A standard land-cover classification scheme for remote-sensing applications in South Africa

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The need for a standard classification scheme

For large areas, satellite remote-sensing techniques have now become the single most effective method for land-cover and land-use data acquisition. However, the majority of land-cover (and land-use) classification schemes used have been developed around specific user objectives (namely, agriculture and conservation), and are often influenced by geographical location and actual data capabilities. Thus very few are directly comparable. At present, no universally accepted standard classification system exists for remote-sensing studies in South (or southern) Africa. There is thus an urgent need for a predetermined framework for land-type classifications that will provide standardized, baseline specifications to ensure consistency and conformity in map data produced by various organizations from satellite imagery.

This paper presents a standard hierarchical framework for the classification of remotely sensed data, designed to suit the South African environment. The framework is based on known land-cover classes that can be derived from high-resolution, remotely sensed data such as SPOT or LANDSAT Thematic Mapper (TM) imagery, and links, as far as possible, to existing classification systems or codes that have been used within various organizations.

The primary means by which the new classification scheme will be promoted will be by its use within the National Land-Cover Database, jointly proposed by the CSIR and the Agricultural Research Council. This project aims to provide standardized land-cover data for the entire country at 1:250 000 scale, derived from LANDSAT TM satellite imagery. The land-cover data will be classified according to the proposed classification scheme and will be made available in digital geographic information system (GIS) formats. The classification scheme will also be promoted at several forthcoming national and international remote-sensing conferences. An illustrated version of the classification has also been prepared for use as a field-guide.

Design criteria for the standard land-cover classification

The following criteria form the basis of the proposed standard land-cover classification system:

(i) The classification will be broad enough to meet the needs of a wide variety of users, and have sufficient flexibility to allow specific user or project requirements to be accommodated, including the use and integration of additional non-remote-sensing data where applicable or required (i.e. GIS-based modelling).

(ii) The classification will be based on an *a priori* hierarchical structure that will allow easy subdivision of broad generic classes into more specific, user or project *a posteriori*-defined subclasses.

By using a predetermined classification system (that is, an *a priori* design), devised before the actual image data are classified, both the user and remote sensing analyst are able to ensure that the final classification structure and category definitions are appropriate for the specific mapping objectives. *A priori* classification systems should be (as far as possible) independent of both the area to be mapped, the data, and mapping techniques that are used.

Alternatively, with an *a posteriori* approach, where the data and actual processing methods define which classes are identified and mapped, the classification is constructed after the data have been classified. Although this often results in a very accurate map in terms of the final cover types recorded, it may result in end-user problems, since the *content* of the final product is unknown until the product is completed.

(iii) The classification will be based on three hierarchical levels:

Level I: 12 broad land-cover types that can be identified off high-resolution satellite imagery, such as LANDSAT TM and SPOT, without the use of ancillary data.

Level II: 23 subclasses that can be identified from remote sensing (RS) data, without the use of ancillary data, if the data format is suitable (i.e. digital, print, scale, season, band combinations, etc.).

Level III: flexible, user-defined subcategories developed by individual planners, RS analysts, etc., specific to their own requirements or resource management disciplines, beyond the scope of the broad CSIR generic framework. It incorporates subclasses defined with the use of additional non-RS data, such as edaphic or climatic parameters (i.e. GIS modelling), or the linkage of land-use parameters (e.g. agricultural management practices or intensities: 'subsistence-level temporary crops').

Note: It is permissible to map or delineate Level I and Level III classes without necessarily having to define a Level II intermediate class, for example, a known case of 'Coastal-Dune Forest' may be identified within a broader area defined as simply 'Forest and Woodland'.

