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Stampriet

Transboundary Aquifer System Assessment

Governance of Groundwater Resources in Transboundary Aquifers (GGRETA) - Phase 1

Technical Report



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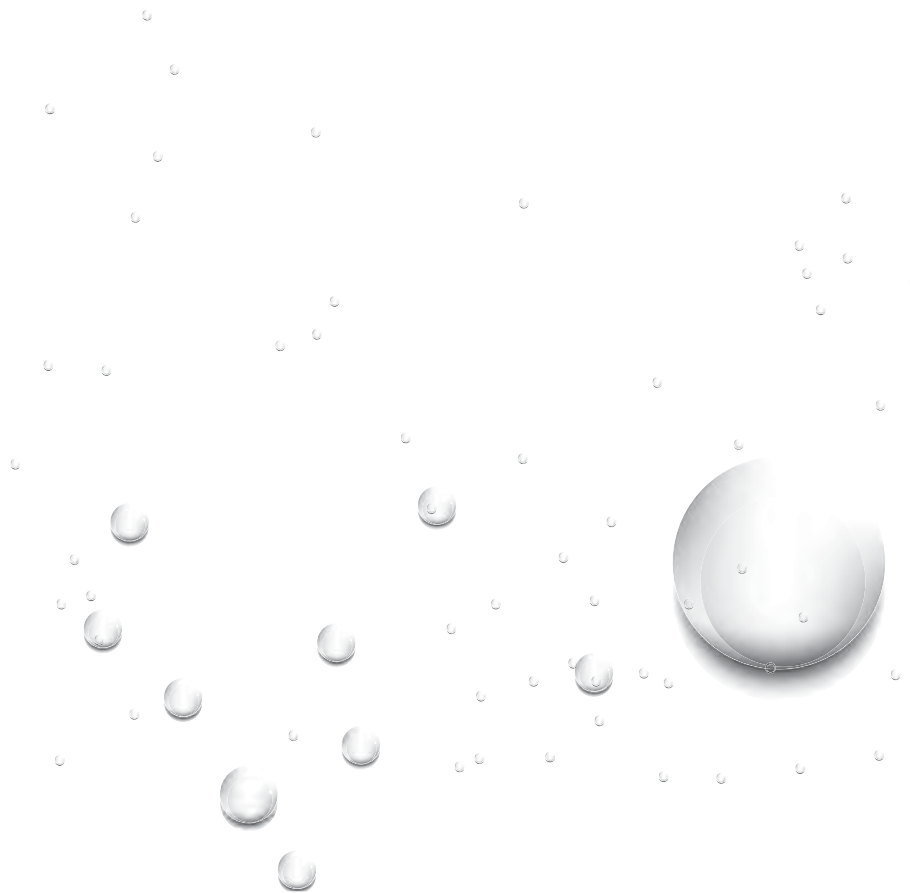


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Acronyms

AfDB	African Development Bank
BMC	Basin Management Committee
CGS	Council for Geosciences
CMA	Catchment Management Agencies
CSIR	Council for Scientific and Industrial Research
CSO	Central Statistics Office
DC	District Councils
DRFN	Desert Research Foundation of Namibia
DWA	Department of Water Affairs, Botswana
DWAF	Department of Water Affairs and Forestry, Namibia
DWS	Department of Water and Sanitation, South Africa
EMA	Environmental Management Act, Namibia
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization
GEF	Global Environment Facility
GIS	Geographic Information System
GGRETA	Governance of Groundwater Resources in Transboundary Aquifers
GMI	Groundwater Management Institute
GTZ	Germany's Technical Cooperation
IAEA	International Atomic Energy Agency
IFAD	International Fund for Agricultural Development
IGRAC	UNESCO International Groundwater Resources Assessment Centre
IPCC	Intergovernmental Panel on Climate Change
IMS	Information Management System
IUCN	International Union for Conservation of Nature
ISARM	International Shared Aquifer Resources Management Programme of UNESCO and IAH
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
KDDC	Kgalagadi District Development Committee
KTP	Kgalagadi Transfrontier Park
MCCM	Multi-Country Co-operation Mechanism
MLG	Ministry of Local Government, Botswana
MMEWR	Ministry of Minerals, Energy and Water Resources, Botswana
MHH	Man Headed Households
MOU	Memorandum of Understanding
MAWF	Ministry of Agriculture, Water and Forestry, Namibia
MWS	Ministry of Water and Sanitation, South Africa
NAU	Namibia Agriculture Union
NDP	National Development Plan
NEMA	National Environmental Management Act, South Africa
NNFU	Namibia National Farmers Union
NPC	National Planning Commission

NWA	National Water Act
ORASECOM	Orange-Senqu River Commission
PCCP	From Potential Conflict to Cooperation Potential
RAD	Remote Area Dwellers
SAB	Stampriet Artesian Basin
SADC	Southern African Development Community
SANParks	South African National Parks
SDC	Swiss Agency for Development and Cooperation
STAS	Stampriet Transboundary Aquifer System
TBA	Transboundary Aquifer
TDS	Total Dissolved Solids
TWAP	Transboundary Waters Assessment Programme
UNESCO-IHP	United Nations Educational, Scientific and Cultural Organization International Hydrological Programme
UNGA	United Nations General Assembly
UNWC	1997 United Nations Watercourses Convention
WAB	Water Apportionment Board
WFS	Web Feature Service
WISA	Water Institute of South Africa
WMA	Wildlife Management Area
WMS	Web Map Service
WHH	Woman Headed Household
WHO	World Health Organization
WUC	Water Utilities Corporation
WRC	Water Research Commission

Executive Summary

Approach and main activities

The assessment of the Stampriet Transboundary Aquifer System (STAS) was undertaken based on a multi-disciplinary methodology developed by the UNESCO International Hydrological Programme (IHP) and the International Groundwater Resources Centre (IGRAC) that includes the collection and processing of national data (hydrogeological, socio-economic and environmental, gender, legal and institutional), and the harmonization of data across all three countries to enable a joint assessment of the transboundary resource.

Activities were done within the framework of the Governance of Groundwater Resources in Transboundary Aquifers (GGRETA) project, executed by UNESCO-IHP, in close cooperation with IGRAC, and funded by the Swiss Agency for Development and Cooperation (SDC). The assessment has been carried out by a team familiar to the area and composed of professionals of Botswana, Namibia and South Africa. Apart from collecting and studying relevant literature for assessment and diagnostics, the team has spent much attention to compiling basic data and to GIS mapping. In total, more than 40 thematic maps were prepared and have been uploaded to the Information Management System (IMS) developed by the project (<https://ggis.un-igrac.org>).

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Location, delineation and type of aquifer

The STAS covers a large arid region stretching from Central Namibia into Western Botswana and South Africa's Northern Cape Province. It contains two confined sandstone aquifers, overlain by unconfined Kalahari aquifer units. The delineation of the STAS area follows the outer boundary of the Ecca Group of geological formations within the catchments of the Auob and Nossob Rivers. The STAS is a very large transboundary aquifer system, receiving insignificant recharge, in a dry region without permanent surface water.

General features of the Stampriet Transboundary Aquifer System (STAS) area

The STAS area is 86 647 km² in extent and has a generally flat topography, gently sloping from NW to SE, between 1450 and 900 m above mean sea level. It has a hot and dry climate, with an annual mean temperature of 19-22 °C and mean rainfall ranging from 140 mm/yr in the SW to 300 mm/yr along the northern and north-eastern segment of the STAS area. During the period May through September there is hardly any rainfall. The Namibian sector of the area covers approximately two-thirds of the area and is almost completely in use as agricultural land. The Botswana sector occupies 19% and includes from North to South three distinct land use zones: agricultural land (mainly in Ghanzi district), wildlife management area and national park. The South African sector (8%) is entirely used as national park. The area is sparsely populated with an estimated population of nearly 50 000 of which more than 90% which is in Namibia. Major settlements are Aranos and Koes, but their population is less than 5000; all other settlements have less than 2000 inhabitants. Commercial industrial and mining activities are absent.

Water and water use in the area

Given the climatic and other geographic features, there are no permanent rivers in the STAS area. Apart from the ephemeral Auob and Nossob Rivers that provide some water during the rainy season, there are surface water pans scattered over the area that collect and store water for livestock watering during rainy season; these reserves can last a few months after the rains. The only permanent and dependable water resource in the area is groundwater. Groundwater is withdrawn from the Kalahari, Auob and Nossob aquifers, by means of dug wells and boreholes. It is estimated that at least 20 million cubic metres per year is abstracted; 66% of this volume comes from Kalahari aquifers, 33% from the Auob Aquifer and 1% from the Nossob aquifer. The breakdown of overall water use is as follows: 47% for irrigation, 37.5% for stock watering, 16% for domestic use, and 0.5% for tourism. In general, the urban centres and villages receive water from governmental and parastatal water supply corporations. Private land owners usually have their own wells.

The Stampriet Transboundary Aquifer System (STAS)

Conceptually, the physical processes taking place in this system of two confined aquifers are reasonably understood in Namibia and not much in both Botswana and South Africa, but quantification is still limited –in spite of many efforts made over a long period of time. Apart from diffuse recharge by downward seepage from the Kalahari aquifers, there are a few recharge zones in the western part of the STAS area where sinkholes facilitate concentrated recharge during rare wet years. The mean annual recharge rate for these confined aquifer units is likely to be significantly less than that of the Kalahari aquifers, for which rates of around 1 mm/year, averaged over the area, have been estimated. The general direction of groundwater flow is from NW to SE. In the SE quadrant of the area, groundwater is presumed to seep upward from the confined aquifers and discharges into the Kalahari formations, from where it evaporates. Groundwater salinity in this zone – known under the name Salt Block – therefore is rather high.

Main groundwater management challenges in the area

Lack of monitoring data (climate, groundwater abstraction, water levels, water quality) seriously hampers a systematic diagnostic analysis. Nevertheless, the findings and combined experiences of the assessment team have revealed a number of challenges.

Groundwater quantity stress has not been observed. Lack of monitoring may be an explanation, but the exceptionally low intensity of groundwater withdrawal certainly plays a major role. If for some reasons (population growth, economic development, water transfer, etc...) the demand for water in the region would increase significantly, then very soon the groundwater resources may run short of meeting these demands. Therefore it is very important to initiate effective control of groundwater quantity, e.g. by some initial practical steps such as solving the problem of water spillage by leaking boreholes in the Auob aquifer and preventing future problems by improved regulation of drilling.

Groundwater quality has its natural variations. Most notable are generally poor conditions in or near the Salt Block zone. Pollution, however, may also lead to groundwater quality degradation elsewhere in the area. The confined transboundary aquifers have very low vulnerability to pollution, but they will experience higher withdrawal pressures if overlying Kalahari aquifers become polluted. The shallower

and usually phreatic Kalahari aquifers are vulnerable to pollution; in particular in the Namibian sector the pollution risk is often medium to high due to irrigated agriculture (using fertilizers and pesticides) and environmentally unfriendly sanitation and waste disposal practices. Partly from the groundwater management point of view and partly for health reasons, there is scope for enhancing water supplies and even more for improving sanitation in the entire area.

Improving groundwater governance

Given the fragility of the aquifer system and the fact that groundwater is the only permanent source of water in this huge area, it is evident that the STAS should be governed and managed wisely. A large part of the provisions and interventions to be considered are of a local nature, but transboundary cooperation will be very useful by sharing information, exchanging experience and by harmonizing interventions across the international boundaries. At the level of the assessment, the three countries have already proven to be willing and capable to cooperate effectively.

Botswana, Namibia and South Africa all possess individually the main elements of a domestic legal framework that provides essential controls on groundwater use and pollution. However, the implementation and enforcement of groundwater quantity and quality regulations raise more challenges. The STAS includes large areas where water abstraction and pollution is not subject to regular inspection and controls.

Botswana, Namibia and South Africa could benefit from further collaboration to develop jointly legal and institutional responses to current and future development of the STAS. The three countries already collaborate through regional bodies notably the Orange-Senqu River Commission (ORASECOM) and the Southern African Development Community (SADC), but there is no arrangement among the three STAS countries that pays attention to the needs of the STAS. Consequently, the need for a multi-country co-operation mechanism has been identified.

The over-arching objective of a multi-country cooperation mechanism for STAS (MCCM) is to transition from GGRETA project-driven cooperation in the study and characterization of STAS to institutionalized cooperation among the STAS countries, beyond the life of the project. In the short-term, the specific objective of the MCCM is to continue the joint study of STAS, also by generating a steady flow of agreed additional/fresh data and information feeding the Information Management System (IMS) for STAS, generated by the GGRETA project. In the long-term, as cooperation takes hold and matures, the MCCM's institutionalized cooperation objective may expand from data collection and exchange to joint strategizing and advising STAS countries on management issues of the STAS groundwater resources.

Two potential models for the establishment of a MCCM for the STAS have been identified. One builds upon national government capacities and institutions in the three STAS countries, and seeks to synergize them towards a common purpose, i.e., the cooperative husbanding of the STAS and its resources. The other model taps into the regional existing institution whose mandate comes closest to the STAS, i.e., ORASECOM, and nests in it dedicated attention to the STAS.



Chapter 1. Introduction



1.1. General background

Groundwater represents some 97% of all liquid freshwater on Earth and is an integral part of the water cycle, inextricably linked to surface waters and ecosystems. It provides drinking water to at least 50% of the world's population (UNESCO-WWAP, 2009) and represents 43% of all of the water used for irrigation (Siebert et al. 2010). Over the past 50 years, thanks to the availability of new and cheaper drilling and pumping technologies, groundwater abstraction has increased by more than 300%, and has brought major socio-economic benefits to users (Llamas and Martinez-Santos, 2005; van der Gun, 2012). However, its development and use has often fallen outside of governance frameworks (FAO, 2015). Hydrogeologists refer to this change in groundwater utilization as 'the silent revolution', since it has occurred in many countries in an unplanned and totally uncontrolled way. It went almost unnoticed.

We have now come to realize that, without proper knowledge of the resource and sound resource governance principles¹ including respect of human rights and adherence to gender equality principles, this huge resource can be rapidly and irreversibly degraded. Pollution of aquifers is hardly ever reversible: over-exploitation may have permanent impacts on aquifer resilience and behaviour. There is a realization that different types of terrestrial and aquatic ecosystems depend on groundwater regimes, as is the case for most semi-arid alluvial plains, wetlands, coastal habitats, and even coastal marine environments. Groundwater cuts across basins and landscapes, sustains ecosystems and biodiversity, mitigates the impacts of climatic fluctuations, and contributes to human health and social-economic development. It is now apparent that groundwater, from the shallowest unconfined aquifers to the deepest hidden reserves, has a critical role to play in addressing the new challenges of adapting to the realities of a changing climate and combating desertification.

The need for groundwater resource assessment and management, and for governance structures of comparable scope, has come to the forefront of the global agenda on sustainable development (FAO, 2015). *This is particularly true, and even more challenging, in the case of transboundary aquifers, which require cooperation and collaboration among the various authorities in charge of groundwater across the national borders, based on mutual trust and on transparency.*

1.2. The GGRETA project

The "Governance of Groundwater Resources in Transboundary Aquifers (GGRETA)" project is a two-phased demonstration project that operates in three pilot transboundary aquifers representative of different natural and socio-economic settings and located in regions of potential conflicts over water among countries, among uses, and among users. It is a technical assistance effort that strives to achieve a better integration of groundwater resources into the water budget of basins, countries and regions, as part of a step-by-step approach to enable and foster transboundary cooperation. UNESCO's International Hydrological Programme (IHP) has embarked on this project, financed by the Swiss Agency for Development and Cooperation (SDC).

1. "Groundwater governance comprises the promotion of responsible collective action to ensure control, protection and socially-sustainable utilisation of groundwater resources and aquifer systems for the benefit of humankind and dependent ecosystems." *Global Framework for Action on Groundwater Governance*, 2015, available at www.groundwatergovernance.org

The main goal of the GGRETA project is to enhance cooperation on water security, prevent transboundary and water-use conflicts, and improve overall environmental sustainability. The project's implementation is focused on pilots, for which three transboundary aquifer (TBA) systems have been chosen: one in Central America (Trifinio), one in Central Asia (Pretashkent) and one in Southern Africa (Stampriet). The latter is the Stampriet Transboundary Aquifer System (STAS) shared between Botswana, Namibia and South Africa. The project aims to reinforce the capacity of Member States in managing groundwater resources; strengthen cooperation among countries sharing the aquifer; and develop a long term strategy for the monitoring and governance of the transboundary aquifer.

The project's overall objectives have been formulated as follows:

- Improve the knowledge and recognition of the importance and vulnerability of transboundary groundwater resources,
- Strengthen cross-border dialogue and cooperation,
- Develop shared management tools; and
- Facilitate governance reforms focused on improving livelihoods, economic development and environmental sustainability.

The expected outcomes and outputs of the first phase of the project are shown in Table 1.1.

Table 1.1 | GGRETA's envisaged outcomes and outputs

Phase	Expected Outcomes	Expected Outputs
Phase 1 Assessment and Diagnostic analysis of pilot TBAs <i>Duration: 2.5 years</i>	Countries sharing the aquifer recognize the transboundary nature and high vulnerability of the resource, and agree to take steps to deal with its transboundary implications.	<p><i>1) Detailed Indicators Based Assessments of Selected TBAs</i></p> <p>The Assessment and Diagnostic analysis will be carried out for each pilot transboundary aquifer, and will amongst others respond to the following questions: (i) what human and ecosystem uses of these groundwater resources are currently affected or impaired; (ii) how are the groundwater systems linked to surface water systems and land use; iii) how will water conditions and uses develop during the next decades; and (iv) where will problems be occurring.</p> <p><i>2) Information Management System.</i></p> <p>Field data will be processed and entered into a database that amongst others will allow production of Thematic Maps showing the values of selected variables or indicators for management purposes.</p>

1.3. The Stampriet Transboundary Aquifer System pilot project

1.3.1 People and organisations involved

The assessment of the Stampriet Transboundary Aquifer System (STAS) has been carried out by a team familiar to the area and composed of professionals of Botswana, Namibia and South Africa. Guided and coordinated by the Regional Coordinator, the National Specialists were responsible for collecting, compiling and analysing relevant data from the different sources which were then structured into tables, maps and other formats and later harmonized to provide a regional outlook on the status of the aquifer. These national specialists reported through the project's National Coordinators to the project

management in Paris, UNESCO-IHP. The project organizational chart is presented in Figure 1.1.

UNESCO-IHP counted with the support of the International Groundwater Resources Assessment Centre (IGRAC), regional entities such as the Southern African Development Community (SADC) and Orange Senqu River Basin Commission (ORASECOM), national institutions and national authorities of the respective countries, namely:

- **Namibia:** Department of Water Affairs and Forestry (DWAF) of the Ministry of Agriculture, Water and Forestry (MAWF);
- **Botswana:** Department of Water Affairs (DWA) of the Ministry of Minerals, Energy and Water Resources (MMEWR);
- **South Africa:** Department of Water and Sanitation (DWS), Ministry of Water and Sanitation (MWS).

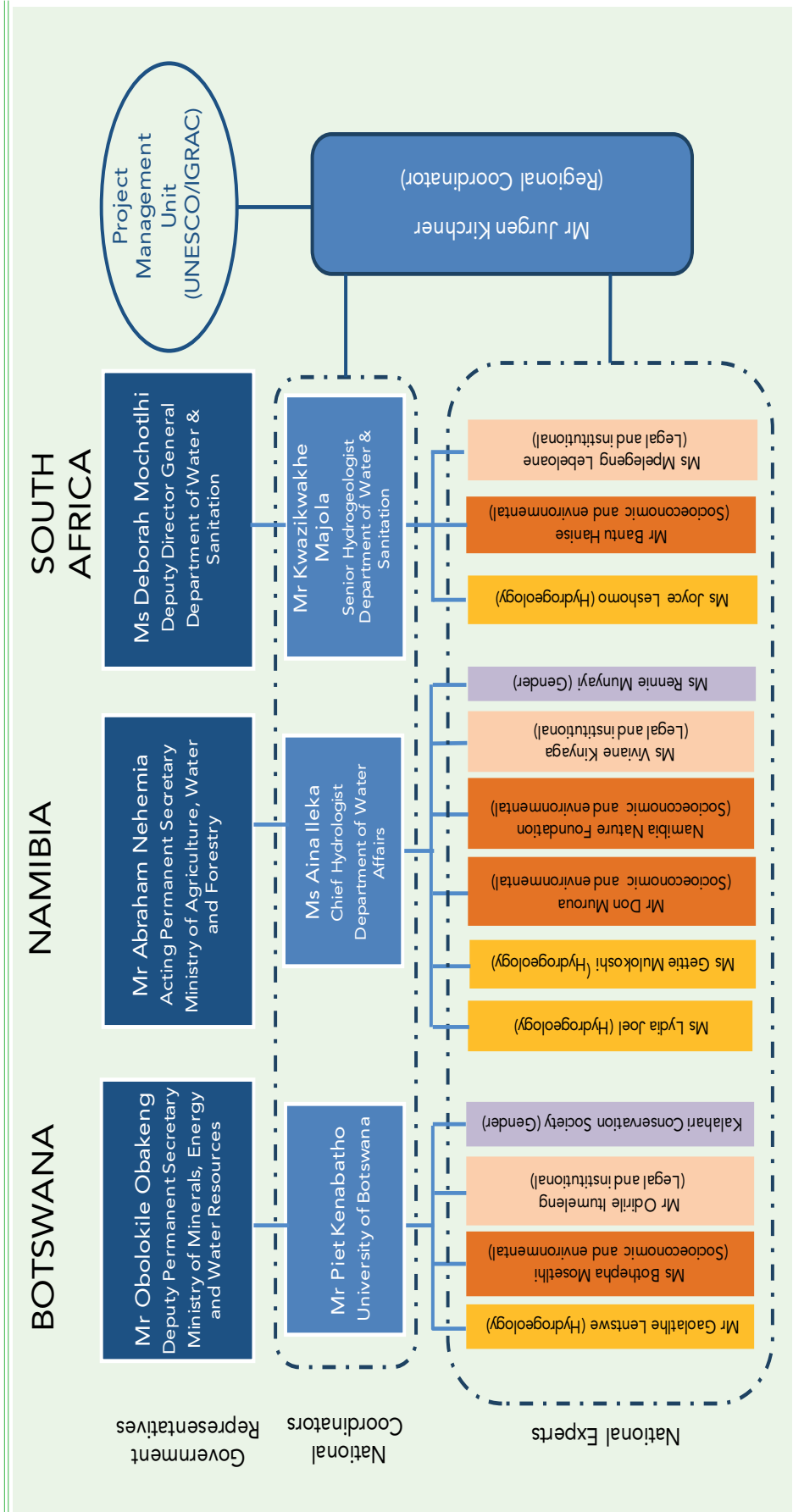
1.3.2 Project approach

In line with the general methodology of the GGRETA project, existing data about the transboundary aquifer was collected, analysed, harmonised by a team of national experts from each country sharing the aquifer, with support from the UNESCO/IGRAC team, the Regional Coordinator and National Coordinators. The data collected cover the following fields: hydrogeology, environment, socio-economics, legal/institutional aspects, stakeholders and gender issues.

This has resulted in achieving output 1: an indicator-based assessment, presented here as the main component of this assessment report. Apart from reporting on the individual variables and other parameters, several of them were also combined into indicators, which generate additional knowledge and provides at the same time a better overview. The data gathered was available in different formats (reports, scientific articles, data sheets, data bases, maps, etc) and was spread over different sources (different ministries, agencies, universities, etc.). In the first phase national experts collected all these different data from the different sources. After collecting the data, the data sets were harmonised and structured into clear tables, maps and other overviews, and in some cases aggregated to provide a regional outlook of the aquifer. Based on these data the actual assessment took place leading to this assessment report.

All processed and interpreted data will be stored in an Information Management System (output 2) which has to become an important governance tool in support of the sustainable management of the transboundary aquifers. The development of this system is led by the International Groundwater Resources Assessment Centre (IGRAC) in the Netherlands under supervision of UNESCO-IHP.

Figure 1.1 | National experts of Botswana, Namibia and South Africa involved in the project



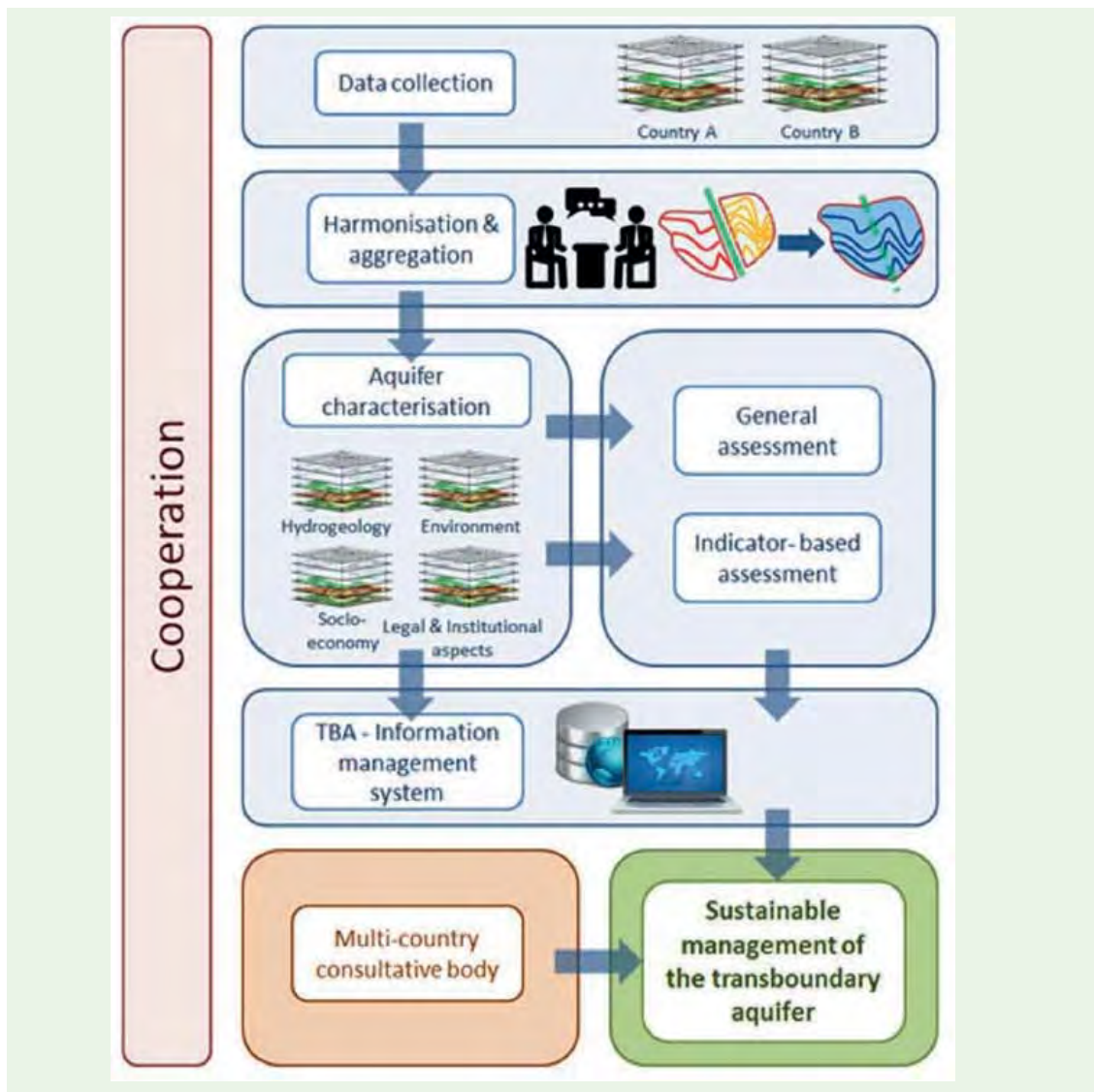
1.3.3. Adopted Assessment Methodology

As the Table of Contents shows, this assessment report consists largely of chapters that describe systematically the different aspects of the STAS and its broad context, as far as the available data allow. At the end of the report, this information on the different aspects is integrated into an aquifer- and area-specific diagnostic. This diagnostic highlights issues that need to be addressed and thus forms an essential basis for guiding groundwater governance and management in the near future.

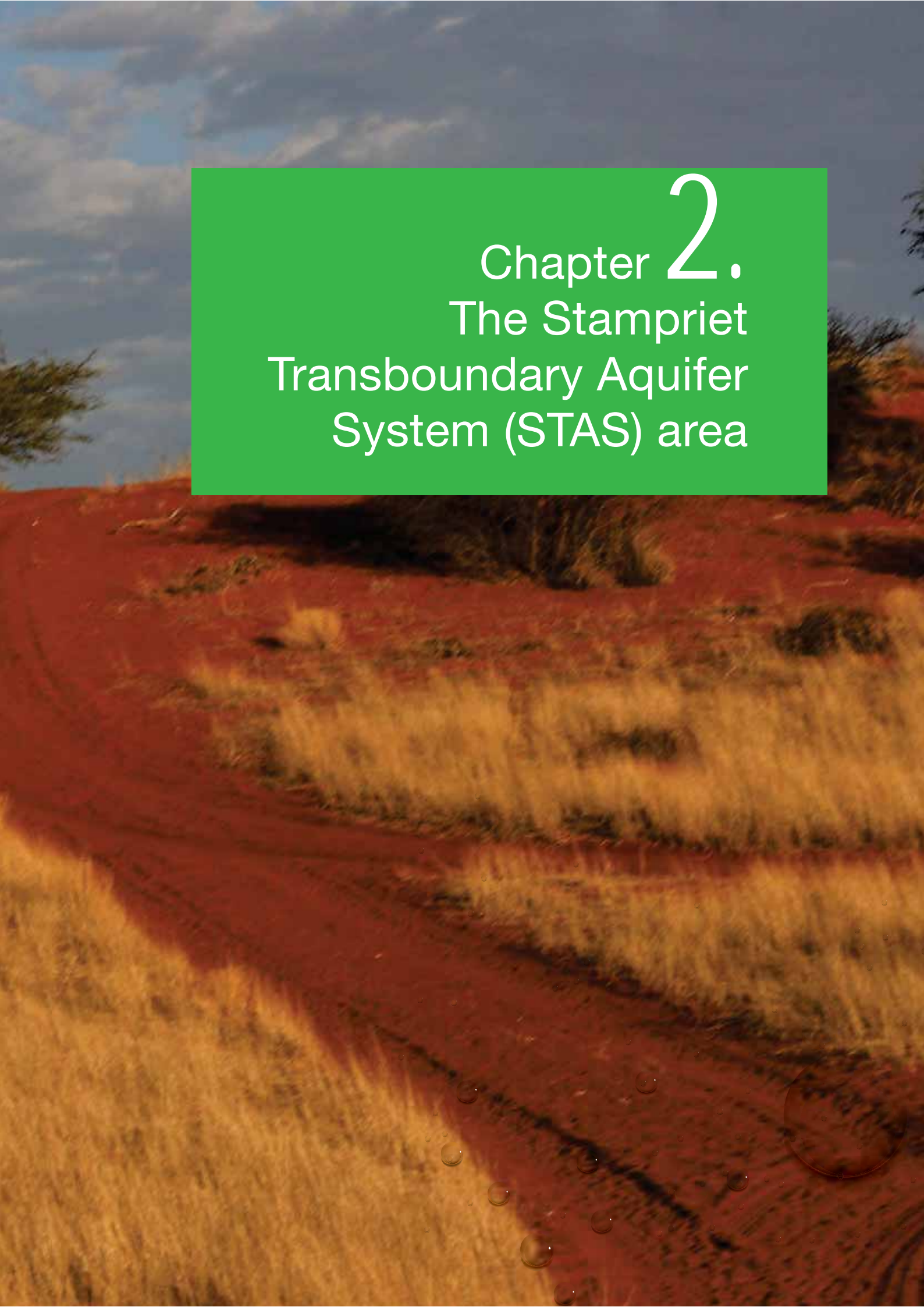
Two methodological tools have played a key role throughout the report, but in particular in the diagnostic chapter: the Drivers, Pressures, State, Impacts and Responses (DPSIR) framework and the Transboundary Water Assessment Programme (TWAP) indicators. The DPSIR framework (OECD, 1993) attempts to describe and understand the dynamics of a system by making a distinction between Drivers, Pressures, State, Impacts and Responses (DPSIR), all of them interacting. The TWAP indicators try to combine variables, aggregated over the entire aquifer or its national segments, in such a way that the overall management or governance issues are revealed and highlighted, although only in a macroscopic way.

To assist the Stampriet regional team and the teams of the two other pilot studies, assessment guidelines have been developed by UNESCO-IGRAC in an early stage, later on laid down in a publication (UNESCO-IGRAC, 2015). Figure 1.2 shows how these guidelines see the role of assessment and information management in the process of transboundary aquifer management.

Figure 1.2 | The role of assessment and information management in transboundary aquifer management (Source: UNESCO-IGRAC, 2015)







Chapter 2.

The Stampriet Transboundary Aquifer System (STAS) area

2.1. Historical background

The discovery of diamonds and gold in South Africa during the late 19th Century instigated a program to explore location of water for steam-driven railway locomotives required along railway lines, aiming at linking harbours with developing mining and industrial sectors in the interior of the sub-continent (van Wyk, 2014). Exploration focused on high-yielding artesian groundwater resources that do not have energy costs and do not require equipment for pumping installations. The Cape Government Railways (1898) opted to explore for deep-water sources in the southern Karoo and drilled down to depths in excess of 300m. It was in 1912 when in the search for coal that Dr. Paul Range struck artesian water in the Stampriet Artesian Basin (SAB) in a borehole at Stamprietfontein in Namibia (Figure 2.1). After World War I, farms were developed for South African ex-soldiers along the Auob River. However little attention was given to this basin until after World War II when further farms were developed for South African ex-soldiers in the far east lying Nossob River area (see Figure 2.2).

Figure 2.1 | First artesian water was struck in 1912 (110 m³/hr free flowing artesian borehole) (Source: National Archives of Namibia)



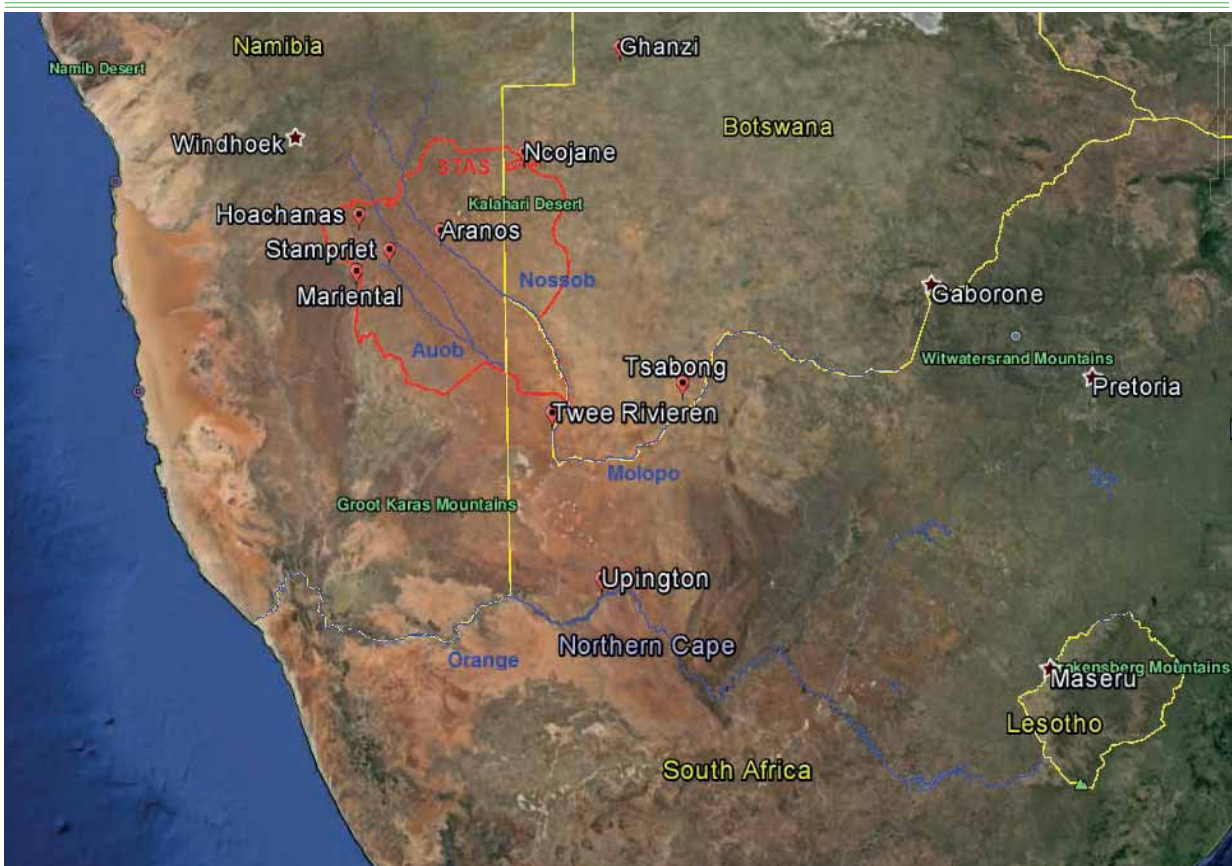
After World War II, when South Africa continued to administer the territory, the search for water became the foremost task in Namibia's arid environment. The newly established Geological Survey of Namibia focused on mapping and hydrogeology. Groundwater investigations and exploration for hydrocarbons (especially in the oil-prone Whitehill Formation) remained a major task from 1960s to 80s, and led to remarkably improving the knowledge of the Karoo Supergroup's stratigraphy (Wilson, 1964; Kent, 1980). In the 1970s and early 80s Tredoux and Kirchner looked in more detail into the hydrochemistry (Tredoux 1981) and (Kirchner and Tredoux 1975) of the basin while the Council for Scientific and

Industrial Research (CSIR) in South Africa contributed with water quality (Huyser 1982a; Huyser 1982b) and isotope analyses (Vogel et al. 1982). Interest on groundwater development of the SAB in Botswana started in the 1980s.

Following the 1948 informal verbal agreement between the then Bechuanaland Protectorate and the Union of South Africa to set up a conservation area in the contiguous areas of the two lands, the intention to merge the Kalahari Gemsbok National Park in South Africa and the Gemsbok National Park in Botswana led to representatives from the South African National Parks Board (now SANParks) and the Department of Wildlife and National Parks of Botswana set up a joint management committee to manage the area as a single ecological unit (Kgalagadi Transfrontier Park - KTP) in June 1992. The bilateral agreement to merge the two parks was signed on 7 April 1999 between the governments of Botswana and South Africa. Groundwater exploration aiming at establishing wildlife ranger camps were undertaken in the late 1980s in South Africa (van Wyk, 1987) and late 1990s in Botswana (Gemsbok, 1999).

Further detailed research in the Stampriet Artesian Basin was undertaken after independence in Namibia during the Japan International Cooperation Agency (JICA) project (1999 to 2002) (JICA, 2002) and parallel International Atomic Energy Agency (IAEA) isotope (Kirchner et al. 2002) and hydrogeological map projects (van Wyk et al. 2001). In Botswana, the Matsheng project (2004-2008) aimed at locating and developing sufficient potable groundwater resources to supply the primary demand centres called as “Matsheng” Villages.

Figure 2.2 | Location map of the Stampriet Transboundary Aquifer System
(STAS boundaries in red, international boundaries in yellow)



2.2. Delineation and general features of the STAS area

This section aims at providing insights on how the study area was delineated, and general features such as geology, topography, and vegetation.

The Stampriet Transboundary Aquifer System (STAS, see Figure 2.2) stretches from Central Namibia into Western Botswana and South Africa's Northern Cape Province, and lies within the Orange River basin. It covers a total area of 86 647km², of which 73% is in Namibia, 19% in Botswana, and 8% in South Africa.

The STAS was delineated based on the occurrence of geological formations belonging to the Ecca Group within the Auob and Nossob River basins². The Auob and Nossob Rivers are the only major streams within the study area and these originate in Namibia and flow in a south-easterly direction towards the Molopo River in Botswana. The Auob and Nossob Rivers are ephemeral and only flow for short periods during heavy rainfall events.

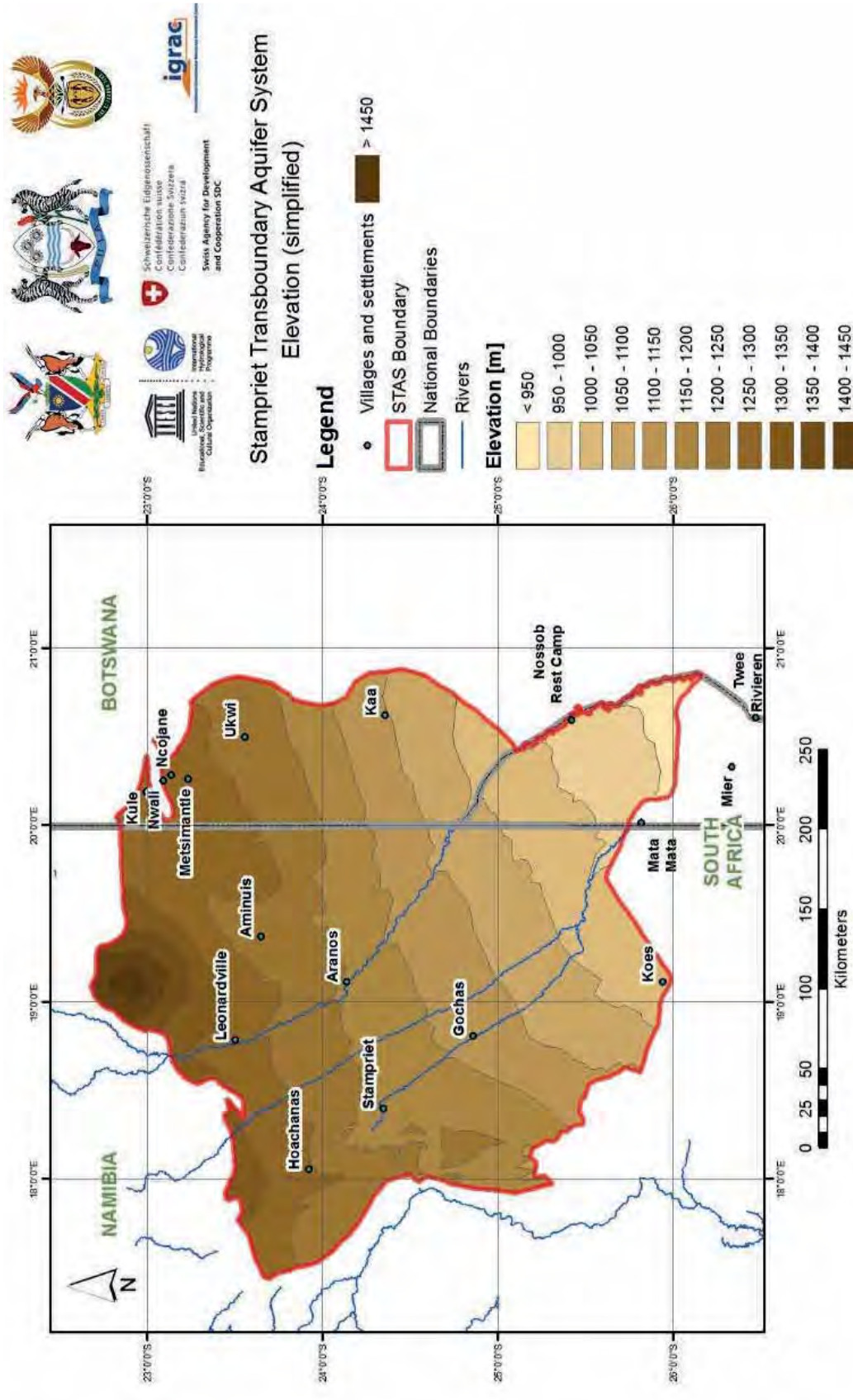
From a geological point of view, the study area is part of a huge sedimentary basin in which a thick sequence of layers has been deposited. The layers of Carboniferous through Jurassic age are together known as Karoo Supergroup and contain mainly sandstones, shales, mudstones, siltstones and limestone. They are covered by a blanket of sediments of the Kalahari Group, of Tertiary-Quaternary age and consisting predominantly of sand, calcrete (duricrust), gravel, clayey gravel, sandstone and marl.

The STAS is formed by the confined artesian Auob and Nossob aquifers, and the overlying phreatic Kalahari aquifers (free water table). The Kalahari aquifers are easily within reach of the local inhabitants. The permeable zones in the Kalahari formations are discontinuous and their lateral extent is limited, hence they form local aquifers, and the Kalahari sediments as a whole do not constitute a transboundary aquifer system.

The topography of the study area is relatively flat with an elevation of 1450m-900m above mean sea level from the northwest to the southeast segment of the STAS area (Figure 2.3). The area is largely dune-covered in the central area with calcrete-underlain plains in the west and east of the study area. The dune area continues southeast into South Africa while the Botswana portion of the study area is generally a flat sand covered area. Groundwater flow in the Auob and Nossob aquifers follow the surface slope from high to low.

2. Boundary uncertainties still exist given that the lack of stratigraphic data does not allow thorough assessment of the extent of formations in the Auob and Nossob River basins. Uncertainties are presented with a question mark (?) in some of the maps (e.g. Figure 2.16)

Figure 2.3 | Topography of the study area



The study area is characterized by various landscapes, including sand dunes in Namibia and South Africa, calcrete/sandy surface area with shrubs and in some cases thick bushes. Pans are also important features found across the STAS. These features are shown in Figure 2.4.

Figure 2.4 | Common landscapes in the study area: dune area stretching from the Auob to the Nossob Rivers (top left), calcrete/sandy surface where pans are quite common (top right), deep cut in the Auob and Nossob Rivers (bottom center)
(Source: J. Kirchner)



The alien *Prosopis* species (native to America) also forms part of vegetation across the three countries. Farmers were encouraged in the past to plant these tree species in large numbers to provide shade, fuel wood and livestock fodder. The arid local climatic conditions and saline and/or alkaline soils provided suitable condition for the survival of these contrary to others species that could not survive (Klein, 2013; Wise et al. 2012 and Zachariades et al. 2011). *Prosopis* trees are found in abundance along the Auob and Nossob Rivers, causing bush encroachment in some parts of the basin as shown in Figure 2.5.

