A biodiversity intactness score for South Africa

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SOUTH AFRICA'S NEW BIODIVERSITY ACT requires the development of a national framework for the integrated management of biodiversity in the country. The act also requires regular monitoring and reporting of the status of biodiversity. We apply a new approach, the Biodiversity Intactness Index (BII), to assess the state of biodiversity in South Africa. The index is a measure of the change in abundance across all well-known elements of biodiversity, relative to their inferred pre-colonial state. The BII can be calculated nationally, by province, municipality, or ecosystem type, or any other defined spatial unit. We estimate that, averaged across plants, mammals, birds, reptiles and frogs, abundances have declined by 19 ± 7% over the past three centuries in South Africa. Losses are greatest in the grassland, fynbos and forest biomes, and mammals are the most affected taxonomic group. It is estimated that 80% of the remaining wild organisms in South Africa are in the extensive areas predominantly under grazing management. This suggests that the policy action with the greatest potential to limit further loss of biodiversity is to prevent the degradation of these areas, which could potentially halve the abundance of the remaining wild organisms.

Introduction

The South African Constitution and Bill of Rights provides all citizens with the right 'to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that i) prevent pollution and environmental degradation; ii) promote conservation; and iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development'.[1] These principles recognize the importance of environmental protection to the well-being and prosperity of the country's citizens. The principles are given effect by, amongst others, the National Environmental Management: Biodiversity Act (Act 10 of 2004).[2]

The link between human well-being, environmental protection and biodiversity conservation is based on the scientifically established (but poorly quantified) notion that biodiversity underpins the provision of ecosystem services.[3,4] Biodiversity refers to the variation among genes, species, and ecosystems and variety in structure, function and composition at each of these levels.[5] It can be measured in terms of diversity (the number of different types), quantity and quality (how much there is of each type, and its condition), and distribution (where different types are located geographically).[6] Ecosystem services include, for example, food, fibre, medicines, pollination, climate regulation, pest and disease control, as well as spiritual, aesthetic and recreational values, and are essential to the economy and human well-being.[7–10] Many ecosystem services rely on the presence of particular organisms or ecosystem service providers,[11] and the level of the service depends on the abundance of those organisms.[12] However, maintaining the composition and relative abundance of species in a community (rather than reducing communities to only the 'useful' species), is important for ensuring the long-term resilience of ecosystem services in the face of change and shocks.[3,13] This corresponds to ideas of 'biological integrity', and the maintenance of system elements and processes in order to preserve the wholeness of the system.[14–16] Loss of biodiversity, including reductions in the extent or condition of ecosystems, in the abundance or distribution of populations of individual species, or in genetic diversity within populations,[17] therefore has adverse implications for ecosystem services and human well-being.[4,18,19]

The Biodiversity Act recognizes the exceptional diversity of South Africa's biological resources, and the responsibility of the state to act as a trustee in conserving those resources. South Africa occupies only about 2% of the world's land area, but is home to about 10% of all plant species, and 7% of the reptiles, birds and mammals.[20] In addition, it contains three of the world's 34 biodiversity hotspots: the Cape Floristic Region, the Succulent Karoo, and the Maputoland–Pondoland region.[21,22,*]

The Biodiversity Act requires, within three years, the development of a National Biodiversity Framework to provide for an integrated, coordinated approach to biodiversity management and to identify priority areas for conservation action and the establishment of protected areas.[2] The Act also requires monitoring and reporting on the status of South Africa's biodiversity, and research into the sustainable use of indigenous biological resources. These requirements fulfil national imperatives as well as the country's obligations as a signatory to the Convention on Biological Diversity (CBD, Article 6).[†] Two key initiatives informing the development of the National Biodiversity Framework have been the National Biodiversity Strategy and Action Plan (NBSAP)[23] and the National Spatial Biodiversity Assessment (NSBA).[24] The NBSAP sets out a framework and plan of action for the conservation and sustainable use of South Africa's biological diversity, and the equitable sharing of benefits derived from its use.