A structured hierarchical format offers a high degree of flexibility, and has formed the basic structure for several international and national classification systems: for example, the US Geological Survey's (USGS) land-cover/use classification system designed by Anderson *et al.*,[1] the FAO's proposed AFRICOVER land-cover classification,[2] the British[3] and Dutch[4] national land-cover maps, the proposed hydrological land-cover classification for South Africa,[5] and various satellite-derived land-cover maps completed by the CSIR.[6-9]

Such a structure provides the user with the ability to accommodate different levels (or sources) of information. Thus, broad-level classes represent aggregates of more detailed (often user specific) subclasses, or several sub-aggregate classes can be recombined into completely new aggregate classes. For example, the classification scheme used in the UK National Land-Cover project was designed so that it was possible to recombine *grassland* and *grass crop* subcategories into a new *gramminoid cover* class.[10]

(iv) Satellite imagery is the intended primary data source for the

proposed land-cover classification, validated by field verification and/or expert local knowledge.

(v) The classification is based on known South African land-cover types that can be identified in a consistent and repetitive manner from high-resolution satellite imagery such as LANDSAT TM or SPOT (or similar airborne or photographic data), using either digital (i.e. spectral) or analogue (i.e. photo-interpretative) methods.

(vi) The classification will conform (as far as possible) to internationally accepted classification standards, and should link to existing or proposed land-cover classification designs and data sets at both national (South African), regional (southern African) and international levels (FAO's AFRICOVER).

(vii) The classification will act as a basic framework or bridging system for land-cover data exchange (i.e. standard format and class definitions at Levels I and II), where locally recognized, project-specific classes (Level III) can be both accommodated and compared by definition.

(viii) In accordance with growing international convention, the proposed land-cover classification will not contain a mix of both land-cover and land-use categories, although these may be accommodated in the user or project-specific classes defined at Level III if so desired.

Land-cover and land-use are closely related parameters, but they are *not* the same and it is important to distinguish clearly between the two in any given classification design. Land-cover refers to all the natural and man-made features that cover the earth's immediate material surface. Land-use refers to the human activity that is associated with a specific land unit, in terms of utilization, impacts or management practices. As such, there can only be one land-cover type associated with a point on the ground, but this may be associated with several land-uses (for example, a grassland may be used for communal grazing within a conservancy area). However, the interdependence of the two components has often resulted in land-cover being used as a major diagnostic tool in the identification of land-use, leading to a common mapping association within many remote-sensing classification schemes, for example, within the USGS land-cover/use model,[13] and the proposed South African hydrological land-cover/use model.[5]

Table 1. Standard land-cover classification for remote-sensing applications in South Africa: class summary.

	Level I	Level II
1.	Forest and woodland	Forest
		Woodland
		Wooded grassland
2.	Thicket, bushland, scrub	Thicket
	forest and high fynbos	Scrub forest
		Bushland
		Bush clumps
		High heathland (high fynbos)
3.	Shrubland and low fynbos	Shrubland
		Low fynbos (heathland)
4.	Herbland	
5.	Grassland	Unimproved grassland
		Improved grassland
6.	Forest plantations	Pine species
		Eucalypt species
		Wattle / other species
		Indigenous species
7.	Waterbodies	
8.	Wetlands	
9.	Barren lands	Bare rock / soil
		Degraded land
10.	Cultivated land	Permanent crops
		Temporary crops
11.	Urban / built-up land	Residential
		Commercial
		Industrial / transport
12.	Mines and quarries	

Because mixed land-cover/use classification schemes can result in confusing or inappropriate classification structures, there is now a universal move towards the development of separate, but parallel land-cover and land-use classification schemes and data sets. Such an approach has been used in the UK National Land-Cover data set[3,10] and the Zimbabwean National Woody Cover Map,[11] and has been proposed for the FAO's AFRICOVER project[2,12] and the IGBP global vegetation/land-cover initiative.[13]

(ix) The classification will use clear, unambiguous terminology and definitions to ensure data standardization.

One of the most common problems associated with the use of a particular classification scheme is the lack of clear, precise and unambiguous class definitions. This results in misinterpretation, erroneous data coding and problems of comparison between different thematic data sets based on the same classification scheme. The classes should be appropriate to both the user's requirements and the objectives of the mapping exercise, and they must be based on cover types that can be reasonably interpreted from the satellite imagery.

