Comparison of extent and transformation of South Africa's woodland biome from two national databases

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THE RECENT COMPLETION OF THE SOUTH African National Land-Cover Database and the Vegetation Map of South Africa, Swaziland and Lesotho, allows for the first time a comparison to be made on a national scale between the current and potential distribution of 'natural' vegetation resources. This article compares the distribution and location of woodland-type vegetation categories defined within the National Land-Cover data and the equivalent 'Savanna-thicket Biomes' class defined within the Vegetation Map data. Significant differences were found, both in terms of the total areal extent, as well as the actual spatial distribution of these two data sets. These differences are a measure of the inherent mapping accuracies of each source, but rather an illustration of boundary delineation distinctions that are a result of different data sources, mapping objectives and information classes, that must be noted when comparing two essentially similar information sets.

Background

Large-area land cover maps are needed in many research and management activities, concerned with global change[1], biodiversity and conservation[2], and biogeography[3]. These thematic maps are, by design, highly generalized abstractions of reality, in terms of spatial resolution, boundary-line sinuosity, and classification detail. The recent completion of both the South African National Land-Cover Database (NLC)[4,6] and the Department of Environment Affairs and Tourism's (DEAT) 'Vegetation Map of South Africa, Swaziland and Lesotho'[7,8] allows for a timely comparison to be made on a national scale between the current and potential distribution of 'natural' vegetation resources. This type of exercise was last conducted by Mall and Bossi[9] for the Fynbos Biome, with a re-interpretation by Fairbanks *et al.*[5]

This paper compares the distribution and location of woodland and bushveld-type vegetation categories defined within the NLC data, and the equivalent 'Savanna Biome' class defined within the DEAT's 'Vegetation Map' data. Significant boundary discrepancies are reported between the two data sets in terms of the overall woodland/savanna extent. This is not (nor was it ever intended to be), a measure of inherent mapping accuracies, but rather an illustration of boundary delineation distinctions that are a result of different raw data sources, mapping objectives and final information classes, that must be noted when comparing two essentially similar data sets.

The results presented are based on a comparison of two *specific* data sets and the characterization of the various vegetation types contained within them. No inference is made, or intended, as to the actual validity of these data sets, since, as in the case of the biomes, it is acknowledged that the Thicket Biome is not universally recognized as being separate from the Savanna Biome.[10]

Description of primary data

The NLC database is intended to provide national, baseline information on land-cover and mappable land-use.[5] The primary objective of the project was to produce a standardized land-cover database for all of South Africa, Swaziland and Lesotho. The product is designed for 1:250 000 scale mapping applications (25 ha minimum mapping unit). It was derived (using manual photo-interpretation techniques) from a new series of 1:250 000 scale geo-rectified 'SpaceMaps' (from the CSIR's Satellite Applications Centre, 1996), based on seasonally standardized, single date Landsat Thematic Mapper (TM) satellite imagery captured principally during the period 1994–95.

The legend used within the land-cover database is based on the classification scheme defined within the standard framework defined by Thompson[11] for remote sensing applications in South Africa. This is a hierarchical framework designed to suit South African conditions, and incorporates known land-cover types that can be identified in a consistent and repetitive manner from high-resolution satellite imagery such as Landsat TM and SPOT. The 'natural' vegetation classes are based on broad, structural types only, and are not intended to be equivalent to a floristic or ecological vegetation classification.

It is important to understand that a combination of both the NLC database's 'Woodland' and 'Thicket, Bushland, Bush-Clump & Tall Fynbos' land-cover classes were used in the comparison with the DEAT defined 'Savanna Biome'. The inclusion of the NLC's 'Thicket, Bushland (etc.)' class was seen as a necessity, since this category also included a significant component* of the traditional 'bushveld' regions in northern and eastern South Africa, on the basis of structural appearance.[12]

Unfortunately, such an approach does not allow a clear separation between true thicket (as in the 'Thicket Biome'), and tall fynbos communities (as in the 'Fynbos Biome'), from the true bushland-type vegetation (such as occurs in the 'Woodland Biome'), since no separation was made at this sub-class level within the original 'Thicket, Bushland, Bush-Clump & Tall Fynbos' NLC-defined land-cover class. This will have resulted in some unavoidable overlap between the extent of NLC-defined Woodland and the DEAT-defined Thicket and Fynbos biomes, especially in the southern and Eastern Cape regions. The NLC Forest class (equivalent to the DEAT-defined 'Forest Biome') was excluded from all calculations. Full class definitions for these NLC vegetation classes are provided in Table 1.