The NSBA is South Africa's first comprehensive spatial assessment of biodiversity in terrestrial, river, estuarine and marine ecosystems.[24] It provides a national assessment of the state of biodiversity in each of these environments, and identifies priorities for conservation action. The main conceptual approach used by the NSBA is systematic conservation planning,[25] which relies on quantitative targets for the protection of biodiversity features (species and ecosystems). Conservation planning is a powerful tool for identifying priority areas for action,[26] but it is not a tool for assessing or monitoring the state of biodiversity. The NSBA therefore developed two ecosystem-level indicators of biodiversity condition: i) ecosystem status, a measure of the amount of land, river or sea left in a natural state in an ecosystem relative to that ecosystem's conservation target;[27] and ii) protection level, a measure of the amount of land, river or sea conserved per ecosystem relative to the ecosystem's conservation target. These indicators are intended to feed into the Biodiversity Act's listing of threatened ecosystems, and hence provide a means of monitoring change through the planned five-year iterations of the NSBA.[24]

While the NSBA measures provide important information, they leave significant gaps. They are based on a binary classification of the landscape (transformed versus untransformed; protected versus unprotected), and thus do not differentiate between the impacts of different types of land use that lie on the continua between these poles. The indicators focus exclu-

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sively on the ecosystem level, and are unable to relate changes at this level to influences at the community or species level. Lastly, they are assessed in terms of conservation targets, which vary by ecosystem type. These targets (for instance, 10% protected area) may be defined more by political feasibility than by scientific knowledge of the extent (and quality) of different ecosystem types that are needed to maintain the production of ecosystem services.

We have been involved in the development and application of a new metric, the Biodiversity Intactness Index (BII),[28] which we believe can complement the information currently provided by the NSBA. The BII was conceived for use in the Southern African Millennium Ecosystem Assessment[8,29] to provide an easy-to-understand overview of the state of biodiversity for policy-makers and the public. It was specifically designed to fulfil the requirements set by the CDB for indicators of biodiversity change,[17,30,31] including scientific soundness, sensitivity to change at policy-relevant spatial and temporal scales, allowing for comparison with baseline or policy targets, amenable to aggregation and disaggregation by ecosystem and political boundaries, practicality (measurable with sufficient accuracy at affordable cost), as well as being simple and easy to understand.[32] The BII is formally defined as the average population size (abundance) of all well-described taxa (that is, in the South African case all higher plants and vertebrates), relative to their reference populations in a particular ecosystem type (nominally those of the pre-colonial period). The BII takes account of the extent of different land uses and provides an integrated assessment of their impact on the populations of wild organisms in a specific area. The BII is not a tool for identifying conservation priorities, although it can help inform approaches with that aim. Rather, it provides for a comparative assessment, across space and time, of the state of biodiversity, as measured by the average abundance of wild organisms relative to their reference populations.

We believe that species-level abundance, as reflected by the BII, is both a practical and meaningful measure of biodiversity status in terms of quantity and quality (or integrity). Species abundance can account for the fact that the landscape reflects a continuum of impact, it is sensitive to habitat degradation and loss (currently the main drivers of biodiversity change[4,6,33,34]), and it has direct links to the provision of ecosystem services. The BII integrates change at the ecosystem level with that at the species level by accounting for change in the communities that constitute ecosystems as well as changes in ecosystem area.

The BII has been applied to southern Africa to assess the current state of biodiversity and rate of loss,[28,35] to project future changes in biodiversity under various scenarios of land-use change, and to reconstruct the pattern of biodiversity loss over the 20th century.[37] For the southern African region overall, there has been an estimated average decline of 16% in the abundance of terrestrial plants and vertebrates since pre-colonial times, and the absolute decline in the index over the decade of the 1990s has been estimated at 0.8%.[28] A scenario analysis for the region suggests a continuing decline in the index for most of the 21st century, with rates of decline likely to accelerate for several decades.[36] The 20th-century reconstruction for South Africa indicates a decline at a varying rate of around 1% per decade. In contrast to the southern African region as a whole, there is some evidence that the rate of biodiversity loss in South Africa may be levelling off.[37]

The objectives of this paper are to show that the BII can be confidently applied, using available data, at all three governance levels in South Africa (national, provincial, and local), as well as at the ecosystem level. We thereby introduce a tool that could be used to complement existing methods in reporting on the state of South Africa's biodiversity, a significant need which has been identified by the Department of Environmental Affairs and Tourism (DEAT).[23,38,39] We highlight the implications of our findings for biodiversity management in the country, specifically in terms of sustainable natural resource use, priorities for further research, and the need for coordination between different government departments, specifically DEAT*, the Department of Agriculture†, and the Department of Water Affairs and Forestry‡.