The definitions relating to natural land-cover classes only apply to 'general types' that are normally distinguishable from one another (since in reality 'general types' grade continuously into one another). In this manner, any uncertainty should be accounted for by applying more general definitions to a particular information class, whilst maintaining class integrity.

(x) Classes should be of informational value (i.e. 'land-cover' as opposed to 'spectral-cover' in terms of satellite imagery) and, within the context of the classification structure, be both exhaustive (in terms of the number of cover types), and mutually exclusive.[14–16]

(xi) The classification system is scale independent, although the expected operating range will be between 1:50 000 and 1:250 000 scales, based on typical LANDSAT TM and SPOT applications. It is, however, suitable for smaller scales (such as 1:1000 000).

The final land-cover classification scheme is intended to be a flexible framework of broad, generic land-cover categories within which each organization can accommodate its own desired mapping requirements. This will allow classified data from various sources to be integrated easily on a broad level, whilst retaining the integrity of the original classification at more specific levels.

Vegetation categories

By their definition, land-cover classifications will include a vegetative component which has often resulted in such systems

Table 2. Standard land-cover classification for remote-sensing applications in South Africa: Detailed review and class definitions.

Level 1: RS only	Definition	Level 2: RS only	Definition	Level 3: ancillary/land-use
Forest and woodland	All wooded areas with greater than 10% tree canopy cover,[1] where the canopy is composed of mainly self-supporting, single stemmed,[2] woody plants >5 m in height. Essentially indigenous tree species,[3] 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 and Savanna biomes in South Africa.	Forest	Tree canopy cover > 70%. A multi-strata community, with interlocking canopies, composed of canopy, subcanopy, shrub and herb layers.	May subdivide all categories *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • floristics, e.g. *Combretum* spp. • edaphic/climatic/habitat defined communities, e.g. Dune forest, Mangrove forest • type, e.g. deciduous, semi-deciduous, evergreen • conservation (land use) • wood collection (land use) • communal grazing (land use) • prefixes such as 'rocky-' or 'desert-' may be used to describe specific localities in terms of localized habitat variations ..../etc.
		Woodland	Tree canopy cover between 40–70%. A closed-to-open canopy community, typically consisting of a single tree canopy layer and a herb (grass) layer.	
		Wooded grassland	Tree canopy cover between 10–40%. An open-to-sparse canopy community, typically consisting of a single tree canopy layer and a herb (grass) layer.	
Thicket, bushland, scrub forest and high 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 > 10%, with canopy height between 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 tall fynbos. Dense bush encroachment areas would be included in this category.	Thicket	Areas of densely interlaced trees and shrub species (often forming an impenetrable community). Composed of multi-stemmed plants with no clearly definable structure or layers, with > 70% cover. A typical example would be Valley Bushveld.	May subdivide category *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • floristics/communities • edaphic/climatic/habitat defined communities • conservation (land use) • wood collection (land use) • communal grazing (land use) • prefixes such as 'rocky-' or 'desert-' may be used to describe specific localities in terms of localized habitat variations ..../etc.
		Scrub forest	Vegetation intermediate in structure between true forest and thicket. A multi-layered community with interlocking canopies, with > 70% cover.	
		Bushland	Similar to 'thicket', but more open in terms of canopy cover levels. Composed of multi-stemmed plants with no definable structure or layers, and with < 70% cover. An example would be Mopane Bush.	
		Bush clumps	Scattered islands of thicket-like vegetation (i.e. > 70% cover) within a matrix of more open bushland or grassland.	
		High heathland (high fynbos)	Fynbos communities between 2–5 m in height, > 70% cover, and composed of multi-stemmed evergreen bushes typically growing on infertile soils. The Proteaceae family typically dominates.	

