



The Future Okavango

Findings, Scenarios, and Recommendations for Action



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The Future Okavango

Findings, Scenarios and Recommendations for Action

Research Project Final Synthesis Report
2010 – 2015

Edited by

M. Pröpper, A. Gröngröft, M. Finckh, S. Stirn, V. De Cauwer,
F. Lages, W. Masamba, M. Murray-Hudson, L. Schmidt,
B. Strohbach, N. Jürgens

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Preface

THE FUTURE OKAVANGO

Over a period of five years (September 2010 – August 2015) 140 researchers from eight countries (Angola, Belgium, Botswana, Brazil, Germany, Namibia, Portugal, South Africa), 23 universities, and additional research institutions – mainly from Angola, Botswana, Namibia, and Germany carried out the integrated transdisciplinary research project ‘The Future Okavango’ (TFO) within the whole Basin of the Okavango-Cubango. TFO was part of the international research program ‘Sustainable Land Management’ funded by the German Federal Ministry of Education and Research (BMBF) which again formed a part of the umbrella initiative ‘Research for sustainable development’ (FoNa). TFO has been faced with the challenge of analyzing backgrounds and identifying drivers of ecological and social change, with the goal of improving the sustainable use of the natural resources within the catchment. The TFO project aimed to provide data and scientific knowledge, scenarios (narratives based on future projections of various possible developmental pathways), and recommendations which will help to maintain the functioning of the ecosystems, their services, and the well-being of its population. This book is one of the outcomes of this endeavour.

The project placed a strong emphasis on the robust measurement of ecosystem functions and ecosystem services, including their economic values. The present state of resources and ecosystem functions related to climate, water, soils, microorganisms, crop plants, and woodlands was studied across the whole larger basin, and also in greater depth at four research sites. Remote-sensing data, GIS and models enabled the project team to generate maps that cover the whole catchment. Climate change and other forms of environmental change were measured, modelled and projected, thereby also integrating studies on the resilience of ecosystems e. g. after slash-and-burn activity, and following the impact of bush fires.

The diversity of land-use practices was studied in depth, also including experiments regarding alternative land-use options as e. g. offered by the ‘conservation agriculture’ approach. Simultaneously, the valuation of the natural resources by the local land users was studied, along with analyses of the rankings of values and goods, as well as threats and risks, by the different stakeholder groups. This also allowed the study of the usefulness of incentives, regulations and other governance instruments at the local, provincial, and national levels; the adequacy of transboundary governance approaches in the frame of the OKACOM commission was investigated as well.

At the end of five years, the project team is now proud to hand over all relevant knowledge to the various stakeholder groups.

A first collection of available **basic information** on the Okavango Basin had already been printed in book format (Oldeland et al. 2013) and is available in the digital Appendix. Additionally, TFO has produced more than 70 Bachelors, Masters and PhD theses, plus numerous journal publications and disciplinary reports (see Appendix). To secure long-term access to the data of the project, the Okavango Basin information system (OBIS) has also been created and established at certain places in the Basin (see as well the Appendix).

The present volume is even more explicit with regard to sharing **knowledge and recommendations** that hopefully will support decision-makers in the region to deal effectively with their daily responsibilities, and to use the natural resources wisely – that is, both efficiently and sustainably.

At the same time the TFO project has now established a new and improved level of data availability that allows users to tackle new steps and to ask new questions.

Acknowledgements

An international, transdisciplinary research project like THE FUTURE OKAVANGO (TFO) is strongly dependent on the many institutions and individuals who support it. First of all, we would like to acknowledge the German Federal Ministry of Education and Research (BMBF) for the main funding of the TFO project under the promotion numbers 01LL091 2A, 01LL091 2D, 01LL091 2E, 01LL091 2F, 01LL091 2G, 01LL091 2H, 01LL091 2J, and 01LL091 2M.

TFO has been working to provide scientific knowledge for the support of multiple stakeholders in the Okavango Basin. We thank all involved stakeholders in Angola, Botswana, and Namibia for making this work possible. We are greatly indebted to the many people who assisted the project in the field in various ways during research activities in different parts of the Okavango Basin. We would like to acknowledge the crucial role of all TFO researchers involved in collecting and processing data for this output, and we are also grateful to our many colleagues for their continuous support and critical discussions in the course of the project. The project team gratefully acknowledges the research permissions granted by the respective authorities in all three African countries. Finally, we would like to express our sincere gratitude to all colleagues who supported this final report.

We acknowledge the DLR for the provision of the data from the RapidEye Science Archive.

Chapter 1

Introduction

TFO and the challenge of sustainable land-management in Southern Africa

Africa, like many other developing regions of the globe, is facing serious challenges in protecting ecosystems while improving the well-being of its populations. IPCC reports have singled out Africa as one of the world's regions hardest hit by global climatic change. By 2020, between 75 and 250 million people are projected to be exposed to increased water stress due to climate change. Extreme weather events will increase in frequency, intensity, and duration, including both floods and droughts. The term **globalization** describes the process in which formerly peripheral regions and their resources are increasingly drawn into the global markets, a fact that leads to a growing global use of local resources. The demand for fertile soils and fresh water will continue to transform former local commons into national and global commodities that are contested by local, national, and international agents with differential access to wealth and power. The impact on humans will be most serious and widespread in sub-Saharan Africa. Climate change, demographic growth, and the increasing and conflicting exploitation of natural resources, land, and

water, call for innovative and sustainable approaches to adaptation and mitigation.

These changes will impact on the whole continent however with different intensity. One region that is presently turning into a global hot-spot of accelerating commercialization, land-use change and potential land-use conflicts is the Okavango Basin, which integrates the active parts of the Okavango Basin in Southeastern Angola, Northeastern Namibia, and Northwestern Botswana. At the same time it is still largely dominated by traditional land-use practices like rain-fed subsistence agriculture, which is the main livelihood for a predominantly rural African population of at least 1,000,000 people¹. This growing population, of which three quarters live in the formerly war-torn part of Angola, is largely poor, and most of its members use savannas and wetlands to secure their well-being and pursue traditional livelihoods on communal territories. In such an environment multiple uses of ecosystem services (ESS) such as crops, fish, wildlife, fuel, timber, fiber, forage, and water to meet the basic needs of energy, food, and water supply are potentially transforming ecosystems through overutilization and commodification, with unknown consequences for the ecosystems as well as for local livelihoods.



Fig. 1: Okavango River Floodplains close to Rundu (photo: H. Göhmann).

¹ Year 2014, counting the populations of all adjacent provinces (Bié, Kuando Kubango, Kavangos, Northwest District) we calculate 2,200,000 people.



Fig. 2: Okavango Delta (photo: H. Seidel).

Against this background the project has sought to generate scientific knowledge to support an integrated transboundary management for the Okavango region that allows a sustainable and equitable utilization of its ecosystem services. To reach this objective, the project, consisting of ten disciplinary subprojects from natural and social sciences, has investigated fundamental ecosystem processes and functions as well as a large range of valuable services that nature provides, ranging from tangible goods such as food and timber to intangible benefits, such as the spiritual values of the environment. The goal of the whole exercise



Fig. 3: Youths selling small game at the roadside (photo: B. Kowalski).

was firstly to provide an assessment of the current status of the ecosystems and the services they are able to provide. For this task scientific measurements and models were used to quantify the functions and services provided under different management regimes. A second, equally important task was to understand how stakeholders at different levels (the land users and land managers) value and actively involve these services in their daily strategic actions as well as their future plans. Thirdly, TFO had to come up with projections for the future illustrating alternative pathways that current land-use dynamics, population trends and management plans might follow. We refer to such projections as **scenarios**, and they are a central tool to help decision-makers to better understand the consequences of their current decision-making. Scenarios are meant to show and visualize under a variety of land-use strategies and development policies the benefits and tradeoffs for all actors involved (from the local farmer or the urban dweller to the global agro-industrial company).

This book is the outcome of the research endeavour called The Future Okavango (TFO), which lasted from September 2010 until August 2015. It presents in several chapters the current state of the Basin as assessed by TFO, plus key findings and recommendations as formulated by all involved disciplines and partners, and presents some future scenarios for the whole basin as well as for three of the local research sites at which TFO worked.

The TFO FORA and core site approach

During the process of delineating a research area the project participants of TFO agreed upon the **FORA** (Future Okavango Research Area, see fig. 5). It has a total area of 228,106 km² and differs slightly from the basin as defined entirely by hydrological criteria, which is for example used by OKACOM. The FORA comprises three sub-areas:



Fig. 4: Women carrying cassava, an important staple food in many rural communities (photo: A. Görngröft).

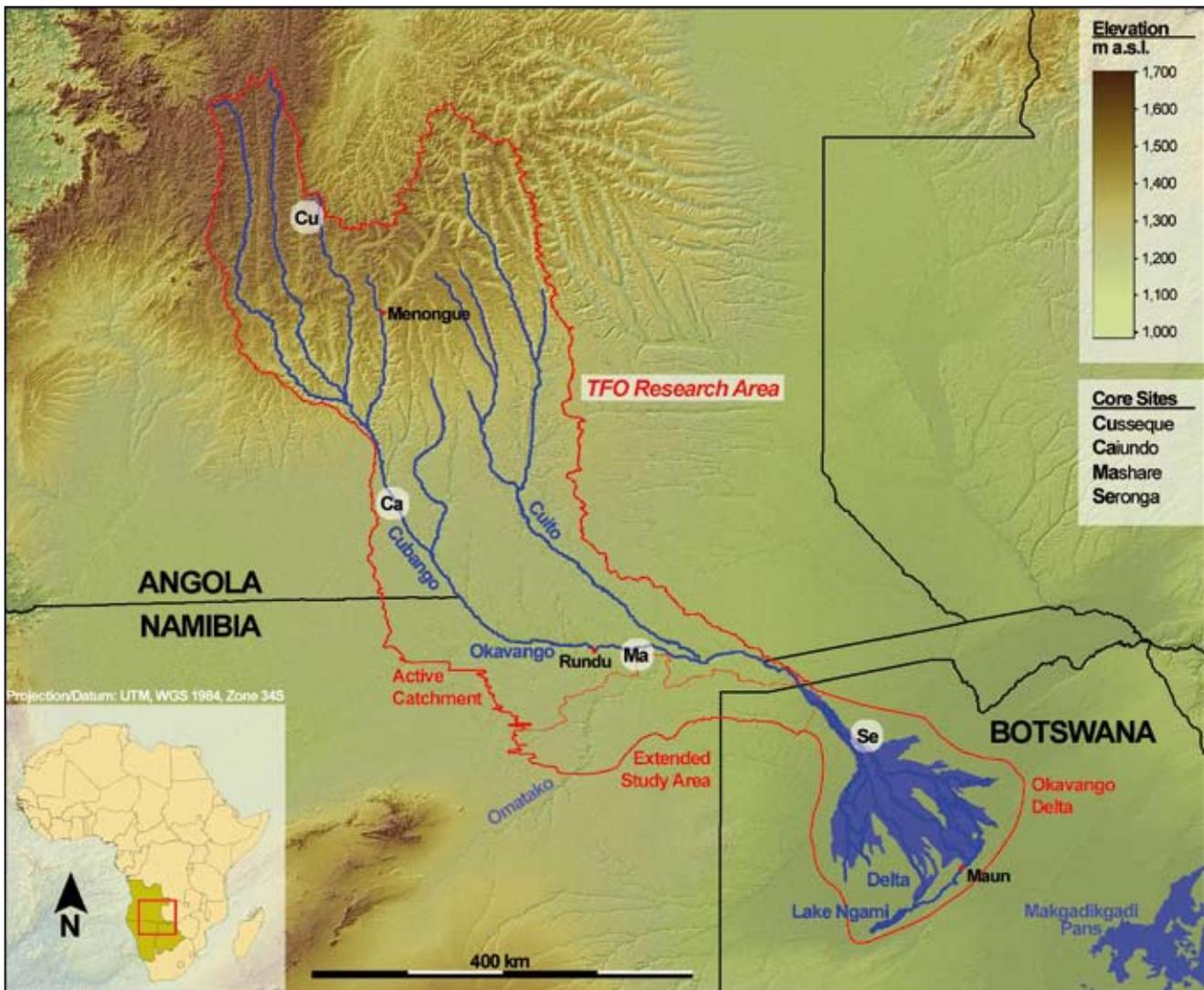


Fig. 5: The Future Okavango Research Area ,FORA'.

- a.) The **Active Catchment** in the northern part according to the hydrological analysis of SP02 as a state-of-the-art delineated watershed area above the Mohembo gauging station, which is the link to the delta. The non-active Omatako Catchment and the Makgadikgadi Pan (Kalahari Basin) are both excluded. However, the definition of the active catchment is very close to that used by OKACOM.
- b.) The **Extended Study Area** connects the active catchment and the delta (see below). It corresponds to the lower parts of the Omatako Catchment and follows as its southern boundary the map contour line indicating 1,000 to 1,200 meters above sea level. Besides the linkage of active catchment and delta (see below), the Extended Study Area is defined to include parts of the socioeconomically important Kavango Region of Namibia. This is necessary within the focus of TFO because of the prevalent resource use in the hinterland.
- c.) The boundary of the **delta** is established on the basis of drawings made by the Okavango Research Institute and by the Environmental Information Service of

Namibia, respectively by Mendelsohn and el Obeid in 2004. The delineation has been adapted to the specific requirements of the TFO partners, e. g. it includes Lake Ngami and areas north of the delta itself, which are strictly defined as grazing areas of the core site Seronga. Thus the sub-area of the **delta** is not defined according to hydrological criteria **sensu stricto**.