Figure 2.5 | Prosopis covered Nossob River upstream of Leonardville (Namibia)
(Source: J. Kirchner)



2.3. Climate in the STAS

2.3.1. Temperature

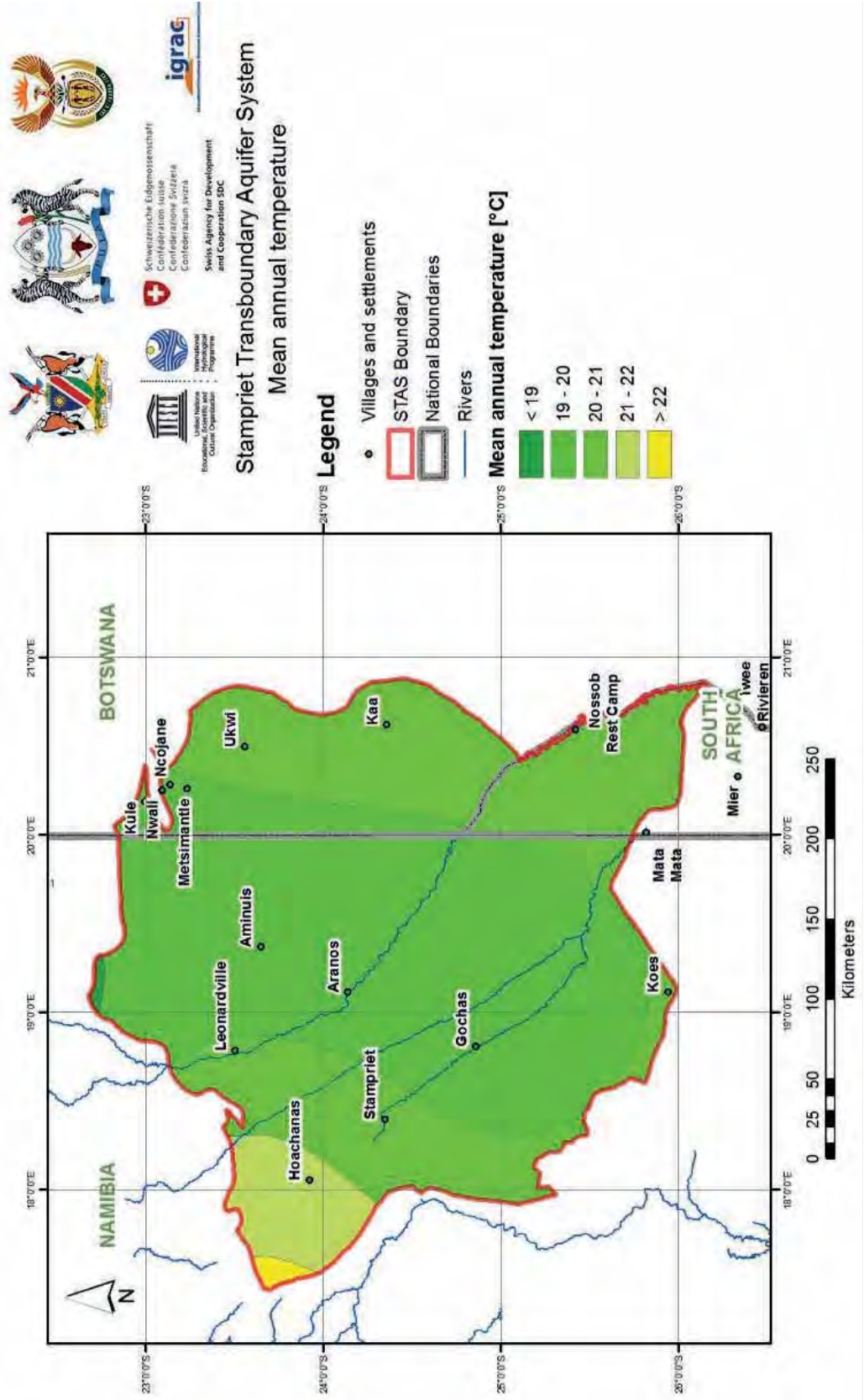
The study area is located in a region of high short-term and seasonal temperature fluctuations owing to the semi-arid conditions. Summer months are from December to February, and winter months from June to August³.

Annual mean temperature does not have high temperature variation across the STAS area and varies between 19 and 22°C (Figure 2.6). Temperature is lower in the northern and central area. However, January mean minimum and July mean maximum temperatures do vary considerably across the STAS area⁴. January mean maximum temperatures are higher in the western, southern and eastern boundaries of the STAS area, and the mean maximum temperature varies between 26 and 36°C (Figure 2.7). During winter, the temperature pattern is reversed with mean minimum temperatures of 1°C in the western, southern and eastern boundaries of the STAS and of 12°C in the STAS northern central area (Figure 2.8). Annual mean, January (summer) mean maximum, July (winter) mean minimum temperature data are presented in Table 2.1.

3. The climate analysis below assumes that January is mid-summer and July mid-winter. Observation period is 1977-2015 with significant data gaps in Namibian stations

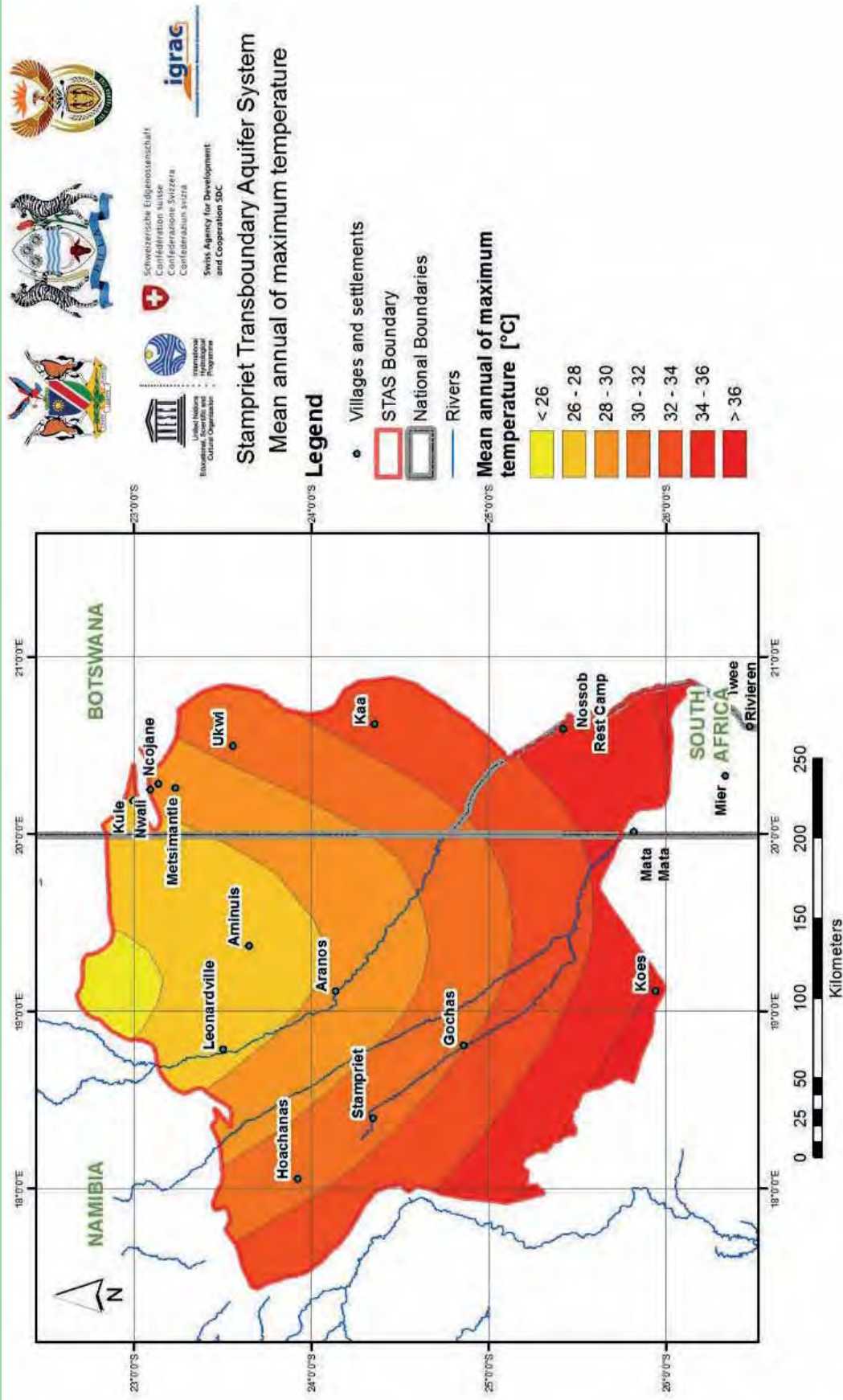
4. Mean maximum (or minimum) temperatures are defined as the long-term mean of all daily maxima (or minima).

Figure 2.6 | Estimated annual mean temperature map of the study area⁵



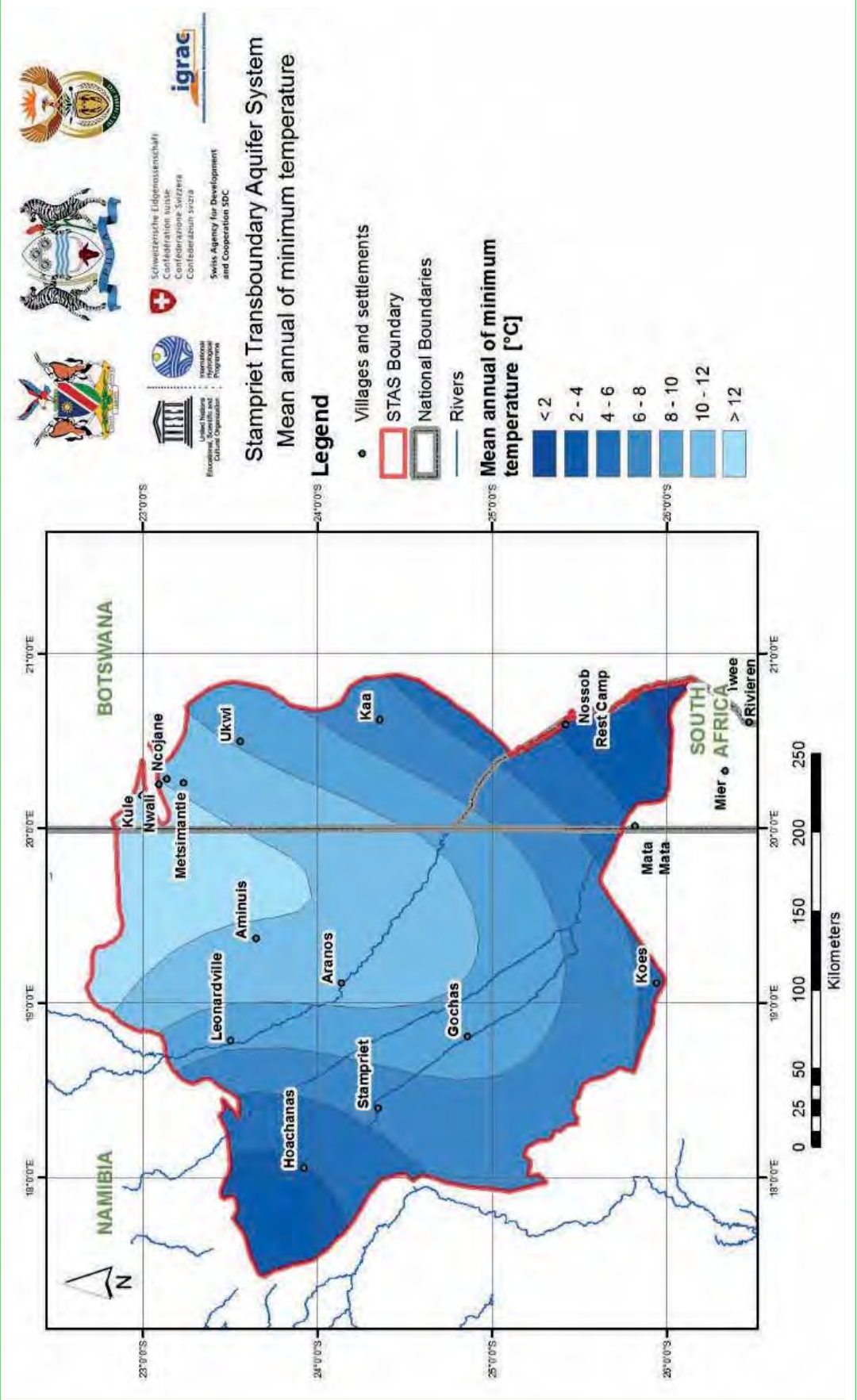
5. Temperature maps were interpolated using the inverse distance squared method available in the Arc View spatial analyst module based on data of stations falling not exclusively within the study area

Figure 2.7 | Estimated January (summer) mean maximum temperature map of the study area⁶



6. Temperature maps were interpolated using the inverse distance squared method available in the Arc View spatial analyst module based on data of stations falling not exclusively within the study area

Figure 2.8 | Estimated July (winter) mean minimum temperature map of the study area⁷



7. Temperature maps were interpolated using the inverse distance squared method available in the Arc View spatial analyst module based on data of stations falling not exclusively within the study area

Table 2.1 | Annual mean, January (summer) mean maximum, July (winter) mean minimum temperature data. Observation period is 1977-2015.

Station	Country	Elevation (masl)	Latitude	Longitude	Annual mean (0C)	January mean maximum (0C)	July mean minimum (0C)
Windhoek*	Namibia	1656	-22.56	17.08	19.3	30.5	7
Mariental*	Namibia	1106	-24.63	17.97	21.5	34.7	4.6
Aranos	Namibia	1189	-24.13	19.12	19.6	28.3	8.5
Hardap*	Namibia	1297	-23.73	17.15	22.5	36.5	4.5
Hoachanas	Namibia	1339	-23.92	18.05	21.5	30.6	3.5
Tshane*	Botswana	1050	-22.4	22.05	21	33.6	6.2
Tsabong*	Botswana	1000	-26.05	22.45	20.3	34.6	1.1
Twee Rivieren*	South Africa	880	-26.45	20.57	20.9	36.6	1.1

* Station located outside the study area

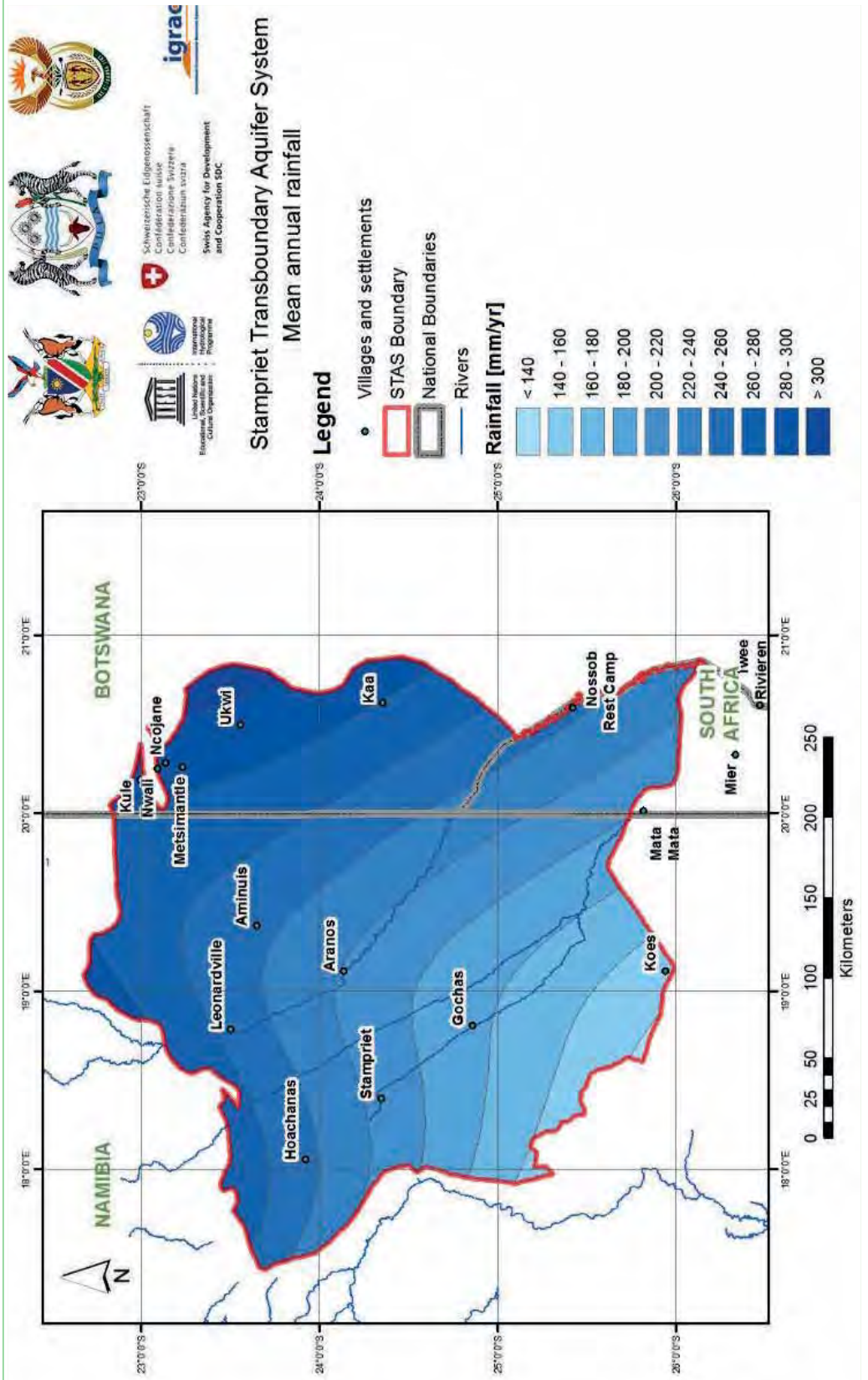
2.3.2. Rainfall

Rainfall normally occurs between October and April predominantly in the form of thunderstorms (high intensity and short duration). The highest rainfall months are from January to March whilst the lowest rainfall months are from June to September.

The average annual rainfall within the study area varies from 140 - 310 mm/y (Figure 2.9)⁸. The rainfall distribution shows maxima of up to 310 mm/y in the north and northeast Botswana segment of the STAS and decreases to about 150 mm/y in the south-western Namibia segment of the study area. Heavy rainfall events can produce the annual rainfall within a few days, and might result in flooding in some areas. A cloud burst in central Namibia in 1960 produced up to 489 mm in just 24 hours (Schalk, 1961) (Figure 2.10). Rainfall during the mid-1970s (1974 and 1976) was also above normal and 600mm/y were recorded at Leonardville (Namibia) for 1974. Another good rainfall season occurred in 1999/2000, in which lakes were forming in the dune areas located close to Hoachanas and Stampriet in the northwestern part of the study area (Kirchner, 2015). An important rainfall event led to flooding of Mariental (Namibia) in 2006 (Figure 2.11). It is estimated by the local Namibian farmers that the 2010-2011 rainy season experienced about three times the annual average precipitation. In 2011, there was water in pans just east of Stampriet (Namibia) (Stone and Edmunds, 2012). Annual mean rainfall data are presented in Table 2.2 and monthly average rainfall at selected stations in the STAS are presented in Table 2.2 and Figure 2.12, respectively.

8. Observation period is 1977-2015 with significant data gaps in Namibian stations

Figure 2.9 | Average annual rainfall map of the STAS⁹



9. Rainfall map was interpolated using the inverse distance squared method available in the Arc View spatial analyst module based on data of stations falling not exclusively within the STAS area

Figure 2.10 | A cloud burst in central Namibia in 1960 produced up to 489 mm in just 24 hours (Source: Schalk, 1961)



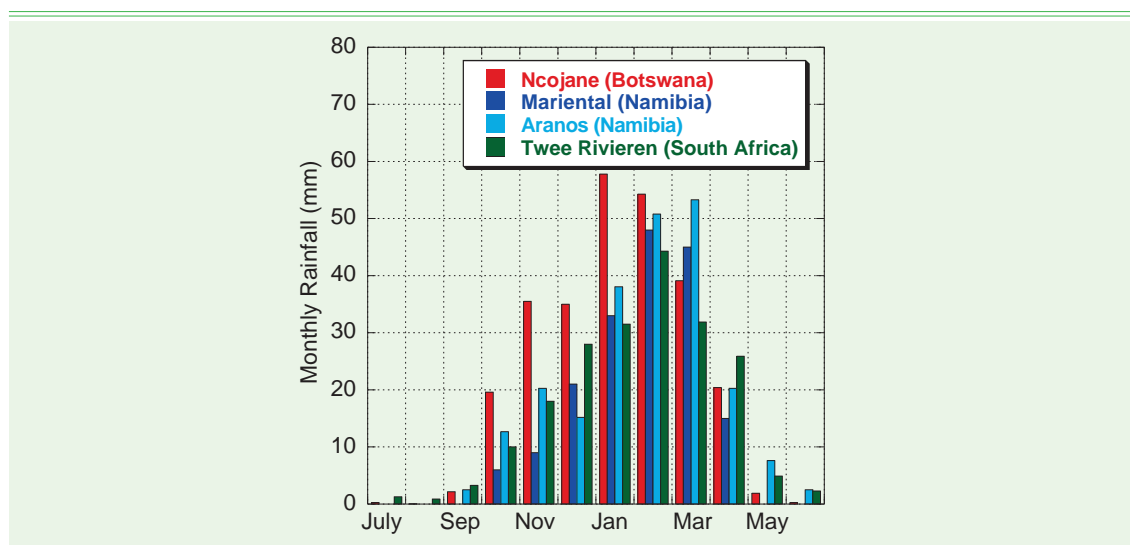
Figure 2.11 | Flooding in the STAS area due to very intensive rainfall events



Table 2.2 | Annual mean rain fall data . Observation period is 1977-2015.

Station	Country	Elevation (masl)	Latitude	Longitude	Mean annual (mm)
Windhoek*	Namibia	1656	-22.56	17.08	363
Mariental*	Namibia	1106	-24.63	17.97	200
Aranos	Namibia	1189	-24.13	19.12	221
Hardap*	Namibia	1297	-23.73	17.15	177
Tsabong*	Botswana	1050	-22.4	22.05	21
Tshane*	Botswana	1000	-26.05	22.45	20.3
Kang*	Botswana	1139	-23.68	22.79	354
Ncojane	Botswana	1268	-23.15	20.47	270
Mamuno*	Botswana	1274	-22.28	20.03	308
Kalkfontein*	Botswana	1276	-22.12	20.90	311
Ghanzi*	Botswana	1153	-21.57	21.78	451
Twee Rivieren*	South Africa	880	-26.45	20.57	20.9

*Stations located outside the study area

Figure 2.12 | Monthly average rainfall at selected stations in the STAS

2.3.3. Evaporation and Evapotranspiration

Evaporation and evapotranspiration form the main water outflow component in the study area. High potential evaporation rates result in huge losses from open water bodies and high potential evapotranspiration rates cause the water demands of crops to be considerable. Potential evaporation in the study area is very high, and was measured to be between 3 000 mm/yr in the north and 3 500 mm/yr in the south of the Namibian segment of the STAS area (MET, 2002). Potential evaporation within the study area was measured only in Namibia in the early 2000s, and has generally been done by observing the water depth in a standard water-tight metal pan¹⁰. This measured evaporation is usually higher than what would be expected from a large open water surface such as a reservoir behind a dam, and a reduction factor thus should be applied (in order to remove effects of advected energy that affects pan evaporation values). In all parts of the study area, mean annual rainfall is much smaller than annual potential evapotranspiration, and indicates aridity. Values of potential and actual

10. Potential evaporation was measured in Botswana in stations falling outside the study area (i.e. Tsabong and Tshane) from 1959 to 2009. Over this period, average potential evaporation was measured to be around 2400 mm/yr in Tsabong and Tshane.

evapotranspiration reach a basin-wide average of 1600 mm/yr (Harris et al., 2013) and 209 mm/yr (MPI, 2010), respectively.

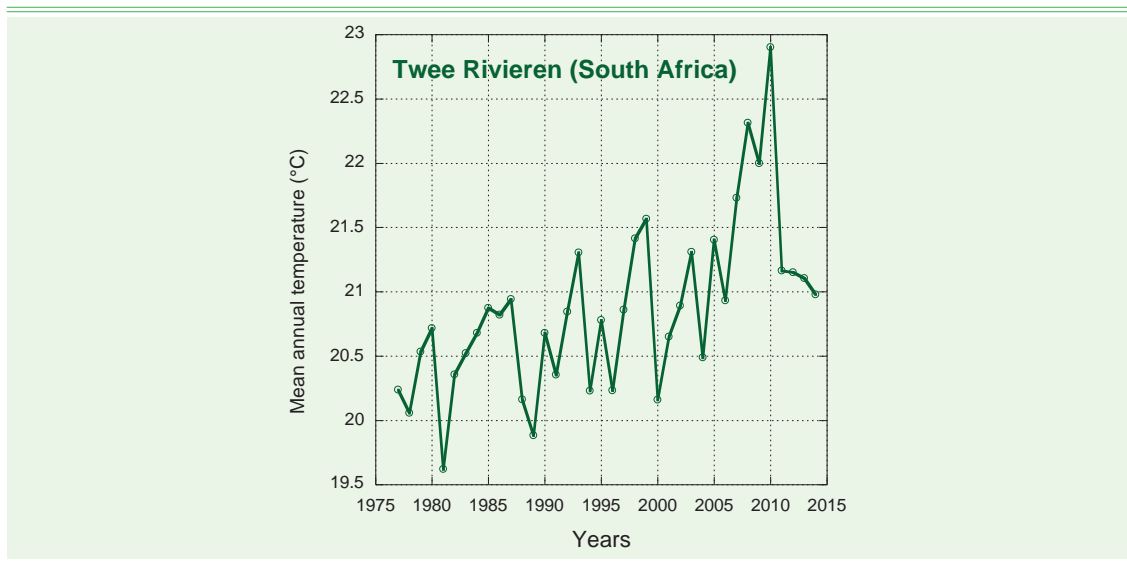
Henceforth, measured evaporation, data computed from global weather datasets (e.g. CRU and MPI) should be used into account with caution.

2.3.4. Climate variability and change

Current vulnerabilities in water resources are strongly correlated with climate variability, due largely to precipitation variability, especially for semiarid and arid regions such as the STAS area (Green et al., 2007; Ouyse et al., 2010). Observed surface air temperatures have shown an accelerating warming trend since 1960, reaching +0.03 °C/yr in Southern Africa (Figure 2.13). Consequently, there has been an increase in the number of warm spells. Global warming is expected to increase the spatial variability in projected precipitation producing both positive and negative changes in regional precipitation, as well as changes in seasonal patterns (Cook et al., 2014). Vulnerability to climate change in the STAS area is expected to result in more frequent droughts, generally longer dry spell duration, and higher variability of rainfall.

The intra-decadal oscillations are recognized to be influenced by the El Niño Southern Oscillation (ENSO) and by interactions with Atlantic and Indian Ocean climates. Changes in the ways these mechanisms influence regional weather patterns have been linked to regional atmospheric-oceanic anomalies before the 1970s (when severe droughts occurred) but to ENSO in more recent decades (Fauchereau et al., 2003).

Figure 2.13 | Mean annual temperature in Twee Rivieren (South Africa) from 1977 to 2014
(Source: CGS, 2015)



During El Niño years (Figure 2.14), limitations in terrestrial moisture supply result in vegetation water stress and reduced evaporation in southern Africa (Figure 2.15). The opposite situation occurs during La Niña years (Miralles et al., 2013). As a rough estimate, potential evapotranspiration over Africa is projected to increase by 5-10% by 2050. However, there is little agreement on the direction and magnitude of predicted evapotranspiration patterns (IPCC, 2008).

Figure 2.14 | Monthly El Niño Southern Oscillation (ENSO) index (Source: National Oceanic & Atmospheric Administration)

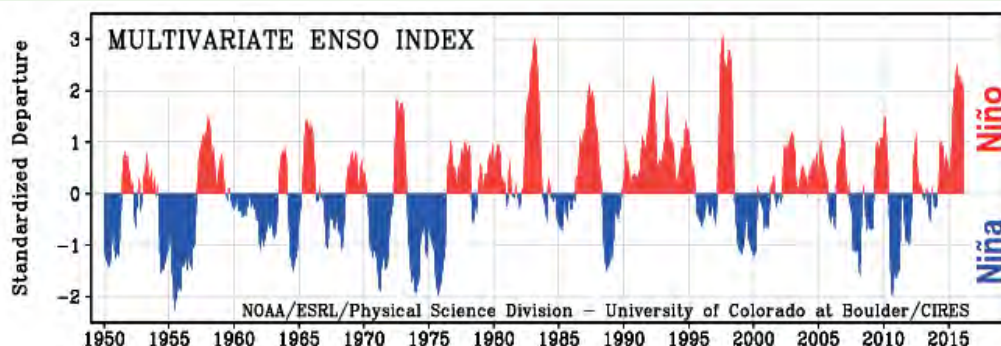
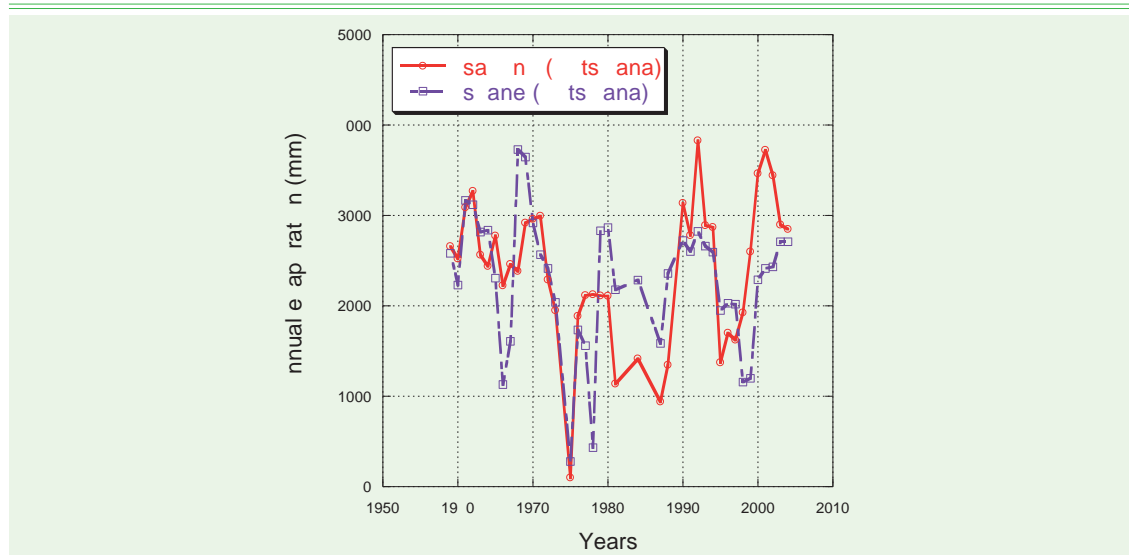


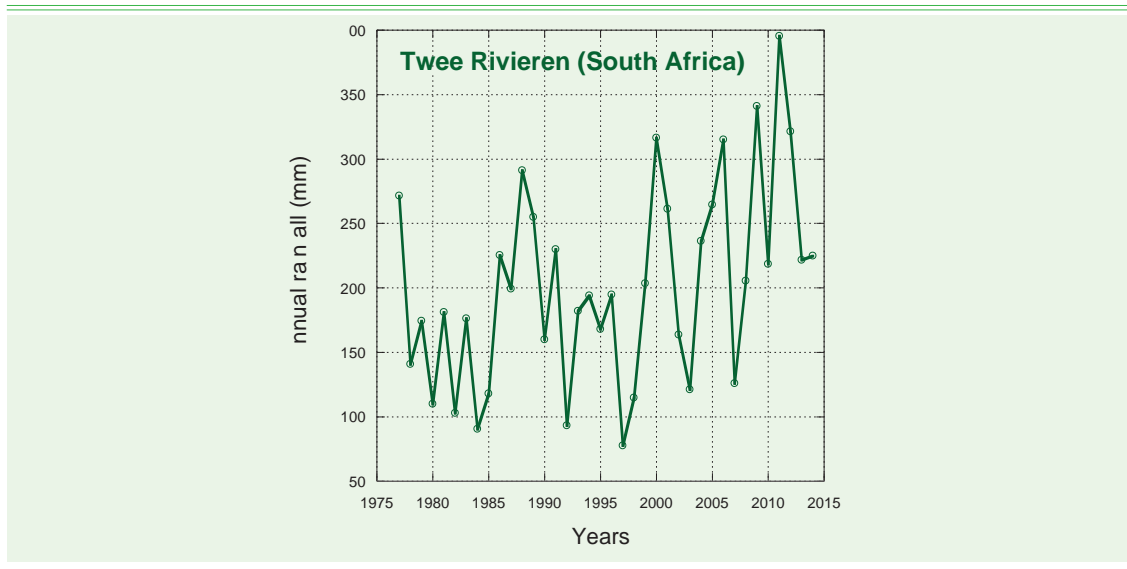
Figure 2.15 | Potential Evaporation in Tsabong and Tshane (Botswana) from 1959 to 2009 (Source: Lentswe, 2015)



The trends in precipitation over Africa are less coherent, with large spatial and temporal variability. Weak long-term trend has been noted in southern Africa, but increased inter-annual variability has, however, been observed in the post-1970 period, with higher rainfall anomalies and more intense and widespread droughts reported (e.g., Richard et al., 2001; Fauchereau et al., 2003). In different parts of southern Africa, a significant increase in heavy rainfall events has also been observed (Usman and Reason, 2004), including evidence for changes in seasonality and weather extremes (Tadross et al., 2005; New et al., 2006).

In the study area, below-normal rainfall can be expected during El Niño years, especially during the main December to March crop-growing period. On the other hand, La Niña years seem to have positive effect on seasonal rainfall (especially from November to April or even May). Generally, the best seasonal total rainfall seems to coincide with La Niña conditions (Figure 2.16). Above normal rainfall events (e.g. early 1960s, mid 1970s, early 2000s) have occurred after very strong El Niño events (1957-1958, 1972-1973, and 1997-1998). Understanding how ENSO events may influence future climate variability in the STAS is therefore critical, and requires further research.

Figure 2.16 | Annual rainfall in Twee Rivieren (South Africa) from 1977 to 2014.
(Source: CGS, 2015)



2.4. Population and administrative units

The STAS study area cuts across three countries with different administrative systems, i.e. three-tier decentralized (National, Regional/Provincial, Local constituencies/municipalities) in Namibia and South Africa, and two-tier centralized systems (National and city/local government) in Botswana (Dipholo and Gumedde, 2013 and Commonwealth of Nations, 2014). The study area is administratively composed of eight constituencies located in four Namibian regions (Kalahari and Aminuis in Omaheke region; Mariental Rural, Gibeon, and Rehoboth Rural in Hardap region; Keetmanshoop Rural and Berseba in Karas region; and Windhoek Rural in Khomas region), two districts in Botswana (Kgalagadi and Ghanzi) and the Mier Local Municipality of the ZK Mgcawu District Municipality in South Africa (Figure 2.17). In South Africa, the study area fully falls within the Kgalagadi Transfrontier Park, which also straddles the border into Botswana, and is one of the world's largest wildlife preserve and conservation areas. Mariental Rural and Aminuis constituencies in Namibia cover at least 80% of the study area, and concentrate the largest population.

The study area is lightly populated and its population is estimated at approximately 50 000 (CSO, 2009; Statistics Botswana, 2012; NSA, 2012). The population was estimated at approximately 30 000 in the early 1990s, and steadily increased to approximately 38 000 in the early 2000s. Namibia has the largest share of population with 91%, followed by Botswana at 8% and South Africa at 1%. The population in the study area is concentrated in small urban and rural settlements, and farms. Major urban settlements are Aranos, Koes and Stampriet in Namibia, Ncojane and Kule in Botswana. Mier is the South African closest urban settlement to the STAS area (Table 2.3 and Figure 2.18). Approximately 37% of the STAS area population lives in urban settlements, while 63% lives in the farming rural area. The available population settlement statistics generally show a balanced gender distribution in the STAS area although it is slightly skewed towards women. On the other hand, men represent approximately 60% of rural population. The total population of the area is difficult to be precisely estimated because it includes an itinerant population that moves into and out of the area.

Table 2.3 | Significant urban settlements within or close to the boundary of the Stampriet Transboundary Aquifer System (STAS) area (Source: CSO, 2009; Statistics Botswana, 2012; NSA, 2012)

Name	District	Country	Total population	Women	Men
Leonardville	Aminuis	Namibia	1191	600	591
Aminuis	Aminuis	Namibia	810	402	408
Hoachanas	Mariental Rural	Namibia	1262	660	602
Aranos	Mariental Rural	Namibia	3683	1873	1810
Stampriet	Mariental Rural	Namibia	1947	1019	928
Gochas	Mariental Rural	Namibia	1163	587	576
Koes	Keetmanshoop Rural	Namibia	4500	2295	2205
Kule	Ghanzi	Botswana	1055	464	591
Ncojane	Ghanzi	Botswana	1958	1029	929
Metsimantle	Ghanzi	Botswana	173	70	103
Ukwi	Kgalagadi	Botswana	523	256	267
Mier*	(Kgalagadi Transfrontier Park)	South Africa	354	160	194
TOTAL			18619	9415	9204

*Settlement located outside the STAS area

In Namibia, population is mainly composed of Black African and White ethnic groups. The Black ethnic group is composed of tribes such as BaTswana, Herero, Nama and San tribes. The tribes depend mainly on raising livestock while most “whites” (predominantly Afrikaaner and Germans) own commercial farms. Settlements in Namibia can be described as centres of the surrounding farming community, and usually have small shops, petrol stations, churches, a school, police station, accommodation facilities, possibly a bank and a garage. Most households in settlements and rural areas are relatively large, as close to 32% of all households consist of 6 and more members (Figure 2.19). Households in settlements and farms are usually either brick houses with iron roof or corrugated iron shacks. In terms of the age composition, around 60% of population is in working-age situation in the Namibian portion of the STAS area, while 22% and 18% are below the age of 15 and above the age of 60, respectively (Figure 2.19). In terms of literacy, around 85% of the population is literate, 15% of the population has never attended school, 23% are currently at school and approximately 60% left school.

In Botswana, the STAS area is inhabited by a minority or small communities referred to as the Remote Area Dwellers (RADs)¹¹ and their localities as RADs settlements (e.g. Ncojane, Kule, Ukwi). The RADs in this area are basically the former hunter-gatherer communities and they are mainly of the San (Basarwa or ‘Bushmen’) ethnicity or origin (Kgabung, 1999). These communities have over time diversified in to other economic activities such as small scale livestock rearing, mainly through government support programmes. These settlements have been encroached by livestock activities particularly Ukwi (Perkins, 1995; Johnson, 1996). Besides residents of the settlements indicated above, there are small numbers of people who reside in the numerous cattle posts and ranches that are scattered in and around the study area. Because of the three-tier home system of Botswana (state land, freehold land, and tribal land – the latter covering the largest part of the country), for most people residency is alternated between these cattle posts/ranches and the main settlements in the study area or elsewhere in the country which are the main homes of the residents.

In the South African segment of the STAS area, population lives entirely in small rural settlements (CGS, 2015).

11. Remote Area Dwellers (RADs) are considered as communal areas in this report

Figure 2.18 | Urban settlements population distribution in the STAS area

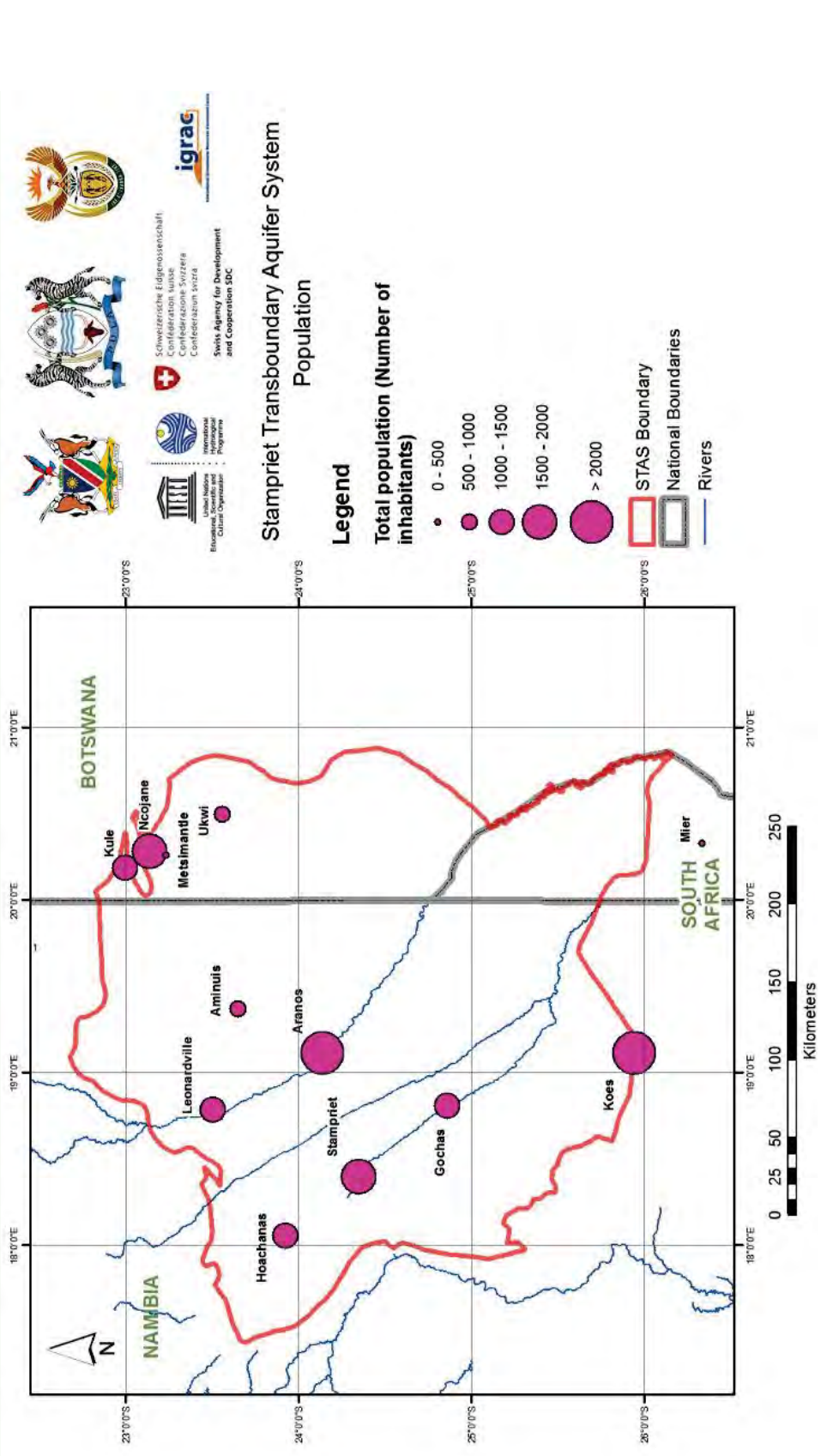
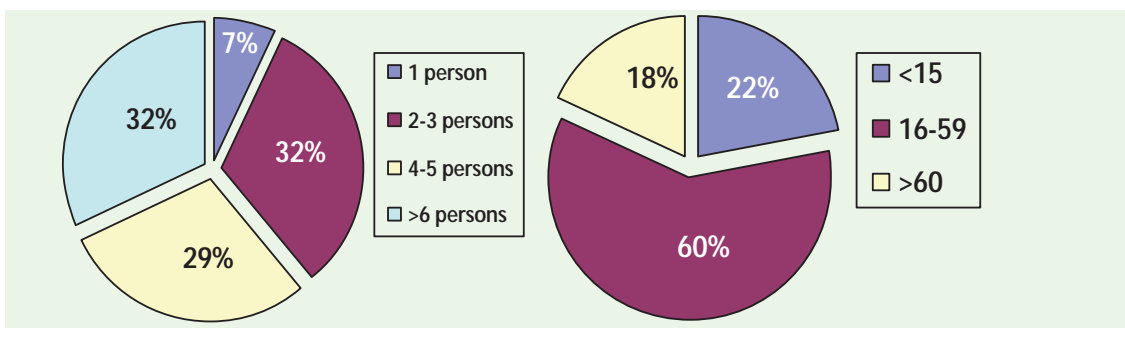


Figure 2.19 | Number (left) and age (right) distribution of household population in the STAS area (Source: NSA, 2011 and Statistics Botswana, 2012)



2.5. Water supply and sanitation

This section aims at providing the current status on access and sources to safe drinking water, sanitation coverage, and waste management in the STAS area. Due to data limitation in rural areas, most of information is available only for urban settlements or villages. The most common sources of water supply to households in the STAS area are piped water and taps in urban settlements, and boreholes in rural settlements. In terms of sanitation, open defecation is still widely practised both in urban and rural settlements. Due to the rural nature of the STAS area, waste management is very poor.

2.5.1. Water supply

It is estimated that about 90% of people in the STAS settlements have access to safe drinking water¹². The urban settlements or villages in the STAS area receive water from government department schemes from Parastatals such as NamWater in Namibia and Water Utilities Corporation (WUC) in Botswana.

There are eight water supply schemes within the STAS area in Namibia benefiting the following settlements: Aminius, Aranos, Kries, Koes, Gochas, Stampriet, Leonardville and Onderombapa. These municipal schemes are located within their respective townlands. Efficient use of water in some schemes encounters major problems as around 49% of all municipal water is lost or unaccounted for e.g. Aranos, Koes, Gochas and Leonardville. Water losses and water unaccounted for represent more than 60% of the water exploited for water supply in Stampriet (Table 2.4). Households without direct household water connections (mainly population in the informal areas) in the study area accesses water from communal standpipes. Aranos reported a total of 24 standpipes, and Gochas reported two. Hoachanas and Kries have their own boreholes for which the settlement is responsible and from which water is pumped. The burden of collecting water to meet the household water needs from the communal standpipes mainly lies with women and girls. The distances travelled by households members vary between one and two kilometers. A prepaid token system is used to access water from the communal standpipes.

12. There is no information about public water supply in the South African segment of the STAS area

Table 2.4 | Water supply, use and losses in urban settlements in the Namibia segment of the STAS Area (Source: MAWF, 2006)

Settlement (District)	Estimated total households	Household use as percentage of water supply	Other uses as % of water supply	Losses as % of water supply	Communal Tap	Boreholes
Leonardville (Aminius)	375	28	23	49	-	6
Aminius (Aminius)	300	-	-	-	-	2
Onderombapa (Aminius)	-	-	-	-	-	2
Hoachanas (Mariental Rural)	200	-	-	-	-	-
Aranos (Mariental Rural)	800	28	23	49	24	9
Stampriet (Mariental Rural)	500	17	15	68	4	2
Gochas (Mariental Rural)	290	28	23	49	2	3
Koes (Keetmanshoop Rural)	371	28	23	49	-	-
Kries (Gibeon)	-	-	-	-	-	2

In Botswana, WUC only provides water for human consumption while farmers usually use private/communal boreholes for stock watering. Prior to the takeover of rural settlements water supply by WUC, the District Councils of the two study area districts were responsible for the operation and maintenance of village water schemes developed by DWA to supply medium-sized villages and smaller settlements, while the towns and bigger villages were supplied by DWA (CSO, 2009). Table 2.5 shows household distribution of public water supply by water source in the Botswana settlements in the two districts. As indicated in the table, the dominant source of water supply is outdoor piped water (31.5%) followed in descending order by use of neighbor's tap (20.9%), use of communal tap (19.9%), indoor piped water (13.6%), use of boreholes (10.8%), and use of bowser/tanker (2.5%). With the water reforms that started in 2009, communal taps (i.e. the free water from public standpipes erected within 400m from the furthest home¹³) will be metered to enable payment and lessen the abuse or overuse of the resource that has been prevailing in these outlets.