Methods

The full derivation and logic of the BII have been described elsewhere.[28] In essence, the index is a richness-and-area weighted average population impact of a set of land-use activities on a given group of organisms, in a given area. The population impact (I_{ijk}) is defined as the relative population of taxon i (as compared to the reference state) under land use activity k in ecosystem j, so that BII gives the average remaining fraction of the populations of all species considered:

$$\mathrm{BII} = \frac{\sum_i \sum_j \sum_k R_{ij} A_{jk} I_{ijk}}{\sum_i \sum_j \sum_k R_{ij} A_{jk}},$$

where R_{ij} = richness (number of species) of taxon i in ecosystem j; A_{jk} = area of land use k in ecosystem j.

For southern Africa, we conceptually define the reference populations as those present before the substantial alteration of the landscape triggered by European settlement (that is, pre-1700 populations). Since records of plant and wildlife populations from this era are virtually non-existent, we use current populations in large protected areas in each ecosystem type as a proxy for the 'pre-colonial state'. In the case of certain large mammals and birds, these proxy numbers were adjusted in accordance with expert opinion (see below) if they were believed to differ from the pre-colonial state. Alien species are excluded from the calculation. A formal calculation of the variance of the BII is possible. For communication purposes, we express the index as a percentage rather than a proportion. The BII score can be disaggregated spatially (by ecosystem or political boundaries), by taxonomic group or by land use activity, to meet the information needs of different users by means of partial summations.

While I_{ijk} (current populations as a fraction of the pre-colonial populations) can in principle be exactly measured, the species-by-species population data needed to do so are currently available only for a few species in a few locations. In the southern African case, expert judgment was used to generate the matrix of values of I_{ijk} and validated against available field studies.[28] Three or more highly experienced specialists for each selected taxonomic group (plants, mammals, birds, reptiles, and amphibians) independently estimated the degree of reduction of populations, relative to populations in a large protected area in the same broad ecosystem type or biome, caused by a pre-defined set of land use activities (Table 1). This was achieved by dividing each taxonomic group into 5–10 functional types that responded in similar ways to human activities. Functional types were defined primarily by body size, trophic niche and reproductive strategy. The experts were asked, for instance: 'Is the abundance of seed-eating birds in a cultivated area in the grassland higher or lower than in a protected area in the same ecosystem type? How much

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Table 1. Land-use classes used to calculate the BII for South Africa.

Land-use class	Description	Examples
Protected	Minimal recent human impact on structure, composition or function of the ecosystem. Biotic populations inferred to be near their potential.	Large protected areas, national, provincial and private nature reserves, 'wilderness' areas and mountain catchments.
Moderate use	Extractive use of populations and associated disturbance, but not enough to cause continuing or irreversible declines in populations. Processes, communities and populations largely intact.	Grasslands grazed within their sustainable carrying capacity, forest areas harvested within their regenerative capacity.
Degraded	Extractive use at a rate exceeding replenishment and widespread disturbance. Often associated with high human population densities and poverty in rural areas. Productive capacity reduced to approximately 60% of 'natural' state.	Areas subject to intense harvesting, grazing, hunting or fishing, areas invaded by alien vegetation.
Cultivated	Natural land cover replaced by planted crops. Most processes persist, but are significantly disrupted by ploughing and harvesting activities. Residual biodiversity persists in the landscape, mainly in set-asides and in strips between fields (matrix), assumed to constitute approximately 20% of class.	Commercial and subsistence crop agriculture, both irrigated and dryland, including planted pastures and fallow or recently abandoned cultivated lands. Orchards and vineyards.
Plantation	Natural land cover permanently replaced by dense plantations of trees. Unplanted areas assumed to constitute approximately 25% of class.	Plantation forestry, typically *Pinus* and *Eucalyptus* species.
Urban	Natural land cover replaced by hard surfaces such as roads and buildings. Most ecological processes are highly modified. Remnant semi-natural cover assumed to constitute 10% of class.	Dense human settlements, industrial areas, transport infrastructure, mines and quarries.