The DEAT's 'Vegetation Map' (and accompanying booklet) was developed with the aim of producing a revised vegetation map of South Africa, based on vegetation structure and species composition,[8] which provided a broad overview of the region's natural plant resources suitable for educators and planners.[7] The boundaries and vegetation types within this map were delineated manually at workshops by teams of botanists and from a number of sources, such as geological, pedological, climatological, remote sens-

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*9.4% (725 018 ha) of the Fynbos Biome and 40.48% (1 681 753 ha) of the Thicket Biome were classified as 'Thicket, Bushland, Bush-Clump & Tall Fynbos' in the NLC database,[5] compared to 43.04% (18 356 631 ha) within the Savanna Biome.

933.XLS

Table 1. South African National Land-Cover database class definitions.

Class name	Definition
Forest	All wooded areas with tree canopy cover greater then 70%, where the canopy is composed of mainly self-supporting, single-stemmed, woody plants >5 m in height. A multi-strata community, with interlocking canopies, composed of canopy, sub-canopy, shrub and herb layers. Composed of mainly indigenous tree species, growing under natural or semi-natural conditions (although it may include some localized areas of self-seeded exotic species). Excludes planted forests (and woodlots). Typically associated with the Forest biome in South Africa.
Woodland	All wooded areas with tree canopy cover of 9–70%, where the canopy is composed of mainly self-supporting, single-stemmed, woody plants >5 m in height. Essentially a broad open-closed canopy woodland community, typically consisting of a single tree canopy layer and a herb (grass) layer. Composed of mainly indigenous tree species, growing under natural or semi-natural conditions (although it may include some localized areas of self-seeded exotic species). Excludes planted forests (and woodlots). Typically associated with the Savanna biome in South Africa.
Thicket, Bushland, Bushclumps and Tall Fynbos	Communities typically composed of tall, woody, self-supporting, single and/or multi-stemmed plants (branching at or near the ground), with, in most cases, no clearly definable structure. Total canopy cover >9%, with canopy height of 2–5 m. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some localized areas of self-seeded exotic species, especially along riparian zones). Typical examples are Valley Bushveld, Mopane bush and many areas traditionally described as 'bushveld'. Dense bush encroachment areas would be included in this category.
Degraded class sub-division	Permanent or seasonal, *anthropogenic* areas of very low vegetation cover (i.e. removal of tree, bush and/or herbaceous cover) compared to *the surrounding natural vegetation cover.* These classes are sub-divisions of each Level I vegetation classes, i.e. *Degraded-Woodland,* in order to allow reconstruction of full class-type extent. Typically associated with subsistence level farming and rural population centres, where overgrazing of livestock and/or wood-resource removal has been excessive. Often associated with severe soil erosion. Characterized on satellite imagery by significantly higher overall reflectance levels (i.e. whiter appearance) and lower NDVI values (compared to the surrounding vegetation).

ing (e.g. only for 'Fynbos' and 'Thicket' biomes), and other relevant cartographic data.

The DEAT map differs from both the NLC data and for that matter Acocks's Veld Types,[13] since the vegetation units are defined as having '... similar vegetation structure, sharing important plant species, and having similar ecological processes... looking at biological resources from a perspective of wise management and potential use.[7] Thus, the DEAT mapped units are the vegetation types that would have potentially occurred today, were it not for the major anthropogenic transformations such as cultivation, afforestation, urban spread and dams that have altered the landscape. By contrast, the NLC data map current vegetation category extent, as influenced by these land transformation factors, and Acocks's Veld Types were designed to look at the regions natural plant resources purely from a potential agricultural perspective. The 'Savanna Biome' of the DEAT Vegetation Map is defined as containing 25 different vegetation types, which are listed in Table 2.

A comparison of the two data sets provides an opportunity to assess, at a national level, the differences in distribution and current status of South Africa's woodland resources, as defined by both the DEAT Vegetation Map and the NLC database, where the DEAT map indicates potential distribution and the NLC map current distribution as a result of ongoing land transformation and alternative land-uses.

934.XLS

Table 2. Summarized comparison of total transformation levels per DEAT vegetation type.