Table 2.5 | Household distribution of water supply by water source in urban settlements in the Botswana segment of the STAS area

(Adapted from 2011 Population & Census District Data Profiles – Statistics Botswana)

Settlement (District)	Piped Indoors	Piped Outdoors	Neighbor Tap	Communal Tap	Bowser / Tanker	Borehole	Dam/ Pan	Total Households
Kule	67	73	61	53	11	67	-	332
Ncojane	92	292	171	145	11	65	10	786
Ukwi	12	30	31	52	9	4	-	138
TOTAL	171 (13.6%)	395 (31.5%)	263 (20.9%)	250 (19.9%)	31 (2.5%)	136 (10.9%)	10 (0.8%)	1256 (100%)

Communal farmers and private land owners (e.g. commercial farms) get water from the state and from private boreholes, respectively. In communal areas, household members travel an average of 6 kilometres to their water source. Typically, this trip is made two times per day (MAWRD, 1994).

In South Africa, the STAS area falls within the Kgalagadi Transfontier Park and groundwater abstraction is limited to tourism activities in rest camps (e.g. Mata Mata, Twee Rivieren, and Nossob) and little wildlife watering.

13. Water consumption norms in Namibia set a 250m walking distance from the communal tap and the furthest home, while South Africa set the walking distance at 200m.

2.5.2. Water sanitation system

Access to safe drinking water does not necessarily translate to access to good sanitation as over 65% of the STAS area households do not have access to any toilet facilities.

Approximately 54% of STAS settlements households do not have access to any toilet facilities (Figure 2.20 and Table 2.6). The sanitation gap is most dire in Kries (90% of the population without access to sanitation) and Hoachanas (80% of the population without access to sanitation)¹⁴. Information also points out to the use of pit latrines in 54% of the STAS Botswana settlements households, which may have implications on groundwater pollution, particularly in the shallow Kalahari aquifers. 34% of settlements households have flush toilets and use septic tanks and soakaways systems because of the lack of sewer reticulation networks. It is estimated that on average, 80% of water used in households becomes wastewater.

Figure 2.20 | Household distribution of toilet facilities in urban settlements in the STAS area (Adapted from NSA, 2012 and CSO, 2009)

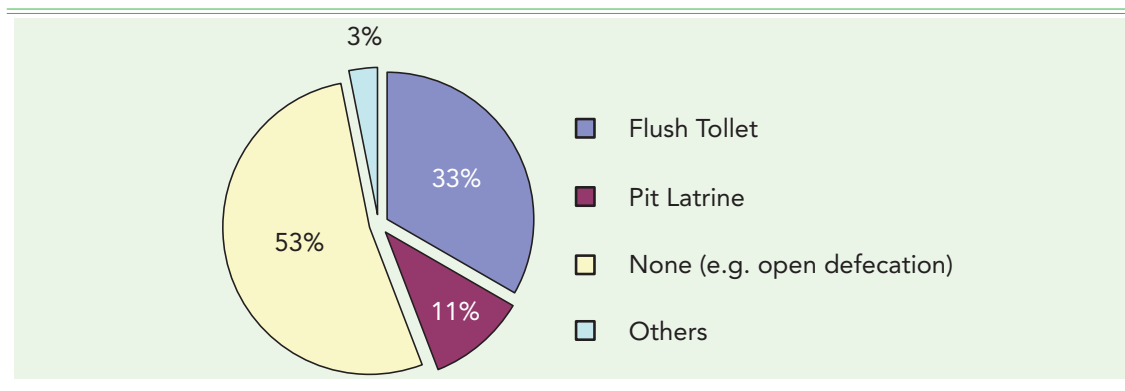


Table 2.6 | Household distribution of toilet facilities in urban settlements in the STAS area (Adapted from NSA, 2012 and CSO, 2009)

	FLUSH TOILET (Own, Shared, Communal & Neighbour's)	PIT LATRINE (Own, Shared, Communal & Neighbour's)	NONE (Assumed to be Using Bush Toilets)	OTHERS	TOTAL (Households)
Aminius and Leonardville (Aminius)	675	60	1955	10	2700
Stampriet, Hoachanas, Gochas, Aranos (Mariental Rural)	1790	159	1922	12	3883
Koes (Keetmanshoop Rural)	196	13	160	2	371
Kule (Ghanzi)	27	150	153	2	332
Ncojane (Ghanzi)	127	434	223	-	786
Ukwi (Kgalagadi)	12	94	31	1	138
TOTAL	2827 (34%)	910 (11%)	4444 (54%)	27 (3%)	8210 (100%)

On the individual commercial farms, septic tanks combined with French drains are usually used, by which sewerage water is disposed by seepage into the ground. On communal land there are

14. Kries and Hoachanas are in the process of constructing 30 communal ablution facilities and 40 flush toilets, respectively. The expected completion of the capital project is May 2016

considerable households and populations that use the bush as toilets. Buckets are used and individuals are responsible for the disposal of the waste, usually in dug up holes a small distance from the homesteads.

In South Africa, there is growing concern with the viability of the wastewater treatment system KTP which currently consists of either septic tanks or oxidation ponds. There is no reported contamination from these facilities, yet with increasing use of the park, they may be reaching the capacity of the existing French drain system (Conti, 2016).

2.5.3. Waste management

Due to the rural nature of the STAS area, waste management is very poor. Settlements in the STAS area have sewage ponds, septic/conservancy tanks and dumping sites. Most of the solid waste generated in the study area is from households because there is no industrial activity or any higher order retail establishments. There are several methods of managing solid waste in the study area as follows:

- 1. Regular Collection:** From households by the concerned authorities to dispose of in dumping sites or landfills.
- 2. Irregular Collection:** From households by the concerned authorities to dispose of in dumping sites which are normally located within settlements.
- 3. Roadside Collection:** Picking waste dumped by the road and other areas by the concerned authorities to dispose of in the dumping sites
- 4. Burning:** Burning of solid waste by households or individuals
- 5. Rubbish Pit:** Households disposing solid waste in a pit dug inside or by their yard / household / homestead
- 6. Other:** Not specified – probably reusing waste, among others

Collected data indicates that waste is regularly collected in only 22% of the households, while most of it is either buried in pit dugs inside households yard (34%) or burnt (30%) (Figure 2.21 and Table 2.7). Dumping sites in the STAS settlements are generally not constructed based on known engineering standards and are generally not controlled (Table 2.8). Hence, a large volume of polluted leachate can have implications on groundwater pollution, particularly in the shallow Kalahari aquifers. Poorer households generally bury their rubbish in shallow pits of not more than a meter deep, and may consequently pose some risk to groundwater quality in the shallow Kalahari aquifers.

In communal and commercial farms, manure is not treated because livestock usually grazes in broad areas.

Figure 2.21 | Household solid waste disposal in urban settlements in the STAS area
(Adapted from NSA, 2012 and CSO, 2009)

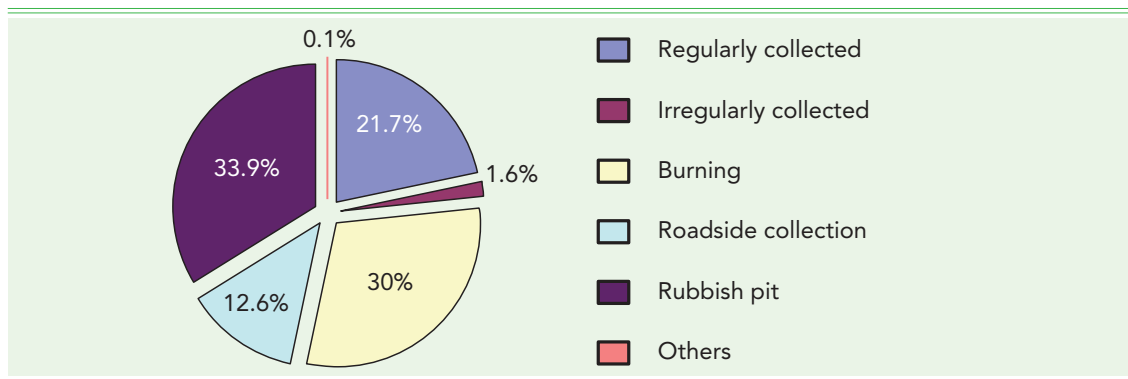


Table 2.7 | Household solid waste disposal in urban settlements in the STAS area (Adapted from NSA, 2012 and CSO, 2009)

	Regularly collected	Irregularly collected	Burning	Roadside collection	Rubbish pit	Others	Total
Aminius and Leonardville (Aminius)	391	35	811	116	1341	-	2700
Stampriet, Hoachanas, Gochas, Aranos (Mariental Rural)	998	66	1413	602	792	12	3883
Koes (Keetmanshoop Rural)	134	3	157	8	68	1	371
Kule (Ghanzi)	47	12	40	139	94	-	332
Ncojane (Ghanzi)	194	15	46	162	367	2	786
Ukwi (Ghanzi)	13	1	-	6	117	1	138
TOTAL	1777 (21.7%)	132 (1.6%)	2467 (30.1%)	1033 (12.6%)	2779 (33.9%)	16 (0.1%)	8210 (100%)

Table 2.8 | Solid waste and wastewater management in the STAS area
(Source: Muroua, 2015 and Moseithi, 2015)

Settlements	Solid waste and wastewater control				
	Sewage System		Dumping Site/ Landfill		
	Oxidation Ponds	Septic Tanks and other	Exist	Controlled/ Fenced	Not Controlled/ not fenced
Leonardville (Aminius)	Yes	Yes	Yes	Yes	Fenced off
Aminuis (Aminius)	Yes	Yes	Yes	No	No fence
Onderombapa (Aminius)	Yes	Yes	No		
Hoachanas (Mariental Rural)	Yes	Yes	No		
Aranos (Mariental Rural)	Yes	Yes	Yes	No	No fence
Stampriet (Mariental Rural)	Yes	Yes	Yes	No	No fence
Gochas (Mariental Rural)	Yes	Yes	Yes	No	No fence
Koes (Gibeon)	Yes	Yes	No		
Kule (Ghanzi)	Yes	Yes	Yes	No	No fence
Ncojane (Ghanzi)	Yes	Yes	Yes	No	No fence
Ukwi (Ghanzi)	Yes	Yes	Yes	No	No fence

2.6. Economic activities and land use

Most of the STAS area is a large farming area with approximately 1200 farms (mostly in Namibia) out of which a relatively small number (80) of commercial farms undertaking a system of mixed livestock (mainly sheep, but also cattle and other animals) and irrigated crop production (Figure 2.20 and Figure 2.21). Crops are dominated by fodder (lucerne), although some farmers have started switching to horticulture (e.g. melons, tomatoes, grapes, beans). Ownership of farms is predominately private, while some areas referred as communal land are under traditional authority (near Aminuis), or government ownership (near Hoachanas). In Botswana there, is a combination of pastoral, arable or residential land uses. Significant portions of the STAS area fall within Wildlife Management Areas (WMAs) in Botswana¹⁵, and a nature and wildlife preservation park (Kgalagadi Transfrontier Park – KTP) in Botswana and South Africa. The KTP is solely used for preservation of nature and non-consumptive uses such as recreation. Therefore, the environment in the park is pristine because the only few developments present in the area are tourism camping facilities and boreholes, and camps for management of park resources or use by park managers (Figure 2.22). No industry and mining activities take place in the STAS area.

15. In Botswana WMAs were designated to buffer protected areas (in this case, KTP) from heavy encroachment by anthropogenic activities, and are where the primary activity is wildlife conservation and utilization by the inhabitants of the areas or private investors (Government of Botswana, 1986)

Figure 2.22 | Land use map of the STAS

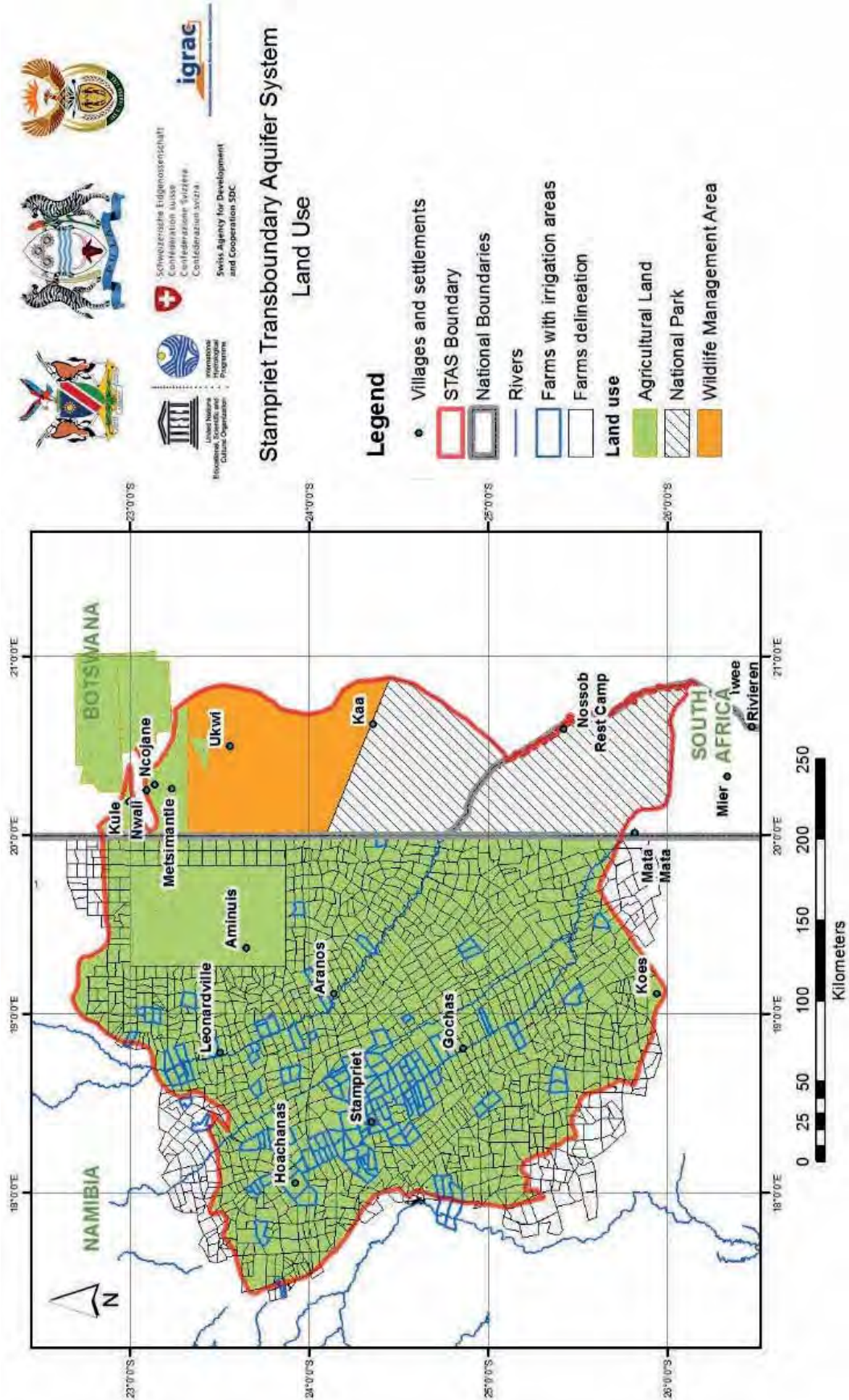


Figure 2.23 | A 15ha horticulture drip-irrigation farm close to Stampriet (Namibia)
(Picture by: T. Carvalho Resende)

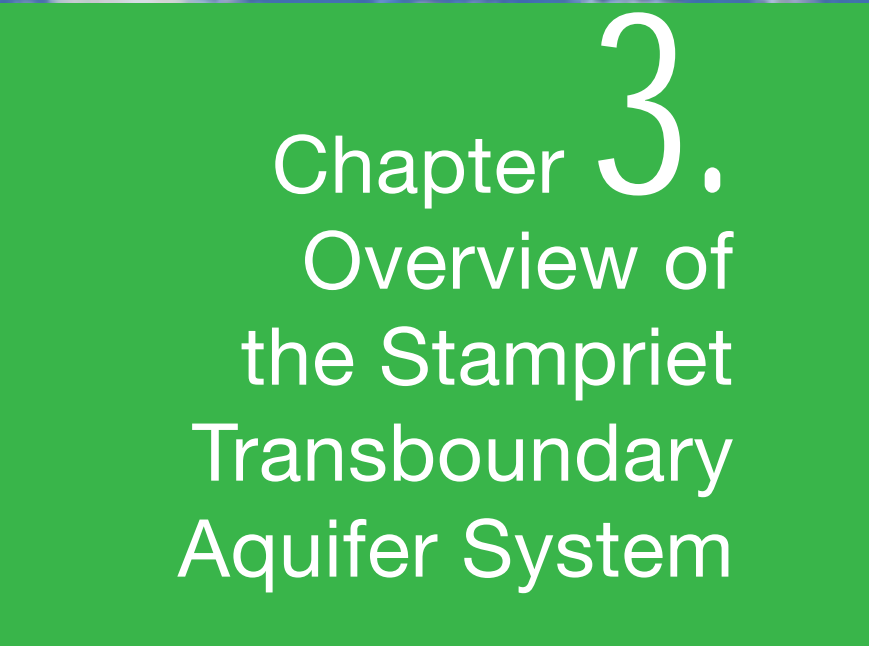


Figure 2.24 | Twee Rivieren Rest camp
(Source: South Africa National Parks)









Chapter 3.

Overview of the Stampriet Transboundary Aquifer System



A good understanding of geology allows locating those parts of the subsurface (aquifers) that function as reservoirs and main pathways for groundwater flow, and from where groundwater most easily can be withdrawn. The geology and hydrogeology of the STAS is comparatively well understood.

3.1. Geological and Hydrogeological framework

3.1.1. Geological framework

From a geological point of view, the STAS is part of a huge sedimentary basin in which a thick sequence of layers has been deposited. The layers of Carboniferous through Jurassic age are together known as *Karoo Supergroup* and contain mainly sandstones, shales, mudstones, siltstones and limestone. They are covered by a blanket of sediments of the *Kalahari Group* (deposited since approximately 65 million years ago), of Tertiary-Quaternary age and consisting predominantly of sand, calcrete (duricrust), gravel, clayey gravel, sandstone and marl (SACS, 1980; Smith, 1984; JICA, 2002 and Miller, 2008).

The *Karoo Supergroup* in southern Africa is of considerable importance for both economic and scientific reasons. From an economic perspective it is unique in that it hosts all the coal deposits of the subcontinent. The combined reserves are estimated to be in the order of 67,000 MT, which according to the World Energy Council makes nearly 10% of the World total. From the scientific perspective, the Karoo strata are famed for their rich non-marine fauna and flora spanning the Permian and Triassic periods, in particular, the reptile-mammal transition (Johnson et al., 1996). Documented basins in southern Africa containing *Karoo Supergroup* strata are the main Karoo Basin of South Africa, and the Great Kalahari Basin, stretching from Namibia (Aranos Basin) through Botswana (Kalahari Basin) into Zimbabwe (Mid-Zambezi Basin) (Figure 3.1). The basin fill is covered by sediments of the Cenozoic *Kalahari Group*.

3.1.2. Defining the Stampriet Transboundary Aquifer System

The STAS is made of different geological Supergroups/Groups/Formations/Members and contains three major aquifer systems: two confined aquifers in the Lower *Karoo Supergroup* sediments (Auob and Nossob), and a discontinuous aquifer system in the overlying *Kalahari Group* and Upper *Karoo Supergroup* sediments. The Auob and Nossob aquifers produce truly artesian conditions in some zones of the depressed valleys of the Auob and Nossob Rivers, which prompted the name Aranos Basin or Stampriet Artesian Basin (SAB). The Dwyka and Nama Groups can be regarded as the hydrogeological basement rocks of the study area. The link between geology (stratigraphy) and its corresponding hydrogeological classification is presented in Table 3.1.

Kalahari Group strata cover large portions of seven southern African countries (Figure 3.2), stretching some 2200 km from South Africa in the south, northwards through Botswana, and up into Angola. *Kalahari Group* sediments were probably originally deposited over a large part of the Democratic Republic of the Congo as well as into countries even further to the north (Haddon, 2005). A large percentage of the *Kalahari Group* sediments deposited in the Congo Basin appear to have subsequently been eroded by the Congo River and its tributaries. The upper unit of the *Kalahari Group*, the unconsolidated sands are the largest continuous erg (dunes) on earth and cover an area of some 2.5 million km² (Thomas and Shaw, 1991). In Namibia, 30% of the land area is covered by the unconsolidated Kalahari sands, and Botswana with its massive diamond wealth, has a cover of Kalahari sediments over some 75% of the country.

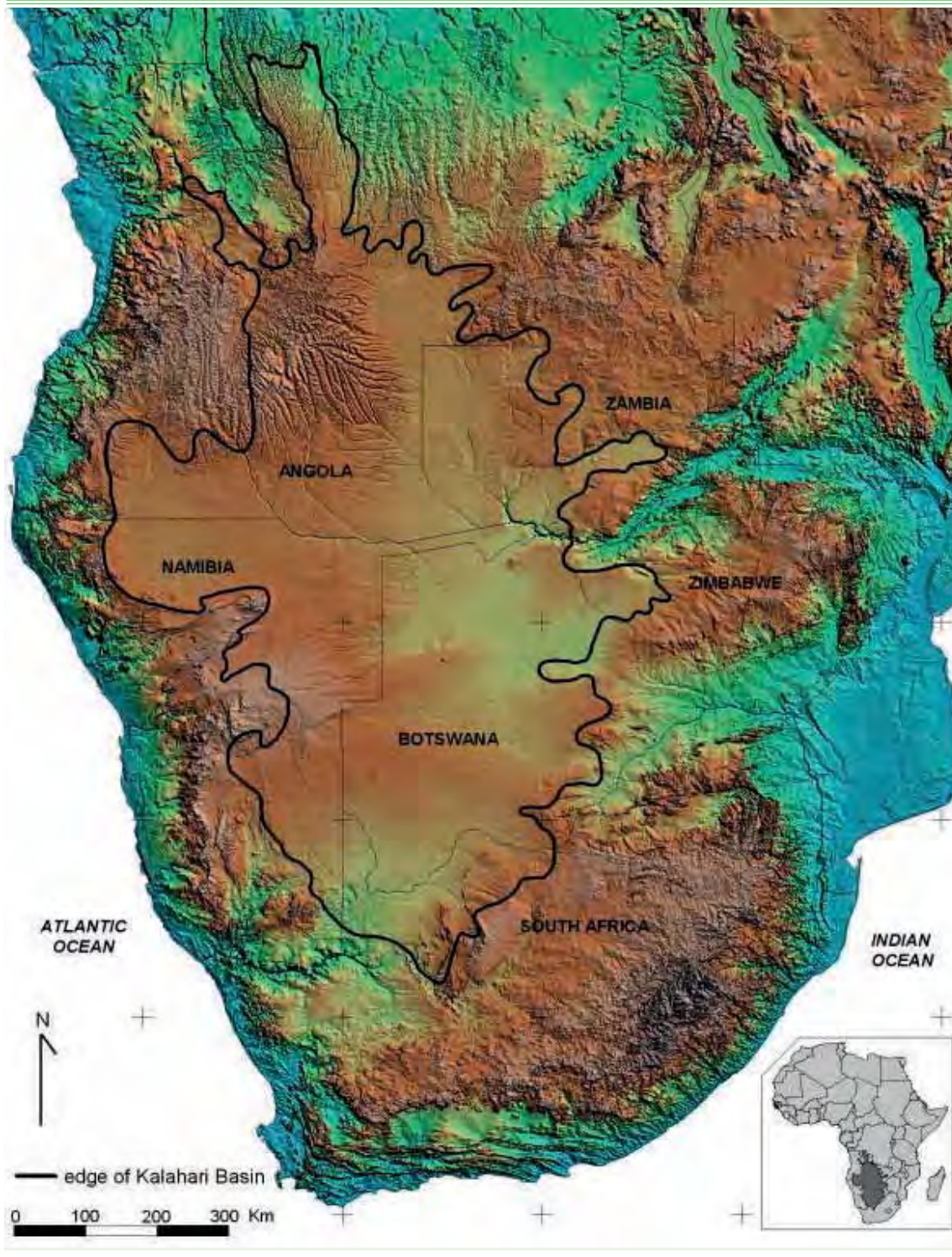
The Lower *Karoo Supergroup* in the Stampriet Artesian Basin is subdivided into the basal Dwyka Group, overlain by the Ecca Group consisting of Nossob (ranging between 0 m and 60 m in thickness), Mukorob (75-160m thick dark greenish-grey shale), Auob (ranging between 0 and 150 m in thickness). The Upper *Karoo Supergroup* includes all formations between (and including) the Rietmond Formation (dominated by laminated dark grey shale with minor thin sandstone bands) and the uppermost Kalkrand (associated with dolerites) Formations. The *Karoo Supergroup* succession is covered by young sediments of the Kalahari Beds. The STAS area largely consists of red sand dunes and is dominated by red sandy soils of the Kalahari Beds. The soils have a considerable water storage capacity and are largely deeper than one meter. The ferralsols developed on the Kalahari Sands have very high infiltration capacity and effective porosity. The Kalkrand basalt covers part of the area in the northwestern area in Namibia.

Table 3.1 | Simplified stratigraphy of the Stampriet Transboundary Aquifer System (STAS) and corresponding classification
(Modified after (SACS, 1980; Smith, 1984; JICA, 2002 and Miller, 2008))

Age	Super group	Group	GEOLOGY				Lithology (simplified)	HYDRO-GEOLOGY	
			Formation/Member					STAS	
			Botswana (Smith, 1984)	Namibia (Miller, 2008)	S. Africa (SACS, 1980)	This report			
Tertiary to Quaternary	Kalahari	Kalahari				Kalahari beds	Sand, silcrete, calcrete (duricrust), gravel, sandstone, marls, clayey gravels	Unsaturated zone	
Jurassic		Stormberg-lava (B) Kalkrand (N) Drakensberg (SA)		Neu Loore		Kalkrand	Basalt and dolerite	Kalahari aquifers	
Triassic		Lebung (B) Etjo (N) Clarens (SA)	Ntane Mosolotsane			Ntane	Sandstone		
Permian	Karoo	Ecca ¹⁶	Kule	Whitehill	Whitehill	Whitehill	Shale and limestone		
			Rietmond	Rietmond		Rietmond	Shale and sandstone	Aquitard/ aquiclude	
			Otshe	Auob	Prince Albert	Auob	Sandstone, interbedded with shale and coal horizons	Auob aquifer	Stampriet Artesian Basin
			Kobe	Mukorob		Mukorob	Shale, mudstone, siltstone	Aquitard/ aquiclude	
			Ncojane	Nossob		Nossob	Sandstone	Nossob aquifer	
Carboniferous		Dwyka				Glacial sediments	Aquitard/ aquiclude		
Cambrian	Pre-Karoo	Nama							

16. A lack of firm palaeontological and lithological evidence makes correlation with the Beaufort Group of the Karoo Supergroup uncertain (Smith, 1984).

Figure 3.2 | Lateral extent of Kalahari Group sediments (Source: Haddon, 2005)



3.1.3. Cross-sections

Several cross-sections in different directions are available for the Namibian part of the STAS (JICA, 2002). Given that 1) the thicknesses of the formations in certain areas are not known, 2) that there are few boreholes with stratigraphic details in the Botswana and South Africa segments of the STAS, the cross-sections presented in this section are tentative.

A NW-SE Namibia-South Africa cross-section through Hoachanas, Stampriet, and Gochas (Namibia) and the KTP (South Africa), a W-E Namibia-Botswana cross-section the KTP, and a SW-NE Namibia-Botswana cross-section through Stampriet, Aminuis (Namibia) and Ncojane (Botswana) as indicated in Figure 3.3, are presented in Figure 3.4 through Figure 3.6.

Figure 3.3 | Location of the cross-sections

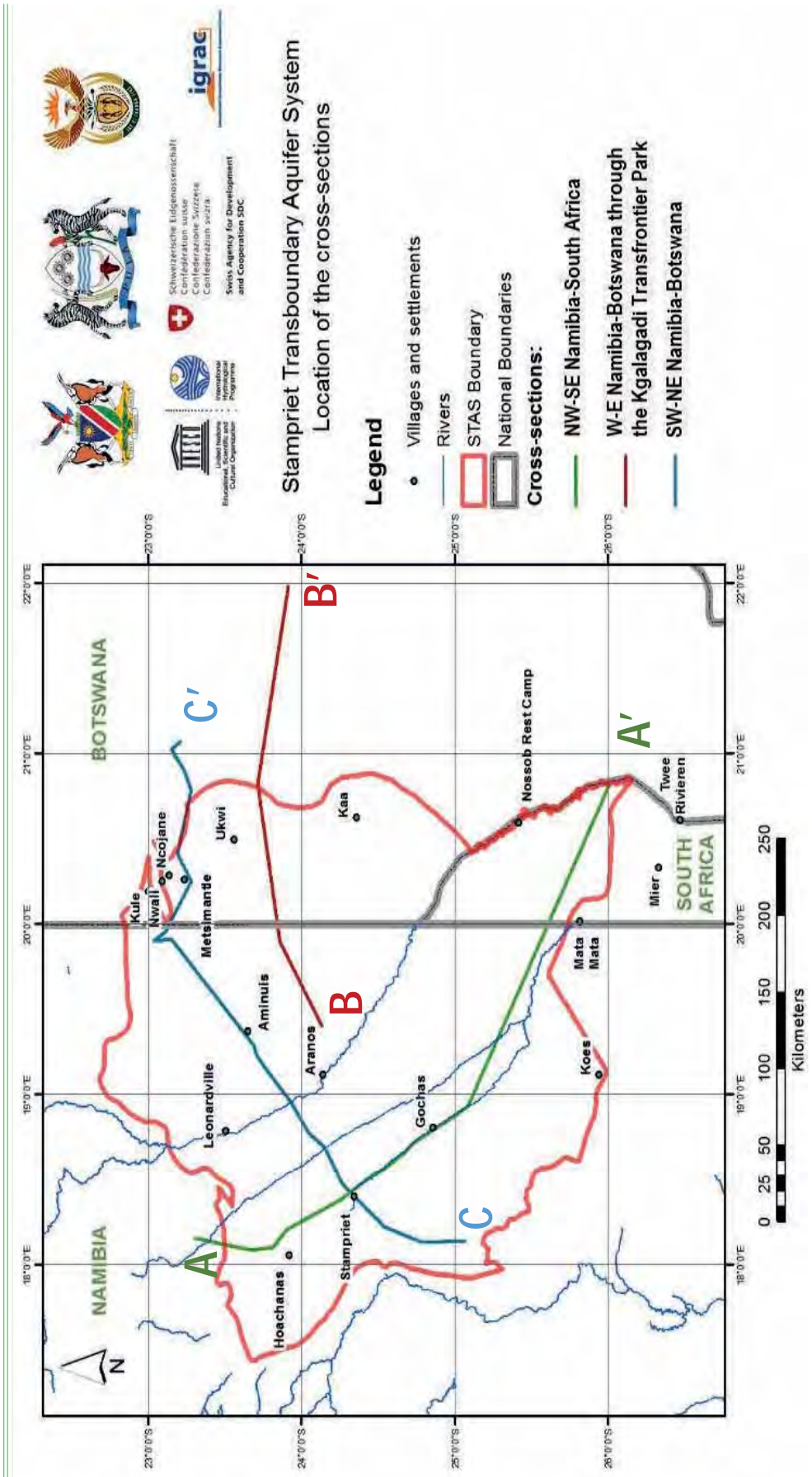


Figure 3.4 | NW-SE cross-section through Hoachanas, Stampriet and Gochas (Namibia) and the Kgalagadi Transfrontier Park (South Africa)
 (Source: JICA, 2002; Van Wyk, 1987). Aquifers are shown in blue colours.

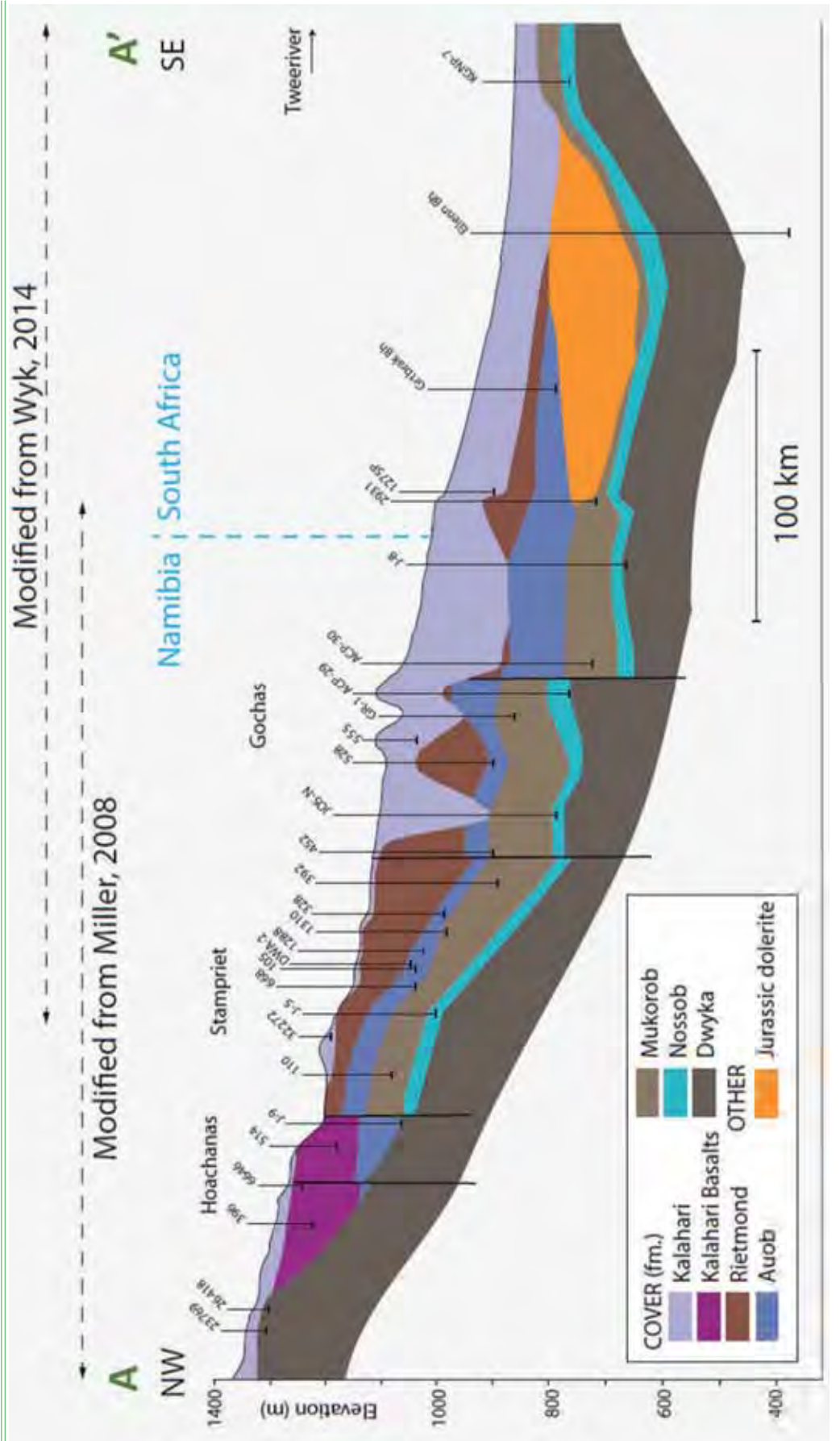


Figure 3.5 | W-E cross-section through the Kgalagadi Transfrontier Park (Namibia-Botswana) (Source: Nxumalo, 2012). Aquifers are shown in blue colours

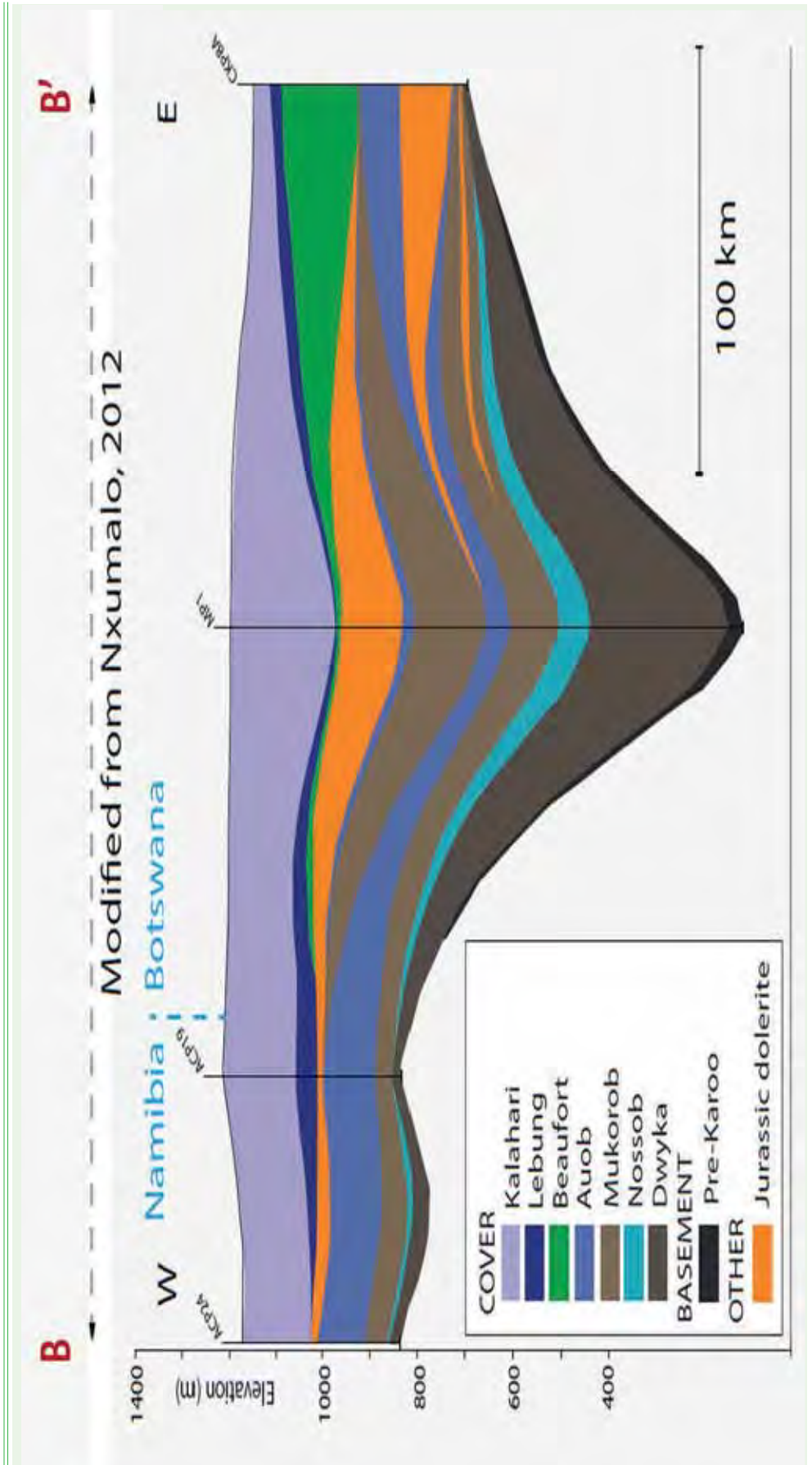
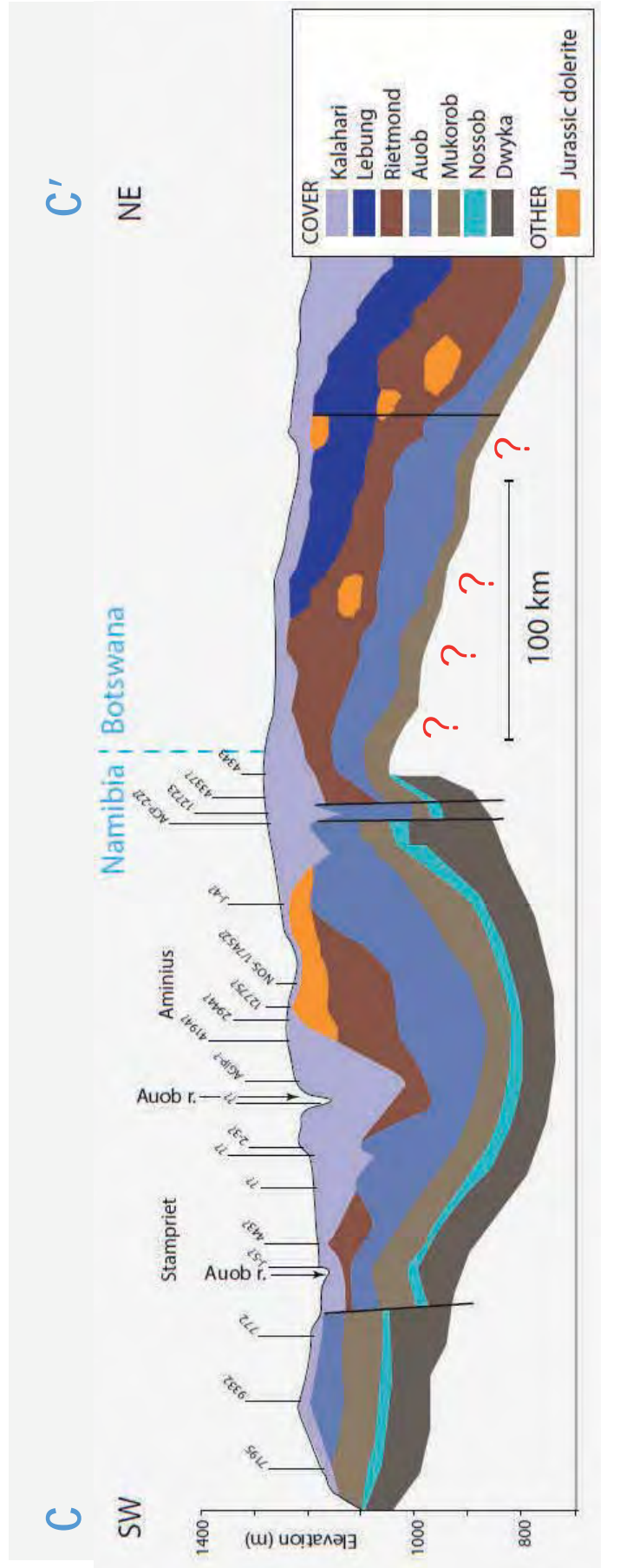


Figure 3.6 | SW-NE cross-section through Stampriet, Aminius (Namibia) and Ncojane (Botswana) (Source: JICA, 2002; Matsheng, 2008). Aquifers are shown in blue colours and question marks indicate the absence of stratigraphic information



3.2. Main hydrogeological units

The confined Auob and Nossob aquifers, and the overlying discontinuous phreatic Kalahari aquifers, form the Stampriet Transboundary Aquifer System (STAS).

3.2.1. Kalahari aquifers

The Kalahari aquifers are the most intensively used aquifers within the study area. They consist of hundreds of scattered small and local aquifers more or less loosely connected forming an unconfined non-transboundary aquifer system in the Kalahari and Upper Karoo sediments. The Kalahari aquifers are in most cases separated from the Auob Aquifer by impermeable shales and mudstones layers (Rietmond Formation).

The Kalahari aquifers consist mainly of fine sand, calcrete, silt and clayey deposits. The thickness of the Kalahari aquifers varies from 0 to 350 m although they generally do not exceed 100m. The Kalahari sediments are relatively thin along their northern and western boundaries of the STAS area, with calcrete and dune sand at the surface; and relatively thick in the south-east. Transmissivity values range from 0.1 (STAS south-east area) to 6 (STAS central area) and 30m²/d (STAS south-west area) (GGRETA, 2015). The most prominent type of porosity in the Kalahari aquifer is the primary porosity (with values of around 30%).

3.2.2. Auob aquifer

The Auob (also called Otshe aquifer in Botswana) is a confined aquifer, consisting of up to three sandstone layers separated by shale, with isolated outcrops in the extreme western part of the STAS in Namibia. The Auob is often called an artesian aquifer because in some zones (of limited size) it has the capacity to feed flowing wells. It can be found at depths varying from 0 to over 300 m, and its thickness varies from 0 to 150 m. However, thicknesses in some areas are not known. The depth of the aquifer is relatively shallower in the central parts of the STAS area. In Namibia, the Auob aquifer comprises thin coal seams and upward-coarsening deltaic sequences of medium-coarse grained, often micaceous, sandstone with local intercalations of sandy shale. In Botswana, it is dominated by micaceous, fine sandstone interbedded with dark grey siltstone, coal, sub-arkosic sandstone with dark grey siltstone and mudstone in an upward-fining sequence. An impermeable shale layer (Mukorob Formation, also called Kobe Formation in Botswana) separates the Auob aquifer from the Nossob aquifer. The Auob and Nossob sandstones are generally poorly consolidated fine-grained sandstones, often grading into siltstones and commonly feldspathic and micaceous. There is also secondary porosity in these lithologies (with total porosity values around 25%), where there are fractures, faults, joints and permeable bedding planes. Transmissivity values generally range from 0.1 to 200m²/d with maximum values going up to 1240m²/d (STAS north-west area) (GGRETA, 2015).

3.2.3. Nossob aquifer

Like the Auob aquifer, the Nossob is a confined aquifer with isolated outcrops in the extreme western part of the STAS area in Namibia. The Nossob is an artesian aquifer that can be found in depths varying from 0 to more than 400m and its thickness varies from 0 to 60m in Namibia and from 0 to 20 in South Africa. However,

thicknesses in some areas are not known. The Nossob aquifer consists of two sandstone units, which are interbedded with thin mudrock layers and siltstones. The Nossob aquifer is underlain by impermeable shales that act as an aquiclude, and glacial tillites of the Dwyka Formation. Transmissivity values generally range from 0.1 to 100m²/d with maximum values going up to 1480m²/d (STAS central area) (GGRETA, 2015).