The land-use map was compiled from the South African national land cover map[44,45] and the national protected areas map[46] at a 1 km × 1 km resolution.

higher or lower?'. I_{ijk} typically lies between 0 and 1, but can take on values greater than 1 in some circumstances. For instance, fruit-eating birds often increase in urban gardens relative to 'natural' areas. Aggregation up to the broad taxonomic level (birds, mammals etc.) was done by weighting the expert-derived I_{ijk} estimates for each functional type by the number of species in that functional type in the particular ecosystem.[41] Where actual species abundance data are or become available, these can be used together with or in place of expert-derived estimates.

R_{ij} is the species richness per broad taxon (plants, mammals etc.) per ecosystem type. Data compiled by Le Roux[20] for plants and vertebrates in the seven terrestrial biomes that cover South Africa were used in this study. The use of such data makes the assumption that each species occurs throughout the extent of every biome in which it has been recorded. This is an approximation, which we have tested and found to introduce an error at the national level of about one-fifth of the uncertainty associated with the estimates of the impacts of various land uses.[28] The BII can be calculated more accurately by using the inferred pre-disturbance distribution maps of individual species. These are available for most, but not all, plant and vertebrate species in South Africa. For studies at finer scales, the use of the more resolved datasets is recommended. For instance, at the level of local government, using biome-level mammal richness data rather than individual species distributions changed the BII score by 3%.[28] The BII can, if necessary, be calculated using a mixture of biome approximation and individual species distribution data; for example, actual distributions for birds and mammals, but biome data for plants.

A_{jk} is the area of a particular land use within a specific ecosystem, derived by overlaying a land-use map on an ecosystem type map. In this study, ecosystem types were defined as the biomes of South Africa.[42,43] Land use was derived by combining the 1995 South African national land-cover map (NLC)[44,45] with a national protected-areas map.[46] A base resolution of 1 km × 1 km was used to correspond to the resolution at which the expert estimates were made. At this resolution, cells classified as cultivated or urban would generally include a fraction of uncultivated or non-built-up land; experts were asked to take this into account in making their estimates. The difference in BII associated with the use of an alternative land-use map has also been tested at the national level, and found to be approximately five times smaller than the error associated with the land use impact estimates.[28]

How finely the taxonomic groups are divided into functional groups, the broad biomes into particular ecosystem types, and how many land uses are defined is largely a pragmatic question. For this study, the selection of an average of eight functional groups for each of five taxonomic groups, three experts per taxonomic group, six ecosystem types and six land-use activities, required about 4650 individual estimates of I_{ijk}, a process that took about 75 man-hours to complete (excluding travel and analysis time).[28]

Results and discussion

The biodiversity intactness of South Africa in the year 1995 is estimated as 81.2 ± 6.9% (Table 2). In other words, we calculate that averaged across all species of terrestrial plants and vertebrates, populations have declined by 18.8% from their presumed pre-colonial levels. The persistence of organisms as estimated by the BII is therefore substantially greater than that indicated by the proportion of the country under formal conservation protection (7%),[46] but considerably less than that given by extinction-based measures (less than 0.5% of known organisms in South Africa have become extinct in the modern era[47]).

Ecosystem level results

The pattern of threats to biomes revealed by the BII agrees with the findings of the NSBA[24] and other national scale assessments.[44,48] The biomes that have lost the most biodiversity are the grassland, fynbos and forest (Table 2). In the case of grassland, which is believed to have constituted 24% of the country's land area before 1700,[42,43] this is due to the disproportionate effects of high-impact land uses: in 1995, 47% of South Africa's cultivated land, 47% of urban land, and 56% of plantation areas lay in the grassland biome. In the case of fynbos and forest, estimated to have occupied 6% and 0.6% of the country, respectively, in pre-colonial times,[42,43] the consequences of land-use

Table 2. A cross-tabulation of BII (%) per major ecosystem type and broad taxonomic group for South Africa.