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Shrubland and low fynbos	Communities dominated by *low*, woody, self-supporting, multi-stemmed plants branching at or near the ground, between 0.2–2 m in height. Total tree cover < 1.0%. Low shrublands and heathlands are combined at Level 1 due to similar overall physiognomic structure and (in many cases) appearance on remotely sensed imagery. Examples would include low Fynbos, Karoo and Lesotho (alpine) communities.	Shrubland	Typically broad-leaved or bushes, frequently deciduous. A typical example would be vegetation from the Karoo biomes. Category also includes dwarf succulent shrublands.	May subdivide category *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • cover class e.g. closed (10–100 %), open (1–10%), or sparse (< 1.0%) • floristics/communities • edaphic/climatic/habitat defined communities, e.g. moist heathland • conservation (land use) • wood collection (land use) • communal grazing (land use) • prefixes such as 'rocky-' or 'desert-' may be used to describe specific localities in terms of localized habitat variations ..../etc.
		Low fynbos (heathland)	Typically small-leaved (i.e. nanophyllous[4]), sclerophyllous, evergreen plants growing on infertile soils. Proteaceae, Ericaceae and Restionaceae frequently dominate.	
Herbland	Communities dominated by *low*, non-woody, self-supporting, non-grass like plants, between 0.2–2 m in height. Total tree cover < 1.0%. Typical vegetation examples are found in Namaqualand, and 'weed' dominated degraded areas.			May subdivide category *on project or user specific parameters as required*, which may be derived from additional non-RS data sources e.g: • cover class e.g. closed (10–100%), open (1–10%), or sparse (< 1.0%) • floristics/communities • edaphic/climatic/habitat defined communities, e.g. moist heathland • conservation (land use) • wood collection (land use) • communal grazing (land use) • prefixes such as 'rocky-' or 'desert-' may be used to describe specific localities in terms of localized habitat variations ..../etc.
Grassland	All areas of grassland with less than 10% tree and/or shrub canopy cover, and greater than 0.1% total vegetation cover. Dominated by grass-like, non-woody, rooted herbaceous plants. Typically associated with the Grassland and Savanna biomes.	Unimproved grassland	Essentially indigenous species, growing under natural or semi-natural conditions. Typically associated with the Grassland Biome.	May subdivide all categories *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • total tree and/or shrub cover (percentages): high (10–1.0% cover) low (< 1.0% cover) • total grass cover (percentage): closed-grassland (100–10% cover) open-grassland (10–1.0% cover) sparse-grassland (0.1–1.0% cover) • management practices, e.g.'irrigated, non-irrigated' • temporal condition, e.g. burnt • floristics, e.g. '*themeda*-dominated' • edaphic/climatic/habitat defined communities, e.g. hydromorphic grasslands (fluctuating water table) • conservation (land use) • fire-break [i.e. managed grassland] (land use) • communal grazing (land use) • prefixes such as 'rocky-' or 'desert-' may be used to describe specific areas in terms of localized habitat variations ..../etc.
		Improved grassland	Planted grassland, containing either indigenous or exotic species, growing under man-managed conditions for grazing, hay or turf production, recreation (e.g. golf courses) etc ...	