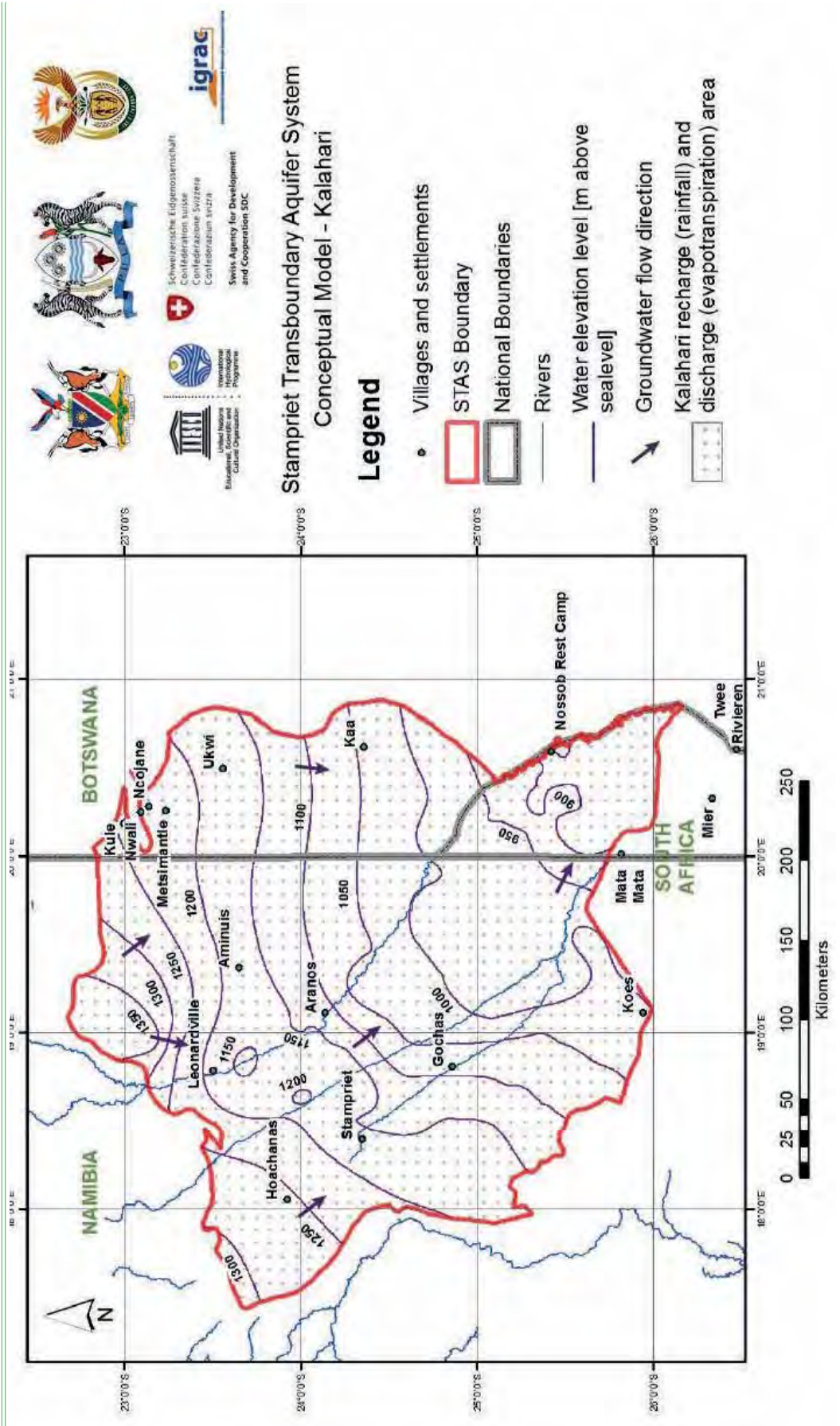
3.3. Conceptual model of the Stampriet Transboundary Aquifer System (STAS)

Conceptually, the physical processes taking place in the STAS are reasonably understood, but quantification is still limited – in spite of many efforts made over a long period of time (JICA, 2002; Matsheng, 2008; and DWS, 2015). The volume stored in the STAS aquifers is large (of the order of one or a few thousands of km³), but more advanced study of the aquifer dynamics (e.g. by modelling) and of the technical and economic aspects of groundwater resources exploitation is required before any underpinned suggestion can be given of an optimal exploitable volume.

3.3.1. Groundwater recharge and groundwater levels

Several studies have improved understanding recharge mechanisms in the STAS (JICA, 2002, Tredoux et al., 2002, Cheney et al., 2006, ORASECOM, 2009, Stone and Edmunds, 2012). Recharge to the shallow Kalahari aquifers can be restricted only to precipitation (as managed aquifer recharge does not occur), and is most likely to occur all over the STAS area. During years with average rainfall, recharge to the Kalahari aquifers is estimated at 0.5% of rainfall (i.e. 0.7 to 1.5 mm/yr), indicating that a substantial proportion of rainfall directly evaporates and consequently does not recharge the aquifers (JICA, 2002). This is exacerbated by the large amount of alien and other vegetation (e.g. Prosopis). Hydraulic connection between the unconfined Kalahari Aquifers and the confined Auob aquifer might exist through geological faults, but most likely also by slow seepage through aquitards, in spite of their very low permeability (van Wyk, 2014). A simplified conceptual model of the Kalahari aquifers is provided in Figure 3.7.

Figure 3.7 | Simplified conceptual model of the Kalahari aquifers¹⁷



17. Because of Kalahari aquifers discontinuity, less consistency and much more variation (both regarding water levels but also in water quality) at relatively short distances.

What is known on the groundwater quantity processes of the confined aquifers is summarized in simplified form on the map of the conceptual model shown in Figure 3.8. It is assumed that recharge to the Auob and Nossob aquifers in normal rainfall years is practically non-existent. Apart from diffuse recharge by downward seepage from the Kalahari aquifers, there are a few recharge zones facilitating concentrated recharge during rare wet years. Recent reassessment of the recharge behaviour of the confined aquifers by Tredoux et al. (2002), Kirchner et al. (2002) and van Wyk (2014) suggest that recharge via sinkholes and faults are the dominant mechanism of recharge in the north-western and western boundaries of the STAS, and specifically to the Auob aquifer. By extension, considering that the flow direction in this multi-layered aquifer basin is north-west to south-east, it is assumed by these authors that focused recharge through sinkholes and faults is the major recharge source for the confined aquifers only. Rain water flows towards the sinkhole depressions where it seeps away within some hours (Figure 3.9). Recharge to the Kalahari and Auob aquifers during above normal rainfall years may be as much as 3% of rainfall (i.e. 4 to 9.5 mm/yr) (JICA, 2002). Recharge into the Nossob aquifer is negligible independently of normal or heavy rainfall events, thus the water resources in the Nossob aquifer can be regarded as fossil water. It is worth mentioning that recharge rates of the Auob and Nossob aquifers are very difficult to estimate because of insufficient long-term rainfall and water level records.

Studies on the Kalahari, Auob and Nossob aquifers in Namibia have shown that groundwater levels for all aquifers follow approximately the same pattern and vary from 1300m above msl in the north to 900 m above msl in the south-eastern part of the STAS (Figure 3.7 and Figure 3.8). In the confined Auob and Nossob aquifers the piezometric head in some zones is up to 25 m higher than the water level in the Kalahari aquifers.

There is very limited amount of information on groundwater level monitoring in the STAS (Table 3.2). The few groundwater level records starts from the late 1960s to early 1990s, and show that the STAS experienced a falling water table in the Kalahari and Auob aquifers from early to late 1990s. An extreme rainfall in 2001 restored the water table to levels previously observed (Figure 3.10 to Figure 3.12). Although groundwater abstraction in the STAS is estimated to have increased by 30% from early 2000s to 2015, above-normal rainfall years in the mid-2000s and early 2010s resulted in a relatively stable groundwater level. Previous results indicate that most years contribute little or nothing to recharge the aquifers, whereas few high rainfall rates years may replenish the systems for years to come. During the last 35 years substantial recharge occurred only three times, namely during the rainy season of the years 1974, 1976 and 2000. Generally, high rainfall rates coincide with La Niña conditions (e.g. early 1960s, mid 1970s, early 2000s) which usually occur after very strong El Niño events (1957-1958, 1972-1973, and 1997-1998). Understanding how El Niño / La Niña events may influence future climate variability in the STAS is therefore critical for groundwater level monitoring, and requires further research.

Figure 3.8 | Simplified conceptual model of the Auob and Nossob aquifers

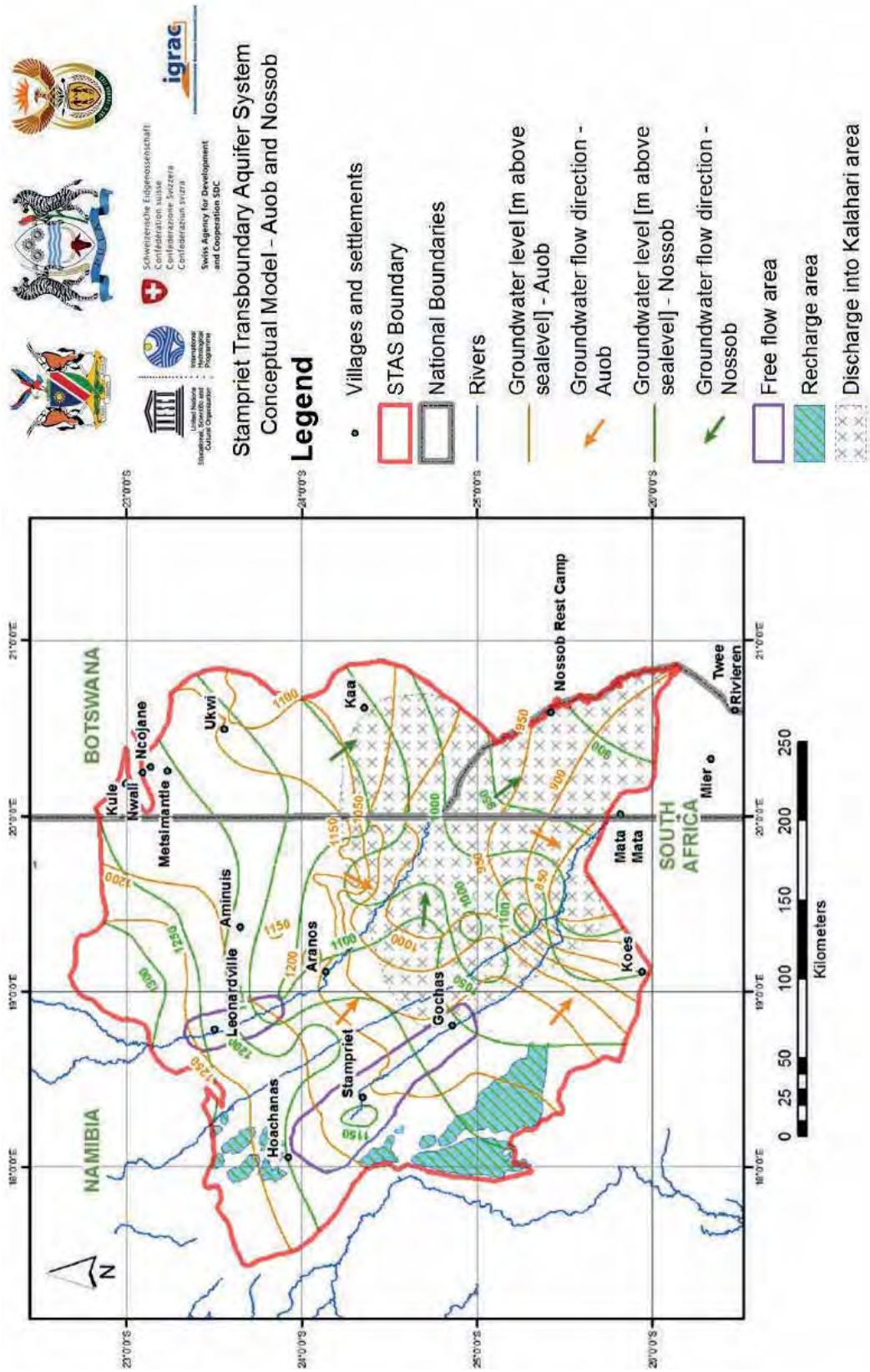


Figure 3.9 | Sinkhole depression (15 hours after approximately 100 mm of rain fell).
 Note the drift material (left) and the tiny puddle (Picture by J. Kirchner).



Table 3.2 | Location of some boreholes in the STAS with known long-term groundwater level monitoring data

Location	Country	Elevation	Latitude	Longitude
Olifantwater	Namibia	1268	-23.68523	18.39241
Tugela	Namibia	1206	-24.82056	18.25379
Steynrus	Namibia	1208	-24.04592	18.79340
Boomplass	Namibia	1164	-24.54949	18.56123
Ukwi	Botswana	1226	-23.58778	20.52694
Ncojane	Botswana	1268	-23.1477	20.47080

Figure 3.10 | Groundwater level variation in the Kalahari aquifers at different locations in the STAS area (Source: GGRETA, 2015)

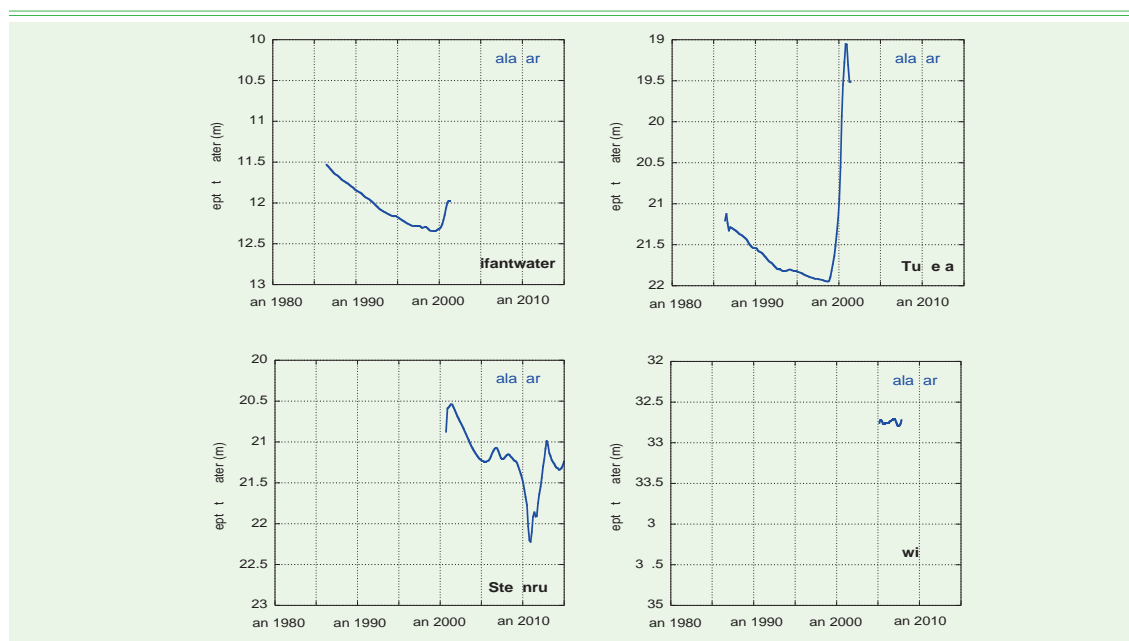


Figure 3.11 | Groundwater level variation in the Auob aquifer at different locations in the STAS area (Source: GGRETA, 2015)

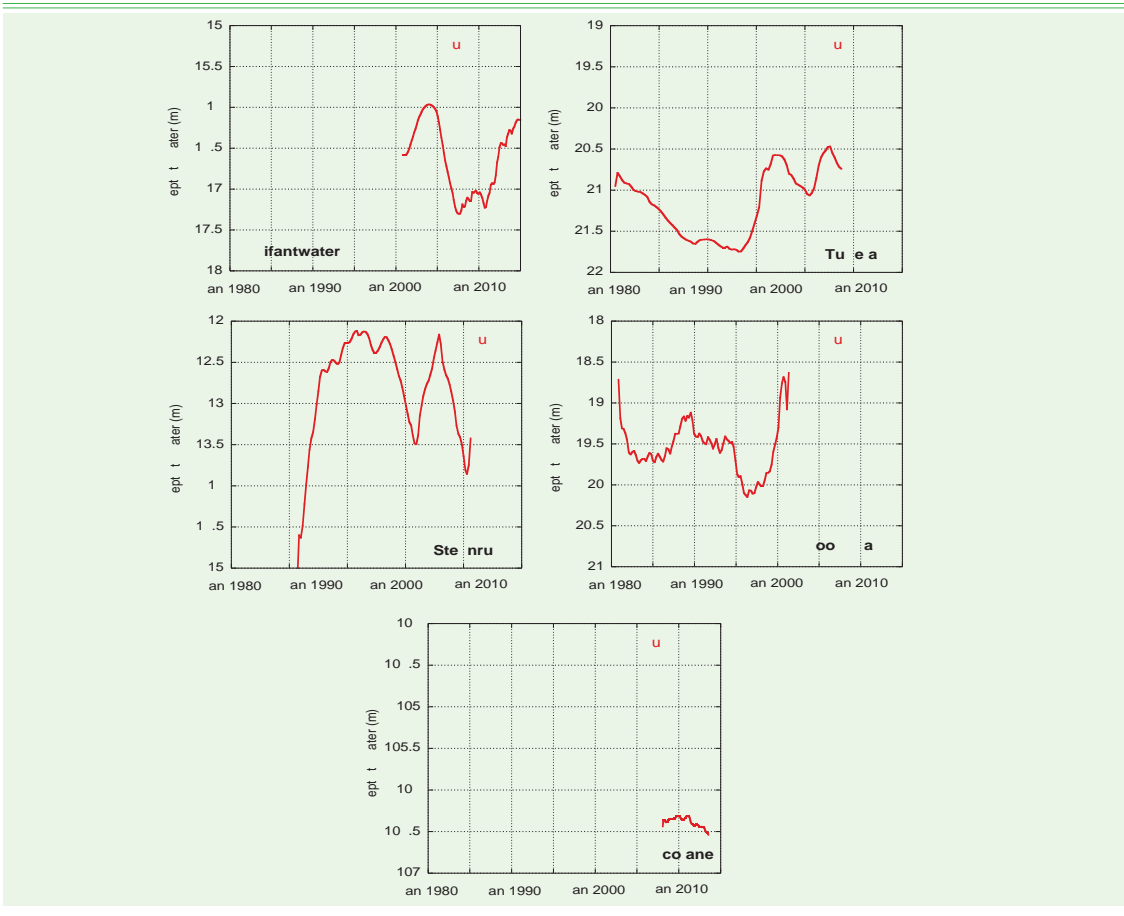
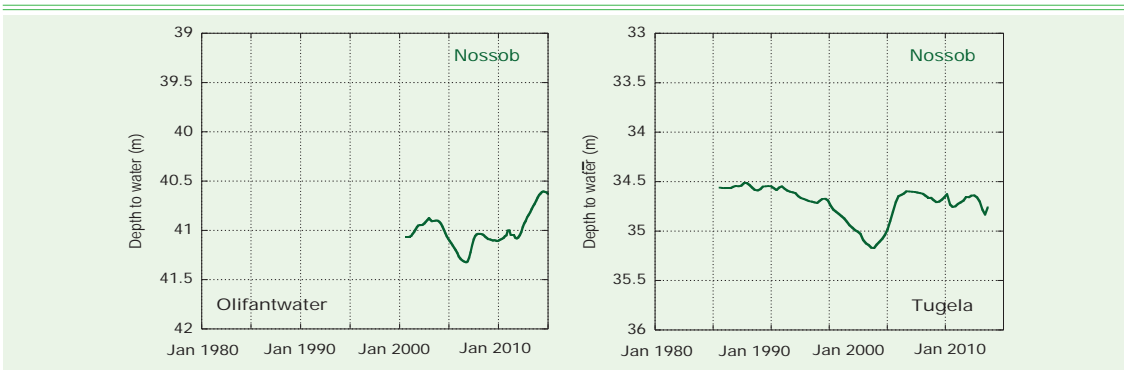


Figure 3.12 | Groundwater level variation in the Nossob aquifers at different locations in the STAS area (Source: GGRETA, 2015)



3.3.2. Groundwater discharge and salinity

The predominant discharge mechanism for the Kalahari aquifers is evapotranspiration. It is estimated that it takes more than approximately 30 000 years for groundwater to travel from the Auob and Nossob recharge zones to the discharge zones (Kirchner, 2015). The only discharge mechanism for the Auob and Nossob aquifers is presumed to be through upwards seepage into the Kalahari aquifers and further towards the surface in 1) the southeast of the Namibia segment of the STAS, 2) the southern Botswana segment of the STAS and it is assumed that this is also the case in 3) the north-western Cape segment in South Africa. In those areas, the Kalahari aquifers consist mainly of fine sand, silt and clayey deposits, which have accumulated mineral salts due to evaporation favored by low rainfall and runoff, resulting in high salt concentrations (that area is also referred to in literature as Salt Block) (van Wyk, 2014).

The general direction of groundwater flow in the STAS is from northwest to southeast. Water levels and ^{14}C analyses have shown that groundwater also flows eastwards into Botswana, then gradually turning through southeast and south to southwest towards the lower Nossob River¹⁸ (JICA, 2002).

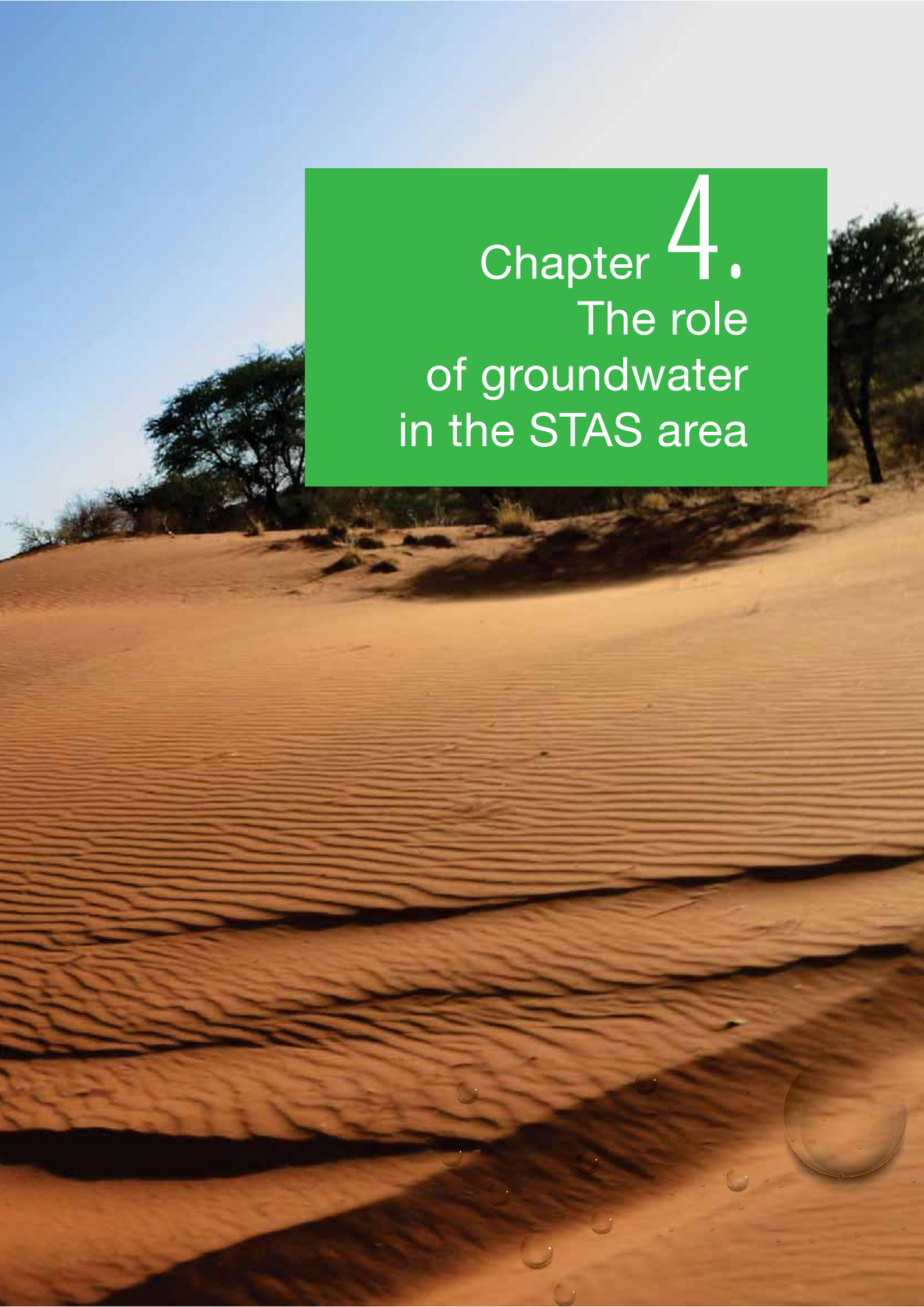
Radiocarbon (^{14}C) analysis of water samples made in Namibia have been carried out and allowed better understanding of how long it takes groundwater to reach a specific point after it entered each particular aquifer by recharge.

The Kalahari aquifers are not continuous and consequently significant lateral and vertical variations are to be expected. In the northern quadrant of the study area, water in the Kalahari aquifers is more or less young (containing tritium indicating at least some water recharged less than 100 years ago). Younger water (< 2000 years) also occurs along the lower reaches of the Nossob River, which confirms recharge from the riverbed during periods of flood. Groundwater with ages below 5000 years of good quality also occurs along the lower reaches of the Auob River, which confirms the importance of floodwater recharge in the basin. On the other hand, groundwater in the Auob and Nossob aquifers are generally older than in the Kalahari aquifers. Groundwater with ages from a few hundred to $\approx 10\,000$ years) is found close to the recharge zones in the northwestern boundary of the study area for the Auob aquifer, and close to the southwestern boundary for the Nossob aquifer. The pattern is relatively consistent in relation to the location of the identified recharge zones (JICA, 2002).

18. The assumption is hypothetical given that there are very few boreholes close to the Botswana/South Africa border







Chapter 4.
The role
of groundwater
in the STAS area

This chapter aims at highlighting the importance of groundwater in the STAS area as it is the only permanent and dependable water resource in the area. Given the climatic and other geographic features, there are no permanent rivers in the STAS area. Apart from the ephemeral Auob and Nossob Rivers that provide some water during the rainy season, there are surface water pans scattered over the area that collect and store water for livestock watering; these reserves can last a few months after the rains.

Groundwater is withdrawn from the Kalahari, Auob and Nossob aquifers, by means of dug wells and boreholes. In section 4.1 some more detailed information will follow on the boreholes: their number and distribution, the aquifers they tap and their yields. No information is available on the number, distribution and characteristics of dug wells in the STAS area.

Next follows information on the volumes of groundwater annually abstracted, with breakdowns according to country, category of water use and aquifer tapped. Evidently, groundwater is of vital importance to meet domestic water demands – it is the only dependable source of drinking water; how people get access to domestic water has already been explained in Chapter 2. Most of the groundwater abstracted is used for economic purposes: irrigation, livestock watering and tourism. Evidently, economic uses create benefits in terms of income and employment. Some information on these uses will be presented in section 4.3. No direct environmental benefits from groundwater have been reported.

4.1. Numbers, categories and distribution of wells and boreholes

The project established a joint STAS borehole database that has been populated with data provided and approved by Countries through national institutions and authorities (DWA in Botswana, DWAF in Namibia and DWS in South Africa). The joint STAS borehole database includes information on 6167 boreholes (GGRETA, 2015); 5844 boreholes in Namibia (JICA, 2002; CSIR, 2001), 168 in Botswana (Matsheng, 2008; DWA, 2015), and 155 boreholes in South Africa (Van Wyk, 1987; DWS, 2015) (Figure 4.1 and Table 4.1)¹⁹. The database contains information on borehole specifications, borehole yield, water level, water quality (Total Dissolved Solids, Nitrate, Sulphate, Fluoride, and Electrical Conductivity), and transmissivity. The database has been uploaded to the Information Management System (IMS) developed by the project (<https://ggis.un-igrac.org>). It is estimated that approximately 80% of these boreholes are currently in use (JICA, 2002).

Data on the distribution of boreholes into the different aquifers is very limited, as this information is available only for approximately 16% of the boreholes identified in the STAS (Table 4.1 and Table 4.2). Approximately 62% of these boreholes penetrate the Kalahari aquifers, while boreholes penetrating the Auob and Nossob aquifers only represent 29% and 8% respectively. The distribution of boreholes in the STAS per aquifer type is shown in Figure 4.2.

Table 4.1 | Total number of boreholes on record in the Stampriet Transboundary Aquifer System (STAS) (Source: GGRETA, 2015)

Country	Number of boreholes	% of boreholes
Namibia	5844	95
Botswana	168	3
South Africa	155	2
TOTAL	6167	100

19. Given the lack of stratigraphy data in Botswana and South Africa, few boreholes falling outside the STAS delineation were considered to provide a better understanding of the aquifer system dynamics

Figure 4.1 | Distribution of boreholes in the STAS (Source: GGRETA, 2015)

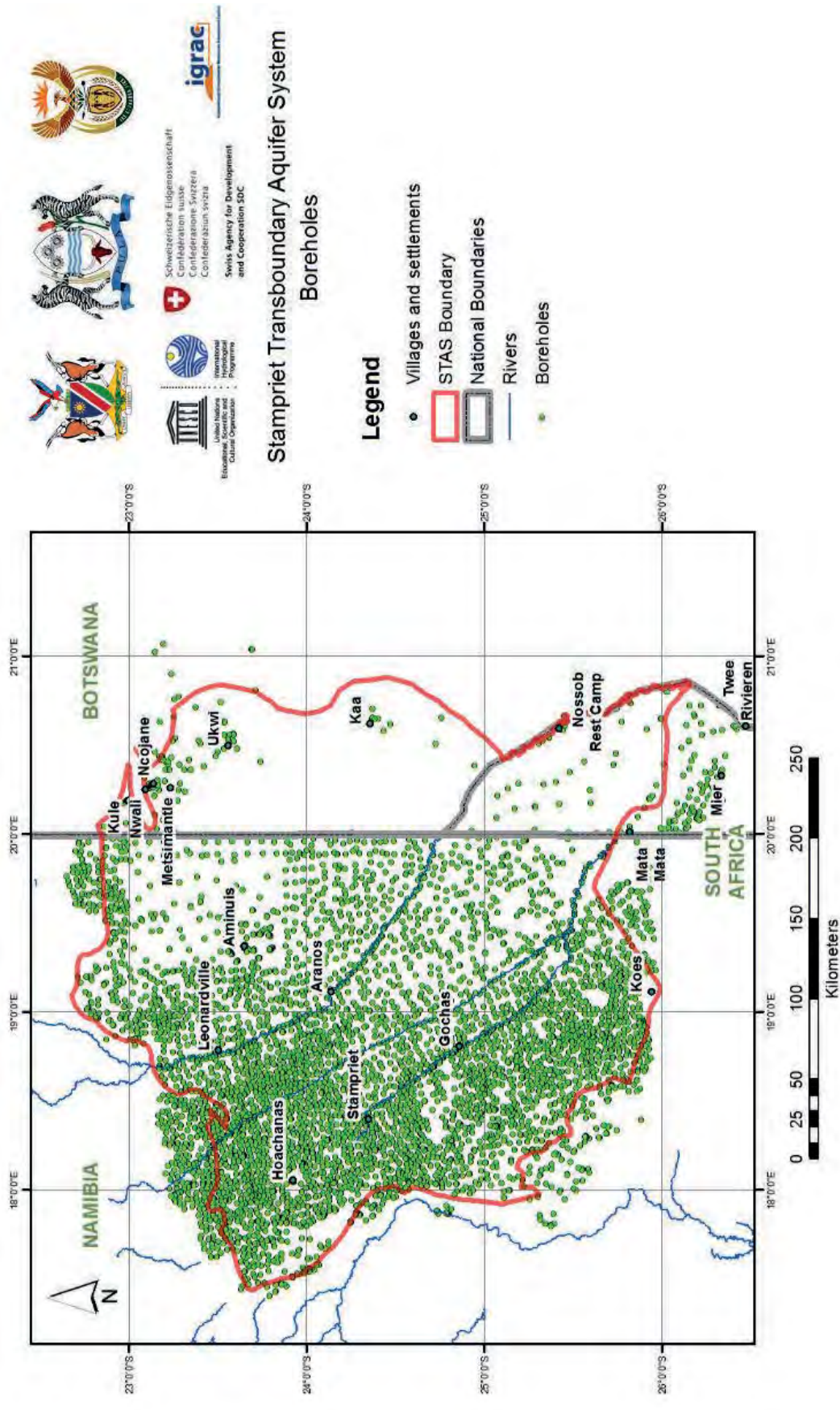


Figure 4.2 | Boreholes known to penetrate into the Kalahari, Auob and Nossob aquifers in the STAS (Source: GGRETA, 2015)

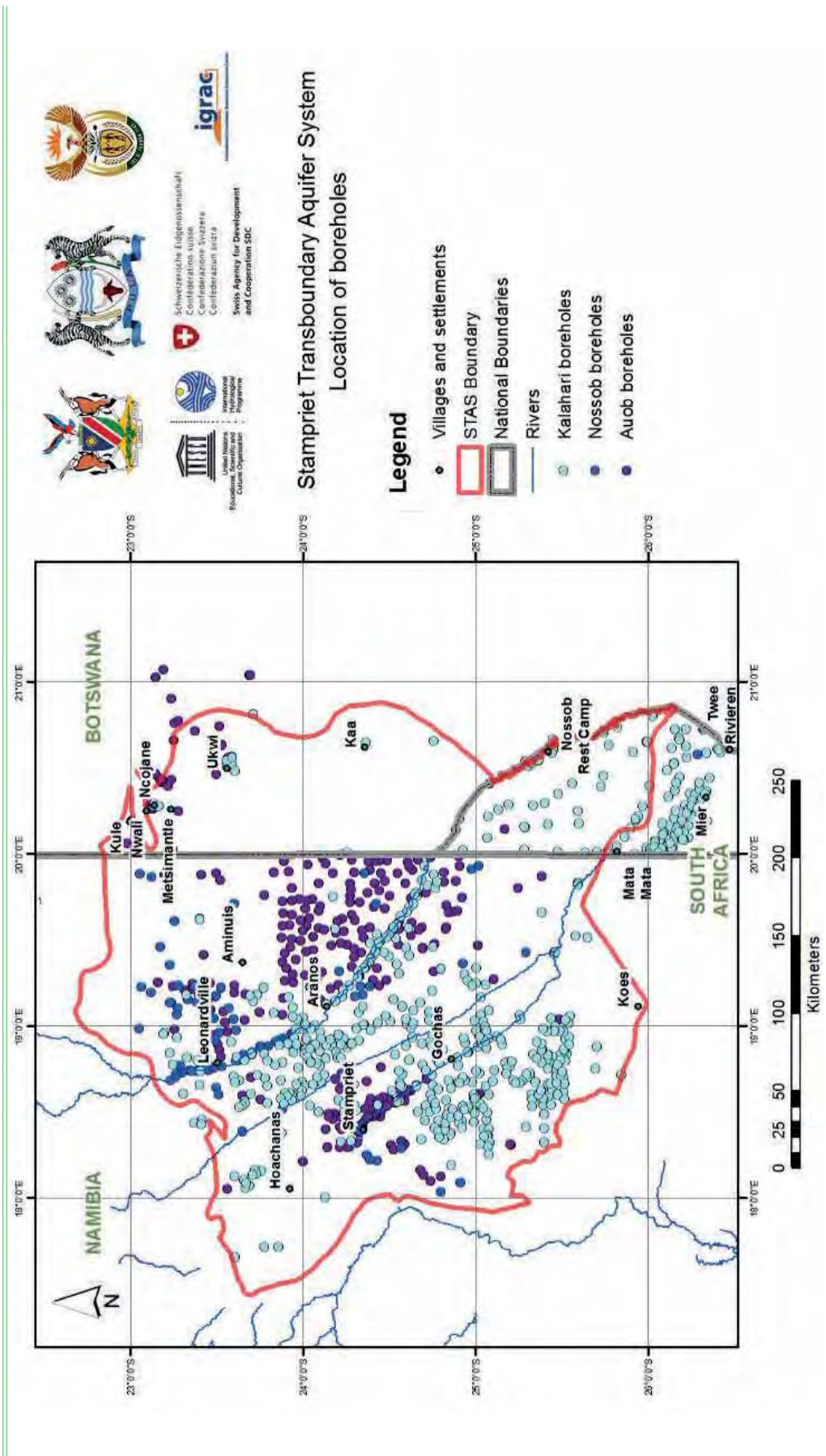


Table 4.2 | Distribution of boreholes per aquifer type in the STAS (Source: GGRETA, 2015)

	Namibia	Botswana	South Africa	STAS	
Aquifer penetrated	Number of boreholes			% of boreholes	
Kalahari	460	13	150	623	62
Auob	258	37	2	297	29.6
Nossob	81	1	3	85	8.4
TOTAL	799	51	155	1005	100

The borehole yields in the Kalahari aquifers generally vary between 0.1 and 6 m³/h (Figure 4.3), but there are areas where higher yields can be obtained (up to 50 m³/h in the northwestern part of the STAS) (GGRETA, 2015). Information provided from drillers indicates that yield tends to increase with depth but the salinity usually increases as well. Van Wyk (1987) also claims that good yielding boreholes can be obtained from approximately 8 m of saturation, but clay layers have a negative effect.

The borehole yields in the Auob aquifer generally vary between 0.1 and 50 m³/h (Figure 4.4). Average borehole yield is around 20m³/h, with areas where higher yields can be obtained (up to 270 m³/h in some parts of Botswana) (GGRETA, 2015). Higher yields are generally found close to Stampriet and between Leonardville and Aminuis.

The borehole yields in the Nossob aquifer generally vary between 0.1 and 12 m³/h (Figure 4.5). Higher yields are found close to Aminuis.

Note that the patterns in Figure 4.3 to Figure 4.5 are based on limited data, unequally spread over the area; therefore, the data points used are shown. In addition, interpolation assumes continuity, which is not necessarily valid, in particular not related to the Kalahari aquifers.

Figure 4.3 | Borehole yields in the Kalahari aquifers (Source: GGRETA, 2015)

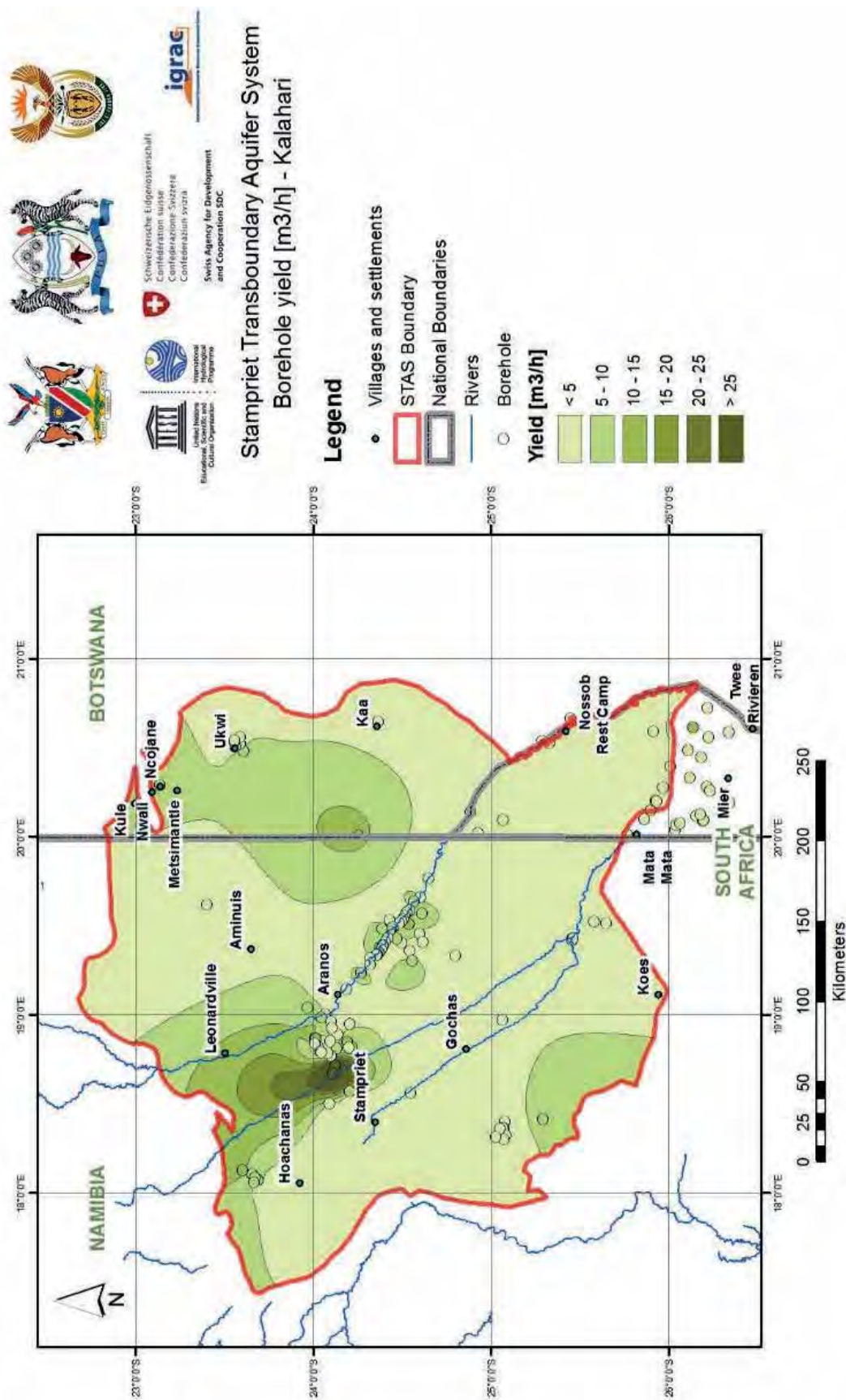


Figure 4.4 | Borehole yields in the Auob aquifer (Source: GGRETA, 2015)

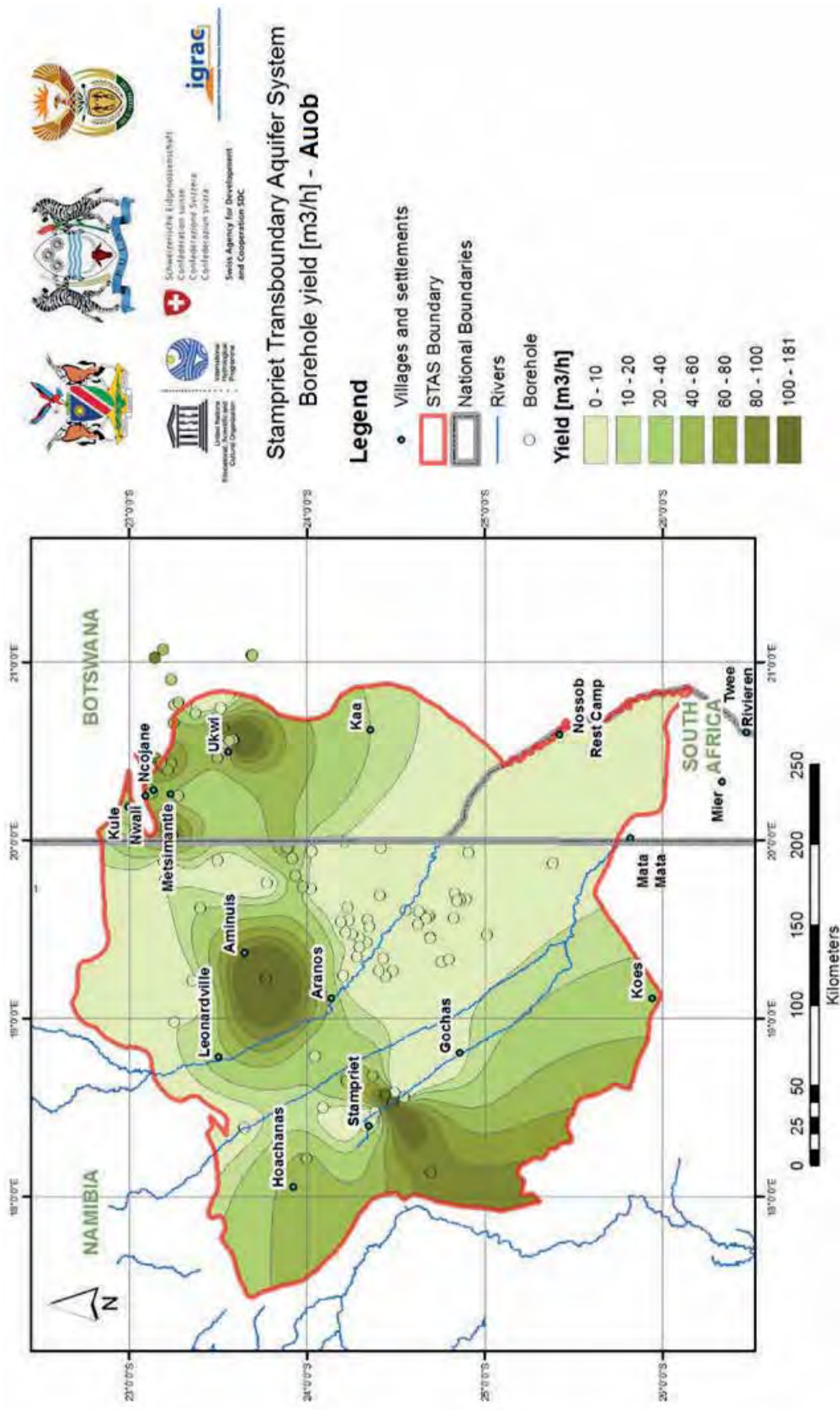
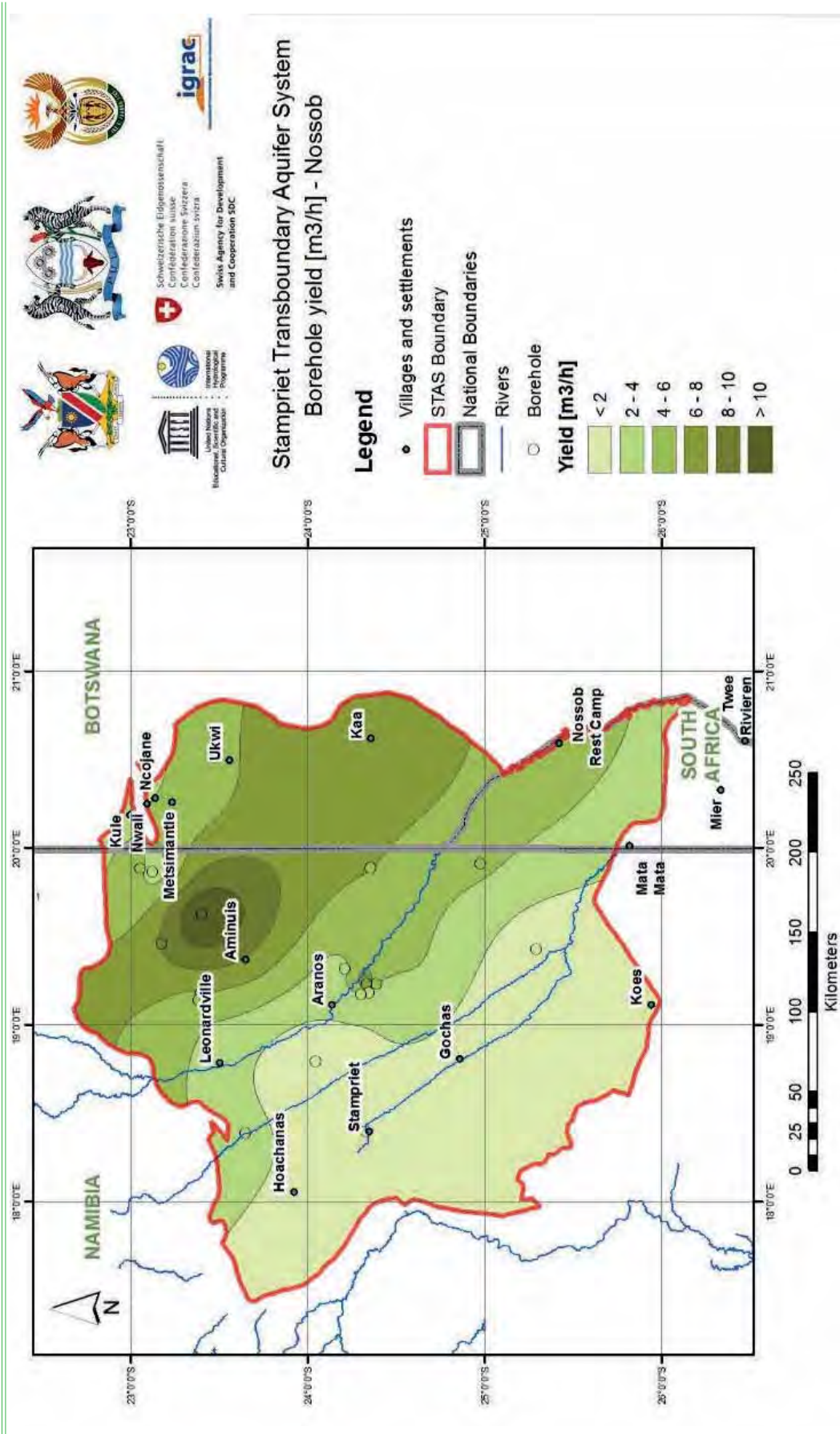


Figure 4.5 | Borehole yields in the Nossob aquifer (Source: GGRETA, 2015)



4.2. Groundwater abstraction and use

4.2.1. Current groundwater use

A total of at least 20 million m³/yr is abstracted from the STAS area, mainly in Namibia (over 90%), the largest consumer being irrigation. In the STAS area, 47% of water is used for irrigation, followed by stock watering at 37.5%, and domestic use at 15%, while a small proportion of less than 1% is used for tourism (JICA, 2002; MAWF, 2014; NamWater, 2014; NSA, 2012; CSO, 2009; CGS, 2015) (Figure 4.6). A breakdown of groundwater abstraction per water use and country is provided in Table 4.3.

