Habitat assessment for ecosystem services in South Africa
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ABSTRACT
Biodiversity is the foundation of life-support systems on earth and underpins the delivery of ecosystem services (ES) important for human well-being. The loss of biodiversity worldwide, however, remains one of the most daunting challenges. Among the major causes of biodiversity loss is habitat loss due to transformation of land to agricultural, mining and urban areas. We applied the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) biodiversity modelling tool to assess the condition of habitats to support the delivery of ES in a biosphere reserve (BR) in South Africa. Results indicated that 72% of the surveyed habitats were of high quality to provide the necessary services. However, some of the habitats were found to be affected by threats as follows: low (0–20%) to moderate (20–32%) habitat loss was recorded in habitats adjacent to mining and plantation areas, and high (32–56%) to severe (56–95%) habitat loss was recorded in habitats in close proximity to urban and cultivated areas. At least 56% of the vegetation types found in the study area were threatened by transformation to agriculture, mining and urban areas. We strongly recommend that existing biodiversity policies and legislation should be enforced to avoid habitat loss and degradation.

1. Introduction
The protection of biodiversity is an international obligation, with approximately 200 nations committing to it (CBD 1992). The term biodiversity originates from the concept of biological diversity, which was coined during the twentieth century (Dasmann 1968; Soule et al. 1980) and has been in use for almost three decades (Wilson & Peter 1988; Bibby et al. 1992; Eldredge 1992; Harper & Hawksworth 1994; Gaston 1996). There are several definitions of biodiversity (CBD 1992; MA 2005; IUCN 2010). Our study adopted the Millennium Ecosystem Assessment’s (MA) (2005) definition which is ‘the diversity of life on Earth’ and ‘an essential component that contribute [s] to the functioning of ecosystems that underpin the provisioning of ecosystem services (ES) that ultimately affect human well-being’. We adopted the MA definition because of its association with the supply of ES.

Sound conservation strategies are needed to effectively protect biodiversity. A protected areas (PAs) system was established with the primary goal of protecting and conserving biodiversity (IUCN 2004; Stolton 2010; Tallis et al. 2011). Despite the presence of conservation strategies such as PAs, biosphere reserves (BRs), stewardship programmes (NPEAS 2008; Stolton 2010; UNESCO 2010; Kurdoğlu & Çokçaliskan 2011) and the ongoing commitment of putting more land aside for conservation purposes (CBD 2011; Venter et al. 2014), the increasing loss of biodiversity remains a daunting challenge facing the world at large (Gurevitch & Padilla 2004; MA 2005; Rockström et al. 2009). Various human-induced threats and forces (Chapin III et al. 2000; Díaz et al. 2006) continually alter and degrade the environment, causing habitat loss, species extinction and climate change (Wilcove et al. 1998; Stuart et al. 2000; Scholes & Biggs 2004; MA 2005; Venter et al. 2006). Among these threats are agriculture (Stolton & Dudley 1999; Rouget et al. 2003; Swift et al. 2004; Power 2010), urbanisation (Marzloff et al. 2001; McKinney 2002, 2008) and mining developments (Brewer et al. 2003; MA 2005).

Agriculture is regarded as one of the most severe threats (Stolton & Dudley 1999; Rouget et al. 2003; MA 2005). Evidence suggests that agricultural activities might negatively affect biodiversity and ES (Swift et al. 2004; Power 2010), among others through high consumption of water (Scholes & Biggs 2004; MA 2005). The use of pesticides could also kill non-target organisms (Swift et al. 2004; Power 2010). Other obvious adverse effects of agricultural intensification on biodiversity are the eutrophication of water systems through use of inorganic fertilizers; reduction in the diversity of organisms responsible for nutrient cycling as well as ground water pollution (Scholes & Biggs 2004; Swift et al. 2004; Bukola et al. 2015).
Urbanisation refers to an increase in the number of cities and size of populations (Uttara et al. 2012). A number of researchers have raised concerns about the impact of urbanisation on biodiversity (Marzluff et al. 2001; McKinney 2002, 2008; Uttara et al. 2012). Urbanisation has been found to adversely affect biodiversity and ES through indigenous species’ extinction and habitat loss (Marzluff et al. 2001; McKinney 2002, 2008) as well as the removal of indigenous vegetation (Uttara et al. 2012).

