



Biodiversity in Southern Africa

Vol. 2

Patterns and Processes at Regional Scale

SPONSORED BY THE



Federal Ministry
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and Research



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Klaus Hess Publishers

www.k-hess-verlag.de

ISBN all volumes: 978-3-933117-44-1 (Germany), 978-99916-57-30-1 (Namibia)

ISBN this volume: 978-3-933117-46-5 (Germany), 978-99916-57-32-5 (Namibia)

Printed in Germany

Suggestion for citations:

Volume:

Schmiedel, U., Jürgens, N. (2010) (eds.): Biodiversity in southern Africa **2**: Patterns and processes at regional scale. Göttingen & Windhoek: Klaus Hess Publishers.

Article (example):

Petersen, A., Gröngröft, A., Mills, A., Miehlich, G. (2010): Soils along the BIOTA transect. – In: Schmiedel, U., Jürgens, N. (eds.): Biodiversity in southern Africa **2**: Patterns and processes at regional scale: 84–92. Göttingen & Windhoek: Klaus Hess Publishers.

Corrections brought to our attention will be published at the following location: <http://www.biota-africa.org/biotabook/>

Cover photograph: Giraffes on the game farm Omatako Ranch (Observatory S04 Toggekry) in the Namibian Thornbush Savanna.

Photo: Jürgen Deckert, Berlin/Germany.

Cover Design: Ria Henning

Article III.2.4

– Author's copy –

Please cite this article as follows:

Strohbach, B. J., Jürgens, N. (2010): Towards a user-friendly vegetation map of Namibia: ground truthing approach to vegetation mapping. – In: Schmiedel, U., Jürgens, N. [Eds.]: *Biodiversity in southern Africa. Volume 2: Patterns and processes at regional scale*: pp. 45–56, Klaus Hess Publishers, Göttingen & Windhoek.

Towards a user-friendly vegetation map of Namibia: ground truthing approach to vegetation mapping

BEN J. STROHBACH & NORBERT JÜRGENS

Summary: Information regarding the vegetation of Namibia is not readily available, and the few concise sources that are available provide only a broad overview, are sometimes grossly inaccurate and provide very little information that is useful for planning and management purposes. For this reason the Vegetation Survey of Namibia project was initiated in 1996, with progress in the beginning being relatively slow.

During the BIOTA project, more information on the vegetation along the BIOTA transects was needed, prompting collaboration between the two projects. This led to a rapid advancement of the Vegetation Survey of Namibia project, not only in terms of the number of plots, which were surveyed, but also in terms of data- management, processing, mapping and presentation.

A short overview of the project's achievements to date is given in this paper, with some examples of mapping results and information presentation.

Introduction

Plant communities form the basis of all ecological processes. Because vegetation dynamics tend to be uniform within a plant community (veld type), such vegetation (veld) types can be used as management units (Daubenmire 1968, Mueller-Dombois & Ellenberg 1974, Tainton 1981, 1999). For example, extrapolation of any grazing trial result is limited to the plant community in which the trial was conducted, but extrapolation is possible wherever this community is found (even outside the borders of a research station).

Baseline data of the vegetation in Namibia has been sorely lacking (Burke & Strohbach 2000). Two projects were completed during the seventies to try and tackle this problem: the demarcation of Relative Homogeneous Farming Areas (Department Landbou Tegniese Dienste 1979) and the Preliminary Vegetation Map of Namibia (Giess 1971).

Relative Homogeneous Farming Areas were delimited in the 1970s (Depart-

ment Landbou Tegniese Dienste 1979), and evaluated farming potential and constraints for the commercial farming areas. No baseline data on the vegetation was given, except for an estimation of a fixed grazing capacity. Since then it has been realised that a fixed grazing capacity is misleading, as seasonal variation in rainfall plays a major role in the production of grazable forage in an area (Lubbe 2005, Espach et al. 2006). In order to determine the grazing capacity both at a local and national scale, a number of field and remote sensing based methods have been developed or are still under development (e.g. Bester 1988, Lubbe 2005, Espach 2006, Espach et al. 2006).

This paper briefly describes the progress made in creating an updated vegetation map of Namibia up to the end of the BIOTA Southern Africa project.