	Area (km²)	Plants	Mammals	Birds	Reptiles	Amphibia	All taxa
Richness		*23 420*	*258*	*694*	*363*	*111*	***24 846***
Forest	*7 148*	75.6	76.5	88.8	83.7	81.5	**76.1** (±6.1)
Fynbos	*77 111*	73.1	81.3	93.4	79.0	81.6	**73.7** (±4.8)
Grassland	*294 815*	71.6	55.5	90.5	75.9	81.0	**73.1** (±6.4)
Savanna	*416 315*	82.5	71.0	91.5	86.7	93.4	**83.1** (±8.1)
Thicket	*41 349*	82.7	69.5	91.9	86.9	93.9	**83.4** (±8.9)
Nama Karoo	*297 806*	87.7	71.3	107.7	94.0	98.8	**89.7** (±5.9)
Succulent Karoo	*82 489*	87.4	73.6	106.5	93.1	98.8	**88.3** (±4.6)
All biomes	***1 217 033***	**80.2** (±6.6)	**68.6** (±10.1)	**94.9** (±9.4)	**85.7** (±5.7)	**90.1** (±7.8)	**81.2** (±6.9)

The overall score (81.2 ± 6.9% at the 95% level) can be disaggregated into column or row scores for ecosystems or taxa, or down to taxa within ecosystems. Note that the aggregations are not simple averages, but are weighted by richness and area. The 95% confidence intervals indicate the uncertainty associated with the population impact estimates I_{ijk}.

change are amplified by the large number of species affected: 38% of South Africa's species are represented in the fynbos biome and 17% in the forest biome.[20]

The biodiversity of the Nama and succulent karoo is overall least affected to date, according to our index. We attribute this to their aridity, which limits cultivation and urban settlement. Note that the BII does not include impacts due to climate change, which are projected to be severe in the succulent karoo during the 21st century.[49] The savanna and thicket biomes, which together made up about 38% of the pre-colonial land area, have experienced an intermediate level of impact. They are particularly affected by degradation: in 1995, 68% of degraded land in South Africa lay in these biomes. Degradation is defined here as uses that substantially modify, but do not replace, the natural land cover, resulting in a reduction of the productive potential of the ecosystem that persists from year to year. The most widespread cause of degradation is herbivory or harvest at levels far in excess of the productive potential of the ecosystem over long periods of time. The resultant loss of vegetation cover is often associated with soil erosion.[50] In the high-resolution satellite images used for national land-cover mapping, degraded areas show up as brighter than their undegraded neighbours. It is widely acknowledged that the NLC map grossly underestimates the extent of degraded areas, particularly in arid regions.[44,50] This suggests that the savanna and thicket may be more heavily impacted than implied by the BII.

Taxon level results

Mammals are the taxonomic group most affected by human activities in South Africa (Table 2). Disaggregated to the level of functional groups (that is, guilds), it is the very large herbivores and predators that are particularly affected. Species in these two groups pose a direct threat to humans, and act as disease reservoirs, predators or competitors with respect to domestic livestock. They are therefore excluded from almost all areas not managed specifically for wildlife conservation. The populations of most other mammal species, and most birds, plants, reptiles and frogs, are estimated to be only marginally reduced in sustainably grazed rangelands. Certain groups specifically benefit from human activities in livestock ranching areas, particularly from the presence of artificial water points. This beneficial effect is especially pronounced for amphibian families such as the Bufonidae, and explains the high scores for amphibians in the karoo areas (Table 2). Concerns about underestimates in the extent of degraded area in the NLC are relevant here too: some taxonomic groups, and particularly species in arid regions may be more heavily affected than reflected in the BII scores.