Although industrial developments such as mining are seen as a quick solution to economic growth (Turner 2012), these kinds of land use (LU) come with a cost to the natural environment (IUCN 2011a, 2011b). Mining may result in habitat destruction due to removal of vegetation (Ashton et al. 2001; Phillips 2001) and high consumption of water and other natural resources (Brewer et al. 2003; DWAF 2004; MA 2005). Mining activities have been found to degrade and alter both terrestrial and aquatic habitats, causing a decline in the abundance of indigenous species (Ashton et al. 2001; Phillips 2001). Many world heritage sites and PAs around the world have been negatively affected by various activities related to mining (Turner 2012). IUCN (2011a, 2011b) found that mining threatened at least 25% of PAs in West Africa. Osti et al. (2011) found that 27% of World Heritage sites in Sub-Saharan Africa were threatened with oil and gas mining. This situation presents a major challenge in dealing with a threat whose solution is beyond the employment of conservation strategies such as PAs.

Perhaps what the above-mentioned forms of LU have in common is the effect on habitats (MA 2005; McKinney 2008; Power 2010; Uttara et al. 2012). Examples of LU effects on habitat quality include various types of pollution and vegetation removal associated with agriculture, urban developments and mining activities (Ashton et al. 2001; Czech et al. 2000; Rouget et al. 2003; Power 2010; Uttara et al. 2012). A habitat can be defined as an area’s condition and resources that contribute to the reproduction and the continuous existence of species (Hall et al. 1997; Tallis et al. 2011). The state of biodiversity in an area can be determined by the condition of its habitat whereas the importance of a habitat depends on its quality. Habitat quality is defined as the environment’s ability and capacity to provide adequate support and conditions to enable the persistence of species (Tallis et al. 2011).

A habitat’s role regarding ES is two-fold. The first role is that of being a service itself by, for example, providing refuge for wildlife. The second role is that of being a supporting service that underpins the delivery of other services such as provisioning (e.g., food and water), cultural (e.g., recreation, aesthetic quality) and regulating (e.g., climate regulation, flood regulation) services, according to MA’s (2005) framework. Due to the fact that the most updated classifications of ES (TEEB 2010; CICES 2011) exclude the supporting service category, this study adopted the MA (2005) framework because it classifies habitat as a supporting service. The MA (2005) further defines ES as the benefits that people derive from ecosystems. However, in the most recent classifications of ES (TEEB 2010; CICES 2011), ES are defined as contributions of ecosystems to human well-being. What is important to note from these definitions is that humans derive something from ecosystems for their well-being. It is worth mentioning that LU choices result in trade-offs between and among services. For example, the conversion of land from conservation to agriculture may have a negative impact on biodiversity and water resources because of the clearing of land and pollution from chemicals used to intensify agricultural production (Rouget et al. 2003; Foley et al. 2005).

If managers are to reach their biodiversity conservation goals, they should conduct biodiversity condition/threat assessments (Margoluis & Salafsky 2001; Tallis et al. 2011). Modelling and biodiversity assessment, which include assessing the impacts of LU on habitat quality in a given area, assist in (1) understanding the patterns of distribution and richness of biodiversity in the landscape, (2) comparison of spatial patterns of biodiversity and ES, (3) identification of synergies and trade-offs across different scales and scenarios and (4) development of strategies for biodiversity conservation (Tallis et al. 2011.) Information on habitat quality allows one to make informed decisions about different conservation strategies (Rouget et al. 2003) such as conservation area expansion, introduction and removal of species and identification of habitats that provide high ES, as well as types of ES provided by different habitats. Modelling is a useful tool for assessing the impacts of threats on a suite of biodiversity features and ES (Nelson et al. 2009; Polasky et al. 2011; Kovacs et al. 2013; Bhagabati et al. 2014).