Even for a research project the size of TFO it is impossible to closely investigate all forms of land use in the diverse social, ecological, and political settings of the huge Okavango Basin. Consequently the team identified and chose four joint local research sites, each 100 km² in size (subsequently referred to as **core sites**: Cussequ, Caiundo, Mashare, and Seronga) spanning the entire basin from the headwaters to the delta (Fig. 5). With this step the TFO project has made a crucial move towards cross-disciplinary and cross-sectoral studies that would represent wider areas and ecosystems within each of the countries. The central idea of joint core sites was that many of the place-based disciplines would concentrate their work and research activities in the same area.



Fig. 6: Impressions from the three core sites Cusseque, Mashare and Seronga (photos: M. Finckh, H. Seidel, L. Schmidt).

The selection of these sites was guided by various reflections (e. g. safety of access in Angola; location between two water gauges in Namibia; location at the populated Panhandle in Botswana) but especially to capture a variety of existing ecological systems, a representative set of current land-use types and intensities, and a spectrum of modern economic impacts (markets, new land-use planning, irrigation schemes etc.). The Cusseque core site was chosen due to it being representative of Miombo woodland areas with a medium population density, and Caiundo was chosen as representative of sparsely populated woodlands. The Mashare core site is likewise representative of densely populated woodlands on Kalahari sands, and Seronga of sparsely populated areas at the transition between the Kalahari dune areas and the wetlands of the Panhandle. Additionally, the sites were chosen according to their geographical properties (size, accessibility) enabling equal involvement of all disciplines. On these sites all involved partners combined an in-depth analysis with data mining and application of existing knowledge in the assessment of ecosystem services and land-use (see exemplary fig. 7).

Taken together, the four core sites also represent regions along the climatic gradient, with increasing annual mean temperature, decreasing precipitation, and less mountainous terrain as one moves from the Angolan highlands to the delta (Weber 2013, Gröngröft et al. 2013).

With this site-specific team effort in three countries, TFO has achieved a sound understanding and analysis of **(i)** socio-ecological system drivers against the background of a growing population; **(ii)** an increasing involvement of formerly local settings and markets in global-level processes; and **(iii)** an increased demand for resources like water, food, and energy. This means especially understanding relevant factors that hamper the system performance and lead to ineffective uses of land and resources (such as e. g. differing levels and perceptions of land user knowledge about best-practice land uses). As has become apparent, the people who use this large basin – the stakeholders – had to be closely involved during the whole research process. How did TFO manage this challenge?

Stakeholder involvement

The Future Okavango project was dedicated to providing meaningful benefits to the local communities, especially at the research sites, but also at a larger scale. Being aware of the project's research nature and the lack of a mandate to implement interventions, the project was intended to improve the living condition of local resource users through a mutual learning process whereby local and formal scientific knowledge systems jointly help to identify innovative sustainable management approaches. From the beginning of the project the idea has been to create permanent local structures with increased capacity to promote community-driven and stakeholder-supported development processes beyond the duration of the project. Different tools for involvement have supported ongoing exchange and interaction with the local resource users. This included the establishment of community-based platforms for stakeholder interaction as well as the employment of para-ecologists as important links and facilitators between local stakeholders and academic researchers. Participatory film making has allowed local land users to communicate their activities and concerns related to natural resource-uses. These films – one from each core site – are open accessible to a broad range of interested parties and also available on the TFO website. In addition, it was planned that the communities would benefit from project

training in innovative resource-management practices. Making research results available to government officials and service providers also served as a way to lobby the interests of the communities, which hopefully will benefit from resulting improvements in service provision.

In order to enable an impact beyond local research sites, the TFO project also continuously engaged with policy-makers in particular as well as with government decision-makers in general. Important in this context was the development of scenarios and the prediction of the consequences associated with particular development interventions. Government officials at both the regional and national level have requested this support. In addition, the TFO research can help to evaluate the suitability of currently implemented policies for achieving the governments' development objectives. The project further provided the authorities with ecological and socio-economic baseline data which will be helpful in future to monitor management, governance, and climate-change-related transformations in the socio-ecological systems. Key findings have been communicated in a condensed way, adapted to the needs of this stakeholder group.

At the same time, the TFO project strongly depended on the support of the government authorities. Their political support is the foundation for the project's success. Policy-makers have the mandate and authority to regulate the management of natural resources.

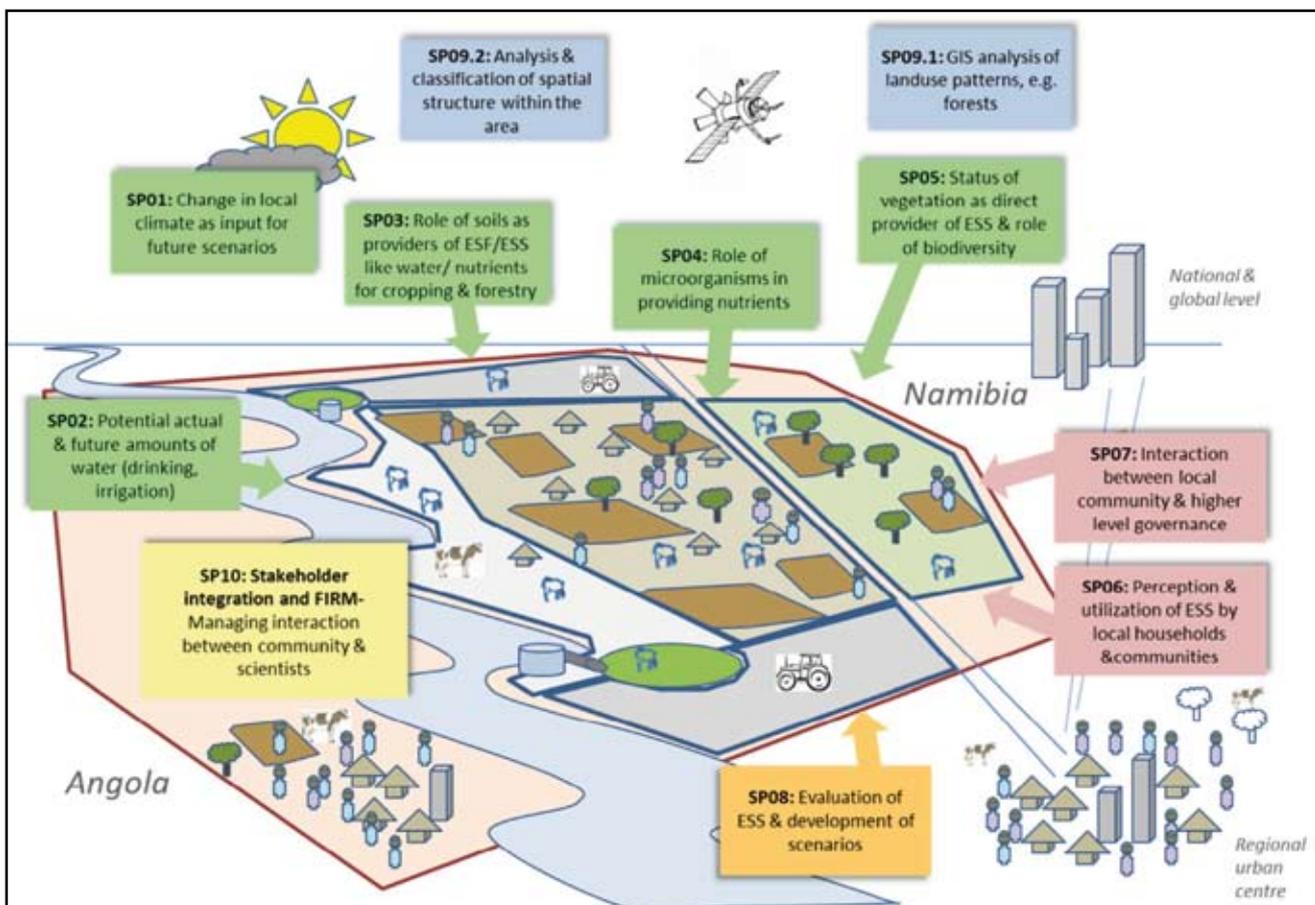


Fig. 7: Inter- and transdisciplinary work at the core site of Mashare, Namibia.

Therefore, the project's impact is eventually dependent on their willingness to discuss, test, and implement policy innovations.

Of particular importance is the close link to the current process of protecting the ecological, social and economic integrity of the Okavango Basin coordinated by the Permanent Okavango River Basin Water Commission (OKACOM). Guided by the spirit of managing the Okavango River Basin as a single entity, the three sovereign states of Angola, Botswana, and Namibia agreed to sign the 'OKACOM Agreement' in 1994, in Windhoek, Namibia. The Agreement commits the member states to promoting coordinated and environmentally sustainable regional water resources development, while addressing the legitimate social and economic needs of each of the riparian states. The three countries recognized the implications that developments upstream can have on the resources downstream (OKACOM 2011).

The Future Okavango project made strong attempts to continuously engage with OKACOM structures in ongoing processes. This started by adapting the TFO research plan to the OKACOM Strategic Action Plan (SAP). TFO has been endorsed by OKACOM as a project contributing to the implementation of the SAP. In this way TFO provided crucial contributions identified by the three riparian countries to be important stepping stones toward a joint, peaceful and sustainable management of the basin.

How to read this document

The entire book is organized into several main chapters, which follow this introduction.

- **Chapter 2, Methodology**, offers an overview of the different methodologies that the various teams and disciplines used. This chapter is meant for stakeholders who wish to better understand the processes by which certain data were acquired and produced, and to comprehend their validity and representativeness.
- **Chapter 3, Current State**, offers a condensed and integrated description of the status quo of the Okavango Basin – as well as the four core sites – as assessed by TFO. It has to be acknowledged that such a description can naturally never be exhaustive, and may be biased by the disciplinary expertise of the scientists involved. However, it offers interested stakeholders the broadest, most factual and empirically-based status description that currently exists. For readers that would like to enquire about the data and literature that have been used to describe certain topics and single subjects: These have been supported by variable descriptions which can be found in the Appendix, and which indicate the specific data and literature used.

- **Chapter 4, Key Findings**, presents an in-depth look at key findings as produced by the various partners involved in TFO. In sum, TFO came up with 45 findings, which have been arranged under five topic headings (Climate & climate change; Water use, availability & management; Conservation and management of living natural resources and their ecosystem services; Agriculture & Food security; and Decision processes/Social interaction). This means that readers can search for a topic of interest and then find several key findings related to that topic. Single findings have been structured into (1) the specific findings; (2) background information; (3) data sources and literature. Recommendations for action related to these findings can be found as summaries at the end of the respective five sub-chapters.
- **Chapter 5, Trends of Possible Future Development** describes the process by which TFO developed 4 projected future scenarios for the basin and the 3 main core sites respectively, and offers descriptions of the possible outcomes of these processes. This is a lengthy chapter that thoroughly – though, again, certainly not exhaustively – discusses four alternative pathways into the future for the representative sites and the basin, and will give interested stakeholders and decision-makers a lot of food for thought.
- **Chapter 6, Synthesis**, offers a summary of the results that this five-year project of African and German partners was and was not able to achieve. It formulates a road ahead for future research.
- **Literature**
- **The Electronic Appendix** consists of 2 DVDs:
 - **DVD A** contains further TFO materials for in depth reading such as background information on the variables used for the scenarios, additional subproject-specific results and the freely accessible TFO special issue Biodiversity & Ecology 5. **The document 'Where to find...?'** outlines how the post-TFO data storage was organized, and where interested readers can find data, maps, publications, and other materials that were produced by TFO.
 - **DVD B** contains spatial data, maps and a version of the Open-Source Software SAGA to handle these mapping products. Altogether these products form a mapping and GIS-based Decision Support Tool that provides stakeholders and decision-makers with an in-depth illustration of the TFO results as well as enabling them to make their own assessments building on TFO know-how.

Chapter 2

TFO Methodology

This chapter offers an overview of the multiple methodologies that were applied by the different disciplines in TFO over the period 2009–2015. TFO inter- and transdisciplinarity had been designed according to the following scheme (fig. 8) which outlines the cooperation between the 10 disciplinary subprojects. The flows of data and products between subprojects are indicated in the figure with numbered arrows, and will be explained below.