Administrative level results

Assessed at the provincial level, Gauteng has the lowest BII score, due to its high level of urban development (Fig. 1a): 21.4% of the province was classified as urban in 1995.[45] Biodiversity in the Free State is particularly influenced by cultivation (28.1% is cultivated, the largest share of any province), whereas cultivation and plantation forestry are major influences in Mpumalanga (comprising 16.2% and 8.1% of the land area, respectively). Degradation is an important factor in the North West and Limpopo provinces, as well as in the Eastern Cape and KwaZulu-Natal. In these four provinces, degradation accounted for between 8% and 12% of the land area in 1995.[44,45] Areas under moderate extractive use make up the principal fraction of all provinces, and preventing degradation of these parts should be a priority throughout. However, these results highlight additional priorities for different regions: in Gauteng, initiatives that prevent urban sprawl and encourage garden and park development that favours biodiversity could have significant benefits; in the Free State, Mpumalanga and the Western Cape, adjustments in agricultural practices (e.g. the use of buffer strips) could potentially provide substantial advantages; and in the North West, Limpopo, Eastern Cape and KwaZulu-Natal, both prevention of further degradation and restoration of existing degraded areas are a particular priority.

Disaggregation of the BII to local government level allows for within-province comparison and finer-level planning (Fig. 1b). The high impact of the main metropolitan areas (greater Johannesburg, Cape Town and Durban) is matched by the effects of cultivation in the region of Bothaville in the northern Free State, and the Bredasdorp area on the Agulhas plain in the Western Cape. Municipalities along the entire seaboard of South Africa, save for a small area near the mouth of the Orange (Gariep) River, have been substantially influenced by human activities, particularly in the Western Cape and KwaZulu-Natal. When the BII is calculated at the finest resolution permitted by the input data (1 km × 1 km), localized impacts, such as irrigated croplands along the Orange in the Northern Cape, become apparent (Fig. 1c).

The value of rangelands

Our findings highlight the role played by the extensive areas *not* under formal conservation management in maintaining South Africa's biodiversity, corroborating the conclusions of other authors.[23,51,52] We estimate that the extensive areas used primarily for sheep and cattle ranching, and stocked within grazing norms, contain 80% of the remaining wild vertebrate and plant populations in the country (Table 3). This suggests that the National

Biodiversity Framework needs to address the management of these areas, particularly in light of the constitutional mandate to secure ecologically sustainable use of natural resources. While cultivation accounts for over 50% of the present impact on biodiversity, there is limited potential for further expansion of this land use in South Africa. It is estimated that only 13.7% of the country is very suitable for crop agriculture, almost all of which is already cultivated (see Table 3).[53] Similarly, although we estimate urban development to reduce wild populations within the urbanized area by nearly 90%, the actual footprint of dense human settlement in South Africa is small (1.14%). Even with high rates of urbanization, the total area of urban land will remain small for several decades. In contrast, a large fraction of the rangelands (74.2% of the country) currently under moderate extractive uses, primarily livestock grazing, could potentially become degraded if not managed appropriately. On average, we estimate that degradation reduces the abundance of wild populations by 40–50%; this compares with an average reduction of only ~7% in areas under moderate extractive use. The rangelands of South Africa are influenced by decisions taken in multiple government departments, including the departments of Agriculture, of Water Affairs and Forestry, and of Environmental Affairs and Tourism (the lead department for the enforcement of the Biodiversity Act and implementation of the NBSAP). The regulation of the key activities affecting biodiversity therefore calls for effective coordination between government departments.

A future research agenda

The sources of uncertainty in our estimate of BII are useful for highlighting topics in need of further research. Our results suggest that our knowledge is most lacking with regard to the actual consequences of different land-use activities on native organisms. Uncertainty is greatest with respect to the effects of degradation and moderate use (Table 3), which are particularly important land-use categories in the savanna and thicket biomes. At the taxonomic group level, we are most uncertain about the impact of different land uses on mammals and birds, followed by amphibians.

More accurate data on the extent and nature of different types of land use will help refine our estimates of BII. The categories which show the biggest variation in South Africa between different land-use maps are urban land and degraded