Of the total annual groundwater abstraction from the STAS, 66% is from the Kalahari aquifers, 33% from the Auob aquifer and only 1% from the Nossob aquifer (JICA, 2002) (Figure 4.6). Approximately 80% of the total irrigation is concentrated in the Stampriet area. Groundwater abstraction in the STAS is estimated to have increased by approximately up to 20% from early 2000s to nowadays (Table 4.4), mainly driven by an increase of identified and reported irrigated area (from 469 ha to 619 ha) and livestock watering. However, a thorough assessment of water abstraction evolution is very difficult because of excessive water use practiced illegally in some farms (i.e. they over irrigate more than the permitted area), limited permit compliance, and irrigation farmers whose farm areas are less than 1 ha and do not require water abstraction permits. Irrigated areas in farms usually do not exceed 20 ha.

Figure 4.6 | Groundwater use and abstraction per aquifer type in the STAS

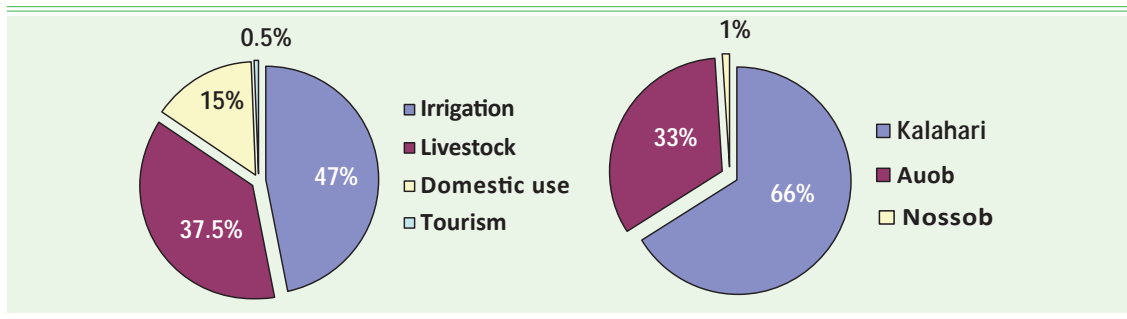


Table 4.3 | Groundwater abstraction, with breakdown by country and by type of water use

	* Namibia Volume of groundwater abstraction [m ³ /yr]	** South Africa Volume of groundwater abstraction [m ³ /yr]	*** Botswana Volume of groundwater abstraction [m ³ /yr]	STAS
1) Domestic water use:	3 000 000	1 600	116 450	3 118 050
Public water supply	770 000	N/A	116 450	886 450
Commercial farms	2 000 000	N/A	N/A	2 000 000
Communal farms	130 000	1 600	N/A	131 600
2) Irrigation	9 545 000	N/A	N/A	9 545 000
3) Livestock	6 022 500	22 700	1 642 500	7 687 700
a) Small	4 380 000	N/A	985 500	5 037 000
b) Large	2 642 500	N/A	657 000	2 628 000
4) Tourism	4 445	11 200	N/A	15645
Total water use per water type	18 571 945	35 800	1 758 950	20 366 695

*NamWater (2014), JICA (2002), MAWF (2014), NSA (2015); ** CGS (2015); ***CSO (2009)

Table 4.4 | Estimated groundwater abstraction evolution from 2002 and 2015

	2002*	2015
1) Domestic water use:		3 118 050
Public water supply	635 000	886 450
Commercial farms	1 594 000	2 000 000
Communal farms	127 000	131 600
2) Irrigation	6 876 000	9 545 000
3) Livestock	5 678 000	7 687 700
4) Tourism	4 000	15 645
Total water use per water type	14 914 000	20 366 695

* Underestimated because of N/A data in Botswana and South Africa.

Groundwater for domestic purposes in larger settlements in the area is mainly extracted from the Auob aquifer. Koes uses water from the Nossob aquifer. Efficient use of domestic water supply encounters major problems as around 49% of all municipal water is lost or unaccounted (e.g. Aranos, Koes, Gochas and Leonardville). Water loss and water unaccounted for is higher than 60% of water supply in Stampriet (MAWF, 2006). Groundwater abstraction from the Auob aquifer in Botswana is expected to increase by approximately 30% in the upcoming years as a result of a water transfer scheme aimed at supplying water to four primary demand centres collectively known as Matsheng Villages (Hukuntsi, Tshane, Lehututu and Lokgwabe) and also other secondary demand centres located in the northern Kgalagadi District and central and southern Ghanzi District. In South Africa, KTP staff is also exploring the possibility of pumping groundwater from the Auob aquifer for desalination.

4.3. Groundwater use for economic purposes

The predominant groundwater use for economic purposes in the STAS area is concentrated on livestock and agricultural production. Major economic activities are concentrated in a relatively small number (80) of commercial farms undertaking a system of mixed livestock (mainly sheep, but also cattle and other animals) and irrigated crop production in Namibia. Other commercial and communal farms mainly rely on livestock farming in grazing areas in Namibia and Botswana (Figure 2.20). There are some aquaculture activities (e.g. growing tilapia in open pond systems tilapia) in Leonardville (Namibia), but its contribution to the economy is relatively negligible as the sector is in its early stages and production is still low. The broad characteristics of the farming and production systems in the STAS area are summarized in Table 4.5.

Table 4.5 | Broad characteristics of the farming and production systems in the STAS area

	Small-scale crops and livestock farming	Livestock farming	Mixed crops and livestock production
Land tenure	Usage rights	Mainly private	Mainly private
Inputs	Low	Moderate	Moderate
Use of production	Domestic subsistence	Commercial sales	Commercial sales
Predominant markets	Local	Local and exports	Local and exports

Gross income generated from crop and livestock farming per annum is estimated at approximately N\$ 110M and N\$ 500M, respectively. Around 50% of the income from crop farming is estimated to arise through vegetables production (Table 4.6). Although small livestock represents 85% of livestock in the STAS area, cattle production is thought to account for approximately 60% of the gross income

generated by livestock farming (Table 4.7 and Table 4.8). Economic benefits from communal farms are difficult to assess, but are meant to be marginal compared to commercial farms, largely due to the inherently low productivity of most farm land, and to the fact that most of communal farms produce sale is mainly used for domestic subsistence.

Given that 63% of the STAS area population lives in the farming rural area, it is estimated that there are approximately 13 000 working age workers (including commercial farm owners and farmers in commercial and communal land), 10 000 non-working age people living in households of the farm owners or on communal land, and 7500 employees which are mainly concentrated on the existing commercial farms.

Livestock and agricultural production are highly dependent on climatic conditions, as severe droughts can lead to reduced crop production and increased livestock mortality. Additionally, owing to STAS area small population and considerable distances to the few sizeable urban markets makes the selling of substantial farm surplus extremely difficult.

4.3.1. Irrigation

The cultivation of rainfed crops is, of climatic necessity, marginal and regionally concentrated in the northern communal areas in Namibia and Botswana. Hence, groundwater is the major source of water for irrigation. Crops are dominated by fodder (lucerne), although some farmers have started switching to horticulture (e.g. vegetables and fruits). Such crops cannot be grown without irrigation because of the arid climate. Since irrigation needs higher investment, crop production is dominated by commercial farmers that can invest in irrigation systems. According to the DWAF in Namibia, the construction of a shallow borehole is around N\$ 50 000, while a deep borehole is around N\$ 300 000. According to local commercial farmers, substantial initial investment in equipment for irrigation (e.g. sprinklers, pivots, etc...) is required and estimated at N\$ 250 000.

It is estimated that approximately 80 commercial farms are irrigating 619 ha of land of a total of approximately 1000ha of irrigable land. Irrigated areas in farms usually do not exceed 20 ha. Drip irrigation is widely applied in the study area. Other methods in use are sprinkler and mixed applications (sprinkler, drip and others). Farms applying only flood irrigation are very few. Therefore, an alteration of irrigation methods might not result in substantial saving in water.

Lucerne represents approximately 50% of the irrigated area (310 ha) and 38% of crop production (6200 tons/yr). It is primarily produced for farmers' own use as feed for livestock, and consequently may not directly generate income for farmers; but reduces expenditure on inputs for livestock farming and is likely more cost effective than importing it from, for example, the Hardap scheme near Mariental, or South Africa. Some farmers have started switching to vegetables (e.g. tomatoes, beans) and fruits (e.g. citrus, grapes, melons, pumpkins). Vegetables and fruits together represent 50% and 8% of total crop production, respectively. Potential income from vegetables and fruits are greatest than other crops (e.g. oats and maize), however they are deemed to have higher labour and initial investment costs, and to be riskier in terms of their yield (mainly due to climatic conditions) and value. Furthermore, for all products the market was perceived to be limited which also prevents upscaling of production. An analysis of crops income is provided in Table 4.6.

Table 4.6 | Key statistic on agriculture in the Namibian segment of the STAS

	Area (ha)	%	Production (tons)	Cost (N\$/ha)	Water consumption (m ³ /ha)	Abstraction	Gross income (N\$/ha)	Gross income (N\$)	Net income (N\$/ha)	Net income (N\$)
Vegetables	142	23	8 520	120 000	10 000	1 420 000	420 000	59 640 000	300 000	42 600 000
Oats	43	7	49	20 000	9 000	387 000	50 000	2 150 000	30 000	1 290 000
Fruits	25	4	1 250	110 000	10 000	250 000	360 000	9 000 000	250 000	6 250 000
Maize	74	12	347.8	25 000	7 000	518 000	66 736	4 938 464	41 736	3 088 464
Lucerne	310	50	6 200	30 000	22 000	6 820 000	93 000	28 830 000	63 000	19 530 000
Hoodia & Scelicea	25	4	100	35 000	6 000	150 000	100 000	2 500 000	65 000	1 625 000
TOTAL	619	100	16 466.8	340 000	64 000	9 545 000	1 089 736	107 058 464	749 736	74 383 464

4.3.2. Livestock

There are almost 1 200 000 head of small stock and 160 000 large stock in the STAS area. While 90% of small livestock is in Namibia, large stock (mainly cattle) is more equally distributed in the STAS area as Botswana accounts for approximately 35% of total large stock (Table 4.7). Small stock in the STAS area mainly consists of sheep (\approx 80%) and goats (\approx 15%). Other small livestock consist of horses, pigs, donkeys, ostriches and poultry. Dependency on sheep farming in Namibia is considered due to low rainfall and grazing capacity of the study area. Livestock is generally marketed to local buyers, and abattoirs, and meat processing companies (e.g. Meat Corporation of Namibia and Botswana Meat Commission).

Natural grazing prevails on the study area for all stock. Carrying capacity in the study area is considerably varied from 3 ha/SSU (STAS south area) to 25 ha/SSU (STAS south area) depending on wild grass production which is affected by rainfall. Large stock is mainly concentrated in the northern segment of the study area (\approx 10-20 heads per square kilometer). Further south, vegetation becomes sparser, making the area better suited to goats and sheep. Grazing conditions from January to March are very good with rainfall and grass, but grass starts yellowing even in March and drying in May. From June to July livestock loses weight due to low temperature. In commercial farms also doing irrigation, supplementary feeding is usually done by crops produced in such farms (e.g. lucerne and wheat).

While the number of livestock has remained relatively stable in Namibia (the carrying capacity of the land does not support a higher number of animals), a fairly steady growth has been observed over the last 20 years in Botswana due to the considered number of boreholes drilled in this period. According to the Ministry of Local Government (MLG, 2003), the number of livestock in the STAS area in Botswana has increased twofold. Areas designated for wildlife use, like the Kgalagadi Transfrontier Park (KTP) and the Wildlife Management Areas (WMAs), were and still are primarily used by the Remote Area Dwellers (RADs) for hunting and gathering. However, these activities have become less important subsistence activities since the beginning of the 1980s. Instead, livestock rearing and wage labour have become significant economic activities as a result of competing land uses and more sedentary lifestyles in settlements.

Table 4.7 | Number of livestock and water consumption rates (source: MAWF, 2003)

	Namibia	Botswana	South Africa	Total	Consumption rate (m ³ /d)	Water consumption (m ³ /yr)
Small stock unit	1 000 000	150 000	N/A	1 150 000	0.0012	5 037 000
Large stock unit	100 000	60 000	N/A	160 000	0.0045	2 6280 000

Large livestock accounts for approximately 60% of the gross income generated by livestock farming although they only represent 15% of total livestock in the STAS area. Some farmers have reported that in wetter (drier) years, livestock farming prioritizes large (small) livestock. A tentative analysis of potential small and large livestock farming income are provided in Table 4.8 and Table 4.9, respectively.

Table 4.8 | Key statistics on small livestock in the STAS area

	Sheep	Source	Goats	Source
(1) Head of small stock	575 000	Adapted from JICA (2002) and Botswana Statistics (2014)	115 000	Adapted from JICA (2002) and Botswana Statistics (2014)
(2) Proportion of stock marketed each year	50%	Meat Board (2011) Avg. 2001 - 2010	26%	Meat Board (2011) Avg. 2001 - 2010
(3) Head of stock marketed each year	287 500	Calculation: (1)*(2)	29 900	Calculation: (1)*(2)
(4) Average kg per carcass marketed	19.92	Meat Board (2012) Avg. 2011	-	-
(5) Average kg marketed to abattoir	5 727 000	Calculation: (3)*(4)	-	-
(6) Price at abattoir (N\$/kg)	34.4	Meat Board of Namibia. Average of monthly sheep producer prices Jan – Aug 2015	-	-
(7) Auction price per head (N\$)	-	-	750	Agra Auction Price 30/10/2015 (Medium Goat)
(8) Gross income per annum (N\$)	197 008 800	Calculation: (5)*(6)	22 425 000	Calculation: (3)*(7)

Table 4.9 | Key statistics on large livestock in the STAS area

	Value	Source
(1) Head of cattle	160 000	Adapted from JICA (2002) and Botswana Statistics (2014)
(2) Proportion of cattle marketed each year	25%	Adapted from Venter (2015) Average of figures from 1996 to 2012.
(3) Head of cattle marketed each year	40 000	Calculation: (1)*(2)
(4) Average kg per carcass marketed	245	Venter (2015) Based on an assessment of cattle farming on a number of farms.
(5) Average kg marketed to abattoir	9 800 000	Calculation: (3)*(4)
(6) Price at abattoir (N\$/kg)	25	Meat Board of Namibia and Botswana Meat Commission Average of monthly beef producer prices Jan – Aug 2015
(7) Gross income per annum (N\$)	245 000 000	Calculation: (5)*(6)

The values presented above assume that all cattle are being farmed under the objective of producing beef commercially for sale either on export or domestic markets; it therefore omits consideration of other goods (such as dairy and skins) that may be produced commercially. However, these goods are unlikely to have a significant overall impact as beef production is the dominant activity (JICA, 2002). Additionally, marketing rate of communal land is usually lower than for commercial farmers which could result in overestimation of results presented in this study.

4.3.3. Tourism

Two specific categories of tourists are identified in the STAS, eco-tourists and business tourists. Tourism can contribute to development and the reduction of poverty in a number of ways. Economic benefits are generally the most important element, but there can be social, environmental and cultural benefits and costs. Tourism contributes to poverty eradication by providing employment and diversified livelihood opportunities. Within the STAS, the major type of tourism related activities are natural resources based or ecotourism; with the rich wildlife biodiversity and vast undisturbed wilderness areas being the major attractions. Development of tourism in Namibia is restricted to a few lodges (MAWF, 2010) accounting for approximately 10 lodges (10-15 rooms). There is also further scope to develop tourism, especially in the Kgalagadi Transfrontier Park (KTP) in Botswana and South Africa.

The Botswana and South African governments signed a bilateral agreement on 7 April 1999 to merge the Gemsbok National Park in Botswana with the Kalahari Gemsbok National Park in South Africa into a single ecological area now called the Kgalagadi Transfrontier Park (KTP) (Figure 4.7). The name Kgalagadi means “land of thirst” or “Thirstland” and is where the original name was obviously derived.

This merger made it possible for wildlife to move freely between the two countries. KTP is located in the Kgalagadi District on the south-western border of Botswana and the Northern-Cape border of South Africa. It can be accessed through five gates in three different countries, namely South Africa, Botswana and Namibia (SANParks, 2006). The park boasts an area of 46 000km² (10 000 km² in South Africa and 36 000 km² in Botswana), making it one of the biggest conservation areas in the world (SANParks, 2006). KTP is classified as a Category 2 park according to the IUCN classification of protected areas (Sandwith et al., 2001).

The KTP has three eco types (dune-veld semi-desert vegetation, Kalahari plain thorn-veld and the salt pans), and there are about 500 kilometers of tourist dirt roads inside the park (excluding the 4x4 roads). Despite being one of the largest conservation parks in the world, the KTP only accounts for approximately 40 000 visits per year (SANParks, 2015) (Table 4.10). The visitation rate should be understood in the context of the park’s remote location (260 km from Upington, 610 km from Kimberly and 904 km from Johannesburg). There are 10 tourist facilities in the KTP (all in South Africa) that can be traditional camps, wilderness camps, or luxury lodges accounting for 330 beds. There are a number of campsites in Botswana which overlook pans in the Mabuasehube section of the park (outside the STAS area) which have rustic latrines, showers and shade shelters.

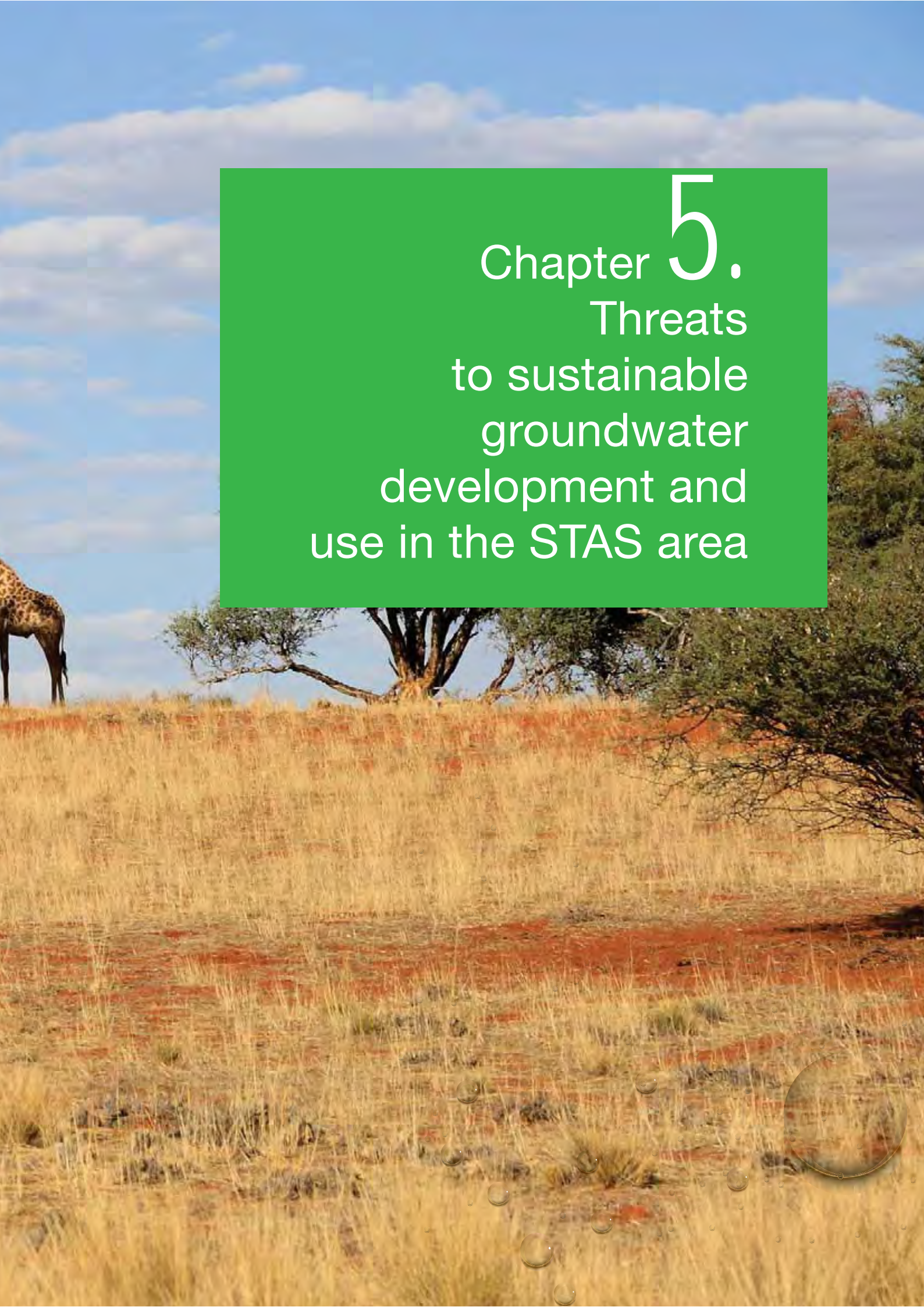
Figure 4.7 | The Kgalagadi Transfrontier Park (KTP) map (Source: FindTripinfo.com and Kruger-2-Lalahari.com)



Table 4.10 | 2014/2015 Tourist information on the Kgalagadi Transfrontier Park (KTP) (Source: South African Parks, 2015)

Unit nights sold	Bed occupancy		Site nights sold	Camping		Guests to Park
	Unit occupancy	Bed nights sold		Camping site	Person nights sold	
31 436	89.4%	72 414	22 063	78%	63 501	40 086





Chapter 5.
Threats
to sustainable
groundwater
development and
use in the STAS area

5.1 Groundwater quality

Groundwater quality has its natural variations. As will be shown below, this results in large parts of the area being endowed with groundwater suitable for all purposes (in at least one of the aquifers), but there are also zones where none of the aquifers contains good-quality water. Most notable are generally poor conditions in or near the Salt Block zone. Pollution, however, may lead to groundwater quality degradation, thus reducing groundwater suitability for intended uses also elsewhere in the area. The shallower and usually phreatic Kalahari aquifers are vulnerable to pollution; in particular in the Namibian sector the pollution risk is often medium to high due to irrigated agriculture (using fertilizers and pesticides) and environmentally unfriendly sanitation and waste disposal practices in and around settlements are a pollution risk all over the STAS area. Partly from the groundwater management point of view and partly for health reasons, there is scope for enhancing water supplies and even more for improving sanitation in the entire area. The confined transboundary aquifers have very low vulnerability to pollution, but they may experience indirect impacts from pollution, in the form higher withdrawal pressures if overlying Kalahari aquifers become polluted.

5.1.1. Regional groundwater quality patterns

Groundwater quality records are available for approximately 1000 boreholes in the STAS area. Borehole groundwater quality sampling and analysis started in the 1970s in Namibia and South Africa and have been sporadically updated during past years (CSIR, 2001). In Botswana, available hydrochemical data is from the early 2000s (Matsheng, 2008).

Botswana, Namibia and South Africa use different classifications for groundwater quality. In this analysis, the World Health Organization (WHO) guidelines for drinking water quality (WHO, 2004) and the United Nations Food and Agriculture Organization of the United Nations (FAO) water quality for agriculture classification (FAO, 1985) have been used for comparative purposes. Groundwater quality has been analysed in terms of Total Dissolved Solides (TDS), Nitrate, Sulphate and Fluoride for each aquifer separately, using the classification presented in Table 5.1. Broadly, the classification indicates whether groundwater is suitable for human consumption, suitable for livestock consumption but unsuitable for human consumption, and unsuitable for human and livestock consumption.

Table 5.1 | Classification for groundwater quality assessment in the STAS according to suitability for human consumption and stock watering (Adapted from WHO, 2004 and FAO, 1985)

	Total Dissolved Solids (TDS) (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)
Suitable for human consumption	<1000	<45	<200	<1.5
Limited health risk for human	1000-2000	45-90	200-400	1.5-3
Unsuitable for human consumption but good for stock watering	2000-5000	90-180	400-1000	3-4
Unsuitable for human consumption and stock watering	>5000	>180	>1000	>4

Groundwater quality generally decreases towards south-western Botswana and the north-western Cape in South Africa (i.e. Salt Block zone) for all the three aquifers, and is generally better in the Auob aquifer than in the Kalahari and Nossob aquifers (Figure 5.1 through Figure 5.4). The patterns in Figure 5.1 through Figure 5.4 are based on limited data, unequally spread over the area, and the

Figure 5.2 | Nitrate concentration [mg/l] in the Kalahari (up), Auob (bottom left) and Nossob (bottom right) aquifers in the STAS (Source: GGRETA, 2015)

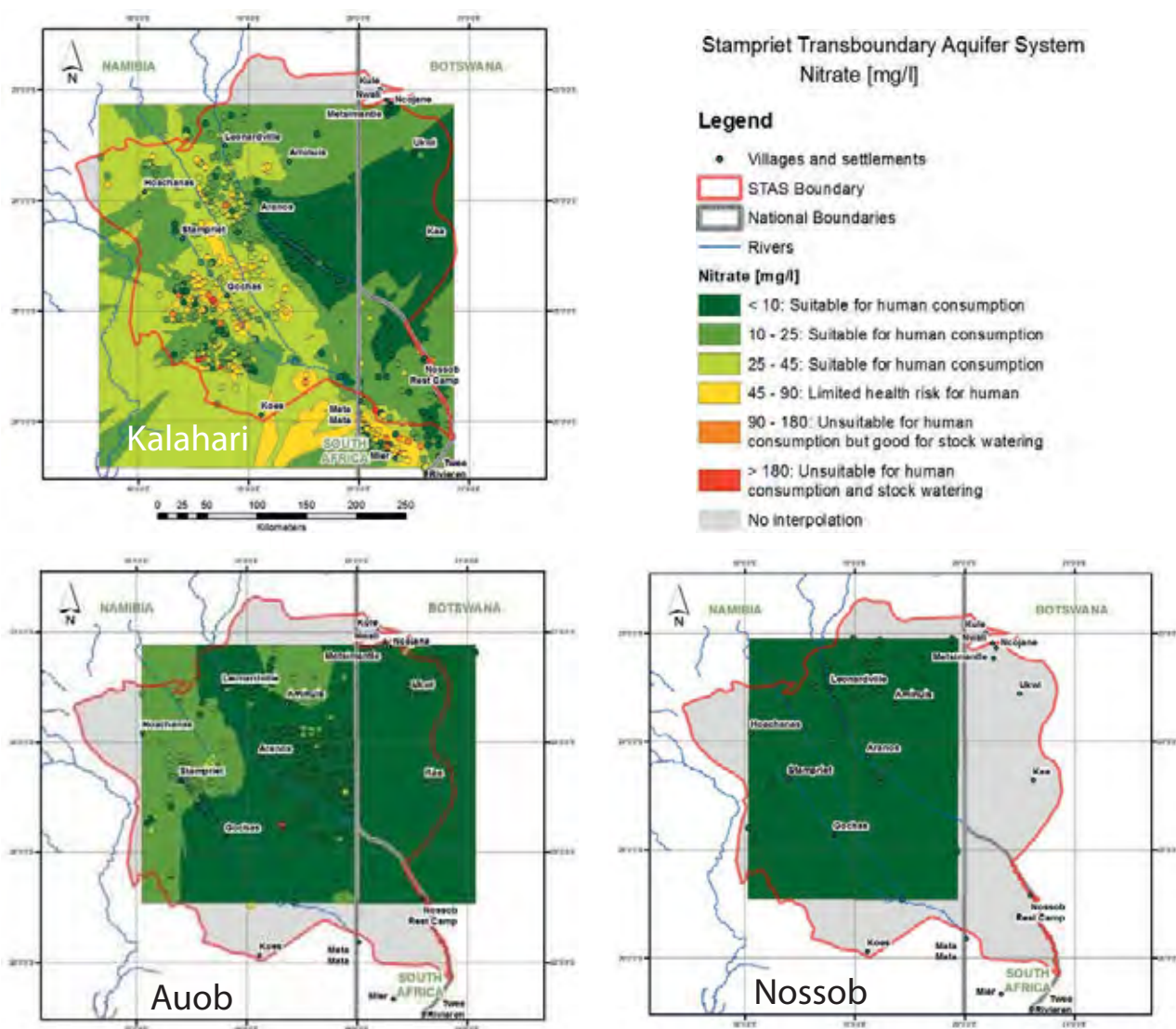
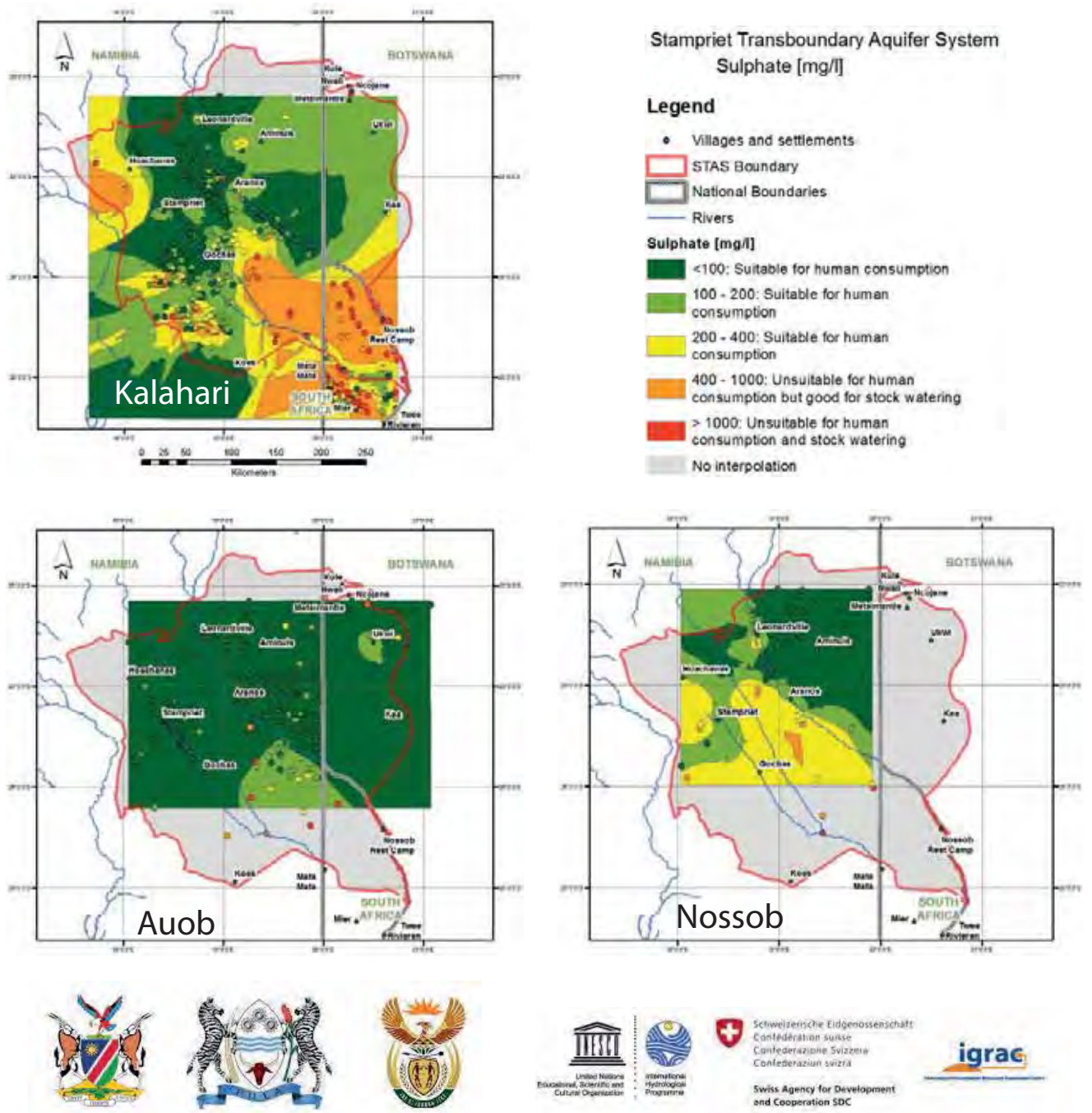


Figure 5.3 | Sulphate concentration [mg/l] in the Kalahari (up), Auob (bottom left) and Nossob (bottom right) aquifers in the STAS (Source: GGRETA, 2015)

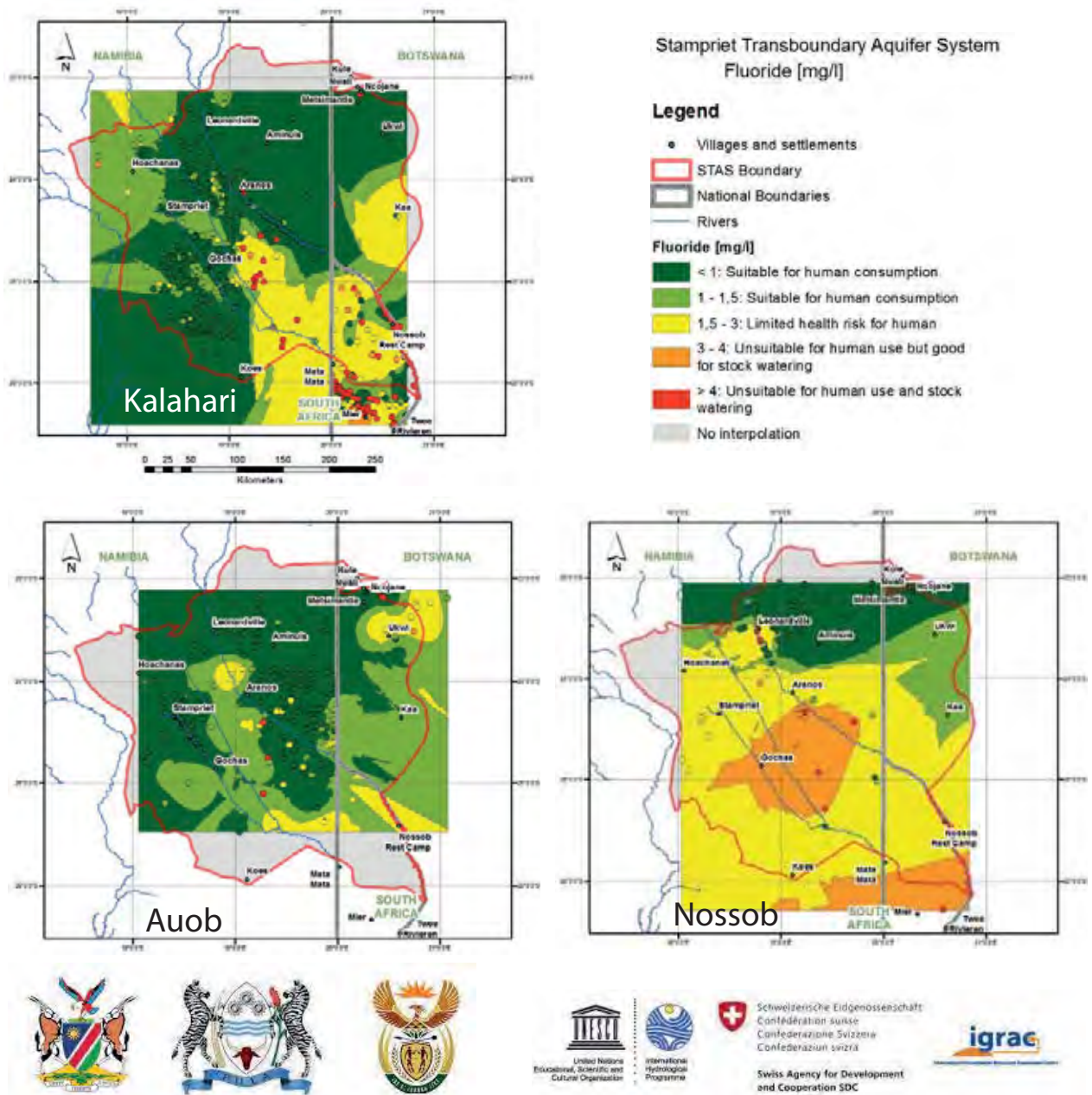


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Figure 5.4 | Fluoride concentration [mg/l] in the Kalahari (up), Auob (bottom left) and Nossob (bottom right) aquifers in the STAS (Source: GGRETA, 2015)



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Most of the Kalahari aquifers have groundwater quality exceeding the guidelines for human consumption in Botswana. In Namibia, the groundwater quality of the Kalahari aquifers is generally poor along the Auob River downstream Gochas (the Salt-Block area). The area of poor water quality continues into South Africa where it also exceeds water quality guidelines limits for human consumption. Areas of good water quality are found in the middle and northern part of the Namibian segment of the STAS. For the confined aquifers, groundwater is suitable for human consumption in most of the Auob aquifer except in some segments of the Salt Block area. Groundwater in the Nossob aquifer is unsuitable for human consumption all along the Auob and Nossob Rivers in Namibia and South Africa (Figure 5.5). No thorough assertion about groundwater quality in the Nossob aquifer in Botswana can be considered.

For livestock watering, the areas of unfit groundwater are limited to the Salt Block area in Namibia and South Africa (Figure 5.6).

Figure 5.5 | Distribution of areas exceeding groundwater human consumption guideline in the Kalahari (up), Auob (bottom left) and Nossob (bottom right) aquifers in the STAS
(Source: GGRETA, 2015)

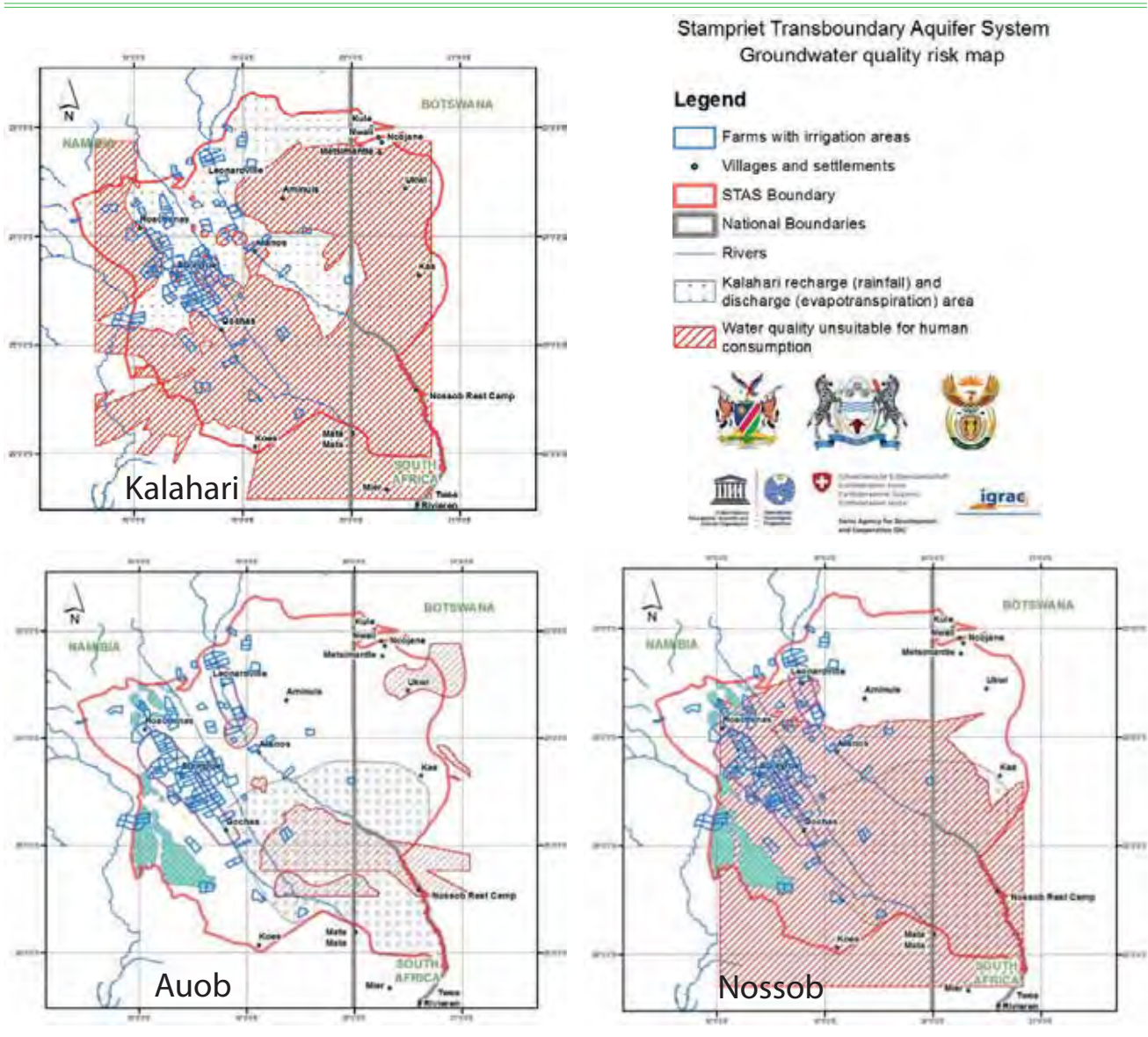
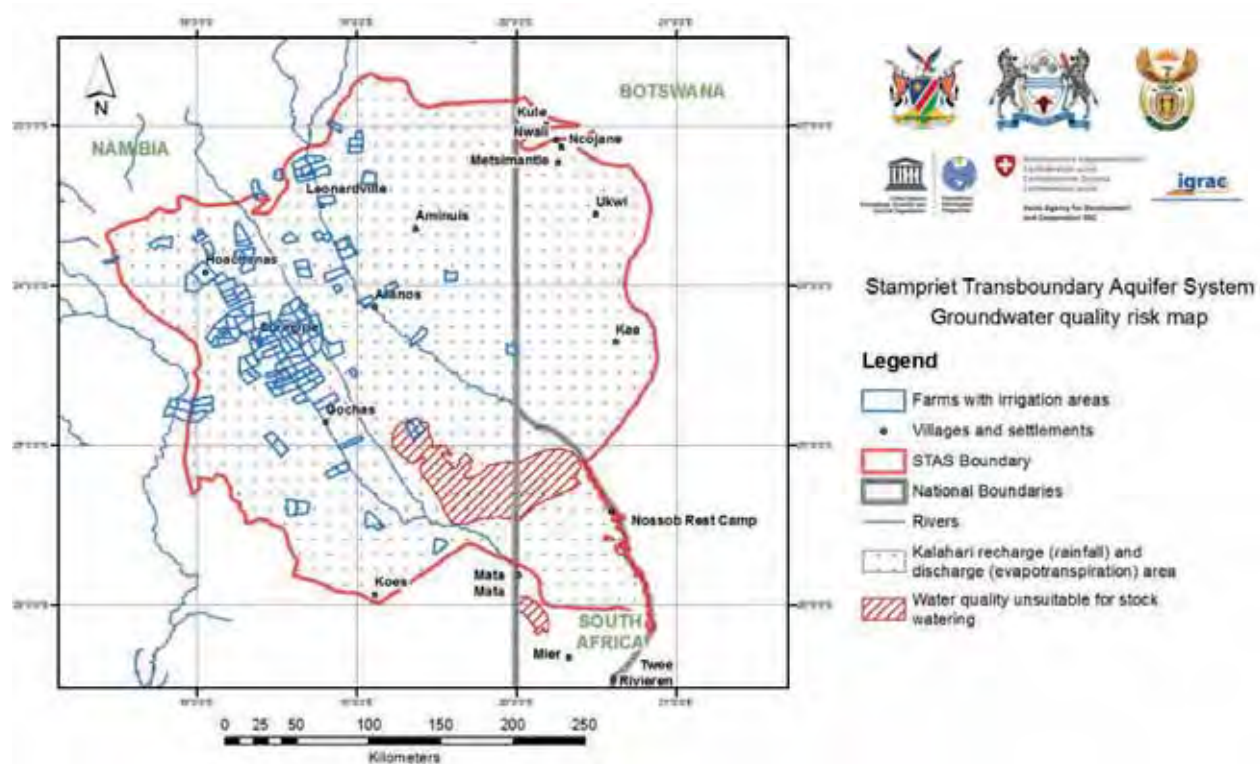


Figure 5.6 | Distribution of areas exceeding groundwater livestock consumption guideline in the STAS (only occurring in the Kalahari aquifers) (Source: GGRETA, 2015)



5.1.2. Groundwater pollution: sources, vulnerability and pollution risk

Currently there is generally very low pollution risk for the STAS area as a whole, but selected locations (settlements) and zones (in particular: irrigated lands) form exceptions. Groundwater pollution risk in the STAS area can arise from localized pollution sources, in combination with the aquifer's vulnerability to pollution. In settlements, this risk is associated with the following sources of pollution:

- Pit latrines,
- Septic tanks and effluent soakways,
- Sewage works & oxidation ponds,
- Burial sites,
- Oil/fuel storage and disposal.