1. Information about the patterns and processes of ESF and ESS were fed into the analysis of social and economic mechanisms and measures to understand and optimize land-use practices. Benchmarks provided sites where ESF and ESS can be assessed comparatively. Social data were used to improve natural science field research.
2. Indicators for establishing the values of various ESS were adjusted. Locally recorded climate data were provided and modelled to assist in the valuation.
3. GIS-based landscape analysis was used to aid the selection of study sites. Data recorded locally were

upscaled to larger areas using satellite-based information and RS-based maps, and additionally productivity estimates were provided for stratification purposes. Locally recorded data, along with climate data, were provided for GIS-based landscape analysis. GIS-based environmental model data were fed back to inform local measurements.

4. GIS-based data were fed back into the scenario process to suggest alternative land-use pathways.
5. GIS-based landscape analyses were used for study-site selection; maps were fed back to inform local, on-the-ground land-use research and institutional regulations. Socio-economic results were integrated into the spatial analysis.
6. Findings on cultural and socio-economic dimensions of land-use changes, institutional improvements, and governance alternatives were used to support the economic valuation of ESS.
7. Findings on ecological, cultural and socio-economic dimensions of land-use changes, institutional improve-

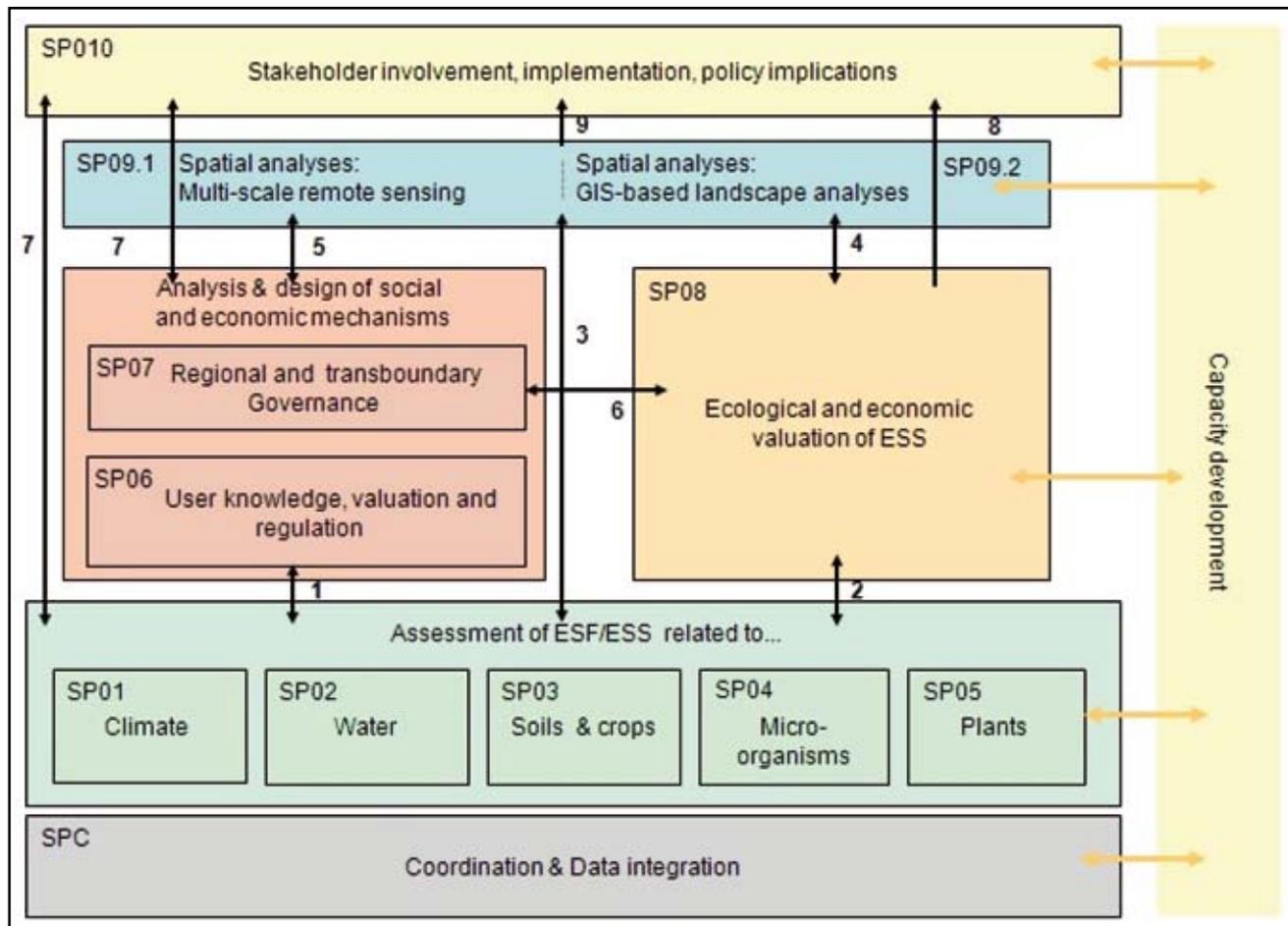


Fig. 8: Schematic flow diagram of the inter- and transdisciplinary collaboration within TFO.

ments, and governance alternatives were fed into stakeholder-related products; stakeholders were involved in local studies.

8. Findings and implications of economic valuation, values, costs, and benefits of ESS were fed into stakeholder-related products and the testing of interventions.
9. GIS-based scenario analysis of valued ESS were used to inform stakeholder-related products and to suggest policy implications.

In the following sections we offer a more detailed description of the methods used by disciplinary clusters for those stakeholders interested in this information. More detailed information and contact details, as well as literature for specialized scientific readers, can be found in the appendix in the subproject reports.

2.1 Natural Sciences

2.1.1 Climatology

For the TFO scenario-building process, climate change scenarios are of the greatest interest, because changes in the climate in the Okavango River Basin may affect all the components of the hydrological cycle, and thus the lives of the people living this region.

In order to develop strategies for sustainable land management in the basin, scientists from various disciplines and decision-makers alike need high-resolution climate change information. To generate such detailed climate projections, regional climate models are used to downscale simulations (i. e. to calculate the climate data at higher spatial and temporal resolution) created by global circulation models. Climate projections, however, contain various uncertainties which have to be considered and estimated. The uncertain-

ty originating from climate models can be estimated by applying different global circulation models and regional climate models. In long-term climate change projections, however, the largest portion of uncertainty is assigned to the human contribution to climate change, which is a result of unknown developments in technology, economies, lifestyle, and policy.

This uncertainty can be tackled using different emission scenarios covering a wide range of possible future anthropogenic emissions. In the TFO project the new Representative Concentrations Pathways (RCPs) are considered, which include both moderate (RCP4.5) and high (RCP8.5) possible anthropogenic emissions scenarios (Moss et al. 2010). Finally, the uncertainty resulting from the climate variability can be reduced by taking the mean of a given meteorological variable over a sufficiently long period of time, e. g. 30 years. In the TFO scenario-building process, only the high-emissions scenario (RCP8.5) was considered, since for the near future the emissions pathway of RCP8.5 is similar to the projections of the former Special Report on Emissions Scenarios (SRES) A1B. Thus, the results can be compared with the SRES scenarios used in other research projects.

In detail, subproject 01 generated climate change projections at a high spatial resolution for the Okavango River Basin. The regional climate-change projections were dynamically downscaled with the regional climate modelling software REMO (Jacob 2001) using data from the global circulation models ECHAM6 (Stevens et al. 2015) and EC-EARTH (Hazeleger et al. 2010). To obtain the high spatial resolution of 25 x 25 km² for the regional climate change projections, a double nesting method was applied (i. e. initially, the climate data were downscaled to a spatial resolution of 50 x 50 km², and then subsequently downscaled again to a spatial resolu-

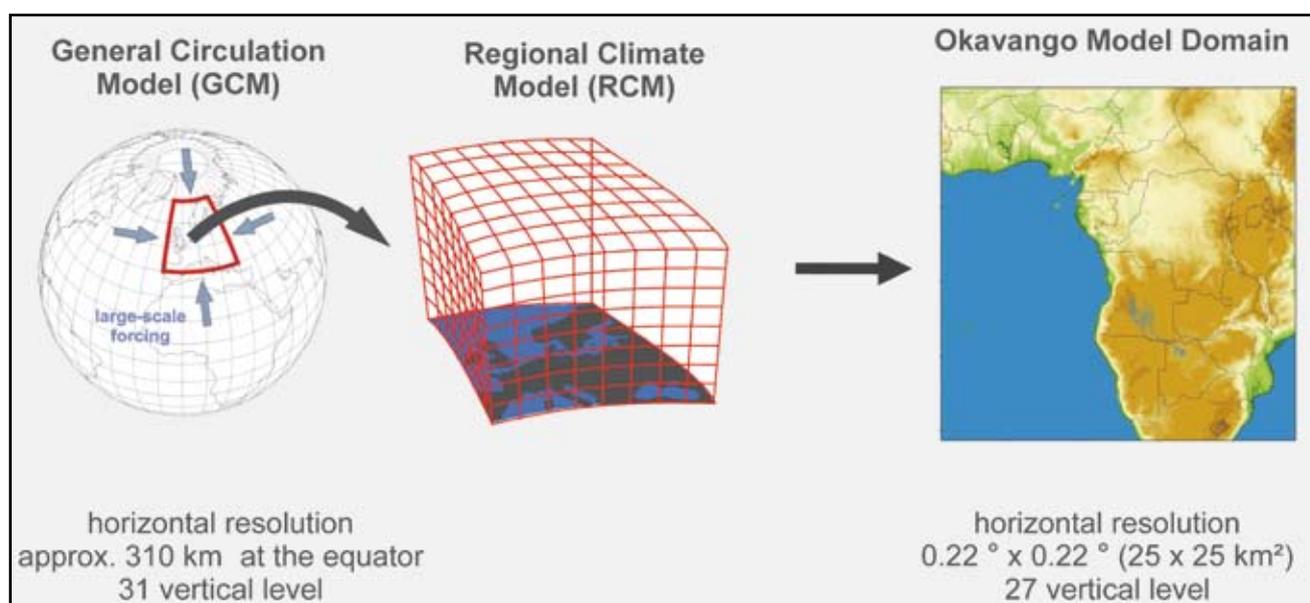


Fig. 9: Methodical approach for the analysis of present and future climate conditions.

tion of 25 x 25 km²). The climate change signals were analyzed for the near-future period 2016–2045, and respective to the reference period 1971–2000. The possible change in each meteorological variable is indicated by a range (between a minimum and maximum value), which expresses the uncertainty resulting from the use of two different global models as input for the regional climate model.

2.1.2 Hydrology

The hydrological research team studied the processes of the hydrological cycle in the Okavango River Basin to assess its current and future states and to understand the interactions between climate and water fluxes in the landscape, ultimately aiming to make a qualitative and quantitative assessment of hydrological ESS/ESF. To address this objective, relevant time-series data (climate and river-discharge data) and geospatial data (maps of

land-use, soils, geology, and relief) of the basin have been collected and analyzed to contribute to a holistic understanding of the hydrological system.

Based on the concept of Hydrological Response Units (Flügel 1996) and the hydrological modelling system JAMS/J2000 (Kralisch and Fischer 2012, Krause 2002), mathematical simulation models of the basin were created, covering different spatial and temporal scales. In regions and time periods with poor coverage of measured climatic data, ERA40 climate reanalysis data were used as input for the JAMS/J2000 model to fill the gaps. Using these models, spatially distributed hydrological system conditions (e.g. evapotranspiration, soil moisture, direct runoff, baseflow, and river runoff) were simulated for relevant sub-basins of the Okavango at daily and monthly temporal resolutions for recent time periods. For model calibration and validation, data from representative headwater catchments in the Angolan part of the basin with a good coverage of measured river runoff data were used.