Overview of available data

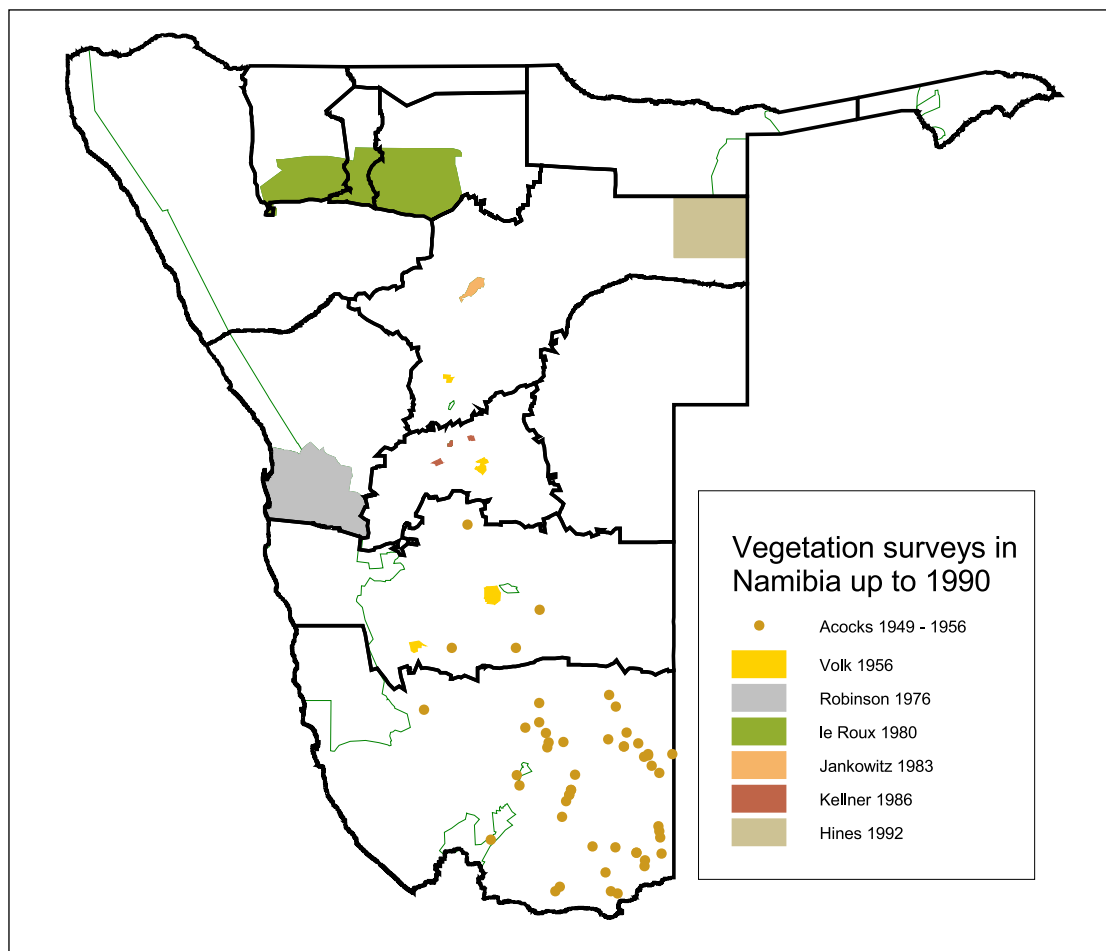
Presently available nation-wide vegetation information

The Giess vegetation map was drawn up in 1971, using basic techniques (Giess 1971, 1998). Although it has been found to be relatively accurate, a number of anomalies have been noted. The description of the vegetation is very basic, giving little baseline data (if any) that can be used for further studies. This map does not compare with John Acocks's Veld Types Map of South Africa, which was first published in 1956, and has seen its 3rd revision (Acocks 1975). Acocks's original field data books are still available, and these sites have recently been proposed as long-term vegetation monitoring sites in South Africa (Westfall & Greeff 1998). In addition, Acocks's map has served as a basis for two further studies on the vegetation of South Africa (Low & Rebelo 1996, Mucina & Rutherford 2006).

The Atlas of Namibia (Mendelsohn et al. 2002) also contains a vegetation map. This map was based on several regional reviews such as the environmental profiles of the Caprivi (Mendelsohn & Roberts 1997), Central North (Mendelsohn et al. 2000) and Kavango (Mendelsohn & el Obeid 2003) regions, some expert opinion and partially based on vegetation data. However, large parts were still based only on the original Giess (1971) map, and little baseline information on the various vegetation types is provided with this map.

In addition to these descriptive data sets, a number of studies on biomass production, as related to the greenness of the vegetation (Sannier et al. 1998, Espach et al. 2006), the biomes (Irish 1994) as well as the biogeography (Craven 2001) have been undertaken on a national basis.

Fig. 1: Vegetation surveys conducted in Namibia before 1990 (1739 plots). Most of the plot positions are unknown, or at best determined from maps presented in various theses, as GPS-technology was not available at the time of surveying.



Regional and small-scale vegetation data

A fair number of regional and small-scale vegetation studies, mostly with the aim of providing management information, have been undertaken in the past:

- Acocks visited southern Namibia on several occasions (1949–1956) during the field work for his epic “Veld Types of South Africa”.
- Volk visited a number of farms during 1956, and again in 1963. Some of his data from 1956 are still available, but only one study was published (Volk & Leippert 1971). Apparently he also visited Namibia before World War II in 1936/37, but information and data from this visit is unavailable, and is likely to have been destroyed during the war.
- The Department of Nature Conservation undertook a number of vegetation-related studies in National Parks and conservation areas during the 1970s and 1980s for management purposes: Robinson (1976) in the Central Namib;

Le Roux (1980, see also Le Roux et al. 1988) in the Etosha National Park; Jankowitz (1983, see also Jankowitz & Venter 1987 and Jankowitz & van Rensburg 1985) in the Waterberg Plateau Park; Kellner (1986) in Daan Viljoen Nature Reserve, Claratal and Bergvlug; Hines (1985 unpublished) in the Mahangu Game Reserve, as well as in eastern Bushmanland (present-day Tsumkwe district) (Hines 1992); M. Strohbach in the Sperrgebiet (unpublished). During the pre-independence era 1,739 plots were surveyed and their spatial distribution is depicted in Fig. 1.

- Since Independence in 1990, renewed interest in Namibia resulted in the initiation of a number of development projects in the agricultural and environmental sector. Some of these included baseline studies on the vegetation as a natural resource, and a number of purely scientific studies were also initiated on the vegetation of various smaller areas. A list of these studies is presented in Appendix 1 (OOO). It was

also decided to include a study on the vegetation of Namibia with the conception of the Agro-Ecological Zoning Programme in 1994. This led to the start of the Vegetation Survey of Namibia project in 1996, with extremely limited resources and manpower. The total number of plots surveyed by the end of 2000, before the start of the BIOTA Southern Africa project, was 3,494 (Fig. 2).