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Forest plantations	All areas of systematically planted, man-managed tree resources, composed of primarily exotic species (including hybrids). Category includes both young and mature plantations that have been established for commercial timber production, seedling trials, and woodlots/windbreaks of sufficient size to be identified on satellite imagery. Unless otherwise stated, Levels 1 and 2 include clear-felled stands *within* plantations. Excludes all non-timber based plantations such as tea and sisal, as well as orchards used in the production of citrus or nut crops. Level 1 category will include associated land-cover/uses such as roads, fire-breaks and building infrastructure if these are too small to be clearly mapped off the satellite imagery.	Pine species	Areas planted with parent and/or hybrid pine species. Also includes *Cedrus*, *Widdringtonia* and *Cuppressus spp.*	May subdivide all categories *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • actual species types, e.g. *Pinus patulla* • age classes (land cover) • management practices, e.g. thinning levels, clear-felled areas, weed-management, rotation sequences (land-use) ..../etc.
		Eucalypt species	Areas planted with parent and/or hybrid eucalypt species. Also includes poplar and oak plantations.	
		Wattle species	Areas planted with either Wattle, Casurina or other exotic *acacia* species.	
		Indigenous species	Areas systematically planted with indigenous species (typically hardwoods of high commercial value)	
Waterbodies	Areas of (generally permanent) *open water*. The category includes natural and man-made water bodies, which are either static or flowing, and fresh, brackish and salt water conditions. This category includes features such as rivers, dams (i.e. reservoirs), permanent pans, lakes, lagoons and coastal waters.			May subdivide the category *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • size • water quality/condition/type • drought effects (i.e. temporal effects) • actual feature, i.e. river, farm-dam, lagoon ..../etc.
Wetlands	Natural or artificial areas where the water level is at (or very near) the land surface on a permanent or temporary basis, typically covered in either herbaceous or woody vegetation cover. The category includes both fresh, brackish and salt water conditions. Examples include saltmarsh, pans (with non-permanent water cover), reed-marsh or papyrus-swamp and peat bogs.			May subdivide category *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • floristics/communities, e.g. *Phragmites* spp. • climatic/habitat/geographically defined features: e.g. dambos e.g. pans type – dry or wet states – grass / reed / salt cover e.g. aquatic (i.e. floating) vegetation • conservation (land use) • ownership (land use) ..../etc.

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Barren lands	Non-vegetated areas, or areas of very little vegetation cover (excluding agricultural fields with no crop cover, and opencast mines and quarries), where the substrate or soil exposure is clearly apparent.	Bare rock / soil	Natural areas of exposed sand, soil or rock with no, or very little, vegetation cover during any time of the year (excluding agricultural fields with no crop cover, and opencast mines and quarries). Examples would include rock outcrops, dune and beach sand, dry river bed material, and gravel plains.	May subdivide category *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • geomorphology/locational nomenclature, e.g. coastal dunes aeolian dunes beach sand dry river bed (granite) inselbergs • mineralogy, e.g. sand, gravel, diamondiferous etc. • conservation (land use) • ownership, land-tenure (land use) • qualitative or quantitative assessments of severity • primary resource loss (i.e. tree cover) ..../etc.
		Degraded land	Permanent or seasonal, man-induced areas of very low vegetation cover (i.e. removal of tree, bush and/or herbaceous cover) *in comparison with the surrounding natural vegetation cover.* Category includes major erosion scars (i.e. sheet and gully erosion). Should be sub-divided by Level 1 vegetation classes i.e. Degraded-Woodland, and Degraded-Grassland wherever possible to allow reconstruction of full class 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 problems. Characterized on satellite imagery by significantly higher overall reflectance levels (i.e. whiter appearance) and lower NDVI values (in comparison with the surrounding vegetation).	