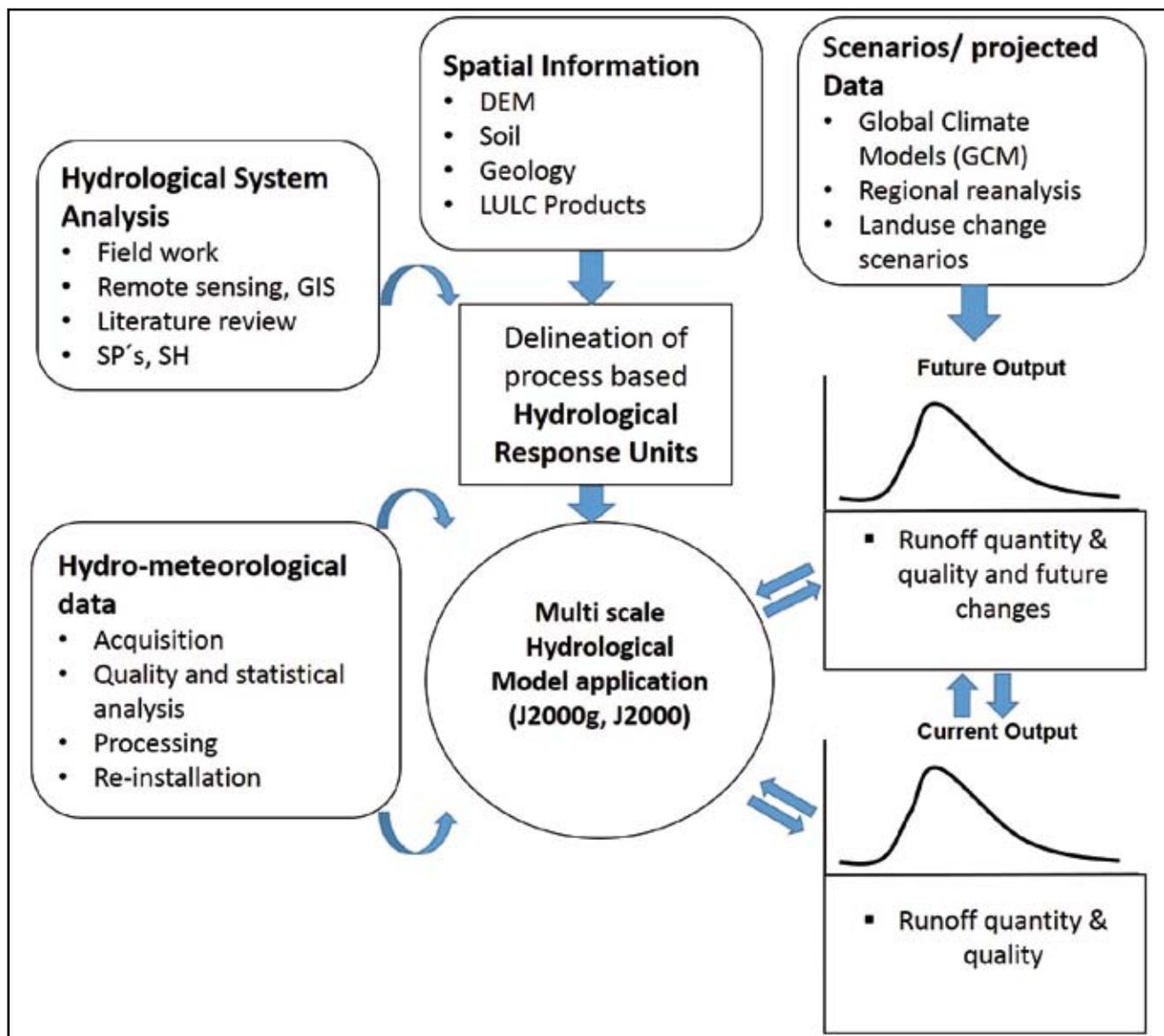


Fig. 10: Schematic flow diagram of the methodical approach of the hydrological research team.



Fig. 11: Soil samples collected in Mashare, Namibia (photo: A. Gröngröft).



Fig. 12: Soil scientist at soil-water monitoring station (photo: J. Luther-Mosebach).

Using the calibrated models of the Okavango River Basin, the future development of hydrological system conditions was projected, assuming changing climate conditions based on both the RCP4.5 and RCP8.5 emissions scenarios and future scenarios of land-use change (e. g. deforestation). Due to its ability to assess the impact of changing climatological and biophysical conditions on hydrological processes, the method applied allows valuable conclusions to be drawn about future development trends, and can inform stakeholders, basin planners, and decision-makers about optimized water resources management options.

2.1.3 Soil Sciences

The soil science research group focuses on the role of soils in enabling the provision of ecosystem services through a number of soil-specific functions. Here, a specific challenge is to balance the in-depth analysis of patterns and processes within the soil with the extrapolation of existing knowledge both spatially and temporally. Additionally, farming practice in the Namibian Kavango, and implementations in conservation farming techniques to improve yields and income for rural communities were analyzed.

The inventory of soil types within the core sites was described. A sampling strategy was designed to cover all important soil functions. The core sites were delineated and stratified according to landscape structure and land-use types, and several independent sampling positions for soil profiles and topsoil mixed samples were chosen in every stratum. In total 1,382 soil samples were taken from 410 point locations, of which 267 were soil profiles and 143 were mixed topsoil samples. The physical and chemical properties of the samples were analyzed using standardized laboratory procedures, and the soils

were classified according to international standards (FAO 2006).

To study the relation between weather conditions, vegetation, and the soil-water balance, two approaches were followed: **(i)** At nine point locations, automatic soil-water monitoring stations were established and maintained for at least one season. These data are used to validate modelled water balances. **(ii)** For typical soils and land-use conditions within the core areas, site-specific data on soil hydraulic properties and vegetation characteristics (root distribution, leaf area indices) were determined. Combined with modelled climate data for the core sites, (see Climatology) for a 30-year period (representing 1980–2010) the soil water properties and balances were modelled using SWAP 3.2 (Kroes et al. 2008). The modelling was performed on a daily basis for 30 different soil- and land-use variants. The advantage of this modelling approach is the possibility of generating knowledge for a long time period under different environmental settings.

Soil carbon stocks were quantified for all landscape and land-use units up to a depth of 1 metre. Local CO_2 -flux and CO_2 soil-gas gradients were measured on three plots per stratum on the most important landscape and land-use units. CO_2 concentration profiles were determined by collecting soil-gas samples at different soil depths using vertically inserted aluminium tubes. Fluxes were measured using a closed chamber method and were compared to fluxes modelled by the gradient method using the CO_2 concentration profile (Maier and Schack-Kirchner 2014).

For the soils of all landscape units we assessed the fertility based on measured acidity and the concentrations of organic carbon and of the nutrients nitrogen, potassium and phosphorous. These values were used to estimate potential yields in applying the QUEFTS model (Quan-



Fig. 13: In situ experiment to determine nitrogen liberating processes i. e. ammonification and nitrification rates under natural conditions (photo: K. Huber).

titative Evaluation of Fertility of Tropical Soils' (Sattari et al. 2014)). This generic model combines empirical relations between the application of the three nutrients N, P, and K on crop yields with theoretical assumptions about nutrient availability in the soils. The general assumption regarding crop growth is that the crops need all three nutrients in specific proportions; however, if in the soil the optimal balance of nutrient availability is not realized, the crops are able to vary the nutrient uptake between a lower and an upper threshold. Additionally, we developed a soil fertility index (SFI) as a site-specific index which is thought to be proportional to the yield potential if both other factors (water supply and management) are at an optimum.

2.1.4 Microbiology

The microbiological subproject first aimed to better understand and analyze soil microbial nutrient cycling. Soil microorganisms are the key drivers of nutrient recovery in soils (i. e. of recovery of carbon, nitrogen and phosphorus) and therefore directly affect the soil fertility, as they are able to release nutrients from crop residues and manure and transfer the often-limited nutrient nitrogen directly from the air to the soil. Analyses of microbial nutrient cycling were based on knowledge of the amount and composition of bacterial biomass and on the quantification of key bacterial reactions in the soils. For this purpose, within the TFO project SP04 has developed and used suitable methods for (i) the determination of soil bacterial biomass, (ii) the detection of shifts in the composition of active soil bacterial communities, (iii) the study of the nutrient-regeneration potential of relevant microorganisms in laboratory cultures, (iv) measurements of the CO₂ flux in the field, (v) the quantification of net ammonification (a nutrient



Fig. 14: Field experiments on smallholder's field on Kavango sand: Planting cowpeas with peat-based inoculant of symbiotic bacteria for nitrogen fixation (*Bradyrhizobium*) (photos: B. Reinhold).

liberation process) and nitrification (leading to nutrient loss) as important parts of the soil nitrogen cycle, as well as assessment of bacterial gene activities in nitrogen cycling, (vi) determination of degradation potential of complex soil organic matter and (vii) the shift in the composition of the active soil bacterial community induced by different soil-relevant substrates.

In another step the microbiological team investigated the coupling of nutrient cycling, microbial diversity and land-management practices. Several soils representing different land-use and/or soil types were chosen as sample media from which bacterial isolates, which are thought to play an important role in soil nutrient cycling and soil fertility recovery potential, were cultured. Intensive isolation methods applied to solidified media yielded more than fifteen pure cultures as relevant members of the soil microbial community, which will improve our knowledge about microbial nutrient cycling in subtropical savannah soils.

Lastly, bacteria as bio-fertilizers responsible for nitrogen inputs were investigated. Nitrogen-fixing symbioses between *Fabaceae* and rhizobia form root nodules that deliver nitrogen from the air to the plant, and enhance the nitrogen content of the soil. Local grain-legumes and pulses from smallholder farms in Namibia and Angola were screened for efficient root nodules, and the symbiotic bacteria were isolated into pure cultures. We gained a collection of 91 rhizobia, and characterized these bacteria (taxonomic relationships and physiology). Symbiotic capacity to form nitrogen-fixing root nodules with local legume hosts was analyzed in the laboratory, and efficient strains were selected for field tests in the Kavango Region. Peat was used as a carrier for the bacteria as inoculant technology for seed coating before planting.

2.1.5 Botany and System Ecology

The botanical and ecological research group studied vegetation patterns and dynamics, and vegetation-based ecosystem services. To analyze the species composition and vegetation structure of the main ecosystem types in the Okavango Basin, several hundred vegetation plots of different sizes were established across the whole catchment, from the highlands of Bié down to the delta. The team followed a random stratified sampling design, aiming to cover all major vegetation units of the four core sites and at basin level. Linking these vegetation data to land cover classifications based on satellite imagery (Landsat, MODIS time-series analyses) allowed the generation of a vegetation map of the basin and the core sites.

The established vegetation units served as spatial baseline information to investigate spatial and temporal changes in vegetation and the provision of specific ecosystem services. Vegetation plots located at different phases of vegetation succession helped researchers to analyze how natural forest and woodland ecosystems regenerate after use (agriculture, exploitation). Size class distribution curves were calculated to assess the regeneration potential of woodlands and gallery forests. As timber and other tree products are important ecosystem services, the team measured tree height, and tree diameter at breast height (DBH) on the plots. Based on these measurements they calculated standing woody biomass by applying allometric functions. At Cusseque core site, underground biomass was assessed by harvesting all woody structures in the first 50 cm depth of small soil pits. Woody biomass was calculated per vegetation unit, and based on the area of each vegetation unit the total woody biomass per core site and for the FORA was extrapolated.

Carbon stocks of the standing woody biomass were than approximated by multiplying by 0.5 (the mean carbon content of woody biomass is about 50 %). Grazing and

browsing potential was estimated locally by making volumetric measurements of standing biomass, harvesting and subsequent fodder analyses, and modelling.

To assess the importance of forest and woodland habitats for the avifauna, bird censuses were taken at the core sites of Cusseque, Caiundo, and Seronga using point counts. To map the landscape integrity of core sites and FORA, the degree of naturalness of the vegetation units was determined, and divided into classes from very high (natural) to very low (non-natural). Major obstacles interrupting ecosystem connectivity at the landscape level, such as roads, veterinary fences, and larger cities, were incorporated into the integrity assessment.

Due to the large and barely accessible hinterland of the Okavango Basin, modelling approaches were indispensable for extrapolating results to the catchment scale. To model the species diversity and the distribution of important tree species we used species distribution modelling techniques (SDMs).

Transpiration of gallery forests in the delta (and associated water losses from the delta) was approximated through sap flow measurement of the dominant tree species and the application of models for plant transpiration.

On the Angolan Plateau micro-climatic conditions shape the vegetation landscapes and limit options for agricultural use. To understand the vegetation mosaic the team thus installed 21 microclimatic measuring stations in the main valley and the in the tributaries of the Cusseque core site.

Provision of services to local communities is at the very centre of the ecosystem-service concept. The vegetation provides medicinal plants, construction materials, and wild fruits, among many other services. In order to assess people's knowledge of and usage of local plants, interviews were carried out at the core sites. Groups of local people were asked to list all the plant species they use according to predefined use categories.



Fig. 15: Scientists establish a vegetation plot in Cusseque, Angola (photo: M. Finckh).



Fig. 16: Weighing a trunk of *Julbernardia paniculata* to determine the consumption of woody biomass in Cusseque, Angola (photo: R. Kissanga).

2.2 Social Sciences

At the core of the activities of the broader TFO social science team was a jointly designed Socio-Economic Baseline Survey (SEBS). From 2011 to 2012, the team conducted a structured household survey in all case study areas in the three provinces adjacent to the Okavango Basin, which contained questions about households' socio-demographic attributes, household consumption and living situation, household production activities, income sources, and expenditure. Data collection was undertaken in November and December 2011 in the Mashare/Kavangos, Namibia, and Seronga/Ngamiland, Botswana. In September/October 2012 a similar survey was conducted in several villages in the greater Chitembo core research area in the Bié Province of Angola. The survey was executed with the assistance of trained interviewers.

2.2.1 Anthropology

The anthropological research design facilitated a comparison of the three communities/core sites, which have all been studied intensively through long-term ethnographic fieldwork by mixed teams of post-doctoral and MA students coming from Germany and Africa. These teams all worked with comparable methodologies, engaged in close exchange with one another, and established a social-science research transect through communities employing various food and income strategies along the Kavango River and in the hinterland. Studies applied intensive ethnographic fieldwork and participant observation. In all sites, the teams collected comparable qualitative and quantitative data on the ecological knowledge, nature-valuation, transformed consumption patterns, and incentives and decision-making structures which influence the management of ecosystems and their services. Observations were a vital complement of an assessment relying purely on oral data.