In rural areas, pollution risk is mainly associated with:

- Irrigation (in combination with the use of fertilizers and pesticides)
- Livestock excreta

In Namibia the main potential pollution sources are oxidation ponds, septic tanks and landfills close to settlements, and irrigation fields. There are some localized threats of pollution to the Kalahari aquifers from polluting sites around settlements, but current information indicates that this pollution does not penetrate to the Auob and Nossob aquifers. Besides these pollution sources, groundwater pollution can occur as a result of the use of fertilizers and pesticides in the irrigated lands and by cattle urine and dung at watering points near wells and boreholes. The shallower Kalahari aquifers are prone to

pollution risk related to irrigation in the Stampriet area (where 80% of the total irrigation of the STAS is concentrated) and along the Nossob River between Leonardville and Aranos. Mining is currently not taking place in the Namibian segment of the STAS area, but prospecting and exploration is being carried out. Currently, these activities do not pose any significant threat to the aquifers, in contrast with future mining activities, if these would be initiated.

Despite the low risk of pollution, there are some indications of pollution taking place. In Botswana the main potential sources of groundwater pollution in settlements are septic tanks and pit latrines. In communal land, risk of pollution could arise in the Ncojane-Ukwi area which is a key livestock area. In this area, there is a tendency to kraal and water livestock by boreholes and pans. For example, there are some 5-20 m deep hand-dug wells at pans that act as concentration points for livestock and small stock, which puts groundwater at risk of pollution as run-off could wash livestock excreta into the boreholes, wells and pans (Figure 5.7).

The South African segment of the STAS area falls within the Kgalagadi Transfontier Park, which implies that there is a very low risk of pollution of the STAS in this area. No waste dumping is allowed within the boundaries of the nature reserve and all the waste generated within the park is collected and dumped outside and away from the park. There are no cemeteries and waste water works facilities in the nature conservation area.

Figure 5.7 | Potential sources of groundwater pollution (Kalahari aquifers) (livestock kraals, hand dug wells, small dams, etc. in a pan in Kgalagadi North, Botswana
(Source: Moselehi, 2015)



Table 5.2 presents a summary of possible pollution sources and their intensity across the three countries.

Table 5.2 | Groundwater pollution sources and their aggregated intensity in the STAS
 (the judgments are made for the national segments as a whole – in a local context, intensities may be rated quite differently) (Source: Muroua, 2015; Mosetlhi, 2015 and CGS, 2015)

	Pollution Source	Rationale for Pollution Source Intensity / Impact		
		BOTSWANA	South Africa	NAMIBIA
Settlements	Pit Latrines	Very low: Pit latrines constitute the common form of sanitation in the Stampriet settlements in Botswana (45.9% out of 1254 households). However the pollution potential is very localised as there are only three settlements in the entire Stampriet area which combined have a population (3229). Also, the general depth of the water table in the broader area is 120m (KDDC, 2008).	Very low: Given the population density of the area	Very low: Given the low percentage of pit latrines (only 3% of households).
	Septic Tanks & Effluent Soakaways	Very low: because out of 1254 households, 13.2% septic tank flush toilets. There is probably a few septic tanks used in campsites in the park (KTP)	Very low: Given the population density of the area	Medium: As there is high use of septic tanks in centres like Aranos Aminuis, Kries, Hoachanas and Leonardville.
	Sewage Works & Oxidation Ponds	No Impact: Because this land use is non-existent	No Impact: Because this land use is non-existent	Medium-High: Because there is use of oxidation ponds to manage effluent in all the urban centres. Also, most of the oxidation ponds were constructed before the new ponds standards were adopted hence they are not sealed with the necessary impermeable structures to avoid seepage effluent in to groundwater.
	Burial Sites	Very low: Given the population density of the area	Very low: Given the population density of the area	Very low: Given the population density of the area
	Oil/Fuel Storage & Disposal	Very low: The intensity of the source relates to storage and disposal of borehole machinery related oils, which if not properly handled and disposed of can be washed down in to boreholes or pans by run-off	Very low: Assumed as there could be some oil or fuel storage & disposal activities in the lodges in KTP.	Medium: This relates to storage & disposal of oils or fuels used in service stations, and irrigation & borehole related machinery.
Rural areas	Irrigation (incl. use of fertilisers & pesticides)	No Impact: Because this land use is non-existent:	No Impact: Because this land use is non-existent:	Medium-High: Irrigation poses the most significant pollution threat to groundwater. However the intensity of this source is reduced by the fact that the irrigation farms area scattered not continuous, and the total area under irrigation is around 620ha.
	Livestock Excreta	Very low: because only a small part is affected; the northern edge of the STAS area (Ncojane-Ukwi area) which is a key livestock area, basically BH led cattleposts & the Ncojane leasehold ranches (a little further north). There is tendency to kraal and water livestock by the boreholes & pans in the districts. This puts the water resources at a high risk of pollution as run-off could wash livestock excreta in to boreholes & pans.	No Impact: Because this land use is non-existent	Very low: because only a small part is affected;

The confined transboundary aquifers have very low vulnerability to pollution, due to the series of poorly permeable layers that separate them from the pollution sources at the land surface. Nevertheless, they will experience higher withdrawal pressures if overlying Kalahari aquifers become polluted. The shallower and usually phreatic Kalahari aquifers have much less natural protection and are therefore vulnerable to pollution; in particular in the Namibian sector the pollution risk is often medium to high due to irrigated agriculture (using fertilizers and pesticides, and applying water which acts as an agent of transport) and due to environmentally unfriendly sanitation and waste disposal practices.

Targeted monitoring needs to be done in the more vulnerable areas (e.g. the recharge zones of the Auob and Nossob aquifers in western Namibia) and in the irrigation areas close to Stampriet (where 80% of the total irrigation of the STAS is concentrated) and along the Nossob River between Leonardville and Aranos. Currently, there are very few irrigation farms overlapping on the confined aquifers recharge zones. In the Stampriet area, although irrigation poses the most significant pollution risk, a recent survey in the area shows that nitrate levels have remained relatively stable through the past years and that groundwater is largely suitable for human consumption (DWAF, 2015). However, there are some indications that over the past years, TDS levels in some boreholes (especially older ones) in the STAS area have increased by 30%.

5.2 Groundwater resources degradation by depletion

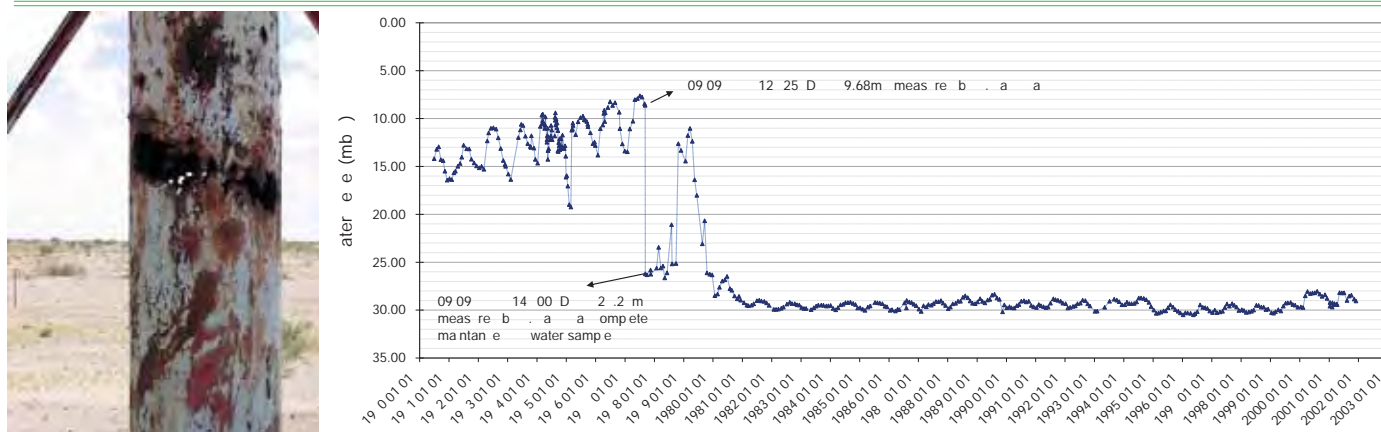
Although the available information on groundwater replenishment is very limited, it may be concluded that the Kalahari aquifers are only weakly recharged, while the Auob and Nossob aquifers receive so little recharge that they preliminary can be ranked in the category of aquifers with non-renewable groundwater resources. This means that progressive groundwater depletion (accompanied by steadily declining groundwater levels) is a realistic threat to the STAS area. Infrequent wet years may produce some recovery of the water levels –as observed several times in the area during the last decades–, but on the longer term this might not be sufficient to prevent long-term depletion, in particular when groundwater abstraction intensities in the area increase. The hydrodynamic regime of the STAS thus is very fragile, which requires special attention to be paid to: (a) controlling groundwater abstractions in order to keep medium- to long-term depletion within acceptable limits; (b) curbing current waste of water and avoiding it to occur in the future. A few comments on the latter will follow.

Leaking boreholes penetrating the Auob and Nossob aquifers are currently a major threat to the STAS' sustainability as they might produce enormous water losses by continuous outflow, and significant impact on water quality in the Kalahari aquifers. Figure 5.8 provides an example. It shows a) a corroded casing at the surface (Gomchanas recorder borehole near Hoachanas in Namibia) and b) the log of the Boomplaas recorder borehole (between Stampriet and Gochas in Namibia) that monitored the Auob aquifer. Leaks in the Boomplaas recorder borehole show that the Auob aquifer water was flowing 24/7 into the Kalahari aquifers with a head difference of about 20 m²⁰. It is expected that such scenario occurs in several other older STAS boreholes given that the Auob and Nossob waters can be corrosive. The threat is less in boreholes where plastic casing has been used. Plastic casing was only introduced in the STAS new

20. The leak in the Boomplaas recorder borehole has been sealed so that no water flows out from the Auob aquifer, and replaced by a new monitoring borehole.

boreholes in the early 2000s and probably even not in all of them. Privately drilled boreholes might still use steel casing nowadays. Mapping malfunctioning boreholes would facilitate possible rehabilitation programmes, but would require an extensive chemical sampling and analysis campaign.

Figure 5.8 | a) corroded casing at the surface (Gomchanas recorder borehole near Hoachanas in Namibia) and b) the log of the Boomplaas recorder borehole (between Stampriet and Gochas in Namibia) that monitored the Auob aquifer



New malfunctioning wells appear because of the lacking control of drilling activities. As a result, the aquifer system is often damaged by permanently wasting water when boreholes penetrating the Auob and Nossob confined aquifers are not properly sealed. The reasons of the latter might be illegal drilling activities, cost-saving, minimal supervision when casing and seals were placed. Careful review, updating and promotion of borehole construction standards and guidelines would be necessary.

5.3 Impact of alien invasive vegetation

Alien invasive species such as the Prosopis trees are found in abundance along the Auob and Nossob Rivers, causing bush encroachment in some parts of the study area. Physical characteristics as deep root length (up to approximately 15m) are effective in enabling the Prosopis trees to reach the water tables of between 3 to 10m below the surface (van den Berg, 2010). This is a source of concern as it could reduce recharge of the Kalahari aquifers. It was found that the density of Prosopis in the Auob and Nossob River basins is highest within and along the rivers (1000 trees/ha) compared to gravel plains (350 trees/ha) and dunes (<50 trees/ha) (DRFN, 2012). The Nossob River upstream of Leonardville is infested by Prosopis, and has an effect on the availability of fresh water in the lower Nossob River as one Prosopis tree can take up to 50 litres per day (Le Maitre, 1999). According to Smit (2005), Prosopis density increases at 18% per annum, resulting in the invaded area to double every five years.

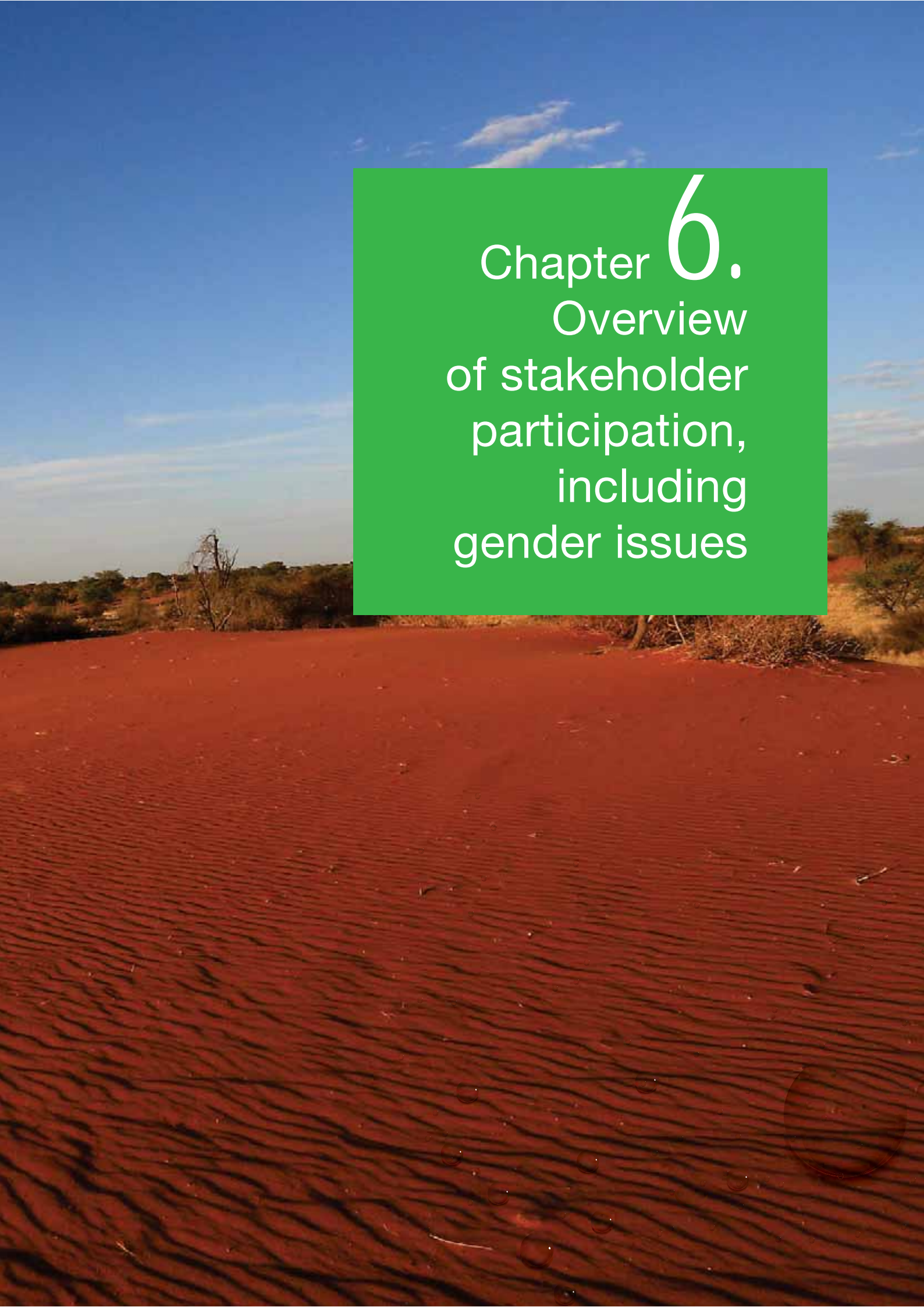
5.4 Water scarcity due to climate variability and climate change

Variability is inherent to the area's climate. In particular during very dry years, water scarcity may have special negative impacts on people and their livelihoods, either because available sources of water become temporarily exhausted or these sources and abstraction facilities cannot cope with increased water demands during droughts.

Climate change in the STAS area is expected to result in even more frequent droughts, generally longer duration of dry spells, and higher variability of rainfall. The expected impacts of droughts on economic activities in the STAS area are the reduction of crops and livestock holdings in two ways: directly through production (e.g. mortalities for livestock) and indirectly through distress sales.

Farmers have reported a reduction in the harvest yield and quality of crops during droughts. Soil fertility may also become a critical factor during droughts; consequently more fertilizers are needed per hectare while seed germination is slow. Farmers claim that they experience high input costs during periods of drought while inflation continues to increase irrespective of drought. Their income becomes therefore less, which results in layoffs of farm workers. The possibilities for distress sales of game animals tend to be lower than those of domestic stock. However, there are no current statistics showing how much drought is affecting the livestock industry.





Chapter 6.
Overview
of stakeholder
participation,
including
gender issues

6.1 Context²¹

6.1.1 Agricultural system characteristics

The STAS area is a large farming area with approximately 1200 farms (mostly in Namibia) whose major activities are livestock and agricultural production. Colonial practices, subsequent privatization of land ownership under commercial farms which cannot be redistributed, shortage of labour, and underdevelopment have resulted in a three-tier agricultural system in the STAS area: established commercial farming; emerging commercial farming; and subsistence farming. Stakeholders involved in this agricultural system do not form a homogeneous group across the STAS area, and their working and living conditions vary starkly across farmer categories:

Stakeholders involved in this agricultural system do not form a homogeneous group across the STAS area, and their working and living conditions vary starkly across farmer categories:

1. *Established (white) commercial farmers in Namibia*²²: This group of farmers (primarily white accounting more than 90% of land ownership) falls in the highest income group (>50 head of cattle) and hence the material conditions they offer to farm workers are better, relative to other groups of farmers. Approximately 800 farmers in Namibia control approximately 1000 farms in the STAS area accounting for over 80% of agriculturally useable land. Black men farmworkers provide the bulk of labour.
2. *Emerging (black) commercial farmers in Namibia*: This group (primarily black) falls broadly in the middle income group and offers material conditions which are lower than those offered by white farmers but higher than those of communal farmers. There are 140 small-scale commercial farmers (mainly livestock farming), primarily from disadvantaged communities, who acquired control of farms as a result of an important land reform programme in Namibia (90 resettlements farms²³ and 50 Affirmative Action Loan Scheme Farmers²⁴) (Table 6.1 and Table 6.2). These farms represent less than 1% of agriculturally useable land in the STAS area. Women account for 25-30% of farmers that acquired farmlands financed under the Affirmative Action Loan Scheme (AfDB, 2006a).
3. *Subsistence farmers in communal areas in Namibia and Botswana*: This group of subsistence farmers (primarily black) falls in the lowest income group and offers the poorest material conditions to farm workers. Subsistence farming mainly occurs in communal areas in Namibia (near Aminius) and Botswana that represent around 15% of the STAS agricultural land, although not all of which is currently being used. In communal land, traditional authorities grant usufruct rights to households for crop production, grazing and access to common pasturage. Rural women gain indirect access through men as wives, daughters and sisters. The security of their tenure is jeopardised by discriminatory marriage customs and inheritance systems (LeBeau et al., 2004). Traditionally, unmarried women have no direct access to property such as land or cattle. Most of communal farmers have but small flocks of goats and sheep, and a few cattle. It is estimated that half of all households have less than 100 goats, more than two thirds have less than 50 sheep, and more than three-quarters of households have less than 10 cattle (Mendelsohn, 2006). Women's unaccounted labour is significant.

21. This section only covers Namibia and Botswana.

22. Some commercial farms exist in Botswana (near Kule), but are not at the scale of the Namibian farms.

23. The resettlement programme is a land reform programme launched by the Government of Namibia after independence aimed at resettling disadvantaged communities on State-acquired commercial farmland.

24. The Affirmative Action Loan Scheme (AALS) is a land reform programme launched by the Government of Namibia after independence aimed at assisting communal farmers to acquire commercial farms through subsidised interest rates and loan guarantees.

Table 6.1 | Numbers of commercial and communal farms in the STAS area
(Source: NAU, 2014; Munyayi, 2015)

			Total area (km ²)	Farmer association affiliation
Commercial farms (Namibia only)	Established	≈1000 farms	≈49 900	80
	Emerging (Resettlement farms and Affirmative Action Loan)	140 farms	≈100	35
	Total	≈1200 farms	≈50 000	N/A
Communal farms (Namibia and Botswana)			≈10 000	25

Table 6.2 | Number of emerging commercial farms per region in Namibia STAS area
(Source: FSP, 2014)

Region	Resettlement farms	Affirmative Action Loan Scheme (AALS)
Omaheke	23	31
Khomas	5	0
Hardap	57	17
Karas	5	2
TOTAL	90	50

Livestock is sold in several ways: at auctions, directly to local buyers, abattoirs and butchers, and on an ad hoc informal basis. Farmers themselves have formed various unions, associations, co-operatives and forums to support their interests. Farmers' affiliation to associations is much higher in established commercial farms (≈80%) than in communal farms (≈25%) (Table 6.1). However, although communal farmers' affiliation to associations is lower, evidence in the field suggests that direct cooperation is higher among communal farmers than commercial ones (Dolberg, 2000 and Thomas et al., 2010).

The two major farmers unions in Namibia are the Namibia Agriculture Union (NAU) and the Namibia National Farmers' Union (NNFU) which represent the interests of commercial and communal farmers, respectively.

The NAU has 70 affiliated local farmers associations throughout the country, and has established a wing for communal farmers associations. No numbers are available on the levels of membership by women in the associations affiliated to NAU, but few women, mostly widows, own commercial farms in Namibia (Partio and Kuhmonen, 2015). In the Namibian segment of the STAS area, affiliated local farmers associations are the Stampriet, Leonardville, and Blumfelde Farmers Association. The Stampriet Farmers Association Organisational Structure is presented in Figure 6.1.

Figure 6.1 | The Stampriet Farmers Association Organisational Structure
(Source: Munyayi, 2015)

<p>It is reported that Stampriet Farmers Association has a total of 52 members and all of them are man.</p> <p>The Association has an executive committee, which includes the following:</p> <ul style="list-style-type: none"> • Chairperson, • Vice chairperson, • Secretary, and • Four members 	<p>Six out of the seven members of the executive committee are man with the exception of the Secretary who is a woman. Important to note, the Secretary is not considered a farmer in her own right but is a wife to one of the farmers. However, during meetings she has an equal opportunity to contribute to the discussions but does not have voting powers.</p>
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The Namibia National Farmers Union (NNFU) is a national federation of regional farmers unions. It was established in June 1992 to serve as a mouthpiece for Namibian communal and emerging farmers. The Namibia National Farmers Union aims to increase food production for household food security, enhance marketing of farming products to increase household income, increase participation and recognition of women in farming, contribute to environmental protection and sustainable utilization of natural resources. NNFU does not have a mandate to provide material support to projects at local village level, but is assisting its development partners (e.g. Food and Agriculture Organisation (FAO) and Germany's Technical Cooperation (GTZ) during implementation of pilot projects in order to demonstrate feasibility and thereafter hand over to local farmers organizations for further implementation. NNFU Organisational Structure is presented in Figure 6.2.

Figure 6.1 | The Namibia National Farmers Union (NNFU) Organisational Structure
(Source: NNFU)



Women comprise an estimated 30-60% of the NNFU affiliate associations. In terms of geographical representation in the STAS area, NNFU members are largely in the southern part of Gochas, Amberbos, Kries, Hoachanas, and Aminuis areas. Women comprise an estimated 30-60% of affiliate associations. In the NNFU Hardap region membership is predominantly male (ratio of 88% male to 12% female). The NNFU members in the STAS area are largely engaged in small stock farming but however there are aspirations to move to irrigation farming. The major limiting factor is access to land ownership, capital to finance operations and equipment to support irrigation farming. The current sources of water for small stock are boreholes in the communal areas. In Botswana, the major farmers associations within the STAS area are the Ghanzi Farmers Association and the Small Stock Farmers Association.

6.1.2 Households demographic characteristics

Most households in the STAS area are headed by men (Table 6.3) who are generally the main income contributor and responsible for planning and managing the farming processes and how the cash earnings are spent (Table 6.5). The number of men headed households could actually be higher because the eldest person (e.g. widow) in the household is usually reported as the head although other members have actually taken over the decision-making within a household.

It is estimated that the sale of animals constitute the main source of cash income in commercial and communal farms. In settlements, about one-third of households rely on pensions as the predominant source of income, about one-third stated wage employment as the major source of income, and about one-third are unemployed (Table 6.3). The majority of the household heads,²⁵ who are government employees, reside in the settlements, where an adequate infrastructure exists. The majority of pensioners (60%) reside in rural areas, as do the majority of household heads who are not formally employed. Women are primarily smallholders engaged in subsistence agriculture in communal areas, who often work as unpaid labourers on family fields. Paid farm workers (manly for land preparation, cattle herding, fencing ...) are predominantly men, and about 20% of all farm workers are women. Most women (80%) are employed as domestic workers, mostly on established commercial farms. Most farm workers (93.5%) are employed on a full-time basis throughout the year and generally live in the farms they work (Karamata, 2006). On established commercial farms, men and women farm workers have quite similar hourly wages (\approx N\$ 5,50 per hour) (Karamata, 2006; NAU, 2014). On average, working weeks for men range between 46 to 49 hours, while women generally have a working week of 35 hours. Workers on emerging commercial farms work for 40 hours and get slightly less than workers on established commercial farms (\approx N\$ 5 per hour). On the other hand, workers on communal farms work for 35 hours and get slightly more than the minimum wage (\approx N\$ 4 per hour) (Karamata, 2006).

On average, women headed households own fewer livestock and are more likely to own no cattle at all. There are still several legal factors that constrain women's land tenure (e.g. customary vs common law in property matters, "property grabbing") (LeBeau et al., 2004). For instance, traditionally, women have no direct access to property such as land or cattle in Namibia and Botswana (Ipinge and LeBeau, 2005 and Alexander et al., 2005). There are however evidences that political reforms and legislation have increased women's access to land and livestock in many Namibian communities as women account for 25-30% of farmers that acquired farmlands financed under the Affirmative Action Loan Scheme and 37% of beneficiaries of livestock purchases loans (AfDB, 2006a).

25. Head of household is considered as the person of either sex who is a member of the household and generally runs the affairs of the household and is looked upon by the other members of the household as the main decision maker (NSA, 2015).

Table 6.3 | Characteristics of settlements, commercial and communal farms in the STAS area (Sources: MAWRD, 1994; IFAD, 1996; AFDB, 2006a; Karamata, 2006; Munyayi, 2015)

	Men	Women	Settlements	Established commercial farms	Emerging commercial farms	Communal farms
Population (%)			49.5		60	
	Men	Women	50.5		40	
Household Head/Land ownership (%)	Men	Women	50-60	80-90	70-75	80
	Men	Women	40-50	10-20	25-30	20
Livestock ownership (%)	Men	Women	60	80-90	70-80	70
	Men	Women	40	10-20	20-30	30
Income activity²⁶ (%)	Men	Women	Self-employed: 30 Employed: 30 Government (including pension): 30 Unpaid (unemployment): 20	Employer: 10-15 Farm worker (paid): 70-80 Unpaid: 0-10 Other: 0-5	Employer: 30-40 Farm worker (paid): 40-50 Unpaid: 10-20 Other: 0-5	Farm worker (paid): 5-10 Government (including pension): 45-50 Unpaid (subsistence): 30-40 Other: 0-10
	Men	Women	Self-employed: 10-20 Employed: 15-25 Government (including pension): 30 Unpaid (unemployment): 20-30	Employer: 0-5 Farm worker (paid): 70-80 Unpaid: 10-20 Other: 0-5	Employer: 10-20 Farm worker (paid): 20-40 Unpaid: 40-45 Other: 0-5	Farm worker (paid): 0-5 Government (including pension): 30-35 Unpaid (subsistence): 50-60 Other: 0-10
Farm workers paid employees (%)	Men	Women	N/A	70-80	90	N/A
	Men	Women	N/A	20-30	10	N/A

26. Only considers people on working age (>15 years).

6.2 Stakeholder involvement in sub-national water governance

6.2.1. Basin scale

There are no formal water governance structures for the planning and management of water resources at basin scale. It was reported that the Ministry of Agriculture Water and Forestry in Namibia has plans underway to establish the Nossob-Auob Basin Management Committee (the STAS falls within the Nossob-Auob Basin). The Basin Management Committee (BMC) would be a formal body of stakeholder institutions elected as representatives on the stakeholder forum. It would represent the interests of the various stakeholder groups on the forum and provide feedback to them on the activities it plans and executes to address prioritized issues, challenges and ongoing efforts pertaining to effective water resources management in the basin. The BMC would facilitate the process to take issues to relevant higher authorities and help source funding to address some challenges. Some members of the BMC would have portfolios to lead specific activities. These portfolio-holders would also be referred to as the Executive Committee.

6.2.2. Local level²⁷

The eight constituencies located within the four regions (!Karas, Hardap, Khomas, and Omaheke) on the STAS area in Namibia have limited influence with regards to groundwater governance. Many aspects of groundwater governance are either centralized at regional councils level or at local level in settlements. At the community level, there are Water Point Committees in the rural parts of the STAS that manage and control water provided through Department of Water Affairs and Forestry infrastructure. The Water Point Committees are mainly engaged in maintenance, control of water access and collection of water use fees (Conti, 2016).

The Aranos town council, Leonardville, Gochas, and Stampriet village councils are directly responsible for the operation and maintenance of the supply distribution network and the maintenance of the communal water standpoints. In the case of Hoachanas and Kries settlements, the Hardap Regional Council is responsible for the maintenance of the communal water standpoints. For this reason, the town and village councils do not have dedicated water governance structures where users can contribute to the planning and management of water and sanitation service delivery exclusively.²⁸

Town and village level consultations on water, sanitation and hygiene (WASH) services are done by elected councilors. The three local authorities in the study area have more women represented in council (59%) compared to men (41%) as shown in Table 6.4. Thus it can be implied that women in the three local authorities have a fair opportunity to participate in decision making processes and have roles to play in the planning and provision of water and sanitation services for the three local authorities.

27. Information from Botswana and South Africa is originally from Conti, K.I. (2016): Supplementary Study on Groundwater Governance in the Stampriet Transboundary Aquifer System.

28. For this reason, the town and village councils do not have dedicated water governance structures where users can contribute to the planning and management of water and sanitation service delivery exclusively.

Table 6.4 | Women and men representation in local Councils of the STAS area in Namibia

Settlements	Women Councilors	Men Councilors
Aranos	3	4
Gochas	4	1
Stampriet	3	2
Hochanas	N/A	N/A
Kries	N/A	N/A

Residents in towns and villages usually engage with councilors and the village council executive management at public hearings. These hearings are aimed at discussing developmental concerns; water and sanitation included. However, in recent years (2014/2015) these meetings have not been held regularly. Elderly female residents usually attend the meetings and both male and female residents participate actively and have an equal opportunity to influence decisions and outcomes. No minutes from previous meetings were available at the time of the study to ascertain the percentage of decisions adopted from women's contributions in meetings.

In the case of settlements, users are represented through the Settlement Development Committee. In Hoachanas representation includes communities, traditional authorities, churches, farmers and selected government ministries. Kries settlement was declared a settlement in October 2014 and at the time of the assessment the Settlement Development Committee had not been established.

The local authorities and settlements involved in the study did not have gender-specific objectives or gender strategies to guide their operations. However, it was reported that the National Development Plan 4 (NDP4), which has explicit gender goals and commitments, guides local authorities and settlements. The National Planning Commission (NPC) is responsible for measuring the extent to which the local authorities and settlements are progressing in terms of meeting set gender goals and targets.

Furthermore, the local authorities and settlements involved in the study did not have gender outcomes and gender-sensitive accountability indicators included in monitoring and evaluation frameworks. However, for capital projects it was reported that there is a deliberate effort to include women, men, the youth and people living with disability. The capital project identification form has clear gender considerations and indicators. For example, the Stampriet Water and Sewerage reticulation project which started in 2013/2014 financial year reports every quarter to the National Planning Commission on the number of men, women, youth and people living with disability that would have benefited in terms of employment.

In Botswana, at the district level, the Ghanzi and Kgalagadi Districts Councils oversee and approve activities of authorities such as the Department of Water Affairs (DWA), Water Utilities Corporation (WUC), Land Board, Department of Environment and Department of Agriculture. In Ghanzi, these authorities and others are part of an interdepartmental Land Use Planning Committee that makes recommendations to the District Council regarding proposed projects and initiatives (Conti, 2016).

In villages and settlements within the STAS area, the most relevant actors in groundwater governance include the WUC borehole operators, borehole syndicates and farmers' associations. Based on field observations and interviews there were not active borehole syndicates in town of Kule, Ncojane or Metsimantle. There were farmer's associations actively managing groundwater in Kule and Ncojane. It is possible that borehole syndicates are operating in the communal lands, north of the KTP boundary in the Kgalagadi district. The borehole operators manage the well(s), pump(s), and water tanks for domestic water supply; ensure operation of the main distribution network, water meters and service points; and

provide education as deemed necessary by the WUC. Borehole syndicates and farmers associations, alike, manage community wells that have been installed either by the communities themselves or the DWA. Borehole syndicates are typically for domestic supply and subsistence agriculture, while farmers' associations are for livestock watering. Both entities are composed of elected officials who are responsible for maintaining the infrastructure, collecting payment for uses, and observing changes in quality and/or yield. There are no borehole syndicates and one active farmers association in the Ghanzi district. In Kule, it was also reported that subsistence cattle farmers will also informally manage and cooperate to supply water for cattle. It is unknown if these entities or practices exist in the communal lands of the Kgalagadi District (Conti, 2016). Almost all boreholes in Botswana are owned by men.

Groundwater management within the Kgalagadi Transfrontier Park (KTP) is under the auspices of the Departments of Environment of Botswana and South Africa. Boreholes on the Botswanan side of the park are only for the purpose of attracting animals - tourists must bring their own water supplies. While in South Africa, boreholes are both for animals and tourist facilities. In Botswana, maintenance and monitoring is conducted by park staff and there is little interaction with the Botswana DWA in this regard. However, newer boreholes are drilled in consultation with the DWA. Nevertheless, the Department of Environment indicated an interest in establishing partnership with DWA for managing groundwater in the park and also drilling additional boreholes to make limited supply available to tourists. On the South African side, the staff conducts weekly water level monitoring and facilities checks, albeit using rudimentary yet affordable equipment (see Figure 6.3). The Northern Cape Province regional office of the Department of Water and Sanitation also conducts routine monitoring of water levels and quality. There is a Joint Management Board composed of the Department of Environment for both countries, and the Khomani San indigenous community and the Mier municipal authority from South Africa. The committee makes decisions about park operations including issues of water management, although water regulators are not included in the committee (Conti, 2016).

Figure 6.3 | Water gauge used in the Kalahari Transfrontier Park (Picture by K. Conti, 2015)



6.2.3. Intra-household level²⁹

It has been estimated that about 50% and 20% of households in settlements and rural areas, respectively, in the STAS area are headed by women. Around 70% of the population were found to be poor, but rural women headed households (WHH) are no poorer than men headed ones (MHH). This can be explained partly by the fact that many of the WHHs are de facto (and often) seasonal WHHs. Men and boys from such households may be away working or hunting. Some designated WHHs are composed of a widowed mother living with her married son and his family. In such instances, the married son will often designate his mother as head of the household out of respect, which does not mean that she has major decision-making power (IFAD, 1996).

The decision-making structure at household level in settlements and rural areas are quite different. While women and marginalized groups tend to be under-represented in the leadership and decision making of structures in rural areas (e.g. the functions and management in commercial farms and communal land - Traditional Authorities and Executive Committees), responsibilities on how cash earnings are spent (e.g. children education, furniture, utensils and family equipment) are made by men and women together in settlements (Table 6.5).

In rural areas, men considered themselves to have overall responsibility for livestock and commercial crops, but also to be the primary decision-maker and financial controller. They were generally responsible for looking after the livestock, watering the livestock, and fixing things around the house. Men were also responsible for preparing the fields for crop cultivation at sites where crops were grown. Women usually contribute to housekeeping, child care, cooking, and small-scale subsistence food production for their families through back yard gardening.

Table 6.5 | Decision-making structure at household level in the STAS area
(Sources: MAWRD, 1994; IFAD, 1996; AfDB, 2006a; Karamata, 2006; Munyayi, 2015)

		Settlements	Commercial farms	Communal farms
Decision making on livestock and crop production (%)	Men	N/A	70-80	60-65
	Women	N/A	0-5	0-5
	Both	N/A	5-10	15-20
	Other	N/A	0-5	15-20
Decision making on how cash earnings are spent (%)	Men	25	60-65	70-75
	Women	15	10-15	0-5
	Both	60	10-20	15-20
	Other	N/A	0-10	5-10
Decision making on water use and monitoring (%)	Men	15-20	N/A	10-20
	Women	60-70	N/A	70-80
	Both	10-15	N/A	N/A
	Other	N/A	N/A	N/A

The responsibility of food production and preparation and the overall wellbeing of the household generally fall on women. Women or mothers are the ones responsible for monitoring water quality once water is home (> 70% of respondents). Women and girls constitute more than 70% of the workforce that fetch water and collect firewood. Fetching water is primarily a female task given that 36% of rural households letting their daughters fetch water compared to versus only 15% who assign the task to sons (AfDB, 2006b). On average, women spend 2 hours more per day more than men in reproductive labor (AfDB, 2006b).

29. This section only covers Namibia and Botswana.

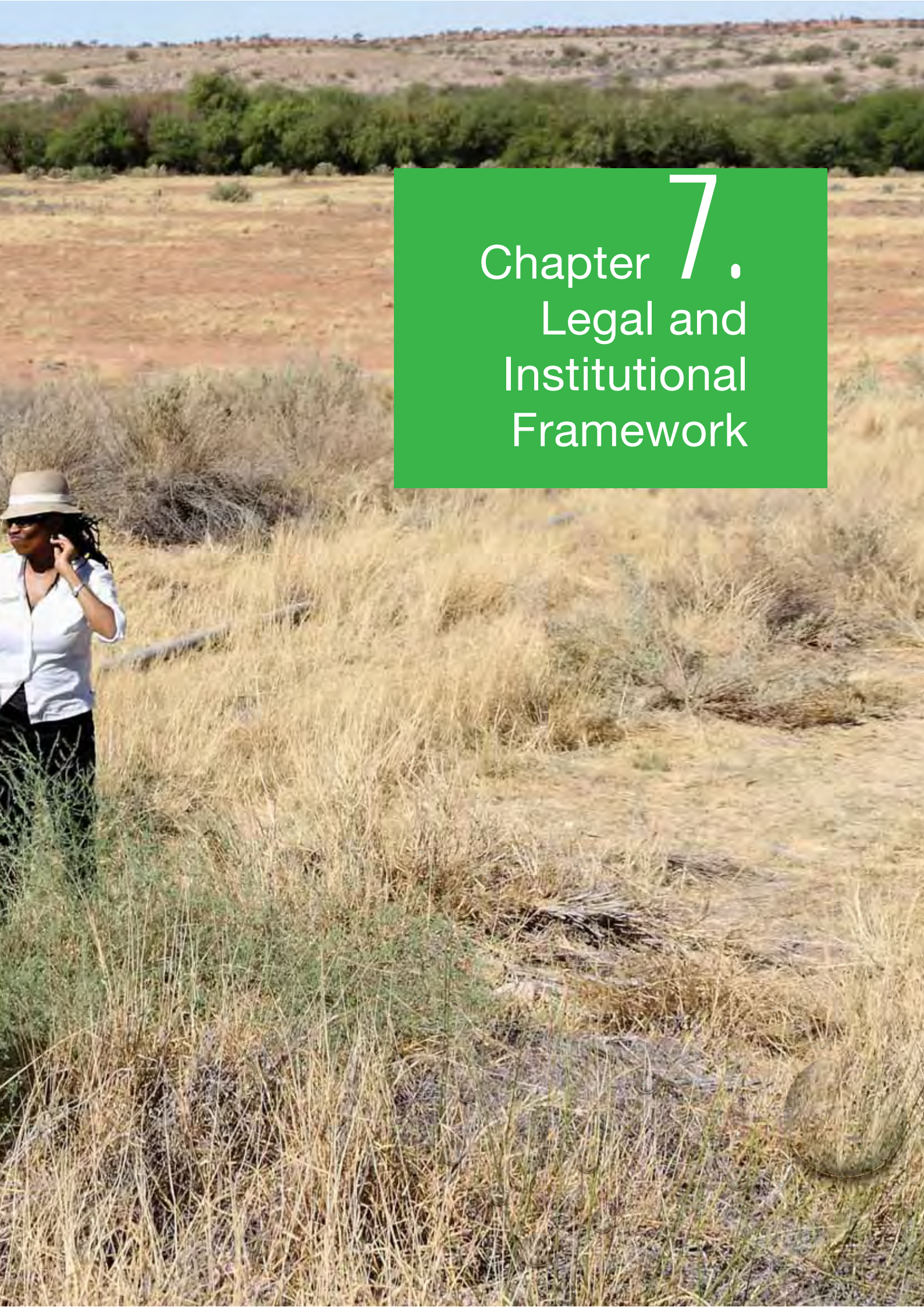
In the absence of household water connections in settlements informal areas, the burden of collecting water to meet the household water needs from the communal standpipes lies with women and girls which expressed dissatisfaction with the distance travelled to access water. Although most households have access to potable water in the areas under study, the distances travelled by households without indoor piped water varies between zero and two kilometers per day (Table 6.6). In the absence of functional communal water standpipes women and children spend at least 30 minutes queuing for water. In communal areas, the average distance travelled per day by households to fetch water is about six kilometers (MAWRD, 1994).

Interesting to note was that households with secure water connections within their homes prefer the prepaid token system instead of being billed at the end of the month. Ninety five percent of both men and women expressed the prepaid token system would allow them to manage their water use in line with their finances thus reducing water cuts as a result of non-payment.

Table 6.6 | Average distance travelled per day by households to fetch water in the STAS area

	Settlements	Commercial farms	Communal farms
Average distance to fetch water per day (km)	0-2	N/A	6



A woman wearing a white button-down shirt, dark pants, and a light-colored hat is walking through a field of tall, dry grass. She is holding a phone to her ear. The background shows a vast, open landscape with sparse vegetation and a clear sky.

Chapter 7.

Legal and Institutional Framework

This chapter deals with the legal and institutional framework in place regarding the Stampriet Transboundary Aquifer System (STAS). Such framework is analyzed and assessed from two separate but complementary perspectives, i.e., the transboundary perspective of the three STAS countries taken together, and the domestic perspective internal to each STAS country taken separately. The analysis and assessment presented in this chapter have been partly guided by an original indicator-based legal and institutional assessment methodology developed by the GGRETA project³⁰.

This chapter is divided into two parts given over to, respectively, the transboundary and the domestic legal and institutional frameworks in place for the STAS. Following the illustration, analysis and assessment of such frameworks, conclusions are drawn and action-oriented recommendations are put forward, separately as regards the transboundary and the domestic legal and institutional frameworks.

7.1 Status and assessment of the transboundary legal and institutional framework of relevance to the Stampriet Transboundary Aquifer System (STAS)

The assessment is aimed at establishing whether there is an enabling environment for cooperation in the management of the Stampriet Transboundary Aquifer System (STAS). It is based on an analysis of core indicators:

1. existence and comprehensiveness of bi- or multi-national level agreements/treaties, specific to the STAS;
2. existence and comprehensiveness of non STAS-specific agreements/treaties, or other non-binding instruments, of relevance to the STAS.

The comprehensiveness of the legal instruments surveyed is assessed in terms of the inclusion of the following:

- water utilisation/abstraction/well drilling
- water pollution control
- settlement of disputes
- institutional arrangements
- other matters such as environmental protection and preservation, prevention of harmful effects, data exchange, prior notification of planned measures, emergency situations.

7.1.1. Relevant legal instruments

The Governments of Botswana, Namibia and South Africa signed the Revised SADC Protocol on Shared Watercourses on 7 August 2000 in Windhoek, Namibia. The objective of the Protocol is to “foster closer cooperation for judicious, sustainable and coordinated management, protection and utilization of shared watercourses and advance the Southern African Development Committee (SADC) agenda of regional integration and poverty alleviation”. The Protocol defines a watercourse as a “system of surface and ground waters consisting by virtue of their physical relationship a unitary whole normally flowing into a common terminus such as the sea, lake or aquifer”.

³⁰. Such methodology has been published separately. In view of the work-in-progress nature of the methodology at the time of its application to the STAS case, the outcome has not been appended to this report.

Following the signing of the Protocol, the Governments of Botswana, Lesotho, Namibia and South Africa formalised the Orange-Senqu River Commission (ORASECOM) through the signing of the 'Agreement for the Establishment of the Orange-Senqu Commission' on 3 November 2000 in Windhoek, Namibia.

The revised SADC Protocol on Shared Watercourses and the ORASECOM agreement are holistic instruments providing a legal basis for the management of transboundary waters (inclusive of surface and hydraulically linked underground waters). There are no specific transboundary aquifer legal instruments in the SADC region.

At the global level, the 63rd session of the UN General Assembly (UNGA) in 2008 adopted Resolution 63/124 on the Law of Transboundary Aquifers by consensus, i.e., without a vote. The resolution encourages the States concerned to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers, regardless of whether they are hydraulically linked to a surface water system or not. The resolution has no binding effect, however its endorsement by States constitutes evidence of their adherence to the basic norms of inter-State behaviour in relation to transboundary aquifers.

7.1.2. Analysis and assessment of the existing international legal instruments for the STAS

At present, there is no legal instrument that is specific to the management of transboundary aquifers, both at the regional SADC level and regarding specifically the STAS. However, groundwater is integrated into the Revised SADC Protocol on Shared Watercourses, to the extent that it is hydraulically linked to a surface watercourse "flowing to a common terminus". To some extent, groundwater is also integrated in the ORASECOM agreement. However the agreement carries oblique references only to groundwater: in Art. 5.2.1, where mention is made of "the safe yield of the water resources of the River System", in connection with the advisory function of the Council to the countries, and where the term "safe yield" is usually associated with groundwater in an aquifer, and has therefore a distinct groundwater connotation; and in Art.7.4, where mention is made of "hydrogeological" data among the data that the countries are obligated to exchange. Moreover, the agreement carries no definition, however it is understood and accepted that the term "River System" refers to both surface and (presumably hydraulically connected) groundwater. Table 7.1 below provides a summary assessment of the comprehensiveness of the two above-mentioned legal instruments, measured by the parameters mentioned earlier, under 7.1.