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Cultivated land	Areas of land that are ploughed and/or prepared for raising crops (excluding timber production). The category includes areas currently under crop, fallow land,[5] and land being prepared for planting. Unless mapping scales allow otherwise, physical class boundaries are broadly defined to encompass the main areas of agricultural activity, and are not defined on exact field boundaries. As such the class may include small inter-field cover types (i.e. hedges, grass strips, small windbreaks etc.), as well as farm infrastructure.	Permanent crops	Lands cultivated with crops that occupy the area for long periods and are not replanted after harvest. Examples would include tea plantations, vineyards, sugar cane and citrus orchards, hops and nuts. Note: in the case of sugar cane, the growing season is typically 15–18 months per ratoon (i.e. harvest), with 2-3 ratoons possible before the crop is replanted.	May subdivide all categories *on project or user specific parameters as required*, which may be derived from additional non-RS data sources, e.g: • crop type/species/variety, e.g. grape vine (pinotage) • cropping system (primary / secondary crops) • management practices ..../etc. Intercropping: Where a mix of permanent and temporary crops occurs suffixes such as '*intercropping*', '*primary-crop*' or '*secondary-crop*' may be used to describe the specific cropping activities. In this classification, the *primary crop* is defined as the dominant cover type that is visible on the imagery, e.g. *avocado orchards* + ground beans. Definitions applied to agricultural practices *within the context of the remote-sensing classification:* (i) Subsistence/semi-commercial cultivation. Characterized by numerous small field units in close proximity to rural population centres. Typically dryland crops produced for individual or local (i.e. village) markets. Low level of mechanization. (ii) Commercial cultivation. Characterized by large, uniform, well managed field units, with the aim of supplying both regional, national and export markets. Often highly mechanized. (iii) Irrigated / non-irrigated. Major irrigation schemes (i.e. areas supplied with water for agricultural purposes by means of pipes, overhead sprinklers, ditches or streams) are characterized by numerous small farm-scale irrigation dams, close proximity to major water sources and/or centre pivot irrigation systems.
		Temporary crops	Land under temporary crops (i.e annuals) that is harvested at the completion of the growing season, that remains idle until replanted. Examples would be maize, wheat, legumes, potatoes, onions, and lucerne.	
Urban / built-up land	An area where there is a permanent concentration of people, buildings and other man-made structures and activities, from large village to city scale. Note: small rural communities are often included within the surrounding land-cover category (i.e. subsistence / semi-commercial agriculture) if mapping scales do not permit identification of such settlements as individual features. Where mapping scales permit, the limits of the urban boundary are delineated to exclude open areas within the built-up region (i.e. vegetated or non-vegetated areas with few or no structures).	Residential	Areas in which people reside on a permanent or near-permanent basis. The category includes both *formal* (i.e. permanent structures) and *informal* (i.e. no permanent structures) settlement areas, ranging from high to low building densities (including smallholdings on the urban fringe).	May subdivide category *on project or user specific parameters as required*, which may be derived from additional non-RS data sources e.g: • ownership / land tenure • building densities / height values • economic levels (land use/social) • specific goods/products e.g. electricity generation, gold or coal mine ..../etc. Note: The terms *formal* and *informal* residential areas within this classification scheme do not imply any level of basic services or legality, but rather a separation based primarily on the expected durability of the buildings, e.g. brick-built townhouse vs. cardboard shack.
		Commercial	Non-residential areas used primarily for the conduct of commerce and other mercantile business, typically located in the central business district (CBD).	
		Industrial / transport	Non-residential areas with major industrial (i.e. the manufacture and/or processing of goods or products) or transport related infrastructure. Examples would include power stations, steel mills, dockyards and airports.	

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Mines & quarries	Areas in which mining activity has been done or is being done. Includes both opencast mines and quarries, as well as surface infrastructure, mine dumps etc., associated with underground mining activities.	May subdivide category *on project or user specific parameters as required*, which may be derived from additional non-RS data sources e.g: • opencast or subsurface activities • ownership • economic levels • specific goods/products e.g. gold or coal mine ..../etc.

[1] Canopy cover refers in *all* cases to projected canopy cover.

[2] Or a few definitive trunks branching above ground level.

[3] Indigenous refers in all cases to plant species that occur naturally within southern Africa.

[4] Nanophyllous — less than 1 cm².

[5] Fallow — cultivated land that is allowed to lay idle during the cultivation season.