Fig. 17: Training of interviewers in the Chitembo area, Angola (photo: B. Kowalski).

It was imperative for the research to gain a solid ethnographic understanding of diverse household activities and transactions by using quantitative micro-surveys, e. g. by free-listing households' environmental knowledge, mapping their environmental valuations with landscape value maps, interviewing subsamples about their income and expenses, inventorying household's possessions, and recording their asset acquisition histories. Collected data on the current socio-economic status quo were complemented with national statistics and report literature to outline national and regional differences regarding population, infrastructure, different historic developments etc.

2.2.2 Institutional Economics

Subproject 7 studied factors and institutions influencing the provision of ecosystem services and promoting the adoption of ecosystem-services-friendly innovations. The analysis, which took place at different levels of aggregation, employed various research tools from social and economic sciences, including theoretical and empirical models, various types of surveys and interviews, and economic experiments and preference-elicitation methods. Households' socioeconomic characteristics, livelihoods, and preference structures were analyzed using household- and individual-level surveys. In the analysis of the relevant decision-making institutions at the level of households as well as within households, the team employed a combination of formal theoretical modelling of intergenerational optimization, qualitative expert interviews about customary rules and education, and semi-structured household interviews about issues related to education and labour. Cooperation patterns and the individual decision-making behaviour of resource users in the management of ESS were investigated by combining framed economic field experiments – which were designed according to real-life situations – and quantitative empirical methods based on survey data.



Fig. 18: Research on household's food consumption (photo: M. Pröpper).



Fig. 19: Choice experiment in Mashare, Namibia (photo: L. Brown).



Fig. 20: Introduction at the experiment session in Seronga, Botswana (photo: L. Brown).



Fig. 21: Interview with land user on their farming system (photo: S. Domptail).

To capture preferences for different development paths, choice experiments at the level of household heads were conducted. The role of the regulatory framework, including customary law and governance structures on higher levels and their influence on the provision of ESS, was investigated through expert interviews and literature reviews.

2.2.3 Agricultural and Ecological Economics

The agronomic team applied a combination of different research methods. First, it conducted a farming system analysis for the identification of typical farming strategies within the basin; it followed Ruthenberg's (1971) conceptual framework for tropical peasant agriculture, and was based on explorative as well as semi-structured expert interviews and focus groups conducted in all core sites with local traditional authorities, knowledgeable farmers, scientists and local extension service officers. This household-level analysis was then complemented with a material-&-energy-flow-accounting analysis in Cusseque and Seronga (MEFA, see Singh and Grünbühl 2003), which depicts rural societies as living organisms and allows an analysis of their internal energy flows and energy use. This analysis was combined with TFO's socio-economic household survey; both data sources allowed subproject 08 to extend the analysis to the village level. The results obtained from these data sources were then interpreted in light of important theories on the typical development pathways of agrarian societies (Boserup 1965, Jayne et al. 2014, Headey & Jayne 2014, Barret 2008, Fischer-Kowalski et al. 2011).

TFO's yield- and soil fertility assessment provided quantitative data to back up these findings. Second, SP 08 conducted an analysis of stakeholder perceptions of the ORB land and resource-use system rooted in the political ecology domain. In this analysis, stakeholders are seen as part of a multi-scale, multi-national and multi-sectorial land-use system and perceptions as well as conflicts were analyzed through this inter-scale research structure. 90 interviews were conducted with key stakeholders at local, regional, national and catchment scales of the Okavango River Basin. 80 were analyzed using content analysis to assess stakeholders' perceptions of the land-use system and resulting potential sources of conflict. Third, choice modelling and semi-structured tourist interviews were conducted to assess tourists' 'willingness-to-pay' an additional amount of money to help conserve certain bio-physical aspects of the Okavango Delta or change managerial characteristics of local tourist enterprises.

2.3 Geosciences

2.3.1 Remote Sensing

An analysis of a complex system like the Okavango Catchment needs to be based on several descriptors that allow for a holistic evaluation of the system. The remote-sensing team accounted for this complexity by first deriving various maps describing the status and dynamics of the catchment. The work was based on satellite imagery, and focused on two spatial scales: the entire catchment (observation period 2000 to 2013) and the greater core sites (observation period 1984 to 2014).

At catchment scale major land-use systems and functional vegetation types were ascertained, along with their changes over time. For this purpose phenology indicators were derived from satellite imagery time series, employing a polynomial spline model. Based on this information, major land-cover systems were delineated. Another constituent is the climatically unbiased assessment of ecosystem productivity and the dependency of vegetation on rainfall variability. To accomplish this, earth observation data, serving as a proxy for net primary productivity, was related to gridded rainfall data. Further relevant maps were created to illustrate the fire regime with regard to its spatial pattern, seasonality, and frequency, which were evaluated based on available remote-sensing-based fire products.

At core site level Landsat satellite time series were employed to assess land cover as well as land-cover changes. Given the high heterogeneity encountered in the test areas, different enhanced remote-sensing classification techniques were combined. Moreover, tree cover was calculated such that in the resulting maps those broad categories could be complemented with information on vegetation density. These techniques were employed for different time steps; thus for every position in the resulting maps the respective development (or stability) could be documented. Additional geospatial data, such as information on roads, settlements, etc. were used to illustrate the spatial patterns of the expansion of agriculture, trade-offs between different land-use strategies, etc.

A third major component dealt with the analysis of herbivore migration dynamics and the establishment of habitat maps. Three buffalos and three zebras were equipped with GPS collars, and their movement patterns were tracked over a period of ca. 2 years. In addition, the nutrition values of different ecosystems they visited during the wet and dry season were analyzed. Combining this information with spatial information collected from various sources allowed the generation of habitat suitability maps depicting the seasonal variability that underlies the movement patterns of herbivores.

2.3.2 GIS Modelling and Upscaling

SP09.2 utilized mainly geographical information systems (GIS) and digital mapping methods. In terms of software, commercial market leader ArcMap by ESRI was used, in conjunction with the free and open-source GIS-software SAGA (System for Automated Geoscientific Analyses) developed by participants of SP09.2. SAGA's modular architecture enabled a detailed customization to the needs of TFO.

Mapping and spatial analysis support for other SPs was provided throughout the project. In cooperation with other SPs the definition of the Core Sites and the Future Okavango Research Area (FORA) was carried out.

In addition to data generated by TFO, available datasets from third parties were included in some analyses. A central input for landscape analysis was the established Shuttle Radar Topography Mission (SRTM) 90 meters Digital Elevation Model (Jarvis et al. 2008). It was used to derive the predominant landscape units in the catchment. The delineation of these discrete terrain units is based on a set of local and regional continuous land-surface variables: SAGA wetness index, altitude above channel network, slope, relative slope position, and terrain classification index for lowlands.

The SRTM was also used for the regionalization of climate scenarios delivered by SP01. By means of an elevation correction and geographically weighted regression, the horizontal resolution of the temperature and precipitation simulations was enhanced from 25 km to 1 km. Subsequently, the data provided the basis for a number of impact assessments, for example of land degradation and crop growth conditions. For these assessments SP09.2 utilized fuzzy logic approaches to combine different datasets and bring them to a comparable scale.

Future crop-growth conditions were evaluated based on soil type and the specific water requirements of maize, sorghum, pearl millet, cassava, and cow pea (FAO EcoCrop) compared to the climate scenarios. To assess land degradation risk, the climate model scenarios were combined with other spatial data sets on topography, land cover, soil type and properties, population, livestock density, and infrastructure to identify hotspots.

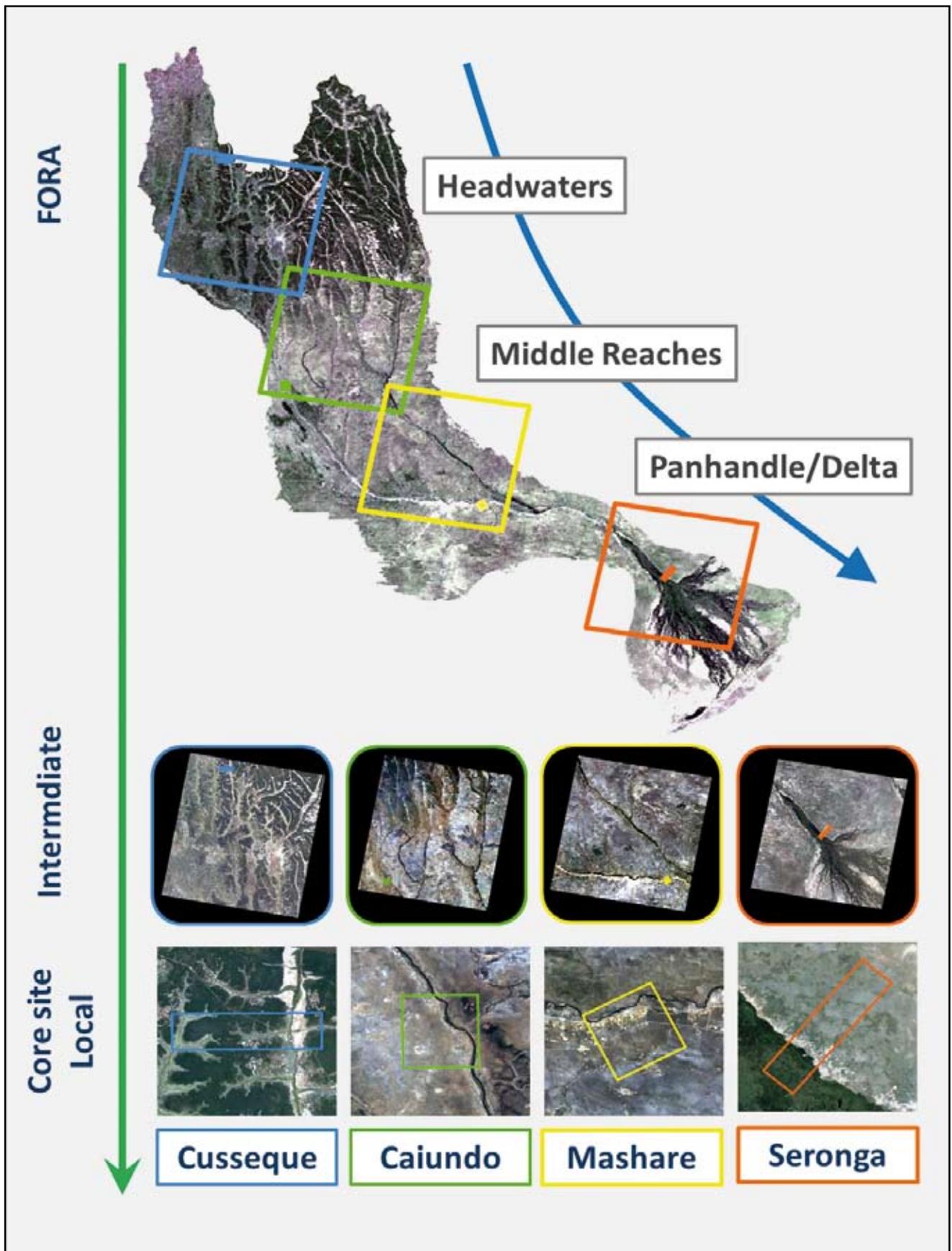


Fig. 22: Distribution of TFO research units and their spatial extension. The core site level is the common reference level for all disciplines; for the FORA level, specific analyses on this level are integrated with the core site analyses, and larger areas covered by satellite imagery are used for integration and upscaling.



Fig. 23: FIRM meeting in Mashare, Namibia (photo: H. Seidel).

2.4 Transdisciplinarity and Stakeholder Involvement

TFO developed a stakeholder strategy which was based on a mix of instruments. On **the local scale** in particular Forums for Integrated Research and Resource Management (FIRMs) have been employed. TFO facilitated their establishment and used them as platform of stakeholder engagement. FIRMs consist of elected community members who regularly meet and initiate consecutive development actions involving all service providers needed and involved in the solution of local-level resource-management challenges. Service providers may be for example traditional authorities, government extension services, NGOs, as well as the scientific community (Kruger et al. 2003). In this sense TFO as a project was acting as a service provider among others to local FIRMs.

TFO supported FIRMs at the focal research sites amongst others in developing interactive plans that were used for implementation, monitoring and evaluation purposes. In this way indirect links to a broad range of local and regional stakeholders were established. This does not mean that the project team did not also establish direct links to them but the FIRMs served as a catalyst for TFO stakeholder integration efforts. The organizational structure of FIRMs was decided by the community and at all sites linked to already existing Village Development Committees (VDC).