DEAT vegetation types within Savanna-thicket Biomes	Extent of DEAT vegetation type located within NLC-defined Woodland area		% of DEAT vegetation type transformed according to DEAT	% of DEAT vegetation type transformed according to NLC (all classes)*
	area (km²)	%		
09. Mopane Shrubveld	2 611	90	0	0
9. Mopane Bushveld	20 979	90	8	8
11. Soutpansberg Arid Mountain Bushveld	4 681	98	Unknown	9
12. Waterberg Moist Mountain Bushveld	12 056	98	28	9
13. Lebombo Arid Mountain Bushveld	4 404	99	Unknown	9
14. Clay Thorn Bushveld	15 846	97	60	41
15. Subarid Thorn Bushveld	2 812	36	Unknown	21
16. Eastern Thorn Bushveld	3 278	35	Unknown	30
17. Sweet Bushveld	17 195	90	27	22
18. Mixed Bushveld	58 817	91	60	31
19. Mixed Lowveld Bushveld	17 420	99	30	29
20. Sweet Lowveld Bushveld	5 754	99	30	15
21. Sour Lowveld Bushveld	14 954	76	76	46
22. Subhumid Lowveld Bushveld	1 346	99	36	16
23. Coastal Bushveld / Grassland	3 770	32	Unknown (high ?)	56
24. Coast-Hinterland Bushveld / Grassland	3 700	36	87	43
25. Natal Central Bushveld	3 415	20	80	28
26. Natal Lowveld Bushveld	6 982	69	35	27
27. Thorny Kalahari Dune Bushveld	125	5	Unknown	0
28. Shrubby Kalahari Dune Bushveld	5 143	14	55	3
29. Karroid Kalahari Bushveld	1 919	9	55	1
30. Kalahari Plains Thorn Bushveld	48 332	95	55	26
31. Kalahari Mountain Bushveld	7 087	54	25	0
32. Kimberley Thorn Bushveld	15 331	56	55	24
33. Kalahari Plateau Bushveld	20 828	89	55	7

*Includes both NLC-defined woodland and non-woodland vegetation classes.

Table 3. National Land-Cover class amalgamations used to define impact classes for woodland groups.

Original National Land-Cover class	Regrouping for areas within the National Land-Cover Woodland Region (including overlap with the DEAT Vegetation Map)	Regrouping for area exclusively within the DEAT Vegetation Map*
1. Woodland	1. Untransformed woodland	–
2. Forest	4. Untransformed (non-woodland)	9. Untransformed (non-woodland)
3. Thicket, Bushland, Bush Clumps, Tall Fynbos	1. Untransformed woodland	–
4. Shrubland and Low Fynbos	4. Untransformed (non-woodland)	9. Untransformed (non-woodland)
5. Herbland	4. Untransformed (non-woodland)	9. Untransformed (non-woodland)
6. Unimproved Grassland	4. Untransformed (non-woodland)	9. Untransformed (non-woodland)
7. Improved Grassland	3. Totally transformed woodland ('lost')	8. Totally transformed (potentially non-woodland)
8. Plantations	3. Totally transformed woodland ('lost')	8. Totally transformed (non-woodland)
9. Water	3. Totally transformed woodland ('lost')	8. Totally transformed (potentially non-woodland)
9. Wetlands	1. Untransformed woodland	6. Untransformed (potentially non-woodland)
11. Bare Rock / Sand	1. Untransformed woodland	6. Untransformed (potentially non-woodland)
12. Erosion (Natural)	2. Partially transformed woodland	7. Partially transformed (non-woodland)
13. Degraded woodland	2. Partially transformed woodland	–
14. Degraded Thicket, Bushland (etc.)	2. Partially transformed woodland	–
15–17. Degraded (all non-woodland classes)	5. Partially transformed (non-woodland)	7. Partially transformed (non-woodland)
18–23. Cultivated (all classes)	3. Totally transformed woodland ('lost')	8. Totally transformed (potentially non-woodland)
24–30. Urban (all classes)	3. Totally transformed woodland ('lost')	8. Totally transformed (potentially non-woodland)
31. Mines and Quarries	3. Totally transformed woodland ('lost')	8. Totally transformed (potentially non-woodland)

*It is possible that both the amalgamated categories (6) and (8) may have included woodland under previous conditions. Such areas do not, however, have any direct adjacency with existing woodland-related features within the NLC Land-Cover database.