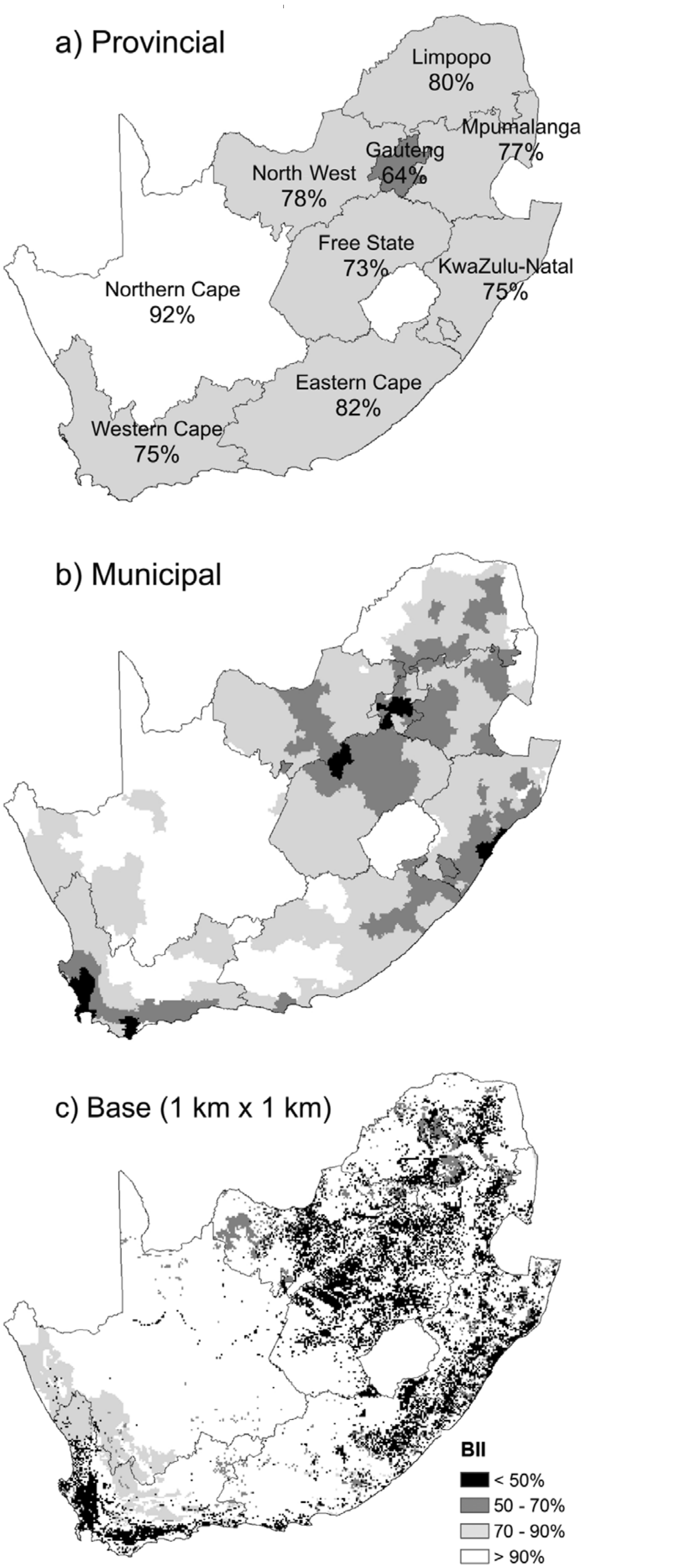

Fig. 1. The Biodiversity Intactness Index applied at sub-national levels of environmental decision-making in South Africa. Results are richness- and area-weighted averages of the index as estimated at a base resolution of 1 km × 1 km . Values of BII obtained at different scales are directly comparable: they refer to the average abundance of all species in the particular area, expressed as a fraction of abundance in the pre-colonial era.

Table 3. Area in South Africa in each land-use category, and the mean richness-weighted BII (%) for each category.

Land use	Area (km^2)	%	Mean BII	(95% CI)	% Decrease in BII	% Remaining BII
Protected	84 750	6.96	100.0	(±0.1)	0.02	11.19
Moderate use	903 322	74.22	93.3	(±7.9)	24.84	80.39
Degraded	56 909	4.68	56.7	(±11.4)	12.27	3.73
Cultivated	142 766	11.73	25.1	(±4.8)	52.13	4.05
Plantation	15 351	1.26	27.2	(±4.1)	5.04	0.44
Urban	13 935	1.14	12.7	(±4.0)	5.69	0.19
South Africa	**1 217 033**	**100.00**	**81.2**	**(±0.069)**		