In addition, TFO employed and trained members of rural land user communities as para-ecologists. By being trained on the job and during annual training workshops in the field, the para-ecologists learned

some of the concepts and methods of various scientific disciplines, gained experience in the monitoring of ecosystem services, and became more aware of trade-offs in natural resource management. As they were rooted in the local communities, para-ecologists helped the project team to develop a close relationship with the land user communities they were living and working in, and supported the communication and translation of research outputs. Para-ecologists were an important link between local stakeholders and academic researchers.

Another tool to encourage discussion with stakeholders and disseminating results is the participatory film-making by local community members. Films are used as a means to involve stakeholders in the project and to communicate project activities to different audiences. Representatives of stakeholders such as local resource users, traditional



Fig. 24: Participatory film-making in Mashare, Namibia (photo: M. Gruber).



Fig. 25: Soil scientists discussing their findings on soil quality with FIRM members in Seronga, Botswana (photo: L. Schmidt).

authorities, and NGOs are facilitated in developing their capacity to conceptualize, direct and shoot films about their concerns. This initiates discussions between and among scientific and non-scientific stakeholders and additionally constituted a platform for the negotiation

of different and even conflicting perspectives. The films are available in the appendix.

In order to enable an impact beyond local research sites, the TFO project also continuously engaged with policy-makers in particular as well as with government decision-makers in general **on higher governmental levels**. Important in this context are the development of scenarios and the prediction of the consequences associated with particular development interventions.

As FIRMs are an important stakeholder platform on the local level, TFO identifies the Permanent Okavango River Basin Water Commission (OKACOM) as a critical forum on the regional level. Guided by the spirit of managing the Okavango River Basin as a single entity, the three sovereign states of Angola, Botswana and Namibia have committed to promoting coordinated and environmentally sustainable regional water resources development, while addressing the legitimate social and economic needs of each of the riparian states. The Future Okavango project has made serious attempts to continuously engage with OKACOM structures in ongoing processes. This started by adapting the TFO research plan to the OKACOM Strategic Action Plan (SAP). In this way TFO intends to provide relevant research findings contributing to the research priorities identified by the three countries. All data generated by TFO will be provided to OKACOM and other stakeholders in the form of the web-based, integrated data base OBIS (see electronic appendix).



Fig. 26: The para-ecologists working in TFO at a training workshop in Chitembo, Angola 2015 (from left to right: Meshack Kwamovo, Robert Mukuya, Snake Vilho Mtuleni (technician in Windhoek), Miguel Sachilulo Hilario, Severino Lucas Segunda Cassoma (junior paraecologist)) (photo: U. Schmiedel).

Chapter 3

The current status of the Okavango Basin

At present, the Okavango River Basin constitutes one of the last major catchments in Africa that are still predominantly in a near-natural state. However, this goes along with it being an area with high indices of poverty and underdevelopment. In the Angolan part of the basin, for example, fewer than 4 % of households have access to improved water supplies, and more than 30 % of the adult population are illiterate. There is a cautious mutual consent between the three riverine states that they all want to push the **socioeconomic development** of the Okavango Basin strongly while avoiding major repercussions for the basin's environmental integrity (and the related ecosystem services).

However, the three states are hesitant to consent to powerful **transnational institutions** for shared decision-making regarding the planning and management of natural resources in the basin. Currently OKACOM is the only basin-wide management entity in place, but it is weak and insufficiently funded. The recommendations of OKACOM are largely ignored in national policy-making. Global environmental public goods such as biodiversity and climate stability are considered only to a limited degree. The three countries in question mainly take into account only the direct benefits to be gained from **natural resources** for the present generation at the local and national scales. The national and regional **economic strategies** lean strongly towards economic growth through market promotion, without a clear strategy for the poor rural population. All countries follow a mixed development policy. There is a strong emphasis on improving education. Simultaneously, new mining opportunities, industrial investments and commercial agricultural projects are encouraged.

The impact of external supra-basin actors is significant. **Large-scale investments** into infrastructure in

Angola and green schemes in Namibia are visible. Cities like Menongue or Rundu are undergoing rapid development of their commercial sectors, advertising and trading modern **consumer goods**. Urban cash-based markets have an impact on the rural peripheries as new incentives emerge and natural resources are commodified. However, this process is not without resistance. A considerable fraction of farmers are clearly interested in a sustainable future for farming.

While tab. 1 displays the population for the adjacent provinces exact **population** figures for the FORA area are unknown, but may range well above 1,000,000 people, with about half of them already living in **urban** settings. Annual population growth is high, probably above 2 %. Migration to urban centres both within and outside the basin is clearly taking place. **Migration** is a result of the 'pull factors' of urban settlements in addition to 'push factors' from poor rural areas. Municipalities, especially in Angola, have not been able to keep pace with the demand for basic services, health services and education.

In all three countries **environmental laws** related to forest, water, and land are not strictly enforced. The society considers other aspects of social life to be of higher priority. **Customary laws** related to natural resource management exist in all three countries. In Namibia and Botswana customary law is recognized by statutory law, and as such is also enforceable by the statutory executive system. Compliance with customary law would make a strong contribution to sustainable resource management. Since **traditional authority** structures are not built on the notion of the separation of powers, however, the states in question are suspicious, and rather try to reduce the powers of such authorities. The security of **land rights** differs strongly between the three basin countries. In Angola most rural land is held

Tab. 1: Complete population in the four main provinces/regions/districts and major urban centres (2014; for information on data sources see appendix).

Main provinces/ regions/districts	Population	Major urban centres	Population
Bié	1,338,923	Chitembo	68,581
Cuando Cubango	510,369	Menongue	306,622
The Kavangos	222,500	Rundu	63,431
Northwest District	152,284	Maun	60,263
<i>Complete</i>	<i>2,225,076</i>		<i>498,897</i>



Fig. 27: Rural livelihoods in the Okavango Basin (photo: A. Gröngroft).

under customary rights. Nevertheless, customary law is not recognized by Angolan statutory law. As such there is a high risk that powerful individuals or organizations will ignore customary land rights, and grab land.

In the Namibian Kavango regions land is also held under customary land rights. In contrast to Angola, in Namibia customary law is recognized by the constitution. The traditional authority system is generally able to allocate and protect land rights. Botswana has had formalized land administration since the 1960s. The

power of traditional authorities was largely given to state-controlled land boards.

Tourist activities in the Okavango Basin are extremely different in each of the three countries. While in Angola tourist activities are almost nonexistent, they play a minor economic role in the Namibian Kavangos. In contrast to both of these countries, the tourism in the Botswanan delta area is highly developed, and generates a strong income for Botswana as a whole. Tourism in the region is mostly nature- and wildlife-based, and thus depends on intact natural ecosystems. However, the movement of wildlife is strongly impeded by the system of **veterinary fences** running through northern Namibia and the Botswana delta area (fig. 28).

A system of tarred main **roads** links most of the major urban nodes in the FORA. Secondary roads are still mainly gravel or earth roads, with partially restricted usability in the rainy season. Airports are located in Menongue, Cuito Cuanavale, Rundu, Calai, Shakawe, and Maun. The Namibe railroad connects Menongue with Namibe, bordering the Atlantic Ocean; the Benguela railroad is important for the northern part of the basin. **Electricity** is available in the main centers as well as in the bigger settlements, especially along the main roads, but only one hydropower scheme exists in the Angolan section of the basin.

Moving across the FORA from north-west to south-east, the **climatic conditions** change from semi-humid to semi-arid, and the spatial distribution of precipitation shows a strong gradient from 1,300 mm per year in the north-western part to 500 mm per year in the south-eastern part of the basin (period 1971–2000) (fig. 29). Between 1950 and 2009 the annual sum of precipita-



Fig. 28: Veterinary fences and main road axes within the FORA.

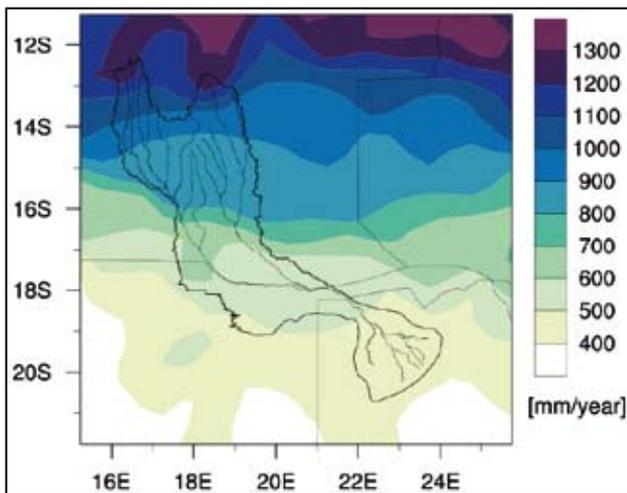


Fig. 29: Mean precipitation from 1971-2000 (data source: Global Precipitation Climatology Centre (GPCC)).

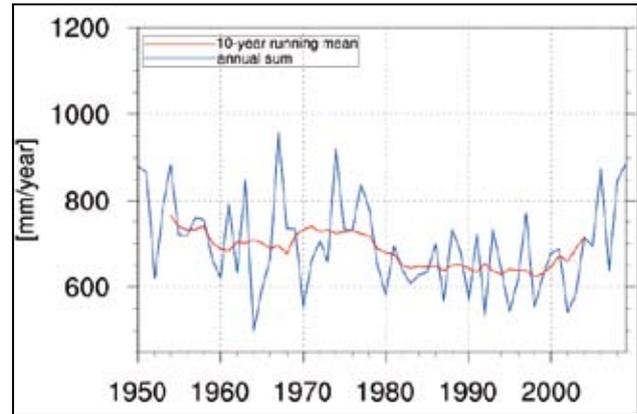


Fig. 30: Mean precipitation as spatial average over the FORA between 1950 and 2009 (data source: Global Precipitation Climatology Centre (GPCC)).

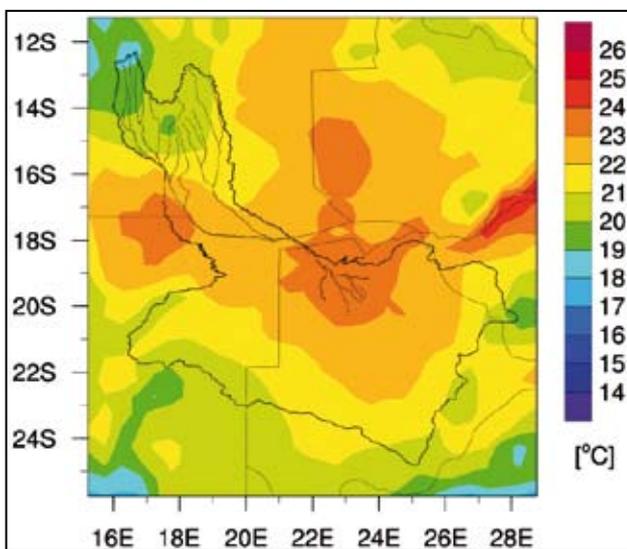


Fig. 31: Annual mean temperature from 1971-2000 (data source: Climatic Research Unit (CRU)) (Weber 2013a).

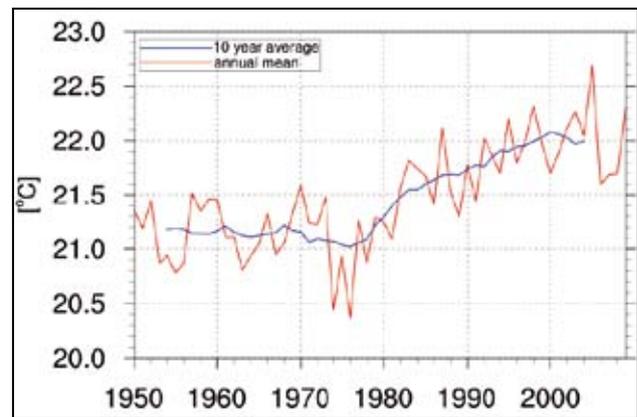


Fig. 32: Annual mean temperature as spatial average over the FORA between 1950 and 2009 (data source: Climatic Research Unit (CRU)) (Weber 2013a).

tion is characterized by a high inter-annual variability without an obvious trend (fig. 30). The annual mean temperature has a high spatial range of about 6 °C in the catchment, with 18 °C in the extreme north-west of the basin, and 24 °C in the Okavango River Delta and in an area covering from Katwitwi to the eastern boundary of the catchment (period 1971–2000) (fig. 31). The long-term timescale of the annual mean temperature shows a low inter-annual variability with an increase in temperature since the late 1970s (fig. 32) (Weber 2013a).

The portion of the basin covered by (close to) **natural vegetation** is still about 90 %; landscape integrity is still rather high (fig. 33). The area of **effectively conserved land** with a high protection status covers 13 % of the Angolan, 6 % of the Namibian, and 12 % of the Botswanan part of the FORA.

We find major hotspots of urban transformation around the larger urban centres (e. g. Menongue, Rundu,

Maun) and agricultural transformation along the densely populated Namibian south rim of the Kavango and on the highlands of the Bié Plateau (north and west of Chitembo). There is a notable lack of effectively conserved land especially on the southern slopes of the Bié Plateau.