Remaining, degraded and lost areas

An estimate of the proportion of each DEAT vegetation type that has been transformed is provided in ref. 7, based on factors such as degradation due to overgrazing, and total conversion to alternative land-uses (e.g. settlements or agriculture). As the authors themselves state, however, this is a somewhat subjective assessment, is likely to be incomplete, and should 'be cautiously interpreted as a rough index of habitat loss ', (ref. 7, p. 9). Although not directly comparable, a similar type of breakdown can be obtained by comparing the individual DEAT vegetation types with an overlay derived from the degraded vegetation and non-natural (i.e. cultivated) NLC land-cover classes (see Table 1 for degraded class modifier definition).

Three levels of transformation have been defined, which are intended to provide a measure of current vegetation resource status. These have been generated by spatially amalgamating several NLC land-cover classes in order to create a series of impact-level categories, namely untransformed, partially transformed (i.e. degraded), and totally transformed (i.e. lost natural cover), that can be compared to each DEAT vegetation type. Table 3 describes the specific decision rules used in the regrouping of the original NLC classes in order to create the three impact-level classes.

The degraded sub-divisions defined within the NLC database are based on qualitative (spectral) comparisons with neighbouring unaltered (or least-affected), equivalent natural vegetation structural cover classes, and are designed to provide a subjective assessment of local land-use impact (i.e. overgrazing or fuel wood collection).

The degraded land-cover vegetation sub-classes can therefore be used to determine the extent of partially transformed vegetation types. Although severely impacted (in terms of image interpretation), partially transformed cover types are not seen as 'lost natural cover', but as being in a negative state of transition that could (theoretically) be reversed and restored. Likewise, a comparison of all NLC-defined non (natural) vegetation land-cover classes such as cultivated, afforested and urban provides an estimate of the area of totally transformed vegetation (that is, lost natural cover).

Comparative procedures

The three impact-level classes were used as masking overlays on the DEAT vegetation map to compare the areas estimated as being transformed according to the DEAT data,[7] with those defined within the NLC database. The impact classes generated areal results for each of the following geographical sub-units:

- areas containing only NLC woodland-related cover classes;
- areas containing only DEAT 'Savanna Biome'-related vegetation types;
- areas containing both NLC woodland and DEAT 'Savanna Biome' vegetation types.

All totally transformed cover types located within, or directly adjacent to, the boundary of the total NLC woodland area were assumed to be 'lost woodlands'. Patches of untransformed and partially transformed non-woodland natural vegetation classes falling within the same boundary were excluded from the area calculations. The total NLC woodland area was assumed to be the sum of all the untransformed, partially transformed, and totally transformed woodland-related land-cover classes.

In areas that were exclusively located within the DEAT 'Savanna Biome', and outside the area defined by the NLC woodland cover boundary, it was necessary to assume that any totally transformed land-cover types (i.e. cultivated, afforested, urban), which were physically adjacent to existing woodland regions, could have potentially been woodland-related classes previously, even though the border of this current cover class may not be equal to the original woodland extent.

In this manner, it was possible to calculate the area difference between the DEAT-defined 'Savanna Biome' and the total NLC-defined woodland region, as well as provide an estimate of the status of each of the DEAT vegetation types compared to the level of transformation as derived from the NLC data. The specific class re-coding rules to define this process are listed in Table 3.

All spatial comparisons between the DEAT vegetation map and the NLC data were based on analysis of digital (map) data*.

*Calculated areas for the 'Savanna-thicket Biomes' (and individual vegetation types) appear to differ slightly between those derived from the digital data and those listed in the original booklet[7] (e.g. Biome: 426 632 km^2 from digital data, and 426 178 km^2 from booklet, a difference of 454 km^2) . The digital copy of the Vegetation Map was sourced from the DEAT.[7] Theses variations in area statistics may be due to factors such as differences in map projection parameters or national boundaries used. Unfortunately, these are not documented in the booklet, and it was outside the scope of this study to try and resolve these differences.

Results

The total woodland area defined by the NLC database is 358 779 km² (i.e. untransformed, partially transformed, and totally transformed classes combined), which is equal to 84% of the DEAT-defined *Savanna Biome* (426 632 km²), a difference of 67 853 km².

Eighty-one per cent (290 527 km²) of the NLC-defined woodland area is classified as untransformed, 9% (33 290 km²) is classified as partially transformed, and 9% (34 961 km²) is classified as totally transformed.

In terms of all NLC vegetation classes (i.e. woodland and non-woodland combined), 77% (329 949 km²) of the DEAT 'Savanna Biome' is untransformed, 9% (36 643 km²) is partially transformed, and 14% (58 691 km²) is totally transformed. In terms of only NLC-defined woodland areas, 55% (235 093 km²) of the DEAT Savanna Biome is classified as untransformed, 7% (30 939 km²) is partially transformed, and 8% (32 778 km²) is totally transformed.