The 95% confidence intervals (CI) indicate the uncertainty associated with the population impact estimates. The right-hand two columns respectively indicate the percentage of the decrease in populations explained by each land-use type, and the percentage of the remaining biodiversity that is now located in each land-use type. Cultivation accounts for over half of the current impact on biodiversity. Four-fifths of the remaining wild organisms in South Africa are estimated to be in the extensive areas under moderate extractive use, mostly rangelands. This highlights the importance of proper management of these areas in the conservation of the biodiversity in South Africa.

land.[54] This is largely due to inconsistency in their definitions across different land cover products, together with problems in the detection of specific categories, particularly degradation. A high quality degradation map for South Africa would likely result in lower BII estimates for several parts of the country where degradation is thought to be substantial but is not captured by the NLC.

Another avenue for research is establishing the relationship between biodiversity intactness and the provision of ecosystem services. The BII score is almost certainly related in some way to the provision of ecosystem services, particularly regulating services such as disease control.[3,36] However, our knowledge does not yet allow us to estimate the minimum level of biodiversity intactness needed to sustain important ecosystem services.

Most freshwater biodiversity, and all marine life, have been excluded in this study. The BII could, however, be extended to cover these systems. An estimate for marine ecosystems could be made by direct application of the area-based BII algorithm. Estimates for linear systems, such as rivers and coasts, may be made on an area basis or potentially by substituting length for area. Species richness data on freshwater and marine plants and vertebrates are available. The main task would be to define impact categories analogous to those presented in Table 1, and to collect expert judgments and published field data regarding the impacts of the relevant activities on the various functional groups. From our experience, this would require several weeks of effort.[28]

Conclusion

This study demonstrates the application of a biodiversity assessment tool that we suggest can complement the information provided by existing approaches in the development of South Africa's National Biodiversity Framework. In particular, the BII is a useful tool for periodic reporting of the state of the country's biodiversity. The advantage of the index compared with existing methods for assessing biodiversity status, particularly listings of different land-cover types and protected areas per biome, is that the BII differentiates between the impacts of different land uses and quantifies their effect on the populations (abundance) of native terrestrial plants and vertebrates. Furthermore, by focusing on changes in abundance, rather than richness (that is, extinction), the BII is sensitive to change at policy-relevant spatial and temporal scales. The fact that the index is scale-independent is particularly useful: municipal-level scores have the same meaning as, and can be compared directly with, national- or biome-level scores. This can greatly help facilitate comparison and coordination of activities and management at different scales. The BII has been shown to meet the criteria set by the CBD for indicators of biodiversity change,[17,32,41] and proposed as a possible tool for assessing progress toward targets such as the CBD target of significantly reducing the rate of biodiversity loss by 2010.[28,40]

The BII is not a tool for identifying conservation priorities, nor is it intended as a single all-purpose indicator. The index assumes that all species are equal: it does not give special weight to endangered or threatened species, nor does it take account of complementarity (the degree of similarity or difference) between species or the level of protection of individual species. Information such as the IUCN Red List of Threatened Species,[47*] biodiversity hotspots,[22†] and systematic conservation planning[25] are appropriate approaches for determining conservation priorities. Rather, the BII is intended as a high-level, synthetic tool for monitoring change in biological integrity (biodiversity quantity and quality) over time, and comparing biodiversity status among different regions. While the use of a very limited number of indicators is called for in communicating with the public and decision-makers, the full complexity and multi-dimensionality of biodiversity clearly cannot be captured by a single indicator. The BII is therefore intended to complement existing approaches to biodiversity assessment and reporting.

Our findings regarding the importance of areas outside reserves do not deny the importance of protected areas, particularly for the conservation of threatened species. Indeed, this study would have been impossible if a system of protected areas were not in place to provide a reference baseline. However, in a country where the livelihoods of nearly half the population depend on the economic use of the landscape, principally through farming crops and livestock, it is unreasonable to expect that most of the land area will be set aside exclusively for nature conservation. Alongside a policy of protection of selected areas, and in line with the South African Constitution and Bill of Rights, our results highlight the critical importance of policies that maintain and encourage biodiversity-friendly land use in the remainder of the landscape, where people live and work.

*www.redlist.org
†www.biodiversityhotspots.org

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