Most areas of the catchment have experienced **fires** except for some parts in the north-eastern and south-western catchment as well as south of the Okavango Delta. Fire frequency is therefore very heterogenous across the Okavango catchment and depends very much on land cover and fire-management practices. As fires are mostly man-made, the burning seasonality corresponds to the agricultural practices in the different seasons. Wildfires strongly boost land cover changes in the northern part of the basin (fig. 34 and 35).

On the basin scale the water quantity varies with the seasonality of rainfalls in the northern part of the FORA. The main contributing tributaries are the Cu-

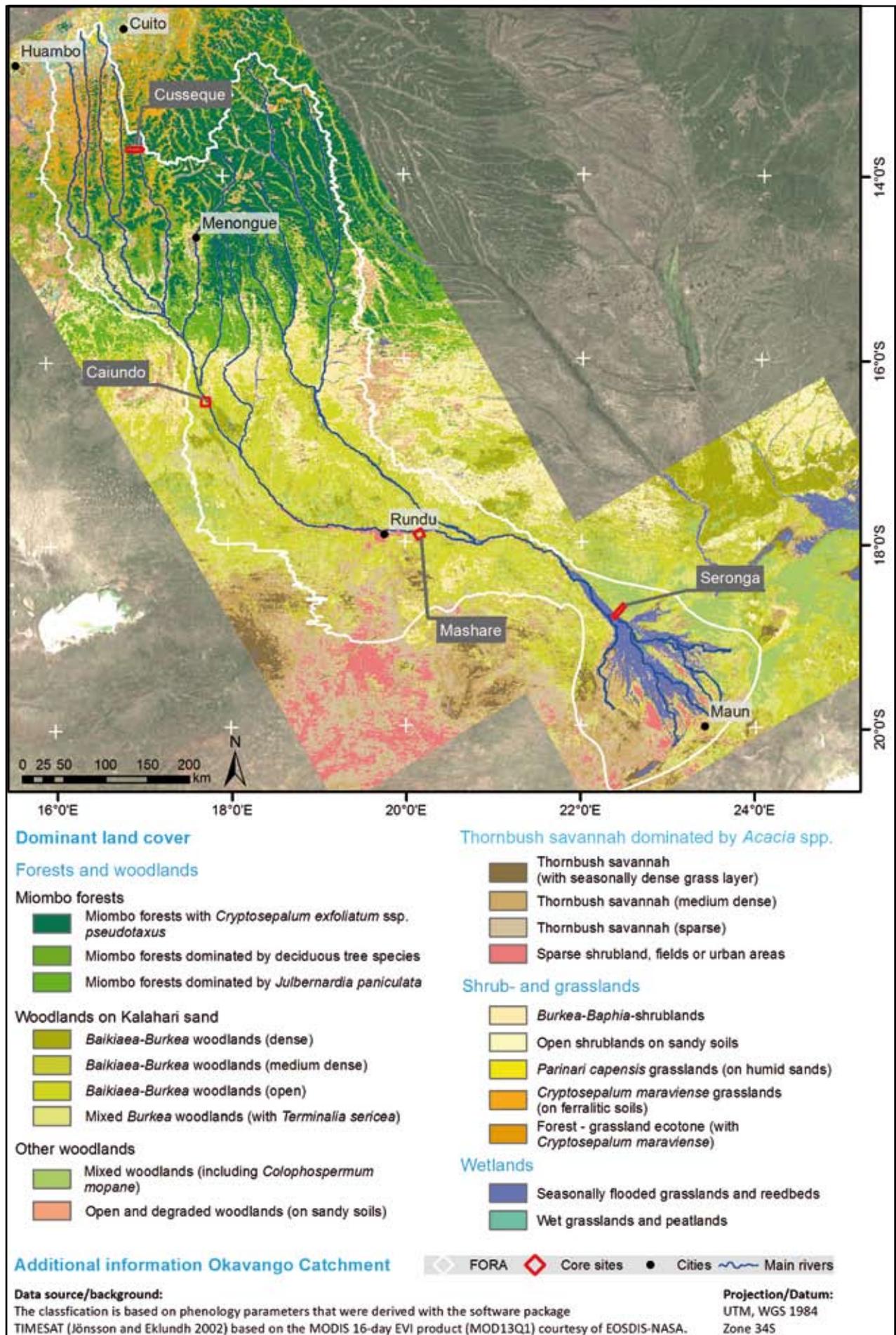


Fig. 33: Dominant land-cover classes.

Tab. 2: Proportions of dominant land-cover classes within the FORA (based on the land cover classification from fig. 33)
(data source: Stellmes et al. 2013).

Land cover class	Area (km ²)	Percent
<i>Miombo forests</i>	58,752	25.8
Miombo Forest with <i>Cryptosepalum exfoliatum</i> ssp. <i>Pseudotaxus</i>	29,811	13.1
Miombo Forest dominated by deciduous tree species	13,805	6.1
Miombo Forest dominated by <i>Julbernardia paniculata</i>	15,135	6.6
<i>Woodlands on Kalahari sands</i>	68,046	29.8
<i>Baikiaea-Burkea</i> woodlands (dense)	3,417	1.5
<i>Baikiaea-Burkea</i> woodlands (medium dense)	16,512	7.2
<i>Baikiaea-Burkea</i> woodlands (open)	28,377	12.4
Mixed <i>Burkea</i> woodlands (with <i>Terminalia sericea</i>)	19,741	8.7
<i>Other woodlands</i>	15,365	6.7
Mixed Kavango woodlands (including <i>Colophospermum mopane</i>)	7,526	3.3
Open and degraded woodlands (on sandy soils)	7,839	3.4
<i>Thornbush savannah</i>	29,177	12.8
Thornbush savannah (with seasonally dense grass layer)	3,641	1.6
Thornbush savannah (medium dense)	9,612	4.2
Thornbush savannah (open)	10,161	4.5
Sparse shrubland, fields or urban areas	5,763	2.5
<i>Shrub- and grasslands</i>	40,098	17.6
<i>Burkea-Baphia</i> -shrublands	17,069	7.5
Open shrublands on sandy soils	13,141	5.8
<i>Parinari capensis</i> grasslands (on humid soils)	738	0.3
<i>Cryptosepalum maraviense</i> grasslands (on ferralitic soils)	4,595	2.0
Forest grassland ecotone (with <i>Cryptosepalum maraviense</i>)	4,555	2.0
<i>Wetlands</i>	16,667	7.3
Seasonally flooded grasslands and reedbeds	12,906	5.7
Wet grasslands and peatlands	3,761	1.6
Total	228,104	100.0

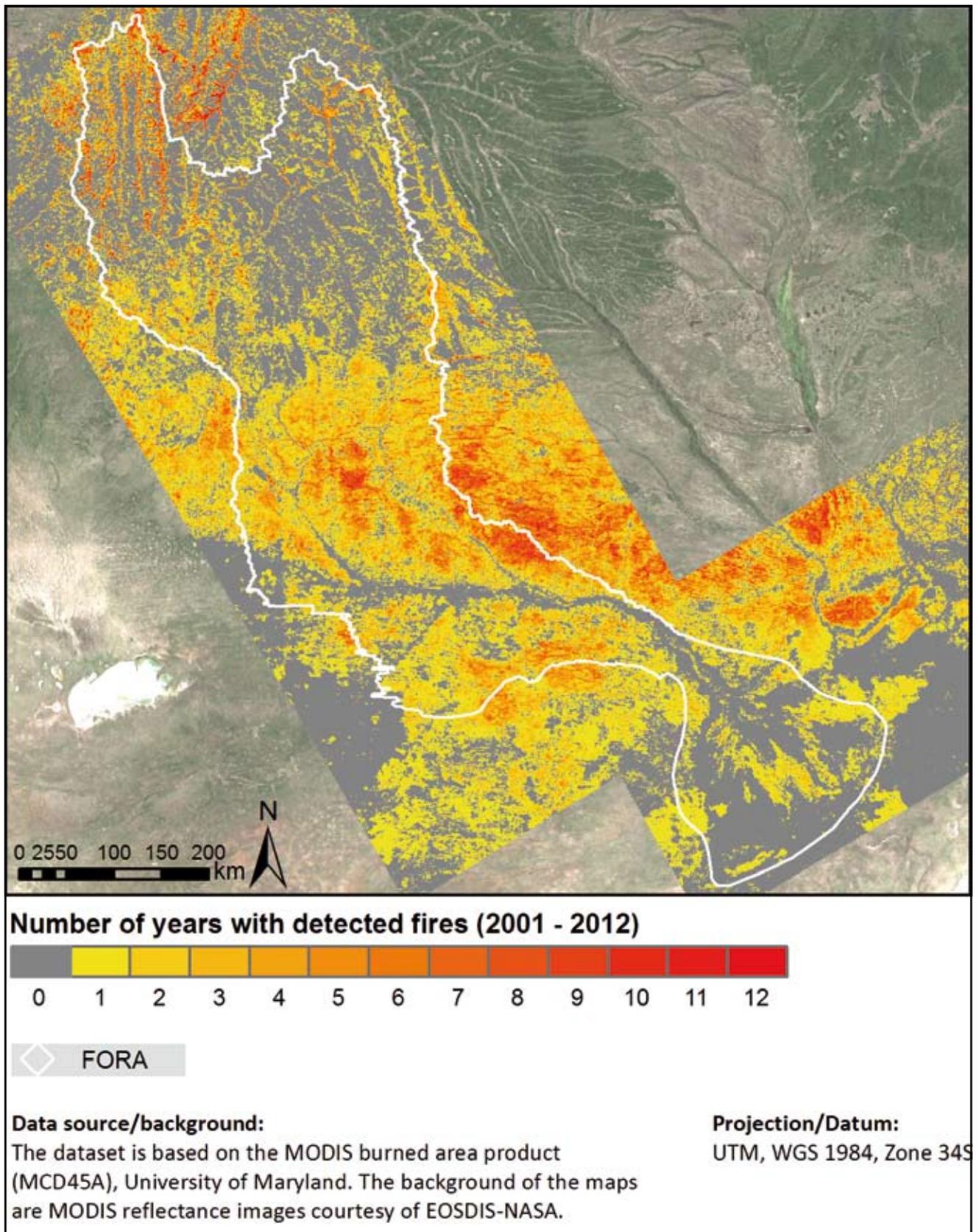


Fig. 34: Number of years with detected fires within the observation period 2001 to 2012.

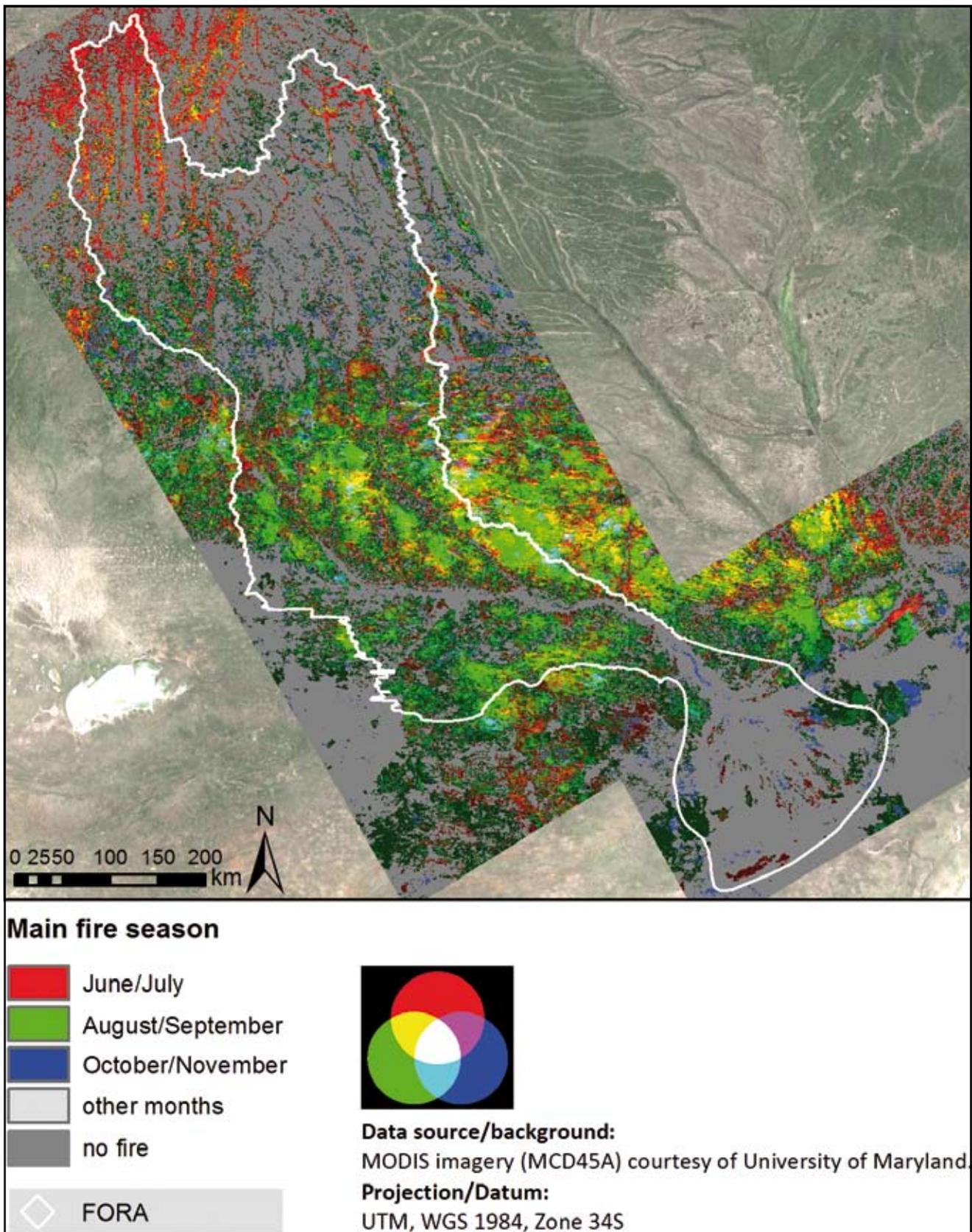


Fig. 35: Main fire season covering the observation period 2001 to 2012. The main fire season is illustrated as a Red-Green-Blue (RGB) false colour composite, where red colours correspond to the main fire season in June/July, green colours in August/September and blue colours in October/November. Yellowish and cyan colours result from the combined occurrence of fires in different periods, where yellow results from fires in the period June to September and green colours from fires during August to November. The brightness of the colours is related to the frequency of fire events. The product is based on the MODIS Burned Area product (MCD45A).