- During the BIOTA project, surveys were initially done only along the BIOTA Southern Africa transects (in addition to the regular continuation of the Vegetation Survey of Namibia project), but were later expanded to include the description of the vegetation in areas adjacent to major Observatory pairs for the purpose of upscaling. This culminated in an attempt to combine the various data sources and start with the development of a single, unified vegetation classification (Fig. 3). With the combined efforts of the Vegetation Survey of Namibia Project, the BIOTA

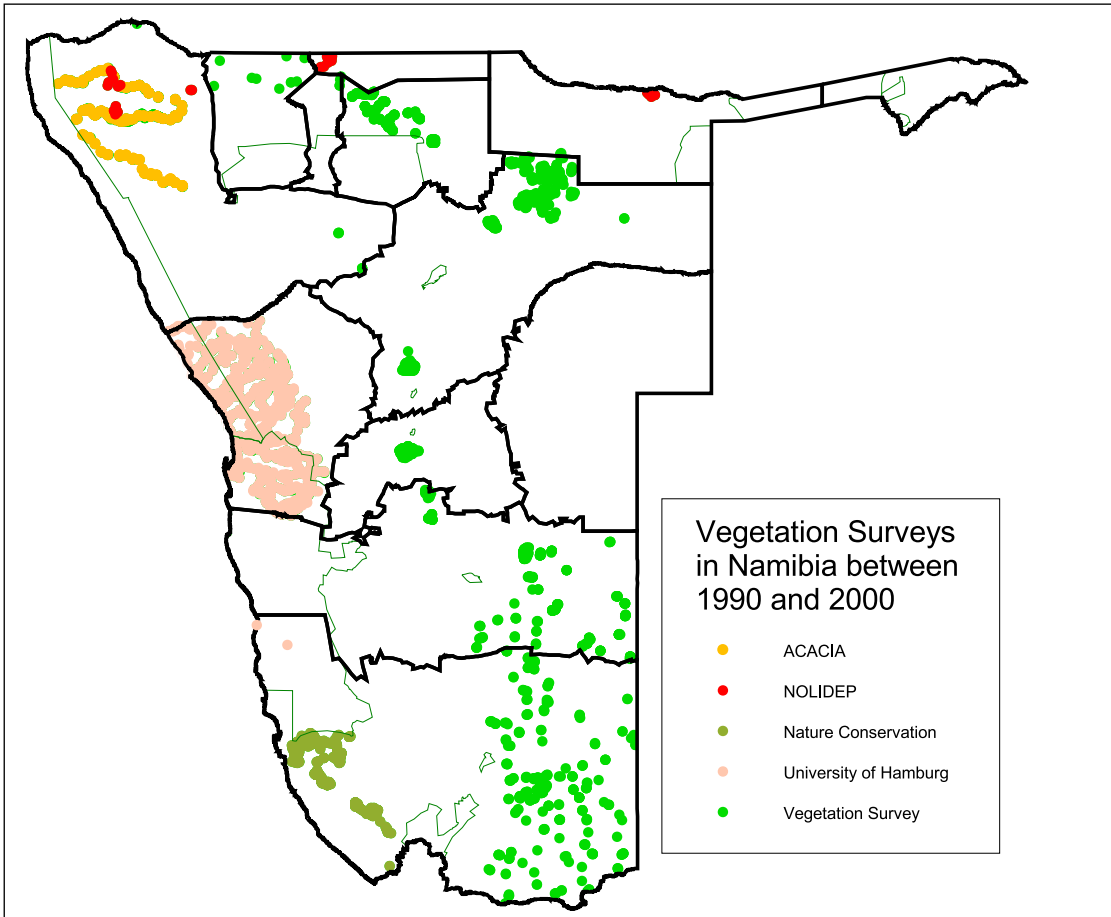


Fig. 2: Vegetation surveys undertaken during the period 1990 and 2000 (3494 plots).