A comparison of the DEAT and NLC estimates of total transformation per individual DEAT vegetation type is provided in Table 2. Significant differences were found between these two estimates, with the DEAT value being consistently higher (paired *t*-test, $t = 6.00$, d.f. = 18, $P < 0.0001$).

Discussion

There are significant differences, in terms of both the total area and the actual spatial extent, between the DEAT-defined 'Savanna Biome' and the NLC-defined woodland area. The total NLC woodland area (358 777 km²) is equal to only ~84% of the DEAT 'Savanna Biome' by area (irrespective of location), and only ~70% of the 'Savanna Biome' (29 889 km²) agrees with the NLC woodland in terms of *actual spatial extent* (irrespective of impact-level status). In general, the two data sets tend to agree in terms of the spatial distribution of 'core' areas (i.e. northern bushveld regions and eastern lowveld areas), with most boundary delineation differences being located in the far northwestern, and southeastern regions, where more transitional-type communities are dominant (e.g. Coastal Bushveld-Grassland and Shrubby Kalahari Dune Bushveld).

According to the NLC data, ~22% (95 334 km²) of the 'Savanna Biome' has been transformed to some degree, (i.e. partially and totally transformed classes combined), compared to ~37% as estimated in ref. 7. This latter estimate is also assumed to be even higher since as indicated in the DEAT booklet, the level of transformation of several of the vegetation types is marked as 'unknown', and in some cases assumed to be high (e.g. Coastal Bushveld–Grassland). On an individual basis there is considerable variation in the level of agreement between specific DEAT vegetation types, corresponding NLC-defined woodland areas, and levels of transformation (see Table 2).

Twelve of the DEAT vegetation types*, covering ~55% of the total 'Savanna Biome', are located (nearly) exclusively within the NLC-defined woodland area (i.e. ~90% of each vegetation type by area). The remaining 13 vegetation types are composed of a mixture of both NLC-defined woodland and non-woodland vegetation classes, of which eight vegetation types† have less than ~40% agreement (by area) with the NLC-defined woodland area. Only four vegetation types (Mopane Bushveld, Sweet Bushveld, Mixed Lowveld Bushveld, and Natal Lowveld Bushveld) appear to show any degree of similarity between the estimates of area transformed as defined by both DEAT and the NLC.

Conclusion

The value of GIS as a decision-making tool is dependent on the ability of decision-makers to evaluate the reliability of the information on which their decisions are based. The methods of database creation can introduce various errors based on positional accuracy, attribute accuracy or horizontal 'positional accuracy'. The accuracy of the results of the map overlay operation depends on positional error in polygon boundaries, attribute error and error introduced by the map overlay operation itself. The analysis defined in this research note has highlighted issues of 'expert' opinion error, both in decisions for laying generalized line boundaries on a map and attribute labelling, with its comparison to a map based on empirical boundary-line delineation. These related but different thematic map products can have serious implications for analysis and results derived from GIS operations.

*Mopane Shrubveld (9), Mopane Bushveld (10), Soutpansberg Arid Mountain Bushveld (11), Waterberg Moist Mountain Bushveld (12), Clay Thorn Bushveld (14), Sweet Bushveld (17), Mixed Bushveld (18), Mixed Lowveld Bushveld (19), Sweet Lowveld Bushveld (20), Subhumid Lowveld Bushveld (22), Kalahari Plains Thorn Bushveld (30) and Kalahari Plateau Bushveld (33).

†Subarid Thorn Bushveld (15), Eastern Thorn Bushveld (16), Coastal Bushveld-Grassland (23), Coast-Hinterland Bushveld / Grassland (24), Natal Central Bushveld (25), Thorny Kalahari Dune Bushveld (27), Shrubby Kalahari Dune Bushveld (28) and Karroid Kalahari Bushveld (29).

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Respect for the word is the first commandment in the discipline by which a man can be educated to maturity — intellectual, emotional, and moral.

Respect for the word — to employ it with scrupulous care and an incorruptible heartful love of truth — is essential if there is to be any growth in a society or in the human race.

To misuse the word is to show contempt for man. It undermines the bridges and poisons the wells. It causes Man to regress down the long path of his evolution.

Dag Hammarskjöld
('Markings')