservation of unique features within areas which currently have lower levels of transformation and are therefore sites recommended for conservation resource allocation.

**Recommendations**

The CBA maps, Biodiversity Management Tool and Biodiversity Hot-spot Map do offer a greater insight into the areas of biodiversity concerns, however, they should be used in conjunction with other supportive information, such as the municipality’s SDF and zoning scheme, as well as any other non-spatial or spatial biodiversity information. This will
enable one to determine which areas are sensitive to development and which areas are more resilient to environmental change or degradation.

It is further recommended that the CBA Maps be consulted prior to any development. In many cases, new activities constitute “listed activities” under the National Environmental Management Act and therefore require environmental authorisation and the necessary investigations. However, this may not always be the case and if consultation of the CBA Map indicates that a proposed activity is located within a CBA or ESA, further investigations should be required before a decision can be made, regardless of whether environmental authorisation is required. The following are the proposed steps to follow when making a decision on land use applications:

**Step 1: Determine the biodiversity category**

- Does the proposed development fall within an area identified as a CBA or ESA?

**Step 2: Consult other information**

- Determine detailed biodiversity information by using the biodiversity spatial support tool
- Determine the Desired Management Objective using a biodiversity management plan
- Consult other datasets such as the alien invasive species layer, species distribution layers, and other available biodiversity tools such as the National Biodiversity Tool for Mining (2012).

**Step 3: Verify the land cover**

- Overlay the transformation layer to determine if the site is in its natural state or not.
- The level of detail available when drafting the CBA maps, as well as changes in land cover through degradation between the time the data used was captured and the time a development is proposed can mean that what was classified as CBA or ESA no longer falls into these categories.

**Step 4: Conduct a detailed assessment**

- A detailed assessment by a suitably qualified specialist(s) should be conducted to determine whether the CBA Map and the GIS Input Layers have correctly depicted the situation on the ground. The biodiversity spatial support tool should be used to determine which specialist studies are required.

**Step 5: Assess the compatibility of the proposed land use**

- Refer to the land and resource use guidelines to determine which land use activities should be allowed or prevented. If the development differs from the categories in the table, refer to the Desired Management Objectives. The biodiversity management tool should also be used to determine compatibility.

**Conclusion and recommendations**

In conclusion this study illustrates how GIS can be used to assist with biodiversity management at a municipality level. The GIS biodiversity spatial support tool offers users the ability to query and thus make better informed decisions behind the biodiversity significance and management guidelines of a particular area within BPDM. Furthermore the Biodiversity Hot-spot Map gives decision makers a better insight on where to invest their biodiversity conservation efforts.

It is recommended that the proposed biodiversity spatial support tools be used in combination with other informative layers such as transformation layer, alien invasive plant species, specialist studies, municipality SDF, zoning schemes, and other biodiversity and ecosystem guidelines that may have been developed. This will allow decision makers to be fully informed about the biological significance of any area within the Bojanala Platinum District Municipality.

**Acknowledgements**

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References


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