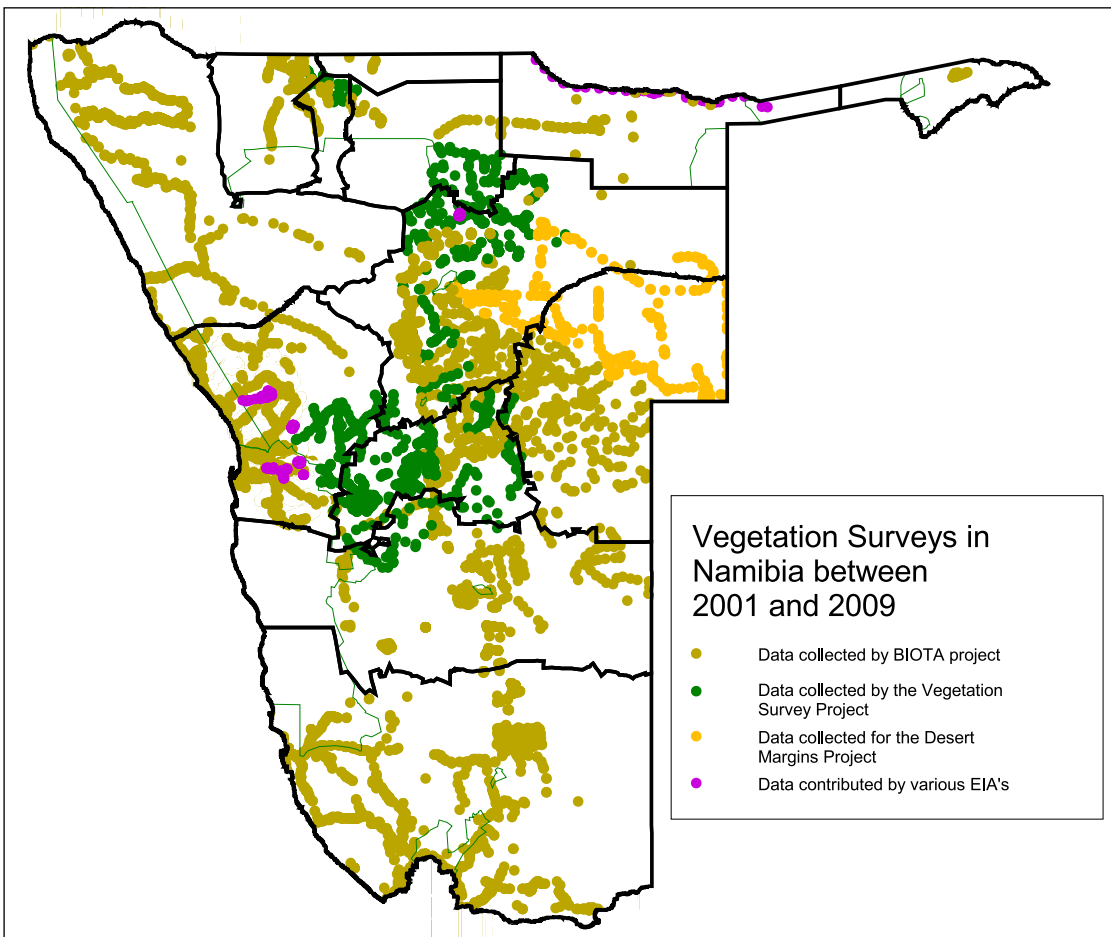


Fig. 3: Vegetation surveys undertaken during the period 2001 and 2009 (8720 plots).

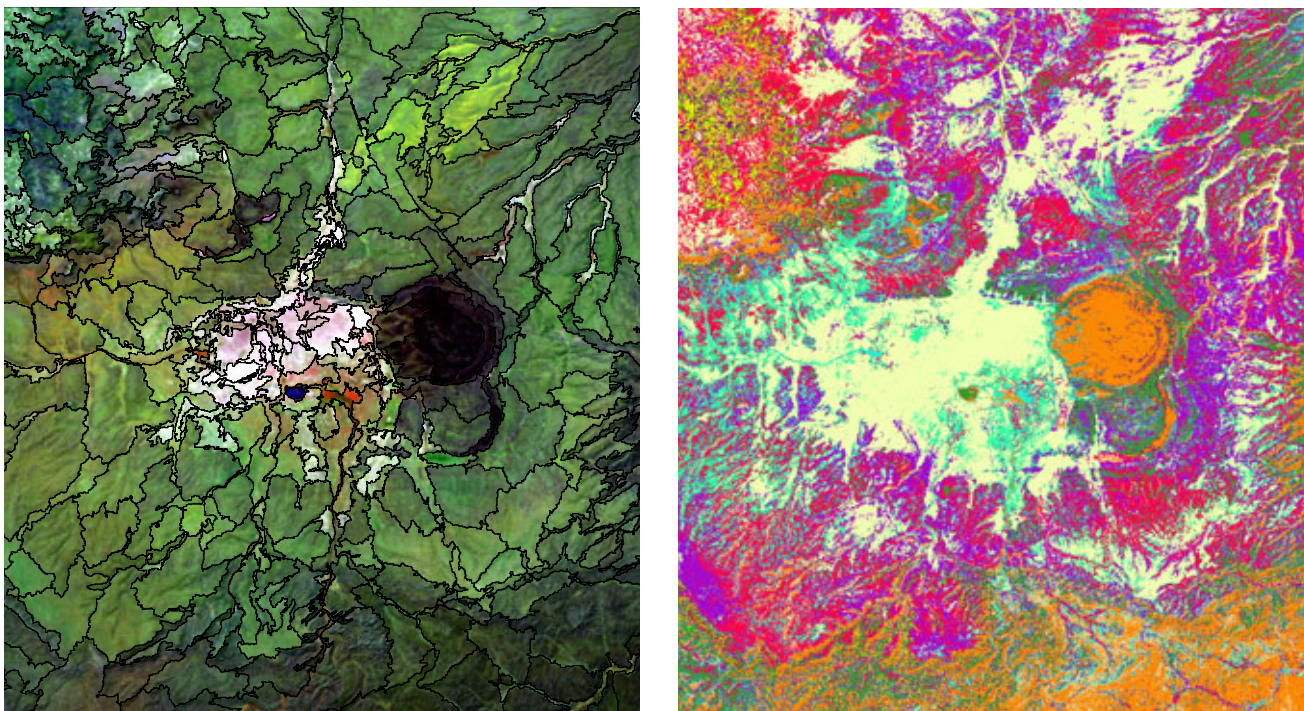


Fig. 4: The pan system at Haribes west of Mariental. a) False colour image of a portion of Landsat ETM scene 177-77, dated 26 March 2001 (left). The superimposed lines are segments of homogenous landscapes created by Definiens Professional 5. This image was used as a field map during surveying. b) Cluster analysis (right). Typical unsupervised classification of the same portion of Landsat ETM scene 177-77. Note the very strong pixelated effect, and the rather confusing colour scheme.

Southern Africa Project, as well as contributions from other projects and environmental impact assessments, a total of 8,720 plots were surveyed during the period 2001 to 2009.

Methods

Approach

The ultimate aim was to produce a vegetation map of Namibia at the scale of 1:1 000 000. Due to the high diversity of habitats (geology, topography, soils and climate—cf. Mendelsohn et al. 2002) a large number of major vegetation types, and an even larger number of minor vegetation types that are typical of niche habitats, were expected. It soon became apparent that small niche habitats and associated vegetation types could not be sampled in detail, but because the purpose of the vegetation map is to serve as a tool for landuse planning, the focus was rather on the mapping of larger vegetation units. The following basic method was applied to achieve this (Strohbach 2001):

Initial stratification

The purpose here was to delimit relatively homogenous mapping units within the study area in order to reduce the sampling effort. The general hypothesis was that plants grow in a specific habitat, and because of that, certain groups of plants (i.e. plant associations) are found in specific habitats.