Table 7.1 | Assessment of completeness of the legal instruments

Non specific instrument	Parameters				
	Utilisation	Pollution control	Settlement of disputes	Institutional arrangement	Other
Revised SADC Protocol	✓	✓	✓	✓	✓
ORASECOM Agreement	✓	✓	✓	✓	✓

A tick implies that provision on the subject is made in the legal instrument

With the above caveats and limitations, both instruments include the necessary set of provisions that make them adequate to creating an enabling legal environment and a basis to build from and upon, to institutionalize cooperation in the management of the STAS.

7.1.3. Analysis and assessment of the existing inter-State institutional arrangements for the STAS

Similar to the international legal instruments, there is no inter-State institution with a specific mandate for the STAS. However, the SADC Water Division and ORASECOM have comprehensive mandates that are relevant to the STAS. These include:

- data collection, exchange and monitoring
- utilization and allocation of TBA waters
- protection of TBA waters from pollution
- resolution of disputes.

The above notwithstanding, the reach of the SADC Water Division and that of ORASECOM to transboundary groundwaters which have no hydraulic connection to a surface watercourse system in general, or to the Orange-Senqu River basin in particular like, notably, the STAS, remains an open issue in the light of the limiting language in the relevant legal instruments, noted earlier.

SADC Water Division

The Southern African Development Community (SADC) has a Water Resources Management and Sanitation unit (commonly known as the SADC Water Division) under the Infrastructure and Services Directorate. The Division oversees harmonisation of national water policies and promotes transboundary water management principles.

The Division implements programmes and projects that support its guiding policy, strategy, and regulatory framework, i.e., the Revised SADC Protocol on Shared Watercourses. Two notable projects that SADC implemented on groundwater management are:

1. the SADC Groundwater and Drought Management Project, and
2. the SADC Groundwater Grey Data Project

A Senior Project Officer supported by two Project Officers heads the Division.

The Orange-Senqu River Basin Commission (ORASECOM)

ORASECOM was established to promote equitable and sustainable development of the resources of the Orange-Senqu River basin, including by implication groundwater. Whether ORASECOM's responsibility is limited to groundwater in aquifers having a hydraulic connection to the Orange-Senqu river system, or whether it extends to groundwater in deep aquifers that have not direct connection with the Orange-Senqu River basin, remains an open question. Be that as it may, the Commission division dealing with groundwater has been revived. The ORASECOM agreement is in line with the Revised SADC Protocol on Shared Watercourses. It provides a forum for consultation and coordination between the riparian states to promote integrated water resources management and development within the basin. The goals of ORASECOM are to:

1. develop a comprehensive perspective of the basin
2. study the present and planned future uses of the river³¹ system
3. determine the requirements for flow monitoring and flood management.

ORASECOM Organisational Structure is presented in Figure 7.1.

³¹. River system refers to the entire Orange-Senqu River System (including groundwater by implication)

Figure 7.1 | ORASECOM Organisational Structure (Source: ORASECOM)

<p>Structure of ORASECOM³²</p> <p>ORASECOM is structured into a Council, a Secretariat and Task Teams.</p> <p>Council</p> <p>The highest body of ORASECOM is the Council, which is supported by a Secretariat and a series of Task Teams that manage projects. The Council serves as technical advisor to the Parties on matters related to the development, utilization and conservation of the water resources of the basin. The Council consists of delegates from each of the four member states. The delegates are comprised of three representatives from the respective government agencies responsible for water affairs.</p> <p>Secretariat</p> <p>The Secretariat is hosted by the Republic of South Africa, in accordance with an agreement signed by the member states. The Secretariat's role in programme coordination and management includes the following functions:</p> <ul style="list-style-type: none"> • coordinate ORASECOM activities and implement ORASECOM decisions • serve as a repository of information related to the Orange-Senqu River basin 	<ul style="list-style-type: none"> • act as a focal point for ORASECOM with all external parties • perform ORASECOM administrative functions • conduct communication and promotion for ORASECOM • programme and project development and management • resource mobilisation. <p>Technical Task Teams</p> <p>Task teams are established by the Council and consist of representatives from the member countries. The task teams undertake tasks delegated by the commission including:</p> <ul style="list-style-type: none"> • communications • financial • legal • technical (including hydrogeology). <p>The Technical Task Teams may establish committees for technical input. These committees provide advisory support to the Task Teams; hence they report directly to Task Teams and not to the Council. A hydrogeology committee exists and operates under the Technical Task Team in charge of technical matters.</p>
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7.1.4. Conclusions and recommendations

There is no legal instrument that is specific to the management of transboundary aquifers, both at the regional SADC level and regarding specifically the STAS. Moreover, transboundary groundwater in general is integrated into the Revised SADC Protocol on Shared Watercourses, but only to the extent that it is hydraulically linked to a surface watercourse “flowing to a common terminus”. Groundwater is also integrated in the ORASECOM agreement, however only indirectly. Moreover, it is unclear whether the reach of the ORASECOM agreement as regards groundwater extends to all aquifers, or only to those which are hydraulically connected to the Orange-Senqu River system. The net result is that extractions of groundwater from the STAS, and the protection of the STAS groundwater resources from pollution, may not, after all, come within the purview of the general norms contained in the SADC Protocol and in the ORASECOM agreement in view of the STAS being unconnected hydraulically to the Orange-Senqu River.

The study is a desk top study and it is thus clear that there are gaps that have been identified and the only way to cure this is by understanding further investigations. There is a clear need to predicate any response to the challenges ahead of the STAS on a firmer institutional footing first, through a *multi-country cooperation mechanism* for STAS. Such mechanism could pave the way for the development of a set of STAS-specific rules of inter-State behaviour, should the need for such rules arise, and for a STAS-specific agreement crystallizing such rules, eventually.

32. From <http://www.orasecom.org/about/structure.aspx>

7.2 Status and assessment of the domestic legal and institutional frameworks of relevance to the STAS

7.2.1. Botswana

Policy and legal framework

Botswana has a policy and legislative framework for water resources management. Although there is no specific provision in the laws of Botswana providing for the protection and management of groundwater resources, the 1968 Water Act carries an expansive definition of water resources, which specifically includes groundwater.

The legal and regulatory framework for groundwater abstraction and use in Botswana is substantial to provide a reasonable reference point for purposes of abstraction and usage. However, implementation and enforcement are lagging. The charges for water abstraction and use in Botswana have been up to now purely for administrative purposes.

The Water Act makes provision for licensing of water abstraction and use. Licenses are valid for a specified period and may be subjected to conditions by the Minister responsible for water resources. Pollution of public water is an offence if wastewater is discharged without the permission of the Water Registrar. The penalties for non-compliance are outlined in the Act. These comprises of fines and/or imprisonment. Pollution control in the Water Act includes provisions for both point and non-point source pollution. Potential impacts of land use on water resources are controlled through the Environmental Impact Assessment Act and the Town & Country Planning Act.

Institutional framework

According to the 1968 Water Act, the State owns all water resources. The State has delegated water user and development rights to various stakeholders:

- The Water Utilities Corporation (WUC) has the duty to provide safe drinking water to all parts of the country. WUC is a monopoly. The WUC has to break even, i.e. charge the full resource costs to end-users.
- The District Councils (DCs) used to operate and maintain the water supply systems in all rural villages, usually through the Water and Sanitation Division but this has now been moved to the Water Utilities Corporation;
- Users, including livestock owners, farmers and mining companies that operate outside villages and settlements. Users must obtain surface or groundwater rights from the Water Apportionment Board (WAB).
- WAB grants abstraction rights with an abstraction ceiling and the duty to return as much water as possible of the original quality back to the system it was abstracted from. Details of boreholes (e.g. yields, depth, water quality etc.) are recorded in the National Borehole Registry.

7.2.2. Namibia

Policy and legal framework

In Namibia groundwater management is incorporated into the existing national policy, legislative and planning environment for water resources. Therefore, there is no distinct policy, legislative and planning framework for groundwater management.

Groundwater is public property, with control vested in the State. The Water Resources Management Act (Act no. 11 of 2013) makes provision for control and protection of water resources from over-abstraction and pollution through a licensing system. The Act has a detailed chapter on control and protection of groundwater.

The water legislation is however not supported by up to date regulations as these are still being drafted. In the absence of regulations, control and protection of groundwater resources is governed by the 'Regulations in respect of subteranean water control areas of South West Africa 1971'.

The existing regulatory framework for groundwater abstraction and use is reasonably adequate. No evidence of sanctions having been applied is available, making it difficult to assess the level of enforcement. It is also not clear whether the charges for water use licences are administrative or if they are in support of the User Pays Principle. The latter seems less likely because the concept of User Pays Principle is not observed anywhere in the legislation and regulations.

Similar to water abstraction, discharging of wastewater is controlled through a permit system. Permit holders are responsible for reporting to the Department of Water Affairs and Forestry on adherence to conditions. The Department of Water Affairs and Forestry also does periodic inspections of wastewater quality that is discharged by permit holders. The Polluter Pays Principle is not explicit in the Act although there is a statement highlighting "that a polluter is held liable to pay all costs to clean up any intentional or accidental spill of pollutants". The Act is also silent on regulations on contamination of closed/unused wells.

Management of the STAS is especially provided for, as the aquifer is declared as a "water protection area" under the Water Resources Management Act 2013. An area is declared a water protection area in order to protect and enhance the water resources or its habitat against risks of significant changes to resource quality, depletion, contamination, extinction or disturbance from any source. Regulatory enforcement within water protection areas is expected to receive due attention.

Other than the Water Resources Management Act 2013 that is focused on freshwater, Namibia also has an Environmental Management Act (EMA), which aims at promoting sustainable management of the environment and use of natural resources. The Environmental Management Act is broad; it regulates land use development through environmental clearance certification and/or Environmental Impact Assessments. The Act provides for clearance certification for surface or groundwater abstractions for industrial or commercial purposes in order to protect water resources.

Despite the favourable policy and legislative situation, implementation and enforcement is incomplete due to the absence of regulations that respond to the revised/updated legislation. Critical water regulations must still be formulated. No records on punishment for violations of groundwater abstraction/use and discharge have been detected. It is reported that permit holders are engaged during monitoring and review of permits to rectify irregularities.

Institutional framework

The State, in its capacity as owner of the water resources of Namibia has the responsibility to ensure that water resources are managed and used to the benefit of all people in accordance with the Water Resources Management Act 2013. This responsibility is delegated to the Minister of Agriculture Water and Forestry. The Minister's functions relate to control, conservation and use of water for domestic agricultural, urban, and industrial purposes. The Department of Water Affairs and Forestry within

the Ministry of Agriculture Water and Forestry has two Directorates: the Directorate of Resource Management and the Directorate of Water Supply and Sanitation Coordination.

The Directorate of Resource Management has five Divisions: Water Policy and Law Administration, Planning, Hydrology, Geohydrology, Water Environment and Basin Management. All except Hydrology are involved in groundwater management and administration.

The Geohydrology Division was specifically established with a mandate on groundwater investigations, monitoring and control. It works closely with Water Policy and Law Administration on licensing. A Deputy Director heads the Division. It is divided into 3 subdivisions, namely: Groundwater Management, Investigations and Maintenance Support. It has about 44 established posts. These staff members work across the entire country. The Water Environment Division deals with all water quality and water environment matters.

Groundwater management is not decentralised to regional/basin level. Provision is however made for stakeholders to organize themselves into basin management committees. The role of a basin management committee is to advise the Directorate on water resources management. Where basin management committees are established, the Directorate of Resource Management provides information and technical support. Basins with committees have a government-paid Basin Support Officer and are allocated staff from central government, depending on the water resources issues. Currently, there is no Basin Management Committee for the STAS.

Water Point Committees may be established at local level for maintenance, control of water access and collection of water use fees of rural water points. Water Point Committees have a management and control function of water supply and not so much of a resource management function.

7.2.3. South Africa

Policy and legal framework

The Republic of South Africa (RSA) has a sound legislative framework that ensures that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways that ensure sustainability for its citizenry, those in the neighbouring states and for global obligations. Ownership and control of groundwater is vested with the State, in terms of the National Water Act, 1998, (Act 36 of 1998 ("the NWA")) supported by several policies and strategies. The National Water Resources Strategy is a five-year plan dealing with water planning for the entire country, and issues of groundwater also find application in there and the Groundwater Strategy 2010. The Minister of Water and Sanitation is the custodian of water resources in the country.

Groundwater abstraction requires the granting of water use licences. Licences are time-bound, charges are levied and conditions are imposed on licences. Licences may be reviewed and amended, as the case may be, and may be suspended and withdrawn for non-compliance. Conditions regarding changes on the quantity and/or quality of a resource may also be imposed on licenses.

Any licensee who does not comply with any condition attached to a licence and/or unlawfully discharging waste or water which cause or has the potential to cause pollution or physical degradation to groundwater is issued with a penalty. This usually takes the form of the issuing of a directive (notice) to the licensee or to any person responsible for pollution to remedy the effects of pollution or physical

degradation, within a specified period in terms of Sections 19 and 53 of the NWA. Failure to act in accordance with a directive may result in the licence being suspended and/or withdrawn for non-compliance. The affected party is entitled to appeal the issuing of a directive to the Water Tribunal in terms of Section 148 of the NWA. The Water Tribunal is an independent body established in terms of section 146 of the NWA.

In addition to the NWA, the National Environmental Management Act, 1998 (NEMA) and the Mineral and Petroleum Resources Development Act, 2002 (MPRDA) also deal with practices and/or activities impacting on groundwater, as well as with the interface between groundwater and land use, including activities of the mining industries impacting on the quality of ground water. Chapter 3 of the NWA deals with the protection of water resources and lays down a series of measures to ensure the comprehensive protection of all water resources in the country. Section 19 of this Act deals with pollution prevention and a situation where pollution of a water resource occurs as well as holding those responsible for water pollution to pay and remedy the effects of pollution as well as measures to prevent pollution. Section 2(4)(a)(ii) of NEMA requires that all relevant considerations should be taken into account to ensure that pollution and degradation of the environment are avoided or minimized and remedied. The Act also advocates that those responsible for harming the environment should be held liable for the costs of remedying pollution, degradation of the environment as well as preventing, controlling or minimizing further pollution.

Section 43(5) of the Mineral and Petroleum Resource Development Act, 2002, stipulates that no Closure Certificate may be issued unless the Department of Water and Sanitation has confirmed in writing that the potential pollution to water resources has been addressed. Section 107 of the same Act, empowers the Minister of Minerals and Energy to make regulations regarding the prevention, control and combating of pollution, including pollution of groundwater, where such pollution is connected to mining operations.

The violations of the groundwater extraction and of the wastewater discharge legislation are punished, and the relevant records are available and accessible. There are records for licences issued (and reviewed, suspended or terminated) and they detail the number of licences issued, of enforcement proceedings and of criminal cases reported. The Directorates of Water Use Authorisations and of Compliance Monitoring and Enforcement are the custodians of the records for water use licences and violations, respectively. There are also records of pre-directives and directives issued for non-compliance with the conditions of licences and for violations, as well as the cases lodged, both with the Water Tribunal as per the NWA and the High Courts. The levels of successful prosecutions are however relatively low.

The provision of and access to water are legislated in terms of the NWA. In terms of the Act, the Minister of Water and Sanitation is the custodian of water rights in the country and as a result, customary law does not find application. However, Schedule 1 of the NWA makes provision for permissible uses of water without a licence, subject to conditions. In practice, this provision will likely legitimize customary practices and smallest-scale, subsistence water users in the rural areas.

Institutional framework

The State, acting through the Minister of Water and Sanitation, is the custodian of the nation's inland water resources, and must ensure that the country's water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all. The Minister,

through the Department of Water and Sanitation (DWS), is responsible for ensuring that water is allocated equitably and used beneficially in the public interest, and for regulating the use, flow and control of all water in the RSA.

The DWS Regulations Branch has two Chief Directorates, namely, the Water Use Authorisations Directorate and the Compliance, Monitoring and Enforcement Directorate, which are responsible, respectively, for the issuing of licences and for monitoring compliance with the relevant terms and conditions, including enforcement of such conditions as well as the suspension and termination of licences in cases of non-compliance.

The Directorate of Surface and Groundwater Information is responsible for the establishment and maintenance of surface flow and groundwater information programmes, including groundwater monitoring and assessment. The Chief Directorate of Water Resource Planning Systems is responsible for water resources availability, planning and development. The Chief Directorates of Classification and Reserve Determinations are responsible for water resources classification, and for determining the water “reserve” for priority purposes respectively, i.e., for the supply of drinking water, and for environmental conservation.

All these Directorates are also responsible for legislative, policy, strategy developments and guidelines. Other institutions are the Catchment Management Agencies (CMAs) responsible for water resource management in their jurisdictions, including groundwater resources. Furthermore, the following organizations are also engaged with water resources, viz, the Water Research Commission (WRC), the Council for Scientific and Industrial Research (CSIR), the Council for Geoscience (CGS) and the Water Institute of South Africa (WISA). All these organizations are formed by different legislative frameworks and perform different functions.

7.3 Conclusions

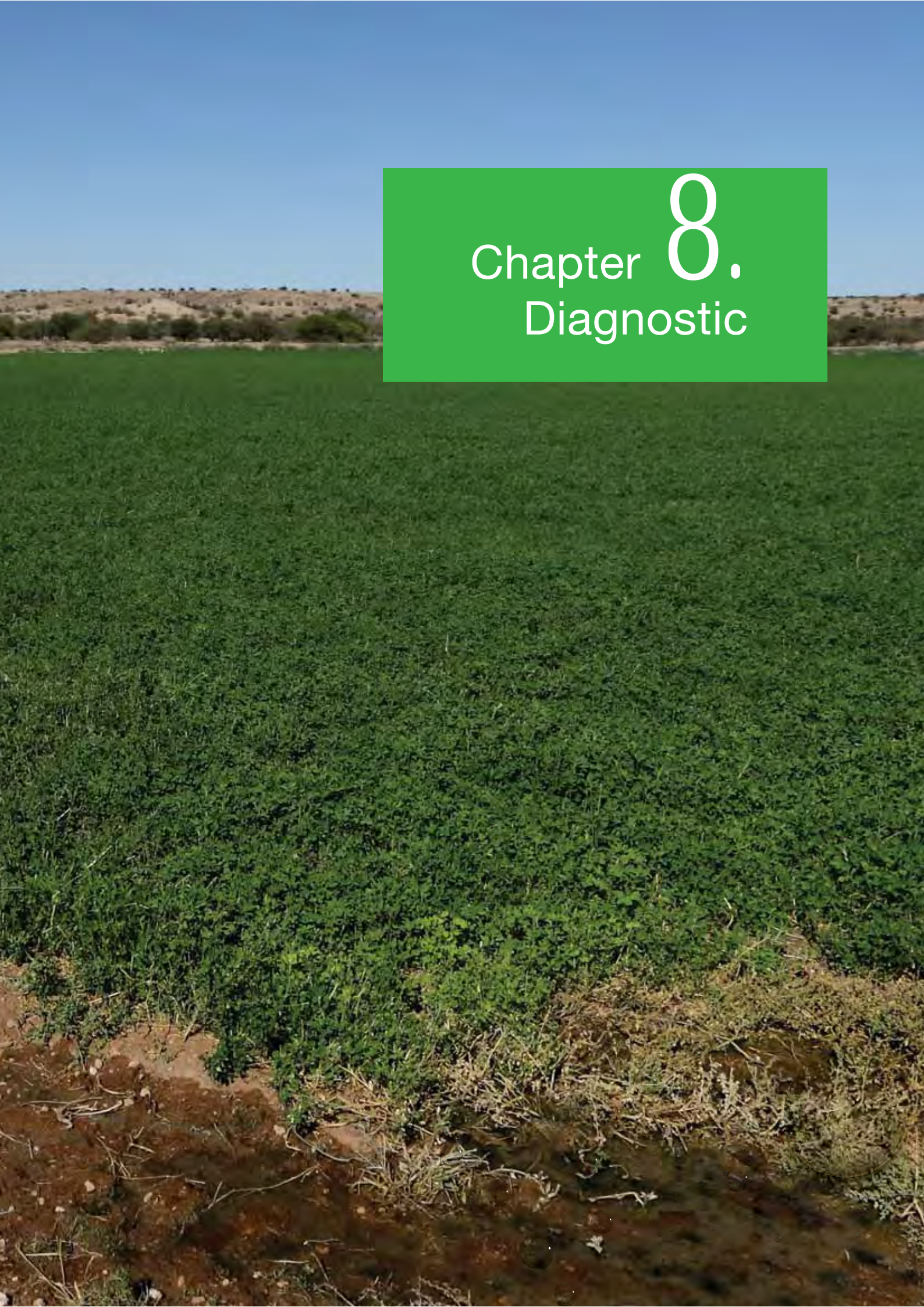
A domestic policy, legal and institutional framework for groundwater is in place in all the three STAS countries. The laws of the three countries regulate abstraction and potential point-source pollution through a permit system. When it comes to non-point source pollution control, other laws step in, typically environmental protection and mining Acts.

The contemporary Namibian (2013) and South African (1998) water laws have dedicated sections on groundwater. So does the Botswana Water Act, which dates back to 1968. Although Namibia has a promising legal and institutional framework, implementing regulations are not yet in place since the promulgation of the Water Resources Management Act in 2013.

From the domestic legal and institutional perspective, it is fair to conclude that the laws in place in the STAS countries are adequate to deal with the challenges ahead of the aquifer. Strengthening domestic capacities in implementation and enforcement is necessary to support cooperation for the management of the STAS.





A large field of green alfalfa under a clear blue sky. In the foreground, there is a small stream or ditch with some dry, brownish vegetation along its edge. A green rectangular box is overlaid on the upper right portion of the image, containing the chapter title in white text.

Chapter 8. Diagnostic

8.1 Purpose and approach

The assessment results presented in the preceding chapters allow a diagnostic to be developed, which provides the foundation for informed and rational groundwater resources management. This diagnostic focuses on the following three questions:

1. How valuable is the Stampriet Transboundary Aquifer System (STAS) and its groundwater resources?

This question does not only refer to economic value, but also to environmental value and in particular to the resources' value to cover vital water needs of humans and animals. Furthermore, the question ideally has to be differentiated in space and time.

2. Which area-specific issues should be addressed by groundwater resources management plans in order to secure or improve sustainable benefits from this aquifer system?

These issues may include both opportunities and threats of sufficient priority to be included in groundwater management plans. If the issues and their causes are properly identified, then possible responses in the form of actions or solutions become visible.

3. To what extent do the current groundwater governance setting and provisions favour adequate management of the groundwater resources?

Here the restriction has to be made that during this assessment phase of GGRETA attention was paid to only a few components of groundwater governance: mainly the legal/institutional aspects, to some extent also the data/information component and gender aspects. Thus no overall picture of groundwater governance conditions has been obtained. Important aspects such as the role of different stakeholder categories, policy and planning, and public awareness raising are still missing.

Developing a diagnostic relies on solid professional understanding and integration of all relevant information, but this process can be assisted and enhanced by using appropriate methodological concepts and tools. In this case study, this has been done by adopting the so-called TWAP indicators, the DPSIR methodological framework and the approach developed by the GEF Groundwater Governance project (2011–2015) for assessing the current groundwater governance status. Some elaboration follows below.

8.1.1. TWAP indicators

The *TWAP indicators* were originally (in 2012) developed by the Transboundary Waters Assessment Project with the purpose to categorize aquifers according to their groundwater management issues, to compare them in order to enable allocation of financial resources to priority aquifers, and to monitor trends in the evolution of the state of the aquifer systems. Given the need to compare large numbers of aquifers, and to do so in a rigorously standardised way, the indicators had to be simple: spatially lumped and reasonably easy to assess with the data available for most of the aquifers.

In the three GGRETA case studies the TWAP indicators have also been used, although these were not developed for single-aquifer case studies, as explained above. The mentioned simplicity (especially the lack of spatial differentiation) limits their usefulness as a diagnostic tool. Anyhow, they were used as a tool, albeit an imperfect one, in the hope that they might contribute to identifying key features relevant for the diagnostics.

The indicators and the values assigned are presented in the Table 8.1 through Table 8.3. The indicator values in Table 8.1 relate to the area and groundwater in general. They highlight a very low population density, but a very high human dependency on groundwater for domestic water supply (it is the only permanent source). Table 8.2 shows the indicator scores for the unconfined Kalahari aquifers. Salient features are the very low rate of renewal, natural groundwater quality unfit for drinking over one third of their area (brackish/saline water), low to medium groundwater development stress, high vulnerability to climate change and an assumed relatively small percentage of the area vulnerable to groundwater pollution (probably by absence of significant flows of liquids to convey pollutants downwards). Table 8.3 shows corresponding scores for the Auob and Nossob aquifers. The scores (although less reliable) show similarity with those of the Kalahari aquifers, except that recharge is even lower (not visible in the score), that they have very low vulnerability to climate change and to pollution, and that they contain over a larger part of their area groundwater fit for drinking purposes. The overall impression is that of a large but fragile groundwater system, still in good condition thanks to the low pressures it is exposed to.

Table 8.1 | Indicators evaluated for the total Stampriet Transboundary Aquifer System (STAS) area (assigned scores and classes are in bold font)

No	Categories and indicator names	Indicator definitions	Score	Classification	Comments
4.1	Population density	Number of people per unit of area on top of the aquifer	< 1 Persons/km ²	1. Very low: < 1 p/km² 2. Low: 1-10 p/km ² 3. Medium: 10-100 p/km ² 4. High: 100-1000 p/km ² 5. Very high: > 1000 p/km ²	
2.1	Human dependency on groundwater	Percentage of groundwater in total water abstraction for all human water uses.	>60%	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	
2.2	Human dependency on groundwater for domestic water supply	Percentage of groundwater in water abstraction for domestic water use.	100 %	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Abstraction of water includes the quantity used and all losses.
2.3	Human dependency on groundwater for agricultural water supply	Percentage of groundwater in water abstraction for agricultural water use (mainly irrigation).	60-80%	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Surface water contributes to livestock watering, in the form of water ponds.
2.4	Human dependency on groundwater for industrial water supply	Percentage of groundwater in total water abstraction for industrial water use.	0 %	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	No industries in the area
2.5	Ecosystem dependency on groundwater	Percentage of the aquifer's area where the aquifer has a phreatic water level shallower than 5 m below surface	<5 %	1. Very low: < 5% 2. Low: 5 – 10% 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	Phreatic water level taken as a proxy
2.6	Prevalence of springs	Total annual groundwater discharge by springs, divided by mean annual groundwater recharge	<5 %	1. Very low: < 5% 2. Low: 5 – 10% 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	Springs are very sensitive for changes in groundwater budget. Therefore a meaningful indicator of change.

No	Categories and indicator names	Indicator definitions	Score	Classification	Comments
5 – Enabling environment for transboundary aquifer resources management					
5.1	Transboundary groundwater management legal framework	Existence, status and comprehensiveness of a binding agreement on the transboundary aquifer under consideration	No agreement in existence, nor under preparation	1. No agreement in existence, nor under preparation 2. Agreement under preparation or available as an unsigned draft 3. Agreement with limited scope signed by all parties (e.g. agreement to co-operate or exchange information) 4. Agreement with full scope for TBA management signed by all parties.	
5.2	Transboundary groundwater management institutional framework	Existence, mandate and capabilities of institutions or institutional arrangements for managing the transboundary aquifer	Such institutions do exist, but with limitations in mandate and/or capability for TBA	1. No institutions in existence that have the mandate and capability for TBA management 2. Such institutions do exist, but with limitations in mandate and/or capability for TBA management 3. Domestic agencies do exist that have full mandate and adequate capabilities for TBA management 4. A special bi- or multi-national transboundary institution has been established with full mandate and adequate capabilities for joint management of the specific TBA.	ORASECOM

Table 8.2 | Indicators evaluated for the Kalahari unconfined aquifers

No	Categories and indicator names	Indicator definitions	Score	Classification	Comments
1 - Defining or constraining the value of aquifers and their potential functions					
1.1	Mean annual groundwater recharge depth (mean annual recharge volume per unit of area)	Long-term mean groundwater recharge, including man-made components (return-flows, induced recharge, artificial recharge), divided by area	<1 mm/year	1. Very low: < 2 mm/yr 2. Low: 2 -20 mm/yr 3. Medium: 20-100 mm/yr 4. High: 100-300 mm/yr 5. Very high: > 300 mm/yr	No reliable recharge estimate
1.2	Annual amount of renewable groundwater resources per capita	Long-term mean groundwater recharge, including man-made components, divided by the number of inhabitants of the area occupied by the aquifer	< 2000 m ³ /yr/capita	1. Low: < 1000 2. Medium: 1000 - 5000 3. High: > 5000	Very low recharge in combination with very low population density
1.3	Natural background groundwater quality	Percentage of the area occupied by the aquifer where groundwater is found of which natural quality satisfies local drinking water standards	35 % (95% for stock watering)	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	WHO drinking water quality standards as a criterion.
1.4	Aquifer buffering capacity	Ratio between volume stored and long-term mean groundwater recharge (equivalent to mean residence time)	>2000 year	1. Low: < 10 years 2. Medium: 10 – 100 years 3. High: > 100 years	
1.5	Aquifer vulnerability to climate change	Extent of expected groundwater budget regime change in response to change in climatic conditions	High	1. Low: confined aquifers containing only fossil water or receiving negligible recent recharge. 2. Medium: weakly recharged aquifers with limited interaction with other components of the hydrological cycle, due to location at considerable depth and/or hydraulic confinement. 3. High: aquifers actively interacting with streams, atmosphere	
1.6	Aquifer vulnerability to pollution	Percentage of its horizontal area where the aquifer is considered moderately to highly vulnerable to pollution	< 5 %	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Pollution risk localized at few settlements and irrigation farms scattered through the study area. The most vulnerable area is around Stampriet given its high density of irrigation farms.
3 – Changes in groundwater state					
3.1	Groundwater depletion	Observed current rate of long-term progressive decrease of groundwater storage (accompanied by steadily declining groundwater levels), expressed as an equivalent depth of water averaged over the aquifer.		1. Absent to very low: < 2 mm/yr 2. Low: 2 -20 mm/yr 3. Medium: 20-50 mm/yr 4. High: 50-100 mm/yr 5. Very high: > 100 mm/yr	
3.2	Groundwater pollution	Observed polluted zones as a percent-age of total aquifer area (due to pollution caused water quality to exceed drinking water quality standards)	<10%	1. Very low: < 5% 2. Low: 5 – 10% 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	
4 - Drivers of change and pressures					
4.2	Groundwater development stress	Total annual groundwater abstraction divided by long-term mean annual groundwater recharge		1. Very low: < 2% 2. Low: 2-20% 3. Medium: 20-50% 4. High: 50-100% 5. Very high: > 100%	

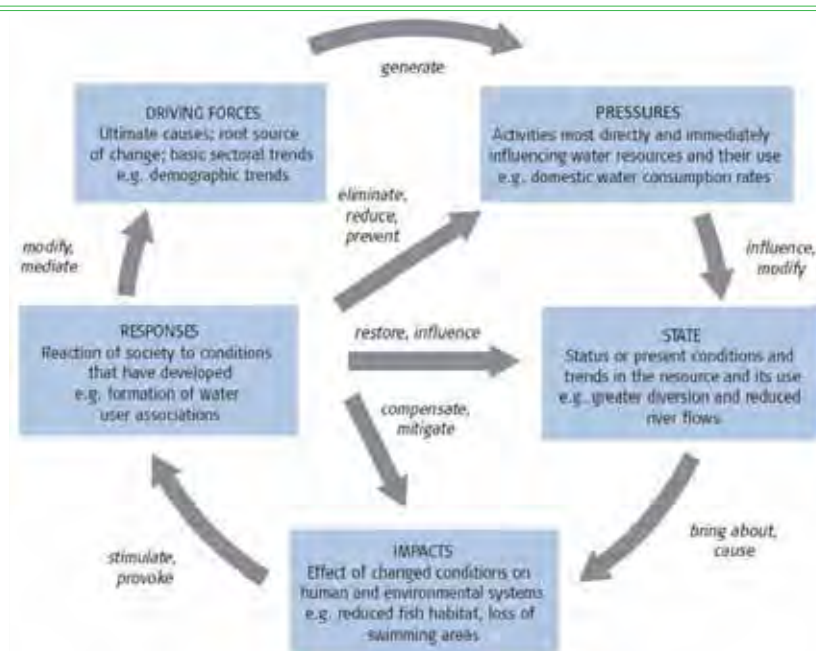
Table 8.3 | Indicators evaluated for the Auob and Nossob confined aquifers

No	Categories and indicator names	Indicator definitions	Score	Classification	Comments
1 - Defining or constraining the value of aquifers and their potential functions					
1.1	Mean annual groundwater recharge depth (mean annual recharge volume per unit of area)	Long-term mean groundwater recharge, including man-made components (return-flows, induced recharge, artificial recharge), divided by area	<1 mm/year	1. Very low: < 2 mm/yr 2. Low: 2 -20 mm/yr 3. Medium: 20-100 mm/yr 4. High: 100-300 mm/yr 5. Very high: > 300 mm/yr	No thorough recharge estimate
1.2	Annual amount of renewable groundwater resources per capita	Long-term mean groundwater recharge, including man-made components, divided by the number of inhabitants of the area occupied by the aquifer	< 2000 m ³ /yr/capita	1. Low: < 1000 2. Medium: 1000 - 5000 3. High: > 5000	Very low recharge in combination with very low population density
1.3	Natural background groundwater quality	Percentage of the area occupied by the aquifer where groundwater is found of which natural quality satisfies local drinking water standards	~ 65 % (100% for stock watering)	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	WHO drinking water quality standards as a criterion.
1.4	Aquifer buffering capacity	Ratio between volume stored and long-term mean groundwater recharge (equivalent to mean residence time)	>2000 year	1. Low: < 10 years 2. Medium: 10 – 100 years 3. High: > 100 years	
1.5	Aquifer vulnerability to climate change	Extent of expected groundwater budget regime change in response to change in climatic conditions	Low	1. Low: confined aquifers containing only fossil water or receiving negligible recent recharge. 2. Medium: weakly recharged aquifers with limited interaction with other components of the hydrological cycle, due to location at considerable depth and/or hydraulic confinement. 3. High: aquifers actively interacting with streams, atmosphere and/or sea	
1.6	Aquifer vulnerability to pollution	Percentage of its horizontal area where the aquifer is considered moderately to highly vulnerable to pollution	< 5%	1. Very low: < 20% 2. Low: 20 -40% 3. Medium: 40-60% 4. High: 60-80% 5. Very high: > 80%	Pollution risk localized at few settlements and irrigation farms scattered through the study area. The most vulnerable area is around Stampriet given its high density of irrigation farms.

No	Categories and indicator names	Indicator definitions	Score	Classification	Comments
3 – Changes in groundwater state					
3.1	Groundwater depletion	Observed current rate of long-term progressive decrease of groundwater storage (accompanied by steadily declining groundwater levels), expressed as an equivalent depth of water averaged over the aquifer.	< 2 mm/yr	1. Absent to very low: < 2 mm/yr 2. Low: 2 -20 mm/yr 3. Medium: 20-50 mm/yr 4. High: 50-100 mm/yr 5. Very high: > 100 mm/yr	No thorough recharge estimate
3.2	Groundwater pollution	Observed polluted zones as a percentage of total aquifer area (due to pollution caused water quality to exceed drinking water quality standards)	< 5%	1. Very low: < 5% 2. Low: 5 – 10% 3. Medium: 10-25% 4. High: 25-50% 5. Very high: > 50%	Local drinking water quality standards as a criterion.
4 - Drivers of change and pressures					
4.2	Groundwater development stress	Total annual groundwater abstraction divided by long-term mean annual groundwater recharge	<50%	1. Very low: < 2% 2. Low: 2-20% 3. Medium: 20-50% 4. High: 50-100% 5. Very high: > 100%	

8.1.2. The DPSIR Framework

Figure 8.1 | The DPSIR Framework of analysis (Source: WWAP, 2006)



The DPSIR framework is a generally accepted analytical framework to understand the structure of processes of change. This framework, graphically shown in Figure 8.1, contributes to understanding the dynamics of changing water resources systems by making a distinction between five interconnected classes of variables:

- Driving forces or drivers (D): root-cause of change.
- Pressures (P): immediate cause of change inside a water resources system, originating under influence of drivers (D) and/or human responses (R).
- State (S): the quantity, quality and other measurable conditions of water inside the water resources systems
- Impacts (I): negative or positive effect of changes in state on human society, ecosystems and/or the environment
- Responses (R): human action triggered by observed or expected undesired changes in state (S) or impacts (I).

The DPSIR framework can help identifying which variables and categories of variables have to be taken into account and how they are linked and interact.

8.1.3. Assessing groundwater governance

The approach developed by the Groundwater Governance project (and assumed to be useful for GGRETA as well) for assessing groundwater governance is based on taking into account the following aspects:

- The area-specific setting (context)
- Locally valid ambitions, goals and political priorities related to water
- Key components of governance

The key components of governance are thought to include the following four main categories:

- a. Actors.** Actors may range from individuals to small or large organizations (either belonging to the government or not - like NGO's, private companies, co-operatives, pressure groups, etc). Each actor is driven by his/her specific personal interest, the shared interest of groups he/she belongs to, or assigned tasks and mandate. Good governance requires the inclusion of all relevant actors in a common endeavour to align all behaviour and action in an area consistently with agreed common goals.
- b. Legal frameworks.** Alignment of groundwater governance actors with policies and plans is pursued –among others– through legally binding norms setting behavioural boundaries in general, and delineating the roles and responsibilities of institutional actors in particular. The bulk of legal norms nowadays is laid down in formal laws – approved by the mandated parliaments or political leaders – and in the corresponding regulations based on such laws. A theme of particular significance in this context is the place of customary law – i.e., the body of un-written norms borne out of long-standing practice, and equally binding on the members of the community observing them.
- c. Policies.** Whereas the law is meant to be enforced, with sanctions for non-compliance, policies are a softer instrument. They express the short- to medium-term preferences related to the field of interest and serve as a general guidance, by providing goals and boundary conditions for action-oriented management plans. They also define whether to be pro-active regarding groundwater and actively promote and promulgate management action plans, or to opt for merely reacting to problems whenever they have emerged.

d. *Information, knowledge and science.* In order to be effective, policies and management plans need to be based on adequate information and knowledge about the conditions in the area concerned. Furthermore, in the particular case of groundwater, assessment and monitoring are the only ways to make groundwater visible to those in charge of management. The mentioned information and knowledge should be related not only to the groundwater systems proper and their time-dependent state variables, but also to the abstraction and use of groundwater (including its social, economic and environmental impacts), related ecosystems and other relevant interdependencies, groundwater management interventions and the overall groundwater governance setting. Information and awareness programmes should ensure that the information is disseminated among the stakeholders to the extent needed. Good governance includes that dedicated information services as outlined above are in place.

8.2 Value of the Stampriet Transboundary Aquifer System

The total groundwater abstraction (around 20 million m³/yr) in the STAS area is rather modest, given the vast area, and thus is unlikely to generate huge economic profits, but this does not mean that the value of the groundwater resources would be low. On the contrary, the assessment results indicate that groundwater is the only reliable permanent source of water in the area (in other words: the human dependency on groundwater is very high). It is indispensable for drinking water supply (using 16% of the volume abstracted) and forms a major source of supply for economic activities such as irrigation (52%) and stock watering (32%). Ensuring the sustainability of the area's groundwater resources is therefore a critical requirement for keeping the area liveable.

Which aquifer units are the most valuable components of the system? Around 65% of all abstracted groundwater comes from the phreatic Kalahari aquifers. These are tapped to meet local demands, are discontinuous but favourably located with regard to recharge; nevertheless, they are vulnerable to climate change and to pollution, and a significant part of them contains groundwater unfit for drinking purposes because of excessive mineralisation (aquifers in the South-Eastern zone, the so-called 'Salt Block'). Approximately 33% of the current groundwater abstraction is from the Auob aquifer and only 2% from the Nossob aquifer. It is obvious that these percentages reflect the higher cost of groundwater abstracted from deeper wells. The confined Auob and Nossob are less vulnerable to pollution and to climate change, but also less resilient to storage depletion. It should be taken into account, however, that the different aquifer units are interconnected by the demand for water: if one of the aquifers would locally become incapable of providing good-quality water, then the corresponding water demand will shift to one of the other ones. This implies that managing the transboundary Auob and Nossob aquifers cannot be done properly without paying due attention also to the Kalahari aquifers.

The Auob and Nossob aquifers are mainly attractive for exploitation in Namibia and the northern part of the Botswana segment – elsewhere the mineralisation levels are too high for almost all uses. This means that mainly Namibia would have an incentive for joint transboundary management (but even not much, since it owns the up-flow part).

8.3 Identified groundwater management issues

As far as available information and knowledge allow, the main groundwater management issues in the area include the risks of groundwater depletion, groundwater pollution and groundwater salinisation, as well as options for expanding groundwater exploitation.

8.3.1. Groundwater depletion

The general perception is that there is until present no long-term groundwater depletion in the area (accompanied by declining water levels), which means that either it does not occur or it occurs but is not noticed and reported. However, it would be short-sighted to disregard the threat of groundwater depletion in this dry area without significant surface water resources. The transboundary confined aquifers contain virtually non-renewable groundwater, and the phreatic Kalahari aquifers, although better exposed to recharge and thus more resilient, enjoy only a very low long-term mean rate of recharge. Information is lacking to understand and predict the hydrological behaviour of the groundwater systems quantitatively and in sufficient spatial detail. Nevertheless, the available information leaves no doubt that the STAS is a fragile system. Especially if the intensity of groundwater abstraction would increase in the future, driven by expanding population and by intensification of economic activity (irrigated agriculture, mining, etc.), then harmful groundwater level depletion is not unlikely to occur, first and for all in the zones where abstraction is concentrated. Since confined aquifers release their water by an elastic response to decompression, groundwater levels in the Auob and Nossob aquifers may decline comparatively quickly. Climate change is an additional driver of change, but how it would affect the groundwater resources in the area (mainly the Kalahari aquifers) has not yet been investigated.

Practical impacts of groundwater depletion will include the loss of 'flowing wells' and rising production cost of groundwater in general. Shallow wells may run dry (in particular in the phreatic Kalahari aquifers) and then require to be deepened and possibly to be provided with a more powerful pump. In cases of excessive groundwater depletion, it may become unfeasible to exploit certain aquifer zones and the resources may even become physically exhausted.

In order to prevent or counteract potential depletion problems in a pro-active way, an obvious step to be taken in the short-term is to reduce currently observed waste of water. This can be done by rehabilitation of leaking wells, by introducing and implementing regulations on well construction and by effective well licensing procedures. Furthermore, protection of key recharge zones may contribute to conserve the resources.

In addition, it will be extremely helpful to raise awareness among the area's inhabitants on what they can do to use and conserve their groundwater wisely, and to enhance the capacity of the institutions responsible for groundwater management in the area.

There is much uncertainty on the properties and present state of the aquifer system, in particular on how it behaves over time, in response to abstractions and climatic variation. Implementing a monitoring system (groundwater levels and groundwater abstraction) is a priority. And sooner or later, a numerical simulation model of the STAS will prove to be indispensable to enable informed decisions on sustainable management of the area's groundwater resources to be made.

8.3.2. Groundwater pollution

What has been commented for groundwater depletion, is *–mutatis mutandi–* also valid for groundwater pollution: there is no evidence yet of regional problems, but it is also obvious that the issue is relevant for the area and should not be disregarded. There are some indications of local pollution cases, but lack of monitoring precludes getting an overall picture. Since the deeper confined aquifers are protected by a thick cover of poorly permeable layers against pollution sources at the land surface, groundwater pollution is mainly a threat to the unconfined Kalahari aquifers. The pollution risk is concentrated in zones where significant pollution sources are present and water to convey pollutants downwards to the aquifers: in and around settlements (untreated wastewater flows and sanitary waste), in zones of irrigated land (where fertilizers and pesticides leak downwards) and in zones where cattle density is high. Improperly constructed and poorly protected wells and boreholes may present another mechanism of groundwater pollution. Obviously, human population and economic activity in the area are drivers behind pollution.

The impact of groundwater pollution is that groundwater locally may become less suitable or even unsuitable for intended uses, in particular for drinking purposes. Unless treated (which bears a cost) the use of this polluted water may cause problems (e.g. diseases). Often the polluted water has to be abandoned as a source of water and replaced by water from another source (either from a deeper aquifer or from the same aquifer, but at some distance).

In response to current or potential groundwater pollution problems, obvious measures are improving sanitation, wastewater treatment and adequate waste management in and around the area's settlements, and modifying the use of fertilizers and pesticides in order to minimize groundwater pollution.

Mapping and monitoring pollution sources in the area, and monitoring pollutants in critical aquifer zones will give guidance on where to focus efforts in this huge area. Awareness raising and strict implementation of pollution control regulations may contribute to local stakeholders changing their behaviour in favour of reduction of pollution.

8.3.3. Groundwater salinisation

In principle, human activities in certain parts of the area may contribute to increasing groundwater salinity levels in some aquifer domains, with negative impact on the water's suitability for different purposes. Already included in the previous groundwater management issue (groundwater pollution) is the salinity enrichment under irrigated land. Irrigation unavoidably enriches the mineral content of the soil, which by flushing –in turn– leads to a progressively increasing mineral content of underlying phreatic groundwater bodies.

Another salinization mechanism –unrelated to the input of pollutants produced at the land surface– is the migration of brackish or saline groundwater into fresh-groundwater bodies, triggered by groundwater abstraction or by vertical shortcuts between different aquifers due to poor well construction.

Actions to control groundwater salinisation include proper regulation of well construction and well licensing, supported by adequate knowledge of the local conditions in order to know in which zones the risk of migrating brackish and saline groundwater really exists.

8.3.4. Groundwater for improved domestic water supply and sanitation

A significant, but not accurately known percentage of the area's population does not have access to safe drinking water and an even larger percentage (54%) has no toilet facilities. Flush toilets (available in 34% of all households) and pit latrines contribute to pollution of shallow groundwater. Solid waste at uncontrolled waste dump site also produce leachate that pollutes shallow groundwater.

From a public health point of view it is highly desirable to improve the water and sanitation situation, including sewerage and wastewater treatment provisions. Groundwater has the potential to play an important role in such projects, as a source of water, but it may simultaneously be affected by higher abstraction intensities and by potentially higher mobility of waste and wastewater flows. Therefore it is important to carry out water supply and sanitation improvements projects in close coordination with the agencies responsible for groundwater management, creating synergy and consistency between the two policy domains.

8.4 Groundwater governance and governance provisions

In this assessment stage of GGRETA, the pilot project did not cover the full scope of groundwater governance and governance provisions, but rather focused on a few selected components: legal and institutional aspects, data and information management, and gender issues. Unaddressed have remained many relevant aspects: the majority of current and potential actors in groundwater governance, including their roles, capabilities and the way they interact; awareness and awareness raising; policy and planning; institutions involved in data acquisition, information and knowledge; and more.

8.4.1. Legal and institutional framework

Here, a distinction has to be made between the international level and the domestic level.