This study applied the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) biodiversity habitat quality model described in Tallis et al. (2011) to assess the condition of habitat as an ES and that of providing a supporting service for the delivery of other ES. The model combined information on LU/land cover (LC) and threats to determine the degradation and extent thereof, on different habitat types in a BR. We selected InVEST because: (1) it can provide estimates of the level and value of ES that are provided by a given area and (2) its models are spatially explicit, with a flexible spatial resolution, thereby enabling users to address questions at different scales.
2. Materials and methods

2.1. Study area

A BR consists of different zones representing different kinds of LU. These include conservation areas represented in the core zones, agricultural systems and settlements represented in the buffer and transition zones of a BR. Vhembe Biosphere Reserve (VBR) is the biggest savannah BR in South Africa (SAMABNC 2014). It has a good balance of representation in terms of the main LUs such as conservation areas, human settlements, industries and other cooperatives, which included mining developments and agricultural systems. Despite its size of 3,070,000 ha, this study purposefully extended the VBR study area to cover the whole of the northern section of one of the two major core areas, the Kruger National Park and the whole western section up to the end of the existing BR boundary. This extension enabled us to obtain additional information on the status of biodiversity within the VBR and its most important buffer areas.

There are diverse LUs in the study area (Dombo et al. 2006). Conservation is one of the dominant forms of LU with about 1,000,000 ha of land under formal protection, including state-owned land (two national parks and provincial reserves) (Dombo et al. 2006). Agricultural systems are also well represented in the Vhembe region. Human settlements are fairly well developed and the human population size is about 1,500,000 (Stats SA 2012). There is also good diversity of vegetation types in the study area, with more than 30 types represented (Mucina & Rutherford 2006).

2.2. Invest biodiversity model

InVEST is a modelling suite that uses LU/LC patterns to estimate values and levels of biodiversity found in a landscape (Tallis et al. 2011). The InVEST biodiversity model 2.2.0 as described by Tallis et al. (2011) uses information about threats (Table 1) to biodiversity together with LU/LC and information on the sensitivity of habitat types to threats (Table 2) to produce habitat quality and degradation maps, which provide information about the quality and degradation of different types of habitat in an area over time. The LU/LC map for the VBR was derived from a 2009 LU/LC map for South Africa (SANBI 2009) which was the most recent one at the time of our study. We selected the InVEST habitat quality modelling tool because it allows for a rapid assessment of the impacts of different threats and LUs on biodiversity and ES (Tallis et al. 2011; Guerry et al. 2012). More details regarding the InVEST biodiversity quality model are contained in Annexure A.

2.3. Running the InVEST biodiversity model

The following process was followed in this study to run the InVEST biodiversity model, as described in Tallis et al. (2011):

Step 1 – Creation of workspace

For each InVEST model, including biodiversity and conservation, a separate workspace was created on the computer hard drive. This was followed by the creation of a folder under the workspace where all output files were stored.

Step 2 – Running the model

After completion of step 1, an ArcMap document was opened followed by adding an InVEST toolbox located on the hard drive. This was followed by double-clicking on the biodiversity InVEST toolbox which created an interface where all required values were authorised.

Step 3 – Progress dialogue

The completion of step 2 brought about a dialogue on the interface, which indicated the model running progress. After the model had been run successfully, it produced either an output or an intermediate folder which contained degradation and quality maps with values. The results were viewed on the ArcMap through an add data button (ESRI 2013). The maps attribute tables contained degradation and habitat quality values.

Table 1. Threat data used to run InVEST.

| Threat  | Maximum_distance | Weight | Decay |
|---------|------------------|--------|-------|
| Cultivation | 0.2              | 0.7    | 0     |
| Mines   | 30               | 1      | 0     |
| Urban   | 60               | 1      | 0     |

Table 2. Sensitivity of different habitat types to threats.

| ROWID | LU/LC CODE | NAME     | HABITAT | L_cultivation | L_urban | L_mines |
|-------|------------|----------|---------|---------------|---------|---------|
| 0     | 1          | Natural  | 1       | 0.5           | 0.8     | 1       |
| 1     | 5          | Water bodies | 1 | 0.8           | 0.5     | 0.8     |
| 2     | 2          | Cultivation | 0 | 0             | 0       | 0       |
| 3     | 3          | Degraded  | 0       | 0             | 0       | 0       |
| 4     | 4          | Urban built-up | 0 | 0             | 0       | 0       |
| 5     | 6          | Plantations | 0 | 0             | 0       | 0       |
| 6     | 7          | Mines     | 0       | 0             | 0       | 0       |
3. Results

Among the seven LC types represented in the study area, two were regarded as natural habitats (water bodies and natural areas) and five as transformed habitats (cultivation, mining, plantation, degraded and urban built-up). Three of these (cultivation, mining and urbanisation) were found to have impacts on natural habitats.