The Agro-Ecological Zones Map of Namibia (de Pauw 1996, de Pauw & Coetzee 1998/99, de Pauw et al. 1998/99) was used as a baseline map. This map was modified so that the Land Type class ‘R’ (inselbergs and rocky outcrops) was subdivided into 54 units according to geology and secondarily to growing period zones. These agro-ecological zones (AEZ’s) were transferred onto standard 1:250 000 topographic sheets, which were then used in the field. Satellite images became readily available through the Agro-Ecological Zoning project and were used as false colour hardcopies in the field. Only later did Definiens Professional 5 (Definiens AG 2006) become available as a tool for initial stratification. This software delimits relatively homogenous areas in images, based on

a group of pixel colour values, forming coherent shapes rather than pixelated unsupervised classifications (Fig. 4). The other advantage over unsupervised classification is that the false colour image can still be displayed as background to the segments.

Field surveying

Plots of 20 m x 50 m (or 1,000 m²) were placed in the homogenous stratified units (segments) in such a way that each landscape type was adequately covered. In many cases, accessibility led to some bias in the selection of sample sites, in order to minimise travelling time. In cases where the topographic unit would not allow a 20 m wide plot (e.g. narrow streams and riverbeds, and the crests of dunes in the southern Kalahari), a narrower plot of 10 m x 100 m was used. The size of 1,000 m² has been found suitable in a wide range of environments within Namibia and has been adopted by other groups working with vegetation in Namibia, e.g. the University of Cologne (ACACIA project). A minimum of 4 to 6 plots was surveyed per mapping unit.

Information gathered at each sampling site. A GPS reading was taken at each plot, preferably in the northwestern corner. Originally the GPS-reference was set to the “Schwarzeck” map datum, but this was later changed to WGS84. Additional locality information included the region, district, farm or locality name, and a short description of the locality.

Habitat information included the slope, the terrain type, aspect, stone cover estimation, lithology (parent material), erosion severity, surface sealing/crusting, disturbances, etc. For this description the SOTER methodology (FAO 1993) was used.

The vegetation information consisted of a full list of species found on the plot, following the standard Braun-Blanquet procedure (Mueller-Dombois & Ellenberg 1974). Geophytes were normally excluded (except if found in flower—i.e. identifiable). Plants, which could not be identified in the field were collected for later identification in the herbarium. Each specimen was accompanied by a standard collection form.

For each species noted, details were provided regarding the plant’s growth form (i.e. tree, shrub, dwarf shrub, grass, or herb) following the definitions of Edwards (1983). The abundance of each species was estimated according to its crown cover, more or less following the Domino Scale (Mueller-Dombois & Ellenberg 1974). The abundance was given as percentage cover. Alternatively, methods like the Plant Number Scale (Westfall & Panagos 1988) or the Log scale of McAuliffe (1990) could also be employed.

A photograph was taken at each plot to document the landscape as well as the structure of the vegetation.

Data capture

TurboVeg (Hennekens & Schaminée 2001) is widely used in South Africa and was made available to the National Botanical Research Institute in Namibia by the University of Pretoria. This database is based on a list of species known to occur in southern Africa, prepared and updated by the National Botanical Institute in Pretoria, RSA (Germishuizen & Meyer 2003). It was extensively used to capture vegetation data in Namibia. An elaborate data clean-up procedure was developed.

This was generally based on a) a full identification list of collected specimens from the National Herbarium, b) checking the species list generated from the captured data against the identification list, and as a last step, c) painstakingly checking the captured data against the original field data sheets. These original field data sheets were also archived together with a copy of the captured data as hardcopies as well as copies on CD.

At present these data sets are being captured to BIOTABase, in the process updating the captured data with appropriate structural data, more detailed GPS data, photos, and updated identifications.

Data processing

The relevés were classified into vegetation communities following the Braun-Blanquet tabulation method (Mueller-Dombois & Ellenberg 1974, Whittaker 1978). The original TWINSpan (Hill 1979), as well as a modified version of TWINSpan (Roleček et al. 2009), Cluster Analysis as part of PC-ORD 5 (McCune et al. 2002) and COCKTAIL (Bruehlheide 2000) are all commonly used classification procedures available in the JUICE software package. The output is a typical phytosociological table, from which the community composition and the characteristic plant species for each community can be determined.

The relationships between the various communities, and between the communities and the habitat were further illustrated with ordination techniques. Here again various routines, including Reciprocal Averaging, Canonical Correspondence Analysis as well as Nonmetrical Multidimensional Scaling (NMS) were available in the software package PC-ORD 5 (McCune et al. 2002).

Synopsis

The full diagnostic phytosociological table is rather complicated to read. A synoptic table condenses the information, listing the species in each community, and their relative affiliation to that particular community.

- These data were then used to describe the community in words. The characteristic species, i.e. species by which the community could be identified.

- The structure of the community according to the definition of Edwards (1983)—from open woodlands to shrubland vegetation.
- The species diversity—i.e. which species occurred within a particular community, including diversity related statistics such as the number of species observed, the estimated number of species, and various diversity indices (Palmer 1990, 1991, Barbour et al. 1987, Gauch 1982).
- The habitat in which the community was found.
- Species with particular traits—exotics, possible encroachers, possible endemics, rare and endangered plants—were highlighted.
- General management information regarding the vegetation type, including the general suitability for grazing, the sensitivity of the vegetation, as well as the general conservation status. For this purpose a set of indices were developed (Strohbach, in prep.). In terms of general sensitivity, the presence of rare, endemic and/or protected species, the topography as related to erosion hazard, and water flow (following Pringle & Tinley 2003, Pringle et al. 2006) were considered. The utilisation potential was biased towards livestock farming, and took into account the climate (especially annual rainfall and rainfall reliability), the soil and topography (as influencing water availability), the vegetation structure, as well as the species composition (average composition of the grass sward in terms of grazing value as well as presence of toxic plants).