At the *international level* there are no dedicated legal and institutional frameworks available for the STAS specifically. However, potentially useful are more general legal tools in the form of the SADC Water Protocol and the ORASECOM Agreement. Regarding institutions, the SADC Water Division and ORASECOM may offer useful platforms for cooperation. The main challenges focus on facilitating data collection (including monitoring), data harmonisation and perhaps also modelling. A possible Multi-Country Cooperation Mechanism (MCCM) will in due time help promoting cooperation between the three countries related to the STAS. Two options for such a MCCM are outlined in Chapter 9.

At the *domestic level*, the policy, legal and institutional framework for groundwater is in place in all the three countries. The framework is inclusive of both groundwater and surface water. The Namibian and South African laws have dedicated sections on groundwater. The Botswana Water Act dates back to 1968 and probably requires updating. Although Namibia has a promising legal and institutional framework, regulations to support enforcement are not yet in place (since the promulgation of the Act in 2013).

The water laws of the three countries regulate abstraction and potential point source pollution through a permit system. When it comes to non-point pollution control, other laws apply, typically environmental and mining Acts.

It has been difficult to determine the level of law enforcement in Botswana and Namibia due to the lack of evidence of cases brought to the courts, but implementation of the legislation is most probably the most challenging component, given the size of the area and the capacity constraint of government institutions.

Governmental institutions need to be more efficient (personnel, finances, etc.) and their activities related to groundwater require more intensive coordination.

8.4.2. Data and information management

Very significant data acquisition efforts made over the years in each of the three countries have produced large quantities of data, although gaps still exist. Data can be accessed in several offices in these countries and have been compiled and harmonised by GGRETA. Among the latter, a STAS database of 6187 boreholes, including 20 standardised attributes, has been developed.

Nevertheless, there is still considerable uncertainty about the properties and behaviour of the STAS and its broader context. In particular, there is little or no information on how relevant variables vary over time; and the values of most time-dependent data used are not of recent date, so it is not sure to what extent reported patterns are still valid.

In order to support informed decision-making for managing the groundwater resources of the STAS, a first priority is establishing and operating aquifer-wide monitoring systems (groundwater levels, groundwater abstraction, groundwater quality, pollution sources). Carrying this out as a joint project will produce synergy. The processed data should be made easily available and shared between the countries. Acquisition of other data should also be undertaken, to the extent needed for developing and calibrating a simulation model or other policy-underpinning tools.

Decision-makers will need information in an easily accessible form that shows them the essential features without recourse to basic data. To that end, an Information Management System has been developed during the first phase of GGRETA. Chapter 10 provides a description.

8.4.3. Gender and some other stakeholder issues³³

Assessment of gender issues in Botswana and Namibia has revealed that the current situation in terms of gender equality needs to be improved. Some key observations can be mentioned:

- Gender sensitivity training is rare in water-related ministries
- Women have a major responsibility for carrying water in the 90% of the households without in-house connection to water. The distance of carrying water has repercussions for the quantities fetched, for under-five mortality and for girls' attendance at school.

³³. This section only covers Namibia and Botswana.

- Absence of toilet facilities in 54% of the households creates special risks for women and girls.
- In agriculture, women mainly do backyard gardening, while men dominate in the medium- to large-scale irrigation and stock farming.
- Planning and management in agriculture (and also the representation in farmer associations) are male dominated and about 50% of women active in agriculture do not get paid for their work.

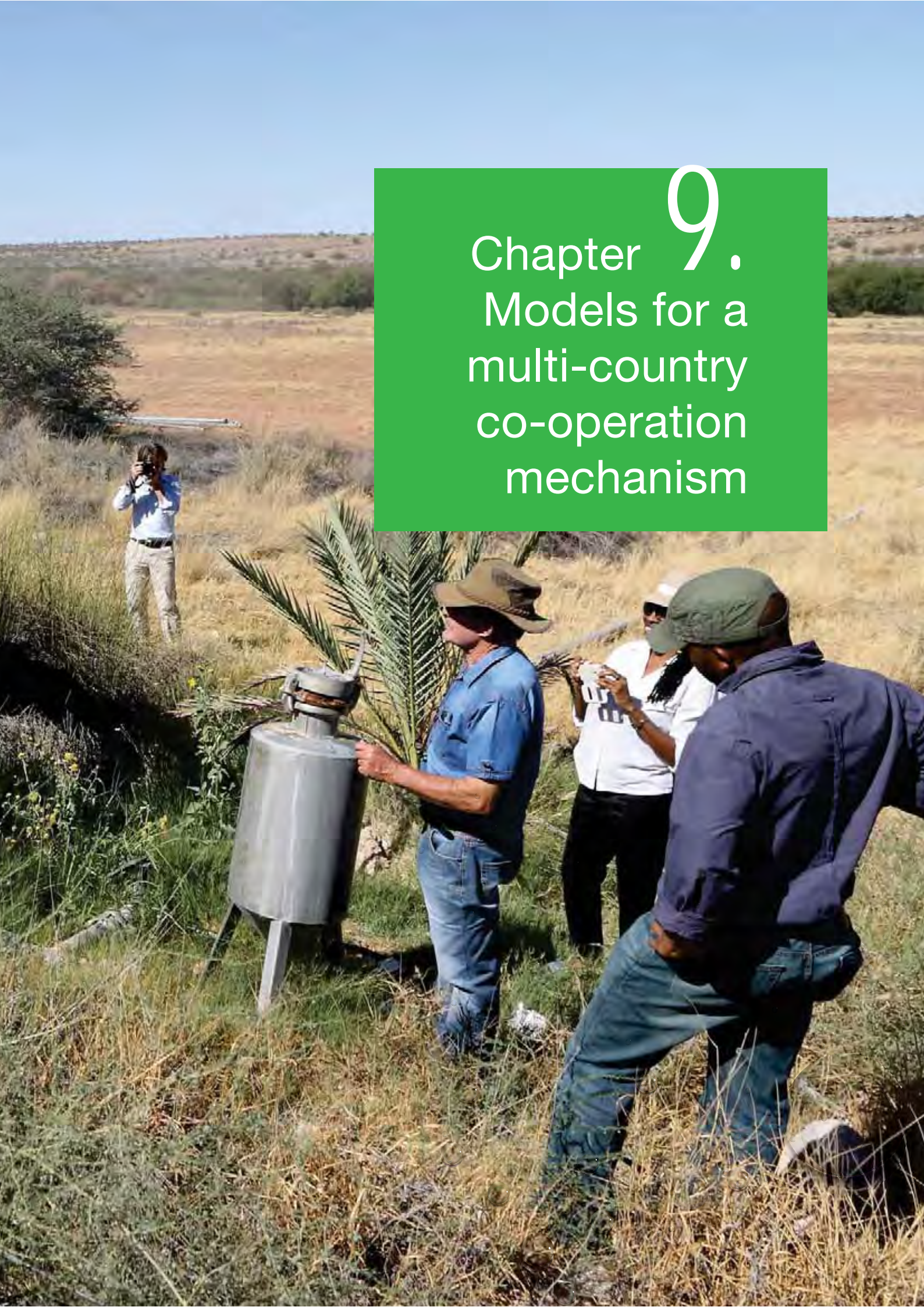
Systematic application and collection of sex-disaggregated data will facilitate a more comprehensive, quantitative gender analysis for policy making. Promising steps towards gender equality are awareness programmes at all levels, training of practitioners in all activities contributing to gender equality, and mainstreaming gender in water-related institutions and decision-making processes. At the more local level, improvement of water supply and sanitation obviously will improve the position of women. The main challenge to gender equality in the STAS is that women lack access to productive resources that would allow them to enhance their economic productivity. Women's lack of access to the use, ownership and disposition of land limits their economic choices and causes economic dependency on men. The priority areas for interventions are: (i) greater access to land and agricultural resources; (ii) monitoring and evaluation of interventions in the agricultural sector; (iii) skills upgrading; and (iv) income generating projects and (v) access to financing.





Chapter 9.

Models for a multi-country co-operation mechanism



9.1 Objectives of a multi-country cooperation mechanism for STAS

The need for a *multi-country co-operation mechanism* has already been identified in section 7.1.

The over-arching objective of a multi-country cooperation mechanism for STAS (MCCM) is to transition from GGRETA project-driven cooperation in the study and characterization of STAS to institutionalized cooperation among the STAS countries, beyond the life of the project.

In the short-term, the specific objective of the MCCM is to continue the joint study of STAS, also by generating a steady flow of agreed additional/fresh data and information feeding the Information Management System (IMS) for STAS, generated by the GGRETA project. As a result, the short-term MCCM's objective is to institutionalize the collection and exchange of comparable/compatible data and information among the STAS countries, for the purpose of augmenting and maintaining the IMS.

In the long-term, as cooperation takes hold and matures, the MCCM's institutionalized cooperation objective may expand from data collection and exchange to joint strategizing and advising STAS countries on management issues of the STAS groundwater resources.

9.2 Value-added of a MCCM

What can a MCCM do better than the STAS countries cannot do by themselves, separately? In the answer to this question lies the key to a case for a MCCM. Conceivably, a MCCM would bring in the following, which the countries alone could not:

- a STAS vision/perspective
- consistency of direction and purpose of domestic STAS-relevant action
- joint control of the flow of data and information feeding the IMS.

9.3 Overview of models for a MCCM

Two models are presented in this report for a multi-country cooperation mechanism:

- Model 1 - Coordinating STAS Committee (Figure 9.1 and Figure 9.2),
- Model 2 - Nesting a MCCM for STAS in the ORASECOM structure (Figure 9.3 to Figure 9.4)

Both would have institutional linkages with SADC and with the Orange-Senqu River Commission (ORASECOM). One would actually sit within the structure of the latter. Obviously nothing prevents the STAS countries from moving progressively and over time from either model to a permanent joint committee of country representatives assisted by a skeleton secretariat, for the performance of incremental functions.

Each model is fleshed out in some detail, regarding in particular:

- core tasks
- structure
- legal arrangements, relative also to the ORASECOM Agreement,
- funding arrangements
- advantages, and
- dis-advantages.

Figure 9.1 | Model 1 - Coordinating STAS Committee – Core tasks, structure, legal and funding arrangements, advantages and dis-advantages

<p>Core tasks</p> <ul style="list-style-type: none"> • collection and exchange of data and information among the STAS countries • managing the flow of data and information to the STAS Information Management System • attracting donor funding for the purposes of the STAS • advising STAS countries on the application of available and relevant SADC guidelines, and adaptation to the specifics of the STAS • liaising with SADC and with ORASECOM. <p>Structure (a depiction is given in Figure 9.2 below)</p> <p>The Coordinating Committee would consist of:</p> <ul style="list-style-type: none"> • a Steering Committee of senior government groundwater officials acting as Focal Points, meeting at regular intervals on a rotating basis in the STAS countries, and • a Research Institution in each STAS country, providing scientific input to the Steering Committee. <p>No separate multi-country support or secretariat facility is contemplated. As a result, no permanent and independent physical seat where the Committee should sit or be placed is necessary. In practice, the Committee “sits” in, and is supported by, the government groundwater administration of the STAS country hosting the meeting of the Committee, and thereafter until the next scheduled meeting, when the host obligations will be shifted on to the next STAS country due to act as host.</p> <p>A formal link with the SADC structure is highly advisable to ensure consistency of STAS-specific activities with SADC policies and programmes, and to benefit from</p> <ul style="list-style-type: none"> • the pool of knowledge available in SADC – in particular, in the SADC Groundwater Management Institute (GMI), in the process of being formed at the University of the Free State in Bloemfontein, South Africa, for scientific input, and • the political clout accruing from the SADC umbrella. <p>Such formal “link” could take different forms, however the most apt to the Coordinating Committee model seems to be regular reporting to the SADC secretariat, and liaising with GMI in particular. A reporting and a liaising obligation can be entered in the legal instrument establishing the Committee (see below).</p> <p>A formal link of the Committee with ORASECOM is equally highly desirable given the overlapping scope of geographic jurisdiction of the two organizations. An obligation to consult with, and regularly report to, ORASECOM would arguably meet desirable “linking” requirements with that organization, and can be entered in the legal instrument establishing the Committee (see below).</p>	<p>Legal arrangements and ramifications</p> <p>A Memorandum of Understanding (MOU), signed by the concerned Water Ministers, should suffice to bring the Coordinating Committee into being.</p> <p>Whether Art.1.4 of the ORASECOM Agreement, providing that any “river commission” established by the ORASECOM Parties among any of them shall be subordinate to ORASECOM, would apply to the Committee or not, is a matter for interpretation. However, if a formal link of the Committee with ORASECOM is established in the manner suggested earlier, arguably the spirit of Art. 1.4 of the ORASECOM Agreement would be satisfied, and the potential for controversy over the interpretation and application of that Agreement provision would be minimized.</p> <p>Funding arrangements</p> <p>Each STAS country would bear, on a rotation basis, the cost of:</p> <ul style="list-style-type: none"> • hosting the regular meetings of the Coordinating Committee on its own soil, and • providing administrative support for the duration of host duties. <p>Advantages</p> <p>The advantages of this model can be summed up as –</p> <ul style="list-style-type: none"> • expeditiousness of implementation, as a decision to establish a STAS Coordinating Committee can be taken at the level of the Ministers responsible for water resources, and formalized in a MOU signed by them • leanness of institutional architecture, as the Committee would consist of the representatives of the three Water Departments meeting at regular intervals as a Steering Committee, at no extra costs to the Governments other than the costs of such meetings • economies of scale, as the Committee would rely on the support facilities available in the government departments hosting the meetings of the Committee on a rotating basis • ownership by the STAS countries • visibility • independence from external support for the functioning of the Committee. <p>Dis-advantages</p> <p>The dis-advantages of this model can be summed up as –</p> <ul style="list-style-type: none"> • relative impermanence of the Committee • dependence on the priorities and political agendas of the government water administration hosting the Committee.
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Figure 9.2 | Model 1 – Coordinating STAS Committee – Structure

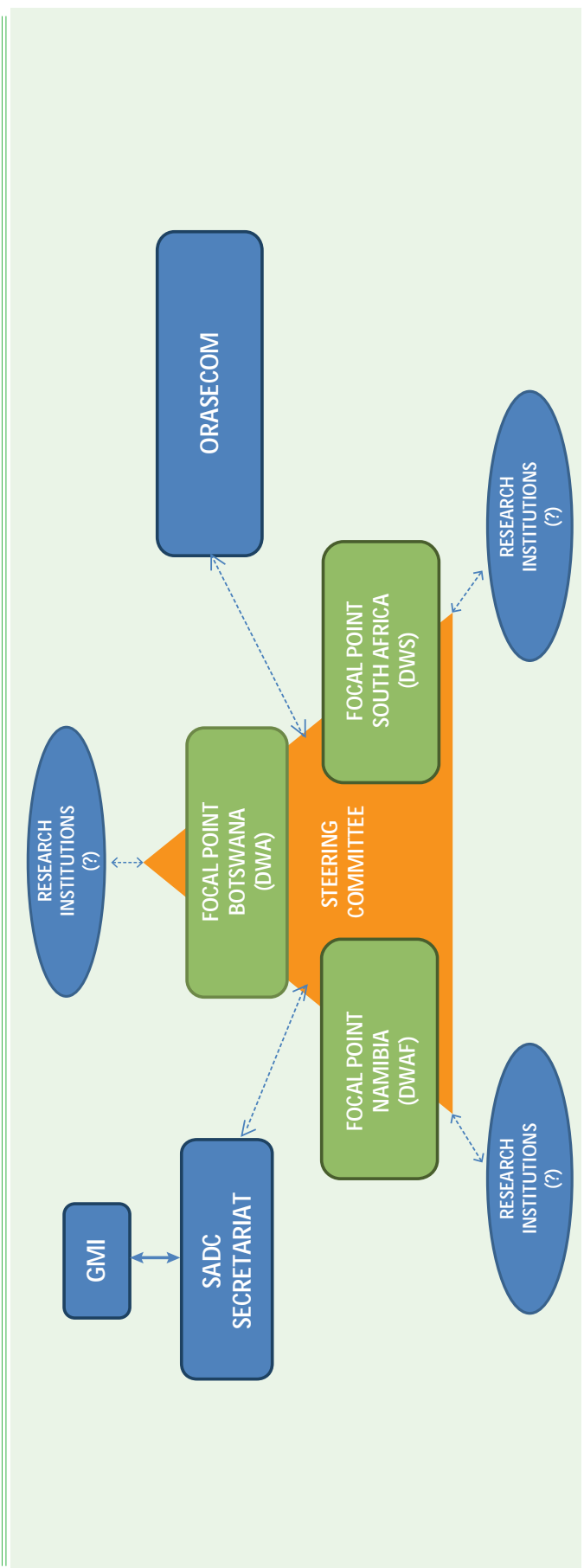
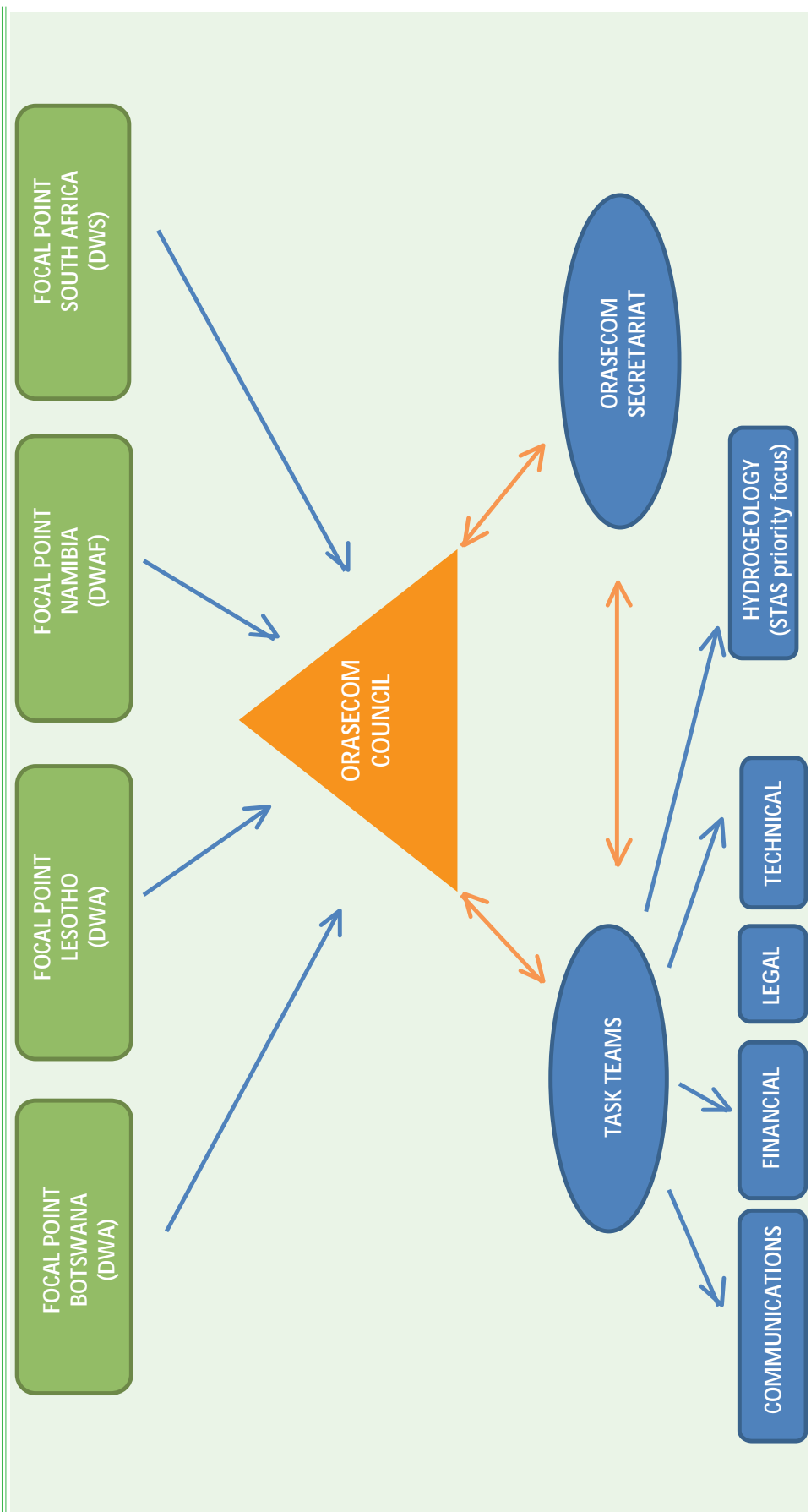


Figure 9.3 | Model 2 - Nesting a MCCM for STAS in the ORASECOM structure - Core tasks, structure, legal and funding arrangements, advantages and dis-advantages

<p>Core tasks</p> <ul style="list-style-type: none"> • collection and exchange of data and information among the STAS countries • managing the flow of data and information to the STAS Information Management System • attracting donor funding for the purposes of the STAS • advising STAS countries on the application of available and relevant SADC guidelines, and adaptation to the specifics of the STAS • all the above tasks, in relation to other transboundary aquifers in the Orange-Senqu River basin, but with a lower priority relative to the STAS. <p>In the essence, these tasks are the same as in Model 1, but without the liaison duties with SADC and ORASECOM, which will be ensured by ORASECOM itself as a matter of course.</p>	<p>River basin – like, notably, the STAS – do or do not come within the purview of the agreement and of the Commission. This is a matter for interpretation eventually, however the issue looms large before the option of nesting a STAS-focused MCCM in the ORASECOM structure, and is flagged here for further consideration.</p> <p>Regardless, under the ORASECOM agreement a Council decision presumably is required to upgrade the existing Hydro-geology committee of the Technical Task Team responsible for technical matters to a new dedicated Hydro-geology Task Team.</p>
<p>Structure (a depiction is given in Figure 9.4 below)</p> <p>A Hydro-geology committee already exists in the ORASECOM structure, under the Technical Task Team for technical matters created by a decision of the ORASECOM Council under Art. 6.1 of the relevant agreement. The committee's scope of work reportedly extends to all trans-boundary aquifers known to exist in the Orange-Senqu River basin, including the STAS.</p> <p>Under this model, interest in the STAS, generated by the GGRETA project, would be captured in the following arrangement:</p> <ul style="list-style-type: none"> • the stature of the extant hydrogeology committee of the Technical Task Team for technical matters would be upgraded to that of a new dedicated Hydrogeology Task Team in the ORASECOM structure, with a mandate spanning all transboundary aquifers in the Orange-Senqu River basin. • the STAS would be prioritized on the new dedicated Task Team's agenda. 	<p>Funding arrangements</p> <p>Each country will bear the cost of its representative on the new Hydro-geology Task Team.</p>
<p>Legal arrangement and ramifications</p> <p>Whether the ORASECOM agreement supports such model may be an issue. The discussion in chapter 7 disclosed that the language in the ORASECOM agreement is opaque at best regarding the hydro-geological reach of its provisions and of ORASECOM itself, i.e., whether the groundwater of aquifers which bear no hydraulic connection to the Orange-Senqu</p>	<p>Advantages</p> <p>The advantages of this model can be summed up as –</p> <ul style="list-style-type: none"> • expeditiousness of implementation, as a decision to upgrade the existing Hydro-geology committee of the Technical Task Team responsible for technical matters to a dedicated Hydrogeology Task Team can be taken swiftly by the ORASECOM Council, in accordance with the provisions of the ORASECOM agreement • leanness of institutional architecture • economies of scale, as the Hydro-geology Task Team would rely on the support facilities and the resources available to ORASECOM • costs to the STAS countries limited to the regular meetings of the new Task Team (assuming this will consist of designated government officials already on the government payroll).
	<p>Dis-advantages</p> <p>The dis-advantages of this model can be summed up as –</p> <ul style="list-style-type: none"> • subordination to the agenda and priorities of ORASECOM • competition with Lesotho's priorities in the new Task Team • competition for attention and resources from the other known transboundary aquifers in the Orange-Senqu River basin.

Figure 9.4 | Model 2 - Nesting a MCCM for STAS in the ORASECOM structure





Chapter 10.

Information Management System

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10.1 Introduction

The GGRETA IMS is a web-based Information Management System, designed and maintained by IGRAC, in close cooperation with UNESCO-IHP and the national assessment teams. It was developed to support decision makers and other stakeholders, involved in the governance of transboundary aquifers, with relevant information. It is a map-based system which allows users to upload map layers resulting from the assessment phase. These layers can be further combined, within the IMS, in order to create thematic maps. Additional data such as pictures, tables and documents can also be uploaded into the system. Data and information from the IMS can (partly or fully) be made available to public upon a decision of data providers/national assessment teams.

10.2 Role of the IMS in transboundary aquifer governance

“Groundwater governance comprises the promotion of responsible collective action to ensure control, protection and socially-sustainable utilisation of groundwater resources and aquifer systems for the benefit of humankind and dependent ecosystems. This action is facilitated by an enabling framework and guiding principles” (FAO, 2015).

The first step for action is to create an adequate basis for governance. This starts with diagnosing the current groundwater governance conditions in the area concerned. This diagnostic step helps defining which governance improvements are most relevant and how they may be adapted to local conditions and challenges. Critical in all cases is leadership, usually vested in a dedicated government organization, and political commitment. Other elements that contribute to the foundations of good groundwater governance are provisions for structural acquisition and management of data and information, awareness raising programmes and mechanisms for effective stakeholder involvement (FAO, 2015).

A general condition for effective governance is that sufficient data, information and knowledge should be available and accessible to all. In order to optimally develop, manage and protect groundwater resources, reliable information is required. Information includes snapshots of static features collected during assessment studies, as well as time-dependent features collected by monitoring activities. Information needs to be converted to knowledge in order to enable stakeholders to take informed management decisions. Information management systems facilitate the presentation of analyses in a form that makes the messages understandable for those addressed. Information systems can also help achieving an effective and low-cost sharing of results among all involved stakeholders. Finally, useful knowledge can be interactively disseminated in the form of tailor-made messages for the general public.

The GGRETA IMS is not just a database to store information. It is developed to assist during the assessment, management and governance of transboundary aquifers. The team involved in the assessment can use the system to share and discuss preliminary results using the password protected

environment. In its final form it is meant to store interpreted and processes data from the assessment of the groundwater resources in order to be used as a tool to support decision makers and relevant stakeholders. In the following sections, the information system is described in more detail.

10.3 Implementation of the GGRETA IMS in the Stampriet case study

The GGRETA IMS has successfully been implemented in this first phase of the GGRETA project. The assessment has resulted in large number of thematic maps and more than 60 map layers have been uploaded into the system. The thematic maps describe the physiography, climate and landuse in the study area, and provide detailed information for each of the three aquifers (Kalahari, Auob, Nossob). Table 10.1 and Table 10.2 lists an overview of the map layers available in the system (status January 2016). Figure 10.1 through Figure 10.3 show some examples of screenshots of the GGRETA-Stampriet IMS.

The GGRETA IMS can be accessed via <https://ggis.un-igrac.org>. At present (status January 2016) the uploaded map layers are only available to authorised users as all map layers are in the password protected environment (private workspace), until the three countries who have ownership over the system decide which map layers can be made publically available.

Figure 10.1 | Overlay of thematic maps: landuse, settlements and population.
(Source: Screenshot GGRETA Stampriet IMS)

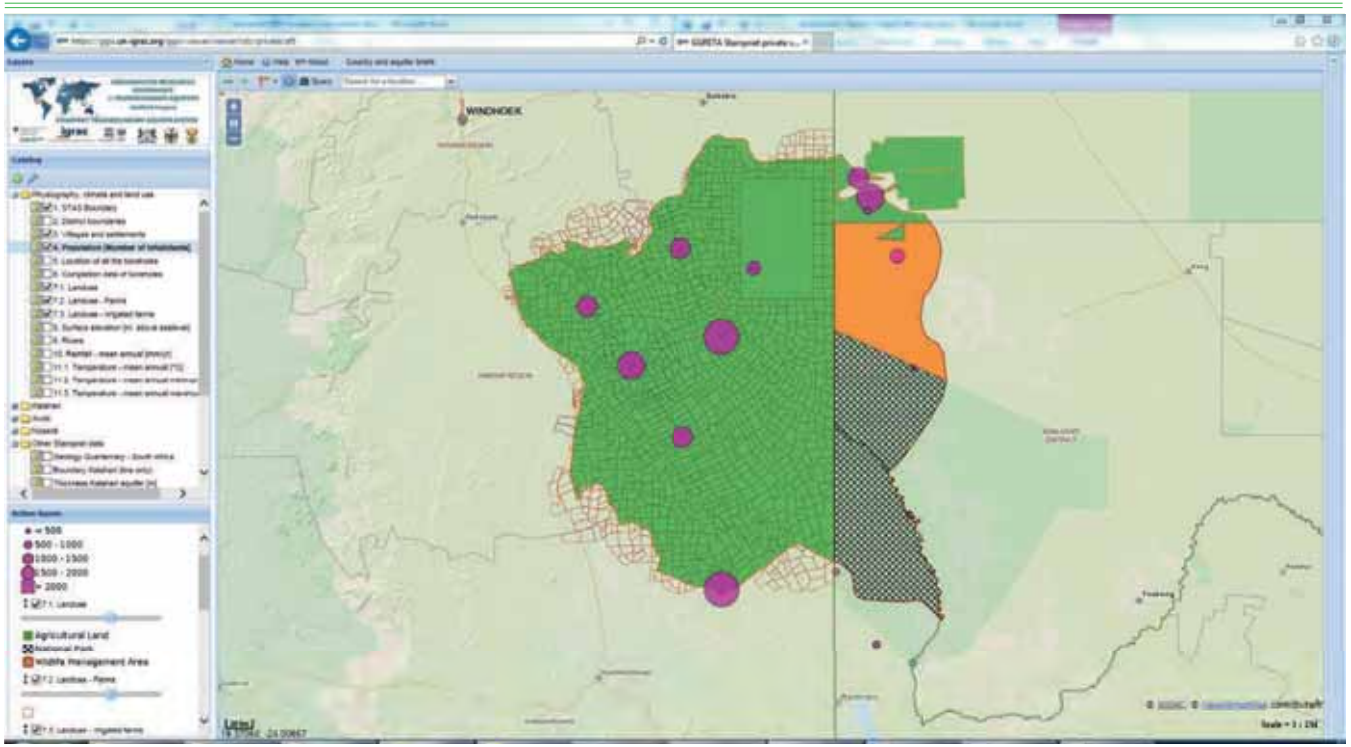
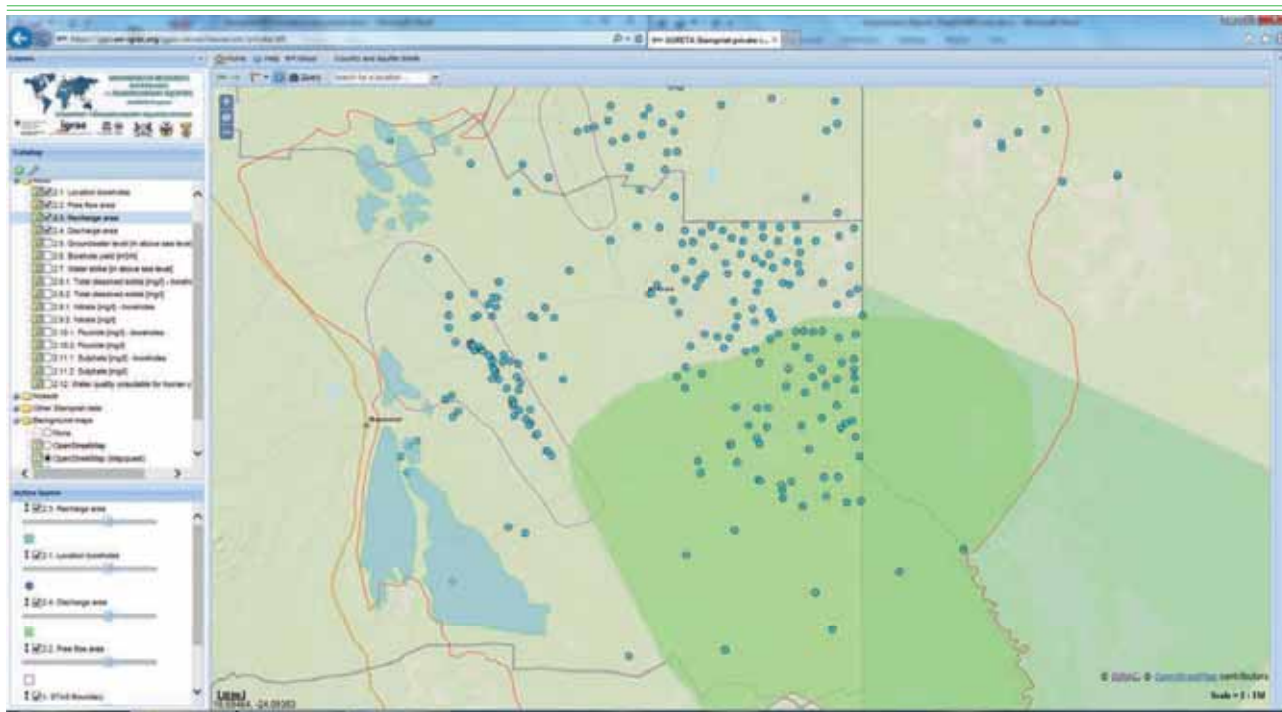


Figure 10.2 | Overlay of thematic maps showing recharge and discharge areas, areas with artesian/free flow conditions and locations of boreholes (all data for Auob aquifer).
(Source: Screenshot GGRETA Stampriet IMS)



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Figure 10.3 | Overlay of thematic maps showing location of boreholes, groundwater (pressure) levels and water quality analyses (TDS) in Auob aquifer.
(Source: Screenshot GGRETA Stampriet IMS)

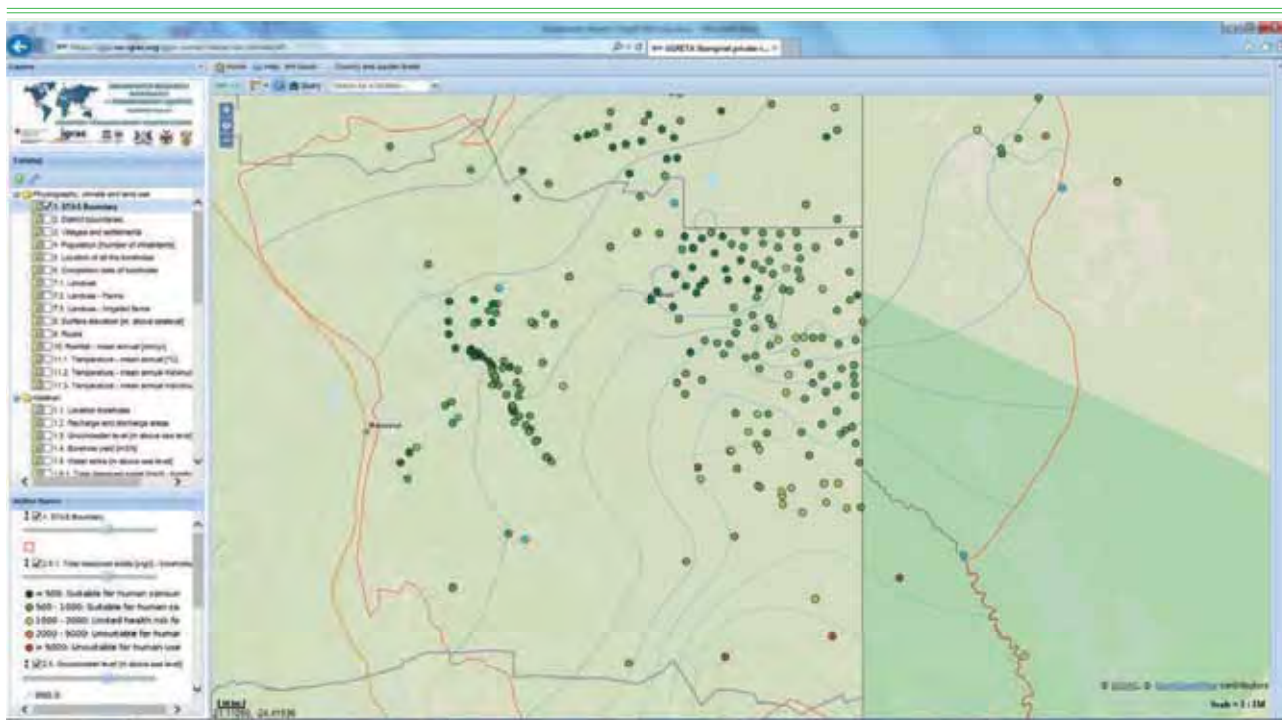


Table 10.1 | Overview of physiography, climate and land use thematic map layers in the Stampriet – GGRETA IMS (status January 2016)

Physiography, climate and land use
1. STAS Boundary
2. District boundaries
3. Villages and settlements
4. Population [Number of inhabitants]
5. Location of all the boreholes
6. Completion date of boreholes
7.1. Land use
7.2. Land use - Farms
7.3. Land use - Irrigated farms
8. Surface elevation [m. above sea level]
9. Rivers
10. Rainfall - mean annual [mm/yr]
11.1. Temperature - mean annual [°C]
11.2. Temperature - mean annual minimum [°C]
11.3. Temperature - mean annual maximum [°C]

Table 10.2 | Overview of thematic map layers per aquifer in the Stampriet – GGRETA IMS (status January 2016)

KALAHARI	AUOB	NOSSOB
1.1. Location boreholes	2.1. Location boreholes	3.1. Location boreholes
	2.2. Free flow area	3.3. Free flow area
1.2. Recharge and discharge areas	2.3. Recharge area	3.3. Recharge area
	2.4. Discharge area	3.4. Discharge area
1.3. Groundwater level [m above sea level]	2.5. Groundwater level [m above sea level]	3.5. Groundwater level [m above sea level]
1.4. Borehole yield [m ³ /h]	2.6. Borehole yield [m ³ /h]	3.6. Borehole yield [m ³ /h]
1.5. Water strike [m above sea level]	2.7. Water strike [m above sea level]	
1.6.1. Total dissolved solid [mg/l] - boreholes	2.8.1. Total dissolved solid [mg/l] - boreholes	3.7.1. Total dissolved solid [mg/l] - boreholes
1.6.2. Total dissolved solid [mg/l]	2.8.2. Total dissolved solid [mg/l]	3.7.2. Total dissolved solid [mg/l]
1.7.1. Nitrate [mg/l] - boreholes	2.9.1. Nitrate [mg/l] - boreholes	3.8.1. Nitrate [mg/l] - boreholes
1.7.2. Nitrate [mg/l]	2.9.2. Nitrate [mg/l]	3.8.2. Nitrate [mg/l]
1.8.1. Fluoride [mg/l] - boreholes	2.10.1. Fluoride [mg/l] - boreholes	3.9.1. Fluoride [mg/l] - boreholes
1.8.2. Fluoride [mg/l]	2.10.2. Fluoride [mg/l]	3.9.2. Fluoride [mg/l]
1.9.1. Sulphate [mg/l] - boreholes	2.11.1. Sulphate [mg/l] - boreholes	3.10.1. Sulphate [mg/l] - boreholes
1.9.2. Sulphate [mg/l]	2.11.2. Sulphate [mg/l]	3.10.2. Sulphate [mg/l]
1.10.1. Water quality unsuitable for human consumption	2.12. Water quality unsuitable for human consumption	3.11.1. Water quality unsuitable for human consumption
1.10.2. Water quality unsuitable for stock watering		3.11.2. Water quality unsuitable for stock watering



11.

Appendixes



11.1 GGRETA Information Management System (IMS)

11.1.1. Description of the IMS

Web application

The GGRETA IMS is a web-based Information Management System, designed and maintained by IGRAC, in close cooperation with UNESCO-IHP and the national assessment teams. It was developed to support decision makers and other stakeholders, involved in the governance of transboundary aquifers, with relevant information. As part of the Global Groundwater Information System (GGIS), the GGRETA IMS has an open and extendable architecture that allows for the implementation of new, dedicated workspaces for new transboundary aquifer projects. The GGRETA IMS meets all the requirements of the OGC international data standards. All data uploaded to the IMS can thus easily be integrated in other external information systems using the Web Map Service (WMS) and Web Feature Service (WFS) standard protocols. Likewise, data from external sources can easily be integrated in the GGRETA IMS.

Figure 11.1 | Entry point for the three case-study dedicated workspaces / viewers.
(Source: Screenshot GGRETA IMS)

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Ownership

All uploaded data is safely stored in the IGRAC’s server in Delft, The Netherlands and is constantly accessible to the working group of a specific project (see Figure 11.1). The data ownership remains with the data providers, namely the aquifer states and their national assessment teams.

Interface components

The interface consist of four main components: 1) a layer panel, including a catalogue containing all map layers with data structured in a systematic way and their associated legends, 2) a map view to visualise the selected data on a geographic location, 3) a feature panel providing tabular output of

the selected data, and 4) main menu with tools. These tools allow the user to search for locations and aquifers, to perform queries on the data and to combine different thematic maps by creating overlays.

Viewing modes

The GGRETA IMS has two viewing modes available to users, depending on the rights they have been granted by the system administrator (Figure 11.2). The *private workspace* is a password-protected area, only available for registered users who have been authorized by the system administrator and who have a special role in the project. In the private workspace, registered users can manage the groundwater information related to the aquifer or region they are responsible for. The authorizations are limited to the aquifer someone is working on. The private workspace allows registered users to upload data such as map information and documents, and to analyse and discuss results before making the data publicly available. Working in a protected environment is particularly useful for sharing draft maps or sensitive information. In the current set-up, the 'regional coordinator' is the only role authorized to move data and maps from the private workspace to the public viewer.

In the *public viewer*, IMS visitors are able to navigate through a map viewer and search for information related to the transboundary aquifer. Aquifer attributes and indicators can be displayed on the map by clicking on the geographical locations of interest. Meta-information is also accessible to facilitate the interpretation of the assessment results. Depending on the project, map layers may be available for download in shapefile format.

Figure 11.2 | Schematic view of functionalities in password protected (private) workspace and public viewer



User roles

Various roles can be defined by the system administrator. Some of the main roles that have been defined so far include:

- *GGRETA partners* have access to the private data in the protected aquifer workspace.
- *GGRETA national experts* can view the data in the protected aquifer workspace, upload map data (Excel, Shape, GeoTIFF) and upload documents to the Meta Information Module (MIM).
- *GGRETA regional coordinators* have the same authorizations as the national experts and can accept/delete data uploaded by national experts. Regional coordinators can also move data from the protected workspace to the public viewer.
- The *system administrator* has the same authorization as the national experts and regional coordinators in order to assist the team with the IMS where necessary.

Data types

Data which can be uploaded to the GGRETA IMS may be of the following types:

- GIS data such as map layers, raster files and tiff images;
- Tabular data in excel file format, such as time series;
- Image files in jpeg, png, and pdf formats;
- Documents in pdf file format.

11.1.2. Data collection and pre-processing

Data collection is primarily carried out by the national expert teams. The national coordinators provide support to the national experts and lead cooperation with other aquifer states. Data sources may include ministries, governmental and non-governmental institutes, universities, literature, etc. Collected data is generally divided into six main categories: 1) physiography and climate, 2) aquifer geometry, 3) hydrogeological characteristics, 4) environmental aspects, 5) socio-economic aspects, 6) legal and institutional aspects. Good coordination, especially during the initial phase of data collection, is necessary to ensure the collected data is of high quality and suitable for the assessment. A main benefit of collecting information in a systematic way is that changes in the various parameters can be monitored over time allowing for the evaluation of whether governance and management actions have been effective. Moreover, data can be stored in an information management system for future use.

The preferred data format depends on factors such as the type of data and the amount of data available. For example, for data that are time dependent it is necessary to structure these into tables and to visualize them in time-series graphs. National experts also need to decide on data collection intervals and on the units to be used, in case parameters are measured in different units. Data that have a spatial variability are preferably shown in maps. Maps often give a quicker impression of the situation than tables or text descriptions. They can also be as detailed as possible and show differences per country, regions and sub-regions, etc.

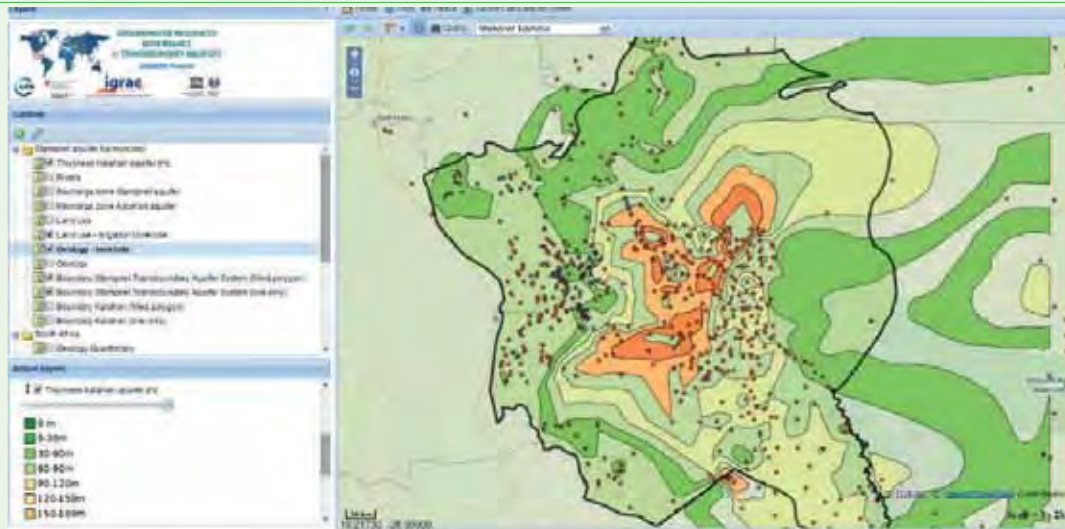
Data processing consists of the steps required to transform raw data collected by the national experts into structured and harmonized products at aquifer level. Data from different sources need to be structured into tables and databases which are internationally consistent. A significant part of the work is related to the processing of map information, including digitizing, reclassification map information, merging of national segment information, creation of new maps and/or spatial calculations. The assessment coordinator, with the assistance of a GIS specialist, ensures that the data meet the required quality standards.



11.1.3. Data harmonization

Harmonization of data and information at aquifer level is a crucial phase in the assessment of transboundary aquifers. Even if information is available, it may not be consistent when it derives from different countries and/or different agencies or projects. To enable cross-border data interpretation, it is essential to restructure the data in a uniform way. Countries use various definitions, formats, and systems to deal with complex data. It is therefore crucial that all parties involved have a common understanding of the aquifer.

Figure 11.3 | Example of spatially distributed aquifer properties in GGRETA IMS map layer
(Source: Screenshot GGRETA Stampriet IMS)



11.1.4. Future developments

It is expected that during the second phase of the GGRETA project, conceptual models will be revised as knowledge gaps still exist on various aquifer aspects. Temporal variations will be considered and observed trends will provide the basis for long term predictions. Data collection will continue and information management systems will be further developed and populated to support and facilitate sharing of data and information between countries and stakeholders. New training modules will be designed and delivered in each country aiming at a more efficient use of the IMS by all interested parties.



12.

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