3.1. Habitat quality

The distribution of habitats with high-quality service in relation to those with low-quality service in the landscape is shown in Figure 1. About 72% of the habitats were of a high quality and were associated with natural areas. The remaining habitats were of a low quality (28%) and were found in areas under different LUs that excluded conservation.

Figure 1. Habitat quality in the Vhembe Biosphere Reserve and the northern parts of Kruger National Park study areas.
3.2. Habitat loss and degradation

The results of habitat service loss are shown in Figures 2–4 and habitat service degradation is presented in Figure 5. Figure 2 indicates that 35% of the habitat services were lost. In sharp contrast, 65% of the habitat services were intact.

We further quantified the extent of habitat service loss across the landscape as follows: low habitat loss from 0% to 20%, moderate habitat loss represented by 20–32%, high habitat loss represented by 32–56% and 56–95% representing severe habitat loss (Figure 3).

Areas affected by habitat services loss are shown in Figure 4. Natural areas and water bodies in formal PAs and privately owned natural areas surrounding PAs had low habitat service loss. Moderate habitat service loss was recorded in areas surrounding cultivation, urbanisation, mining and plantations. Areas adjacent to mining, urban development and cultivation had high habitat service loss and severe habitat service loss was mainly recorded in areas in close proximity to cultivated areas.

Figure 2. Habitat changes in the Vhembe Biosphere Reserve and the northern parts of Kruger National Park study areas.
The degradation of vegetation types in the study area is illustrated in Figure 5. At least 19 of the 34 vegetation types (i.e., 56%) were degraded.¹

4. Discussion

4.1. Habitat quality

Most habitats (72%) were in good condition. A habitat in a good state has the capacity to deliver a service of providing suitable living conditions for plants and animal species, and as a supporting service which underpins the delivery of other services such as provisioning, cultural and regulating services (MA 2005). Furthermore, a habitat is considered to be in good quality due to the high-quality resources that maximise species survival such as food and nesting sites among other things (Morrison et al. 2006; Johnson 2007). Habitat quality is also influenced by the proximity of sources of degradation (Tallis et al. 2011). High-quality habitats are associated with intact ecosystems with minimal human influence (Tallis et al.)
An area dominated by high-quality habitats represents high biodiversity (Johnson 2007). We attributed the dominance of high-quality habitats in PAs to their regulation (NEMPAA 2003), the presence of deterrents and law enforcement, which in privately owned conservation areas were moderately provided (Personal observation). Other researchers have also shown that legal protection of habitats mitigates the impacts of threats on biodiversity (Stolton & Dundley 1999; Tallis et al. 2011).

The presence of high-quality habitats within conservation areas suggested that these areas had the potential to support the delivery of a suite of ES such as cultural (recreation), provisioning (medicinal plants and timber) and regulating services (Dombo et al. 2006; Stolton et al. 2010; WBR 2012). Although the habitats were generally found to be of good quality, they could still be vulnerable to degradation, since human pressure/threats are likely to intensify in future. This normally happens with growing demands

Figure 4. The extent of transformed habitats and natural habitats in the Vhembe Biosphere Reserve and the northern parts of Kruger National Park study areas.
on ES due to growing human populations (Clay et al. 1994; MA 2005). The adverse impacts of agriculture, mining and urban developments on natural ecosystems are thus expected to continue especially in developing countries where poverty and population growth are high (Tilman et al. 2002; MA 2005; NPC 2011).

About 28% of the habitats were of a low quality due to anthropogenic threats. These habitats were in close proximity to mining, plantations, cultivated areas and urban settlements. Low-quality habitat was attributed to habitat destruction due to removal of vegetation which is usually carried out during implementation of different LU activities (Ashton et al. 2001; McKinney 2008; Koh & Gardner 2010). Conversion of natural systems to agriculture was found to reduce some ES (Rouget et al. 2003; Power 2010). However, low-quality habitats in areas designated for agricultural activities were found to be doing well in delivering food-provisioning services such as crops and livestock (Dombo et al. 2006; LDA 2012; WBR 2012). Nevertheless, these low-quality habitats are poor in terms of biodiversity value (Rouget et al. 2003; Tallis et al. 2011). Low habitat quality has been associated with degraded areas (Lindenmayer et al. 2008; Koh & Gardner 2010).
Low habitat quality has furthermore been associated with low biodiversity in general (Bender et al. 2003; Fahrig 2003; Tischendorf et al. 2003), since a habitat in a poor state has limited ability to provide suitable conditions for species and to support the provision of other services needed to support human well-being (MA 2005).