The text was to be accompanied by photographs (if possible). An information sheet for each described association was developed for this purpose, following the idea of Burke (2008; Strohbach, in prep). See Appendix 2 for examples of these information sheets.

Final mapping

This stage was still part of the description stage: the final classification was compared with the original map, and the spatial extent of the communities was defined. This was done using various base maps and remote sensing applications, combined with processed, sorted

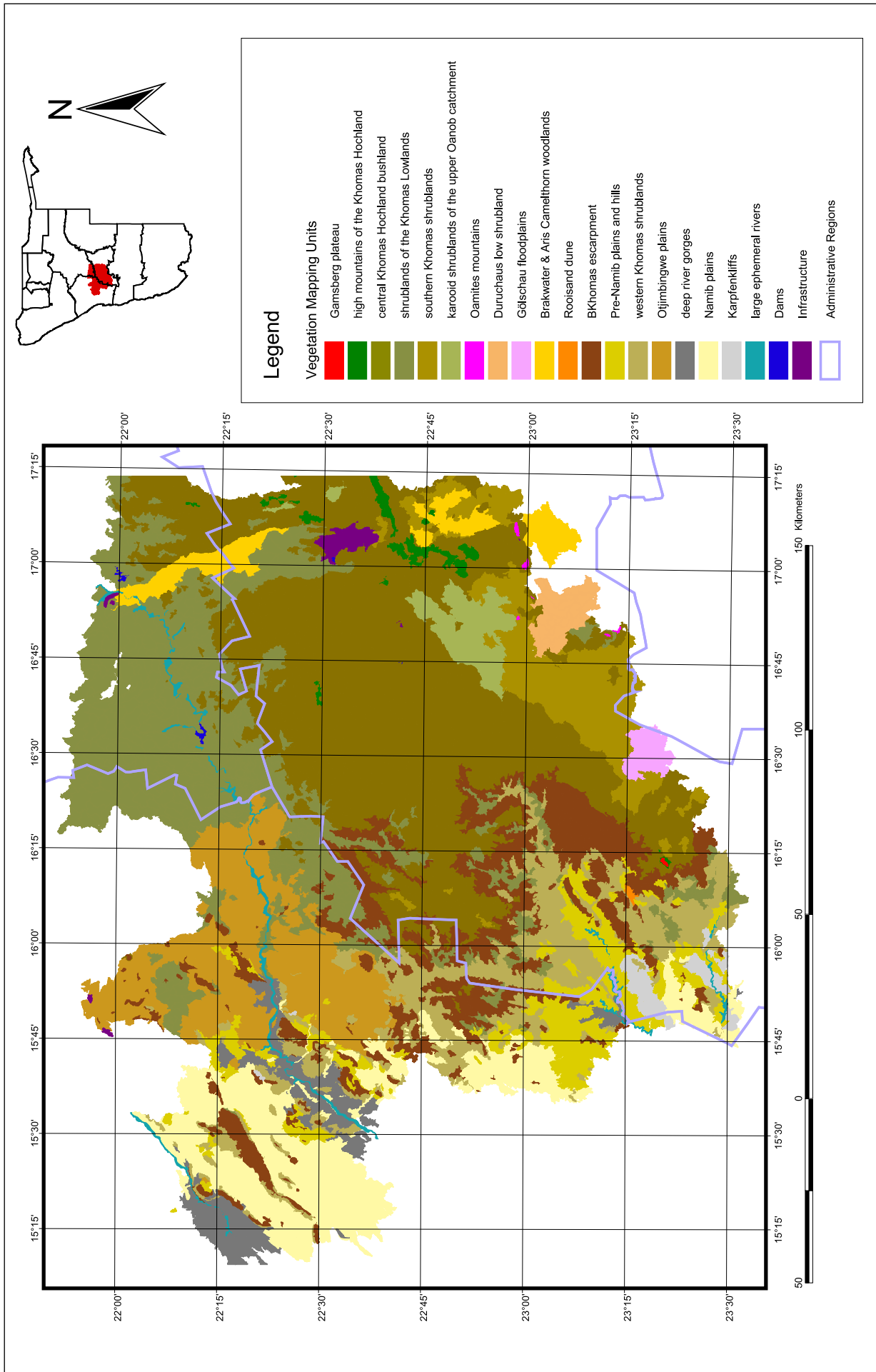


Fig. 5: Example of a completed vegetation map for the Khomas Hochland, based on the classification of segments derived from Landsat ETM scenes 178-75 dated 2000-05-17, 178-76 dated 2001-05-04, 179-75 dated 2001-02-20 and 179-76 dated 2000-04-06 (from Strohbach, in prep).

field data. The generally used approach for classifying satellite images (supervised classification) was found to be unsatisfactory, due to the large areas to be mapped. Therefore, the units identified for the initial stratification were classified with Definiens (Definiens AG 2006), using a nearest neighbour analysis. Sample units were selected based on the position of classified relevés representing a typical mapping unit. Here it should be pointed out that due to the large scale of the final map, it was impossible to map each identified vegetation type. Instead, a vegetation mapping unit was mapped, comprising one (or a few) major vegetation types, but which included several smaller azonal or niche vegetation types (e.g. pans, rivers, etc.). Using Landsat satellite images, the segmentation classification results had a general spatial accuracy of up to 30 m (Fig. 5).

A second approach developed by Hütlich et al. (2009) used a MODIS time series. Here the phenological patterns of the vegetation, displayed over a number of years, was used for classification. This approach was especially promising in large, often very uniform areas like the eastern communal lands (Fig. 6). Here the use of traditional supervised classification of Landsat scenes was found to be highly unsatisfactory, as climatic variation within some scenes caused misclassifications, with up to a 50% error (Strohbach et al. 2004). The cross-border matching between different images scenes was also especially problematic (Fig. 7).