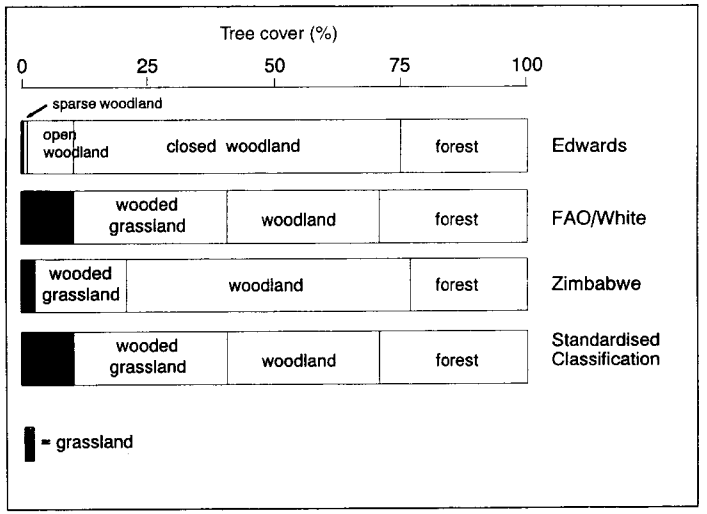

Fig. 1. Comparison of woodland category structures and naming conventions used in various classification schemes, based on tree cover percentages.

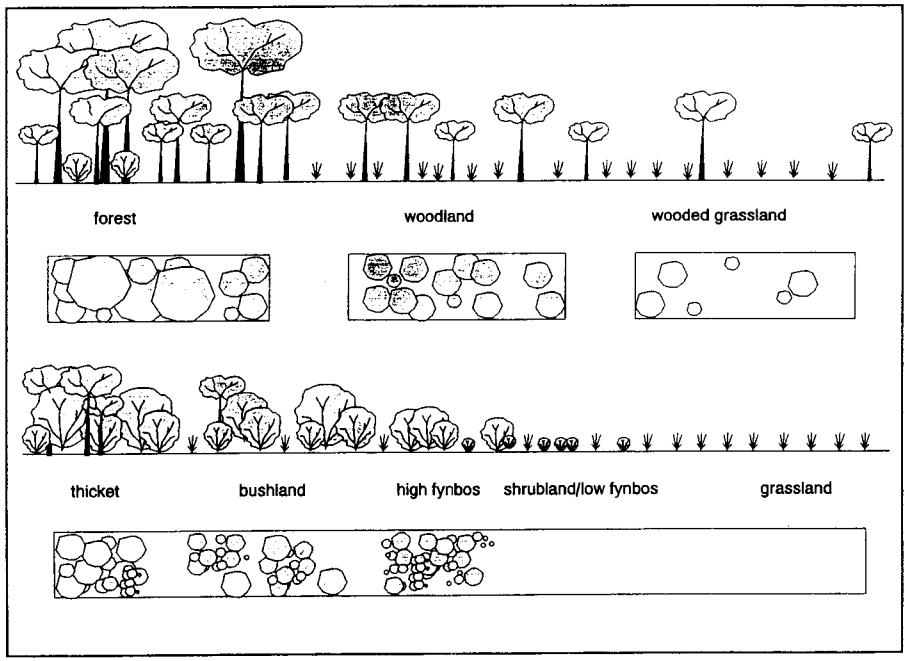

Fig. 2. Schematic representation of the vegetation structure for standard cover types.

utilizing (to a certain extent) existing vegetation or botanical classification schemes. Vegetation categories derived from satellite imagery are typically based on structural or physiognomic characteristics, since these are most easily observed or inferred from remotely sensed (optical) spectral data (such as LANDSAT TM or SPOT). This is not the same as botanical classifications that are typically based on floristics or habitat. This is advantageous because a physiognomic (or structural) classification can be compared on national or international levels far more easily than floristic or habitat-based classifications.

In South Africa, there are two vegetation classifications that have been widely used, namely, Acocks'[17] community-type classes (based on agricultural potential), and Edwards'[18] hierarchical, physiognomic classification scheme (designed for remote sensing and aerial photographic-type surveys). Unlike Acocks' classes which are locationally specific to South Africa, Edwards' classification design is independent of location, and thus can be easily compared with other (national or international) structure-based classification systems. Even so, from an international perspective, very few structural class definitions (i.e. canopy cover and height parameters) are exactly comparable.