4.2. Habitat loss and degradation

About 35% of the habitats were lost. This resulted in loss of services associated with the provision of suitable living conditions for wildlife and with supporting the delivery of other ES. Cultivation was the greatest cause of habitat loss, followed by urbanisation and plantations, with mining causing the lowest impact. Other researchers have also recorded the contribution of different LUs such as agriculture (Rouget et al. 2003; Venter et al. 2006; McKinney 2008; Polasky et al. 2011), mining (Ashton et al. 2001; Phillips 2001) and urbanisation (Rouget et al. 2003; Venter et al. 2006; McKinney 2008; Utarra et al. 2012) to habitat loss. For example, Rouget et al. (2003) found that 30% of sub-tropical thicket had been transformed due to conversion of land to agriculture leading to significant loss of biodiversity in this global biodiversity hotspot.

Areas with low habitat loss fell within the core areas (represented by PAs) of the BR (Dombo et al. 2006; WBR 2012). Low habitat loss in areas represented by PAs means insignificant loss of habitat services such as living spaces for wildlife and gene pool protection, thus protecting species from decline. Low habitat loss in PAs provides an opportunity for the delivery of recreational, raw materials and a host of regulating services, among others (Stolton et al. 2010). Low habitat loss in natural areas was not surprising since PAs are expected to be effective tools for conserving and protecting biodiversity (IUCN 2004; Stolton 2010; Tallis et al. 2011). Moreover, core areas are strictly protected by legislation and activities in these areas are highly regulated (NEMPAA 2003).

Areas that suffered significant habitat loss were surrounded by human dominated landscapes such as urbanisation, agriculture and mining. These landscapes fall within the transition zone of the BR which caters for different LU systems (Dombo et al. 2006; WBR 2012). It is important to note that, urbanisation, mining and agriculture are spatially disparate LU systems as permitted by the current LU zone management (Dombo et al. 2006; WBR 2012) and are not necessarily degraded areas. However, these LUs are regarded as major threats which lead to habitat service loss and ultimately to biodiversity and other ES loss (Ashton et al. 2001; MA 2005; Utarra et al. 2012; Chaplin-Kramer et al. 2015).

The finding of high habitat loss in areas surrounded by urban areas confirms the conclusions of other workers who found urbanisation to be the second highest driver of habitat loss (Czech et al. 2000; Venter et al. 2006; McKinney 2008; Utarra et al. 2012). Severe habitat loss in areas adjacent to cultivated areas confirms the findings of other studies (Stolton & Dundley 1999; MA 2005; Venter et al. 2006; Power 2010). Agriculture has been found to be the greatest cause of habitat loss in many landscapes (Rouget et al. 2003; Chaplin-Kramer et al. 2015). Habitat service loss is regarded as the main cause of extinction of species (Foley et al. 2005; MA 2005; Lindenmayer et al. 2008; Rockström et al. 2009). Mining has been found to have a negative impact on biodiversity (Ashton et al. 2001; Brewer et al. 2003; MA 2005). South Africa is not exempted from this phenomenon (DWAF 2004; Munnik et al. 2010; van der Burg 2012). Legislation has been put in place to address the negative impacts of mining activities on biodiversity (DEA et al. 2013), although more resources need to be channelled towards implementation of the policies (DEA et al. 2013).

The finding that Makhado Sweet Bushveld was the most degraded vegetation type of the 19 vegetation types found in the study areas (Figure 5), is not surprising, as this vegetation type has been found to be hardly protected (Mucina & Rutherford 2006). Similarly, vegetation types found to have been moderately affected by habitat loss were also at great risk, as they were poorly protected or unprotected (Mucina & Rutherford 2006). The degradation of vegetation under protection might be a result of threats such as pollution, edge effects and habitat fragmentation which are not prevented by the presence of physical/legal or other types of protection (Tallis et al. 2011). Degradation of vegetation has a negative impact on the delivery of ES (MA 2005; Tallis et al. 2011).