Semi-detailed, small-scale studies of research stations and other areas of interest

In addition to the national survey, semi-detailed studies of various research stations of the Directorate Agricultural Research and Training, as well as other study sites, were undertaken. This was to provide baseline data on these stations and/or farmers associations. In this programme the vegetation of the following areas was described: eastern communal farming areas (Strohbach et al. 2004); a strip transect of the vegetation along the BIOTA transects (Strohbach 2002); Alex Muranda Livestock Development Centre (previously Mile 46 LDC) (Strohbach

& Petersen 2007); the Sandveld Research Station (September 2006); the Ogongo Agricultural College (Kangombe 2007); and the Sachinga LDC in Caprivi (Lushetile 2009). Still to be published are accounts of the vegetation of Sonop Research Station, Uitkomst Research Station, Kalahari Research Station, Gellap Ost Research Station, as well as the farms Erichsfelde and Haribes. These latter two accounts are part of a follow-up on historic data collected by Volk in 1956.

The same methodology as above was used, with the exception that more emphasis was placed on smaller vegetation types, including azonal vegetation types. Studies covering slightly larger areas, such as the main and east-west BIOTA transects, or at conservancies, served as “seeding areas” in which vegetation types were described in more detail than could be at a national level. The data of both small-scale and regional studies, and from several Environmental Impact Assessments—if done to standard—were included in the national database.

Way forward

The Vegetation Survey of the Namibia project is not yet completed, although remarkable advances have been made over the past 9 years in close collaboration with the BIOTA project. The National Botanical Research Institute will continue with the task of collecting vegetation data, especially in areas, which have not yet been surveyed, and collating the information in a database. The following steps are envisaged over the next years:

The existing data sets need to be completely transferred to the BIOTABase. In the process, data captured in the field, but not in the TurboVeg data base (e.g. structural data) needs to be captured. The reason for this is that BIOTABase contains more detailed data compared to TurboVeg, and will form an integral part of a database system together with the South African Plants Photodatabase and an Herbarium database, to be developed during the planned Regional Science Service Centre project.

The existing data sets need to be classified, and the resulting units need to be

matched to previously defined vegetation types. For all vegetation types, an information sheet (as per Appendix 2) is to be compiled.

The vegetation types are to be mapped. For the initial scale of 1:1,000,000, it will be necessary to combine various vegetation types into one mapping unit (similar to a landscape type being mapped); as more data becomes available, it will be possible to map smaller areas in more detail, teasing out the various associations.

A web-based vegetation information system is to be developed. The aim is to have the map searchable in a very similar way to Google Earth, and linked to the various mapping units and the appropriate vegetation association information sheet. This will also allow the publication of initial results in areas already well-covered, while data is still to be collected in other areas of the country.

Further studies (from various sources) are to be integrated into the National Phytosociological Database, as well as the database on vegetation types as they become available. The web-based vegetation information system will be updated accordingly, thus making the information available and easily accessible to the broader public.

Acknowledgements

The authors' general acknowledgements to the organisations and institutions, which supported this work are provided in Volume 1.

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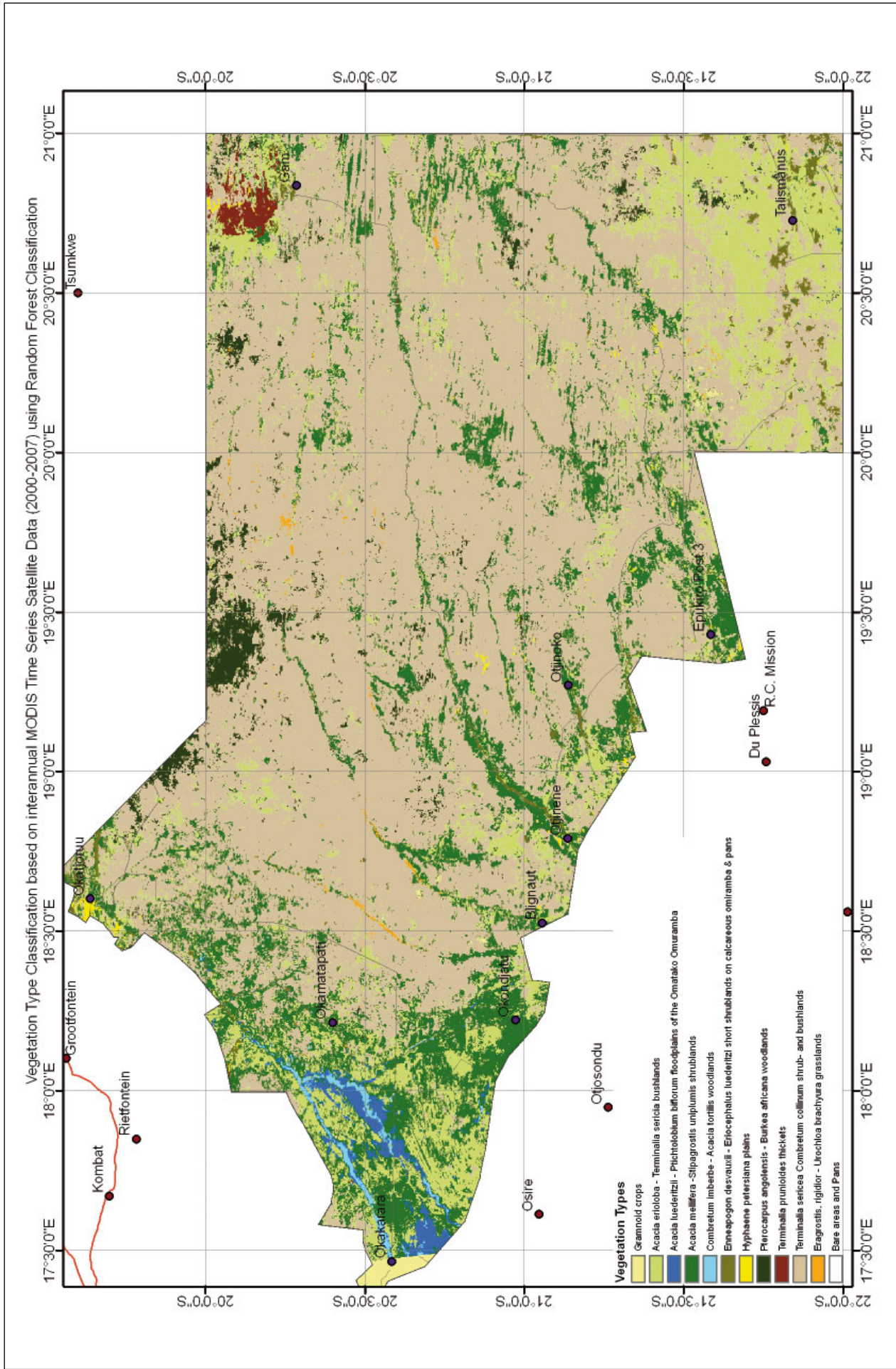