The vegetation categories and class definitions proposed for the standard land-cover classification scheme are based primarily on those proposed or defined in Edwards,[18] the FAO's AFRICOVER project[2] (which utilizes White's 1983 physiognomic vegetation classification for Africa), the Zimbabwean National Woody Cover Mapping project,[11] previous classifications used by the CSIR,[6–9] and terminology defined in the *Dictionary of Forest Structural Terminology.*[19]

The naming conventions for the vegetation categories within the standard land-cover system have been developed to ensure direct compatibility and unambiguous linkage to the proposed AFRICOVER[2] project, which is expected to become an important regional and international standard in the near future. Similar naming conventions have also been used within the Zimbabwean National Woody Cover project.[11] This is illustrated in Fig. 1, which provides a comparison between the woodland category structures and naming conventions used in each of the above classification schemes, based on tree cover percentages.

The classification is based on broad structural vegetation types that are recognizable on satellite imagery and in the field, and is not intended to be a floristic or ecological vegetation classification. Figure 2 is a schematic representation of the natural vegetation structures associated with the proposed standard cover types.

Commercial plantations are separated from the indigenous forest and woodland categories and have been allocated a Level I status in keeping with the proposals by Schulze and Hohls,[5] due to their importance as a major water resource user in South Africa. Commercial plantations are somewhat easier to identify from satellite imagery in South Africa than some of the forest/woodland subclasses due to characteristic planting in grassland areas, where the evergreen, exotic tree cover is easily discernible, with clear fence-line boundaries. The genus and species types specified within each Level II class are based on those used in the Forest Map of Southern Africa.[20]

The 'Improved Grassland' category has been listed within the 'Grasslands' category, rather than 'Cultivated Land', because it is a grassland in terms of land cover.

Using the proposed framework, broader classes 'above' Level I can be created if so desired, based on common-sense linkages. For example, all the natural vegetation cover types (excluding 'Improved Grasslands') can be grouped into a single 'Natural Veld' category.

Wetland categories

The classification hierarchy for both waterbodies and wetlands has been left purposely broad (i.e. Level I), since wetland nomenclature and classification schemes are often very specific in terms of mapping or management requirements (e.g. physical, botanical or wildfowl habitat suitability). To attempt to provide an exhaustive set of Level II subclasses that satisfied all requirements would be impractical.

It is important to understand that the structure presented is not intended to be a rigid definition of wetlands *per se*, but only a guide to their standard coding in terms of satellite-derived land-cover maps, and the exchange of such data between organisations. For example, although 'Hydromorphic Grasslands' are classified as a subclass within the 'Grasslands' category in the classification scheme presented here, this does not imply that they cannot be linked to 'Wetlands' if this is required as part of a specific mapping objective. In such cases, it is recommended that the standard classification hierarchy be employed only when data are exchanged between organizations.

Proposed standard land-cover classification

Our proposal is shown in summary form in Table 1, and documented with full class definitions in Table 2.

The South African national land-cover database project

One of the primary incentives for the development of a standardized classification scheme for remote sensing applications was the proposal to develop a national database of land-cover, based on satellite imagery. At present, no single, standardized database exists for current land-cover information for South Africa, despite the fact that such information is a critical component of environmental planning and management. The CSIR and the Agricultural Research Council (ARC) have therefore jointly established a project to produce a single, standardized, digital land-cover database for all of South Africa, Swaziland and Lesotho.

The land-cover data are being mapped (using manual photo-interpretation) from a new series of 1:250 000 scale geo-rectified space-maps, based on seasonally standardized LANDSAT Thematic Mapper satellite imagery (captured primarily in 1994–95). The final land-cover data will be suitable for 1:250 000 scale use (minimum mapping unit 25 ha), and will be supplied in vector format suitable for GIS (geographic information system) mapping applications. The land-cover database will provide national, baseline information on land-cover (not land-use), based on 12 Level I and 10 Level II classes, as defined in the proposed standard classification scheme.

The data are being produced in three phases, covering separate geographic regions in South Africa. Phase 1 covers primarily the Gauteng, Northern, North West, Mpumalanga and northern KwaZulu-Natal provinces, Swaziland and Lesotho, and is expected to be completed by June 1996. The entire country is expected to be incorporated by June 1997.