Our study could be compared with that of La Notte (2012) with regard to the use of environmental indicators such as habitat sensitivity to threats and the impact of human pressure on habitats, as well as the application of the mapping approach. However, thorough comparison of La Notte (2012) and our findings was difficult due to the following differences. First, La Notte (2012) used the Benefit Transfer (BT) technique to value the services, we used InVEST. Second, it valued services in monetary terms; in our study services were valued in biophysical terms. Lastly, our study assessed and mapped habitats for ES in response to human pressure such as urbanisation, mining and cultivation, La Notte’s (2012) study valued and mapped habitat services using three
The affected vegetation types were Granite Lowveld Bushveld, Polokwane Plateau Bushveld, Mmabolo Mountain Bushveld, Northern Mistbelt Forest, Soutpansberg Mountain Bushveld, Tzaneen Sour Lowveld, Musina Mopane Bushveld, Woodbush Granite Grassland and Gravellote Rocky Bushveld. Low degradation was recorded in the following vegetation types; Granite Lowveld Bushveld, Lowveld Rugged Mopane Veld, Tsende Mopane Veld, Soutpansberg Mountain Bushveld, Strypooport Summit Sourveld, Subtropical Alluvial Vegetation, Limpopo Ridge Bushveld, Limpopo Sweet Bushveld and Makuleke Sandy Bushveld. Despite the fact that some of the vegetation types are well protected such as Musina Mopane Bushveld and Limpopo Ridge Bushveld, they are still affected by degradation.

5. Conclusions

We demonstrated the contribution of anthropogenic threats to habitat loss. Habitat loss often followed a pattern with more degradation found in human-dominated systems than in natural systems such as conservation areas. Although PAs systems are still crucial for preserving and protecting biodiversity, they are vulnerable to threats. Human-induced impacts resulted in loss of habitat service and degradation that negatively affected the delivery of other ES. There were trade-offs between human-induced LUs and biodiversity conservation.

LUs such as urbanisation, agriculture and mining should find ways to accommodate biodiversity conservation. Strategies should be put in place to inform management of vegetation types that are threatened by degradation. Habitat condition assessment is highly recommended to serve as a basis for assessing delivery of ES and for informing LU planning.

Note

1. The affected vegetation types were Granite Lowveld Bushveld, Gravellote Rocky Bushveld, Makhado Sweet Bushveld, Roodeberg Bushveld, Tzaneen Sour Lowveld, Polokwane Plateau Bushveld, Lowveld Rugged Mopane Veld, Tsende Mopane Veld, Mmabolo Mountain Bushveld, Northern Mistbelt Forest, Woodbush Granite Grassland, Soutpansberg Mountain Bushveld, Musina Mopane Bushveld, Soutpansberg Summit Sourveld, Strypooport Summit Sourveld, Subtropical Alluvial Vegetation, Limpopo Ridge Bushveld, Limpopo Sweet Bushveld and Makuleke Sandy Bushveld. Of these, Makhado Sweet Bushveld was found to be most degraded. Moderate degradation was recorded in Roodeberg Bushveld, Polokwane Plateau Bushveld, Mmabolo Mountain Bushveld, Northern Mistbelt Forest, Soutpansberg Mountain Bushveld, Tzaneen Sour Lowveld, Musina Mopane Bushveld, Woodbush Granite Grassland and Gravellote Rocky Bushveld. Low degradation was recorded in the following vegetation types; Granite Lowveld Bushveld, Lowveld Rugged Mopane Veld, Tsende Mopane Veld, Soutpansberg Mountain Bushveld, Strypooport Summit Sourveld, Subtropical Alluvial Vegetation, Limpopo Ridge Bushveld, Limpopo Sweet Bushveld and Makuleke Sandy Bushveld. Despite the fact that some of the vegetation types are well protected such as Musina Mopane Bushveld and Limpopo Ridge Bushveld, they are still affected by degradation.

Disclosure statement

No potential conflict of interest was reported by the authors.

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