Fig. 6: Vegetation map of the eastern communal areas based on MODIS time series (from Hüttich et al. 2009). Note the simplified legend of the map.

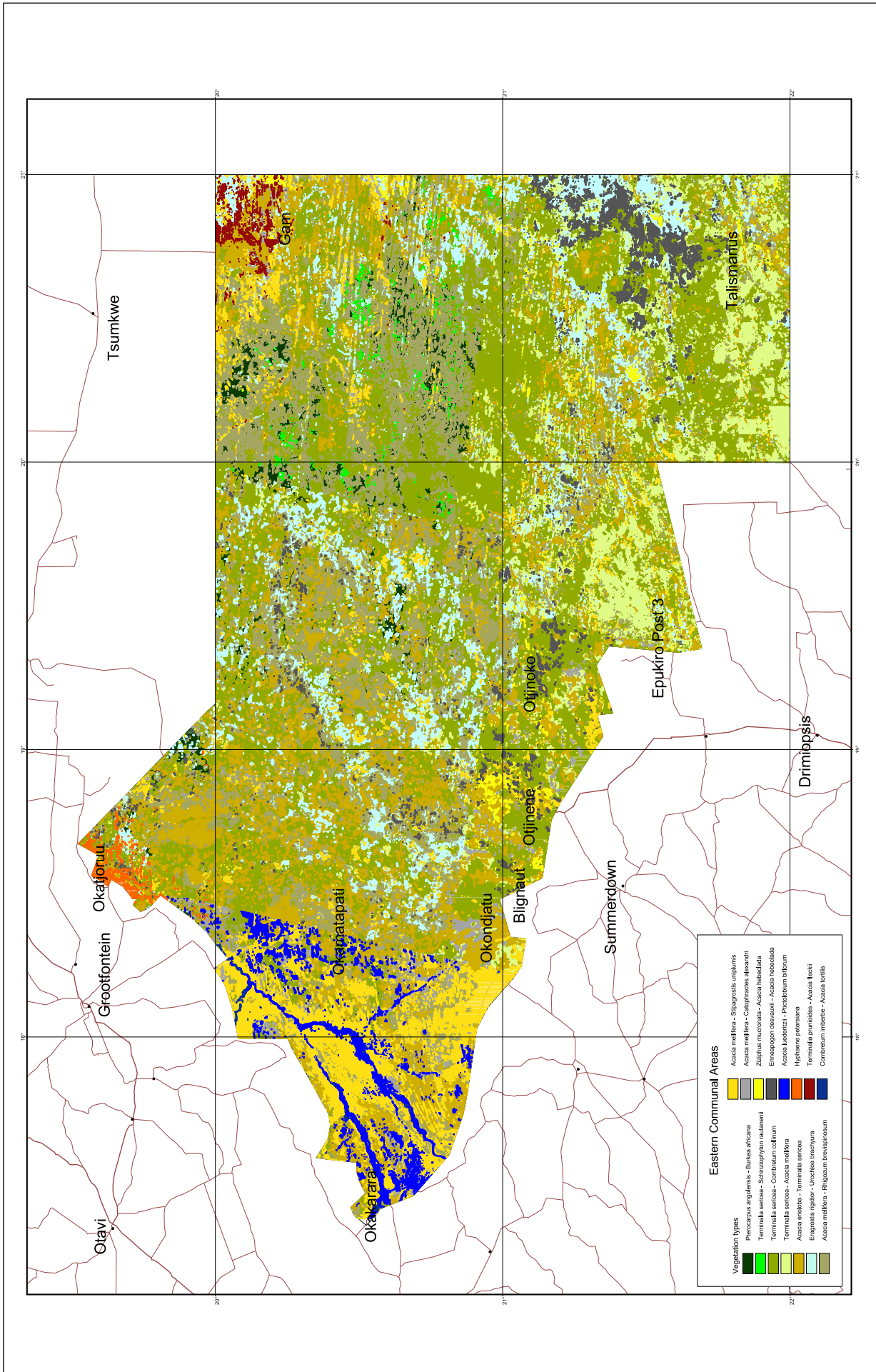


Fig. 7: Original vegetation map of the eastern communal areas based on supervised classification of Landsat TM scenes 177-74, 176-74, 177-75, 176-75 and 178-74. Note the discontinuities between the five different Landsat scenes (especially in the west and the north-east), as well as the very detailed, often confusing map. A mapping accuracy of only 48% was achieved with this procedure (Strohbach et al. 2004).

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