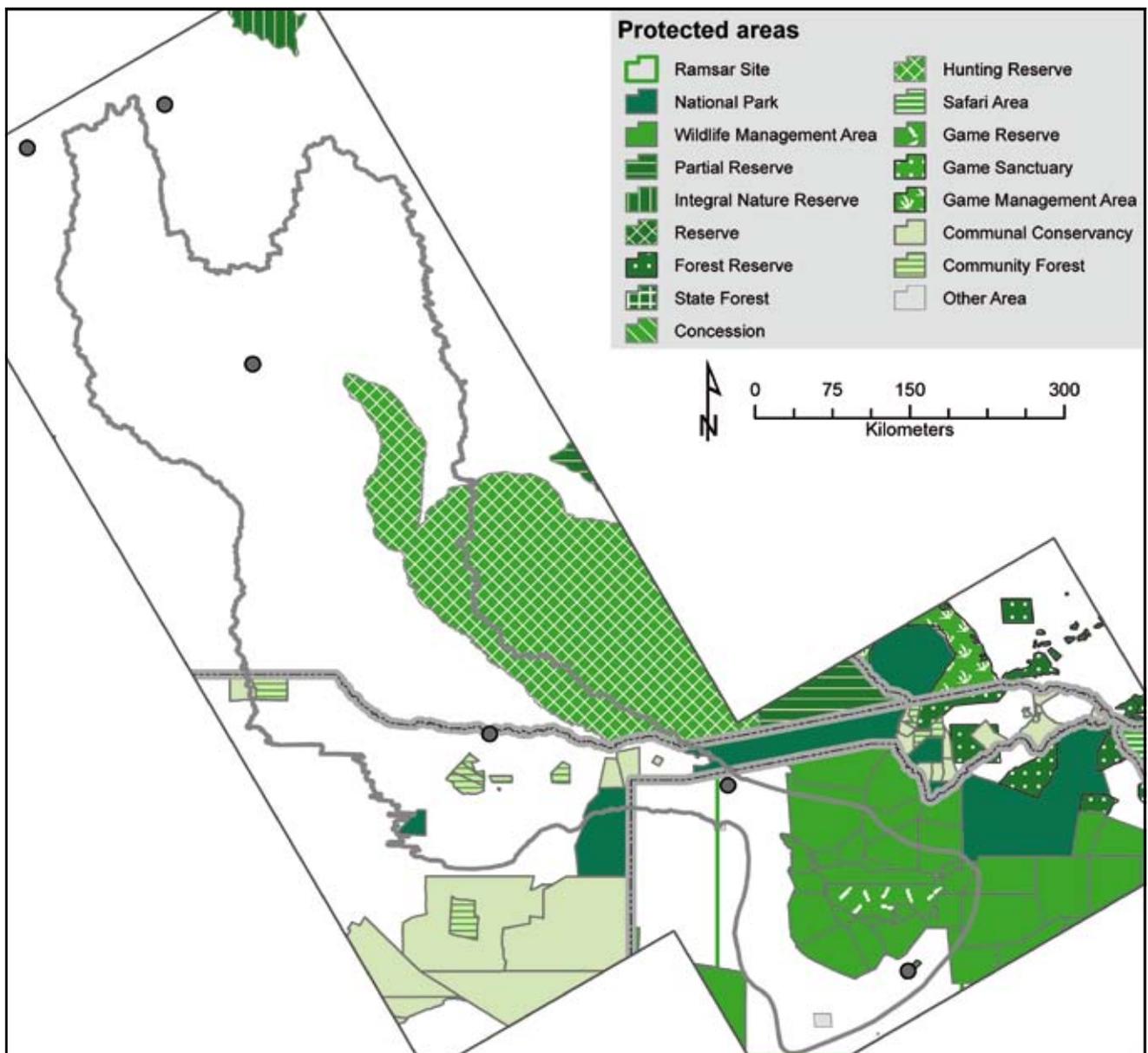


Fig. 36: Protected areas within the Okavango Basin (data source: World Conservation Union and UNEP-World Conservation Monitoring Centre).

bango, with a catchment of 108,000 km² and a flow length of 1,260 km; and the Cuito, with a catchment of 57,470 km² and a flow length of 920 km. The actual area under irrigated industrial **agriculture** covers an area of 2,200 ha in the Namibian Kavangos; about 1,100 ha in the Angolan Longa valley; and 31 ha in Botswana. The total amount of water abstracted from the Okavango is currently accumulated to be less than 5 m³/s, where Namibia is currently the biggest water-user with around 3 m³/s. The areas in Botswana are very small, having almost no impact on the water flow and amount of water.

A large number of different resources are extracted from non-cultivated areas by the communities of the Okavango Basin. In general, the intensity of **extraction of natural resources** is positively correlated with the population density in an area and with the ease of access to cash markets. These resources include fish,

honey, medicinal plants, and wood for various uses (see tab. 3). Depending on the local availability of the resources and the local access to markets, their market value may vary greatly.

Smallholder agriculture is still predominant in the Okavango Basin. In the Angolan highlands, smallholders practice mostly shifting cultivation, while we find semi-permanent cultivation within the more densely populated Namibian Kavangos. Both stages can be classified as pre-industrial agriculture, where manual labour is still the prime energy input, and not fossil fuels. In both stages, slash-and-burn techniques are used for the extension of cultivation areas, if there is sufficient land available.

Cattle are found mainly in the drier hinterland of the middle and lower basin, with stronger economic relevance especially in the regions south of the veterinary fences in Namibia and Botswana.

Tab. 3: Estimates of total resources extracted at the three TFO core sites in 2012.

	Cacuchi	Mashare	Seronga
Fish in kg	11,100	3,680	12,500
Medical plants in kg	3,800	0	448
Roots in kg	10,500	0	474
Nuts in kg	0	3,250	1,000
Thatch grass in kg	44,300	253,000	512,000
Reeds in kg	4,950	172,000	129,000
Timber in kg	2,710	142	2,870
Wood for construction in pieces	1,680	14,500	18,700
Worms/Larvae/Caterpillars in kg	1,650	52	1,590
Game in kg	21,600	0	0
Firewood in bundles	14,300	3,440	19,300
Honey in l	8,810	0	0
total LSU	105	3,400	7,620
annual biomass drymatter used for livestock grazing in kg	238.429	7,750,000	17,400,000
number of households	237	518	943
total size of area in km ²		96	1,470

Tab. 4: Overview of productivity per farming system.

Farming System	Average Yield in kg/ha	SD	Data source
Shifting cultivation	503 (cereals, esp. maize) + 374 (manioc) + 188 (pumpkins, beans, sweet potatoes)	264 (maize) + 362 (manioc) + 278 (pumpkins, beans etc.)	TFO yield assessment Cusseque (mixed cropping of maize, manioc and tertiary crops)
Semi-permanent cultivation	320	n/a	Calculation; value assumed to lie in-between shifting cultivation cereal yield (maize) and degraded permanent cultivation yield (pearl millet); values of Seronga not used because rainfall conditions not representative of mid-river areas
(Degraded or degrading) Permanent cultivation	137	83	TFO yield assessment Mashare (pearl millet only fields without inputs)
Permanent cultivation (CA) - agrarian	710 (Maize + pearl millet + cowpeas)	354	TFO yield assessment of Conservation Agriculture (CA) fields, using all available inputs (manure, fertilizer, probio)
Permanent cultivation (irrigation) - agrarian	567	n/a	Unpublished Master thesis by J. Mutero, at Polytech Namibia (Ibo Zimmermann)
Industrial smallholder agriculture	8900	n/a	Unpublished Master thesis by J. Mutero, at Polytech Namibia (Ibo Zimmermann); data refer to large-scale Green Schemes



Fig. 37: Use of natural resources: 1) Traditional fish traps in Cussequ, Angola; 2) Craftsman manufacturing baskets in Angola; 3) Fences made of thatch grass in Mashare, Namibia (photos: M. Finckh; R. Kissanga; H. Seidel).

3.1 The socio-ecological system at Cussequ

National and provincial framework

Angola's overall development priorities are to enhance economic growth, eradicate poverty, and secure livelihoods. Currently the national economic strategy leans strongly towards economic growth through market promotion and considerable external investment. The rebuilding of infrastructure is omnipresent, and involves a lot of foreign labour and capital. Diversification of agricultural production systems is seen as an important step in this regard. As a result, agricultural intensification is encouraged (fig. 38). However, the government lacks sufficient capacity to actively provide incentives for domestic or foreign investors. At the same time a strategy for the large rural population, which is dependent on agriculture, is not visible. Current land-use mostly reflects the interests and decisions of local and municipal actors. Urban hubs like Menongue and, increasingly, Chitembo experience a rapid development of their commercial sectors, with trading in all sorts of modern consumer goods. Furthermore, advertisers incite new desires. Regional political and legislative bodies clearly facilitate investments and the creation of such new cash-based markets. These developments have an impact on the rural peripheries as new incentives emerge and natural resources like wood, bushmeat or honey are commodified. Cash-based transactions increasingly play a role in rural contexts.

Existing environmental laws related to forest, water, and land are hardly enforced – with the exception of cases of severe pollution and degradation. Enforcement is specifically poor due to largely inefficient natural resource administration. This creates insecurity and reduces incentives to manage the land sustainably. Traditional authorities play an important role in the enforcement of customary laws.

The process of integrating environmental concerns into the legal framework is ongoing but delayed. There are critical limitations on environmental and social infor-

mation (OKACOM 2011, Jürgens 2014). As a result decision-makers have to decide on the basis of poor information. A critical shortcoming is the insufficient sectoral integration of environmental policies (Malzbender et al. 2010, Setlhogile and Arntzen 2012). The legislation makes provisions for environmental impact assessments (EIAs) which, however, are hardly enforced (Setlhogile and Arntzen 2012). This is one reason why ecosystem services are insufficiently taken into account when making decisions about land- and resource-use. Trade of natural resources like charcoal, timber and bushmeat is rather unclearly regulated by law.

The core site of Cussequ

The upper reaches of the Cubango catchment are characterized by the rolling slopes of the southern Bié Plateau. The core site of Cussequ presents a mosaic of Miombo forests on the hills and grasslands in the valleys; small fringes of peatland accompany the small fast-flowing creeks and rivers (fig. 41). Currently, we observe a pattern of pristine natural landscapes and seminatural agricultural landscapes. The valleys are still mostly covered by pristine grasslands, due to the woody shoots of *Cassamba* preventing non-mechanized agriculture, or too low nutrient status. The forests are locally cleared for slash-and-burn agriculture, especially within a radius of ca. 10 km around villages. This pattern is very visible at the core site, as the eastern part shows a patchy mosaic of fields, fallows and secondary woodlands, while the more remote western part is still covered by fairly intact forests.

The climate at Cussequ is characterized by semi-humid conditions, with a pronounced rainy season between November and April. Between 1971 and 2000, the mean annual precipitation was estimated to be 987 mm (Weber 2013) with a high interannual variability and a decreasing trend starting from the 1970s. Cussequ has a mean annual temperature of 20.4 °C, with October being the hottest (23 °C) and July the coldest month (16.1 °C). Due to the local topography, valleys experience night frost much more frequently than elevated



The core site of Cusseque

Current national and provincial framework

- National economic strategy leans strongly towards economic growth through market promotion and considerable external investment.
- Rebuilding of infrastructure involves foreign labour and capital.
- Agricultural intensification is encouraged.
- Urban hubs like Menongue and Chitembo undergo rapid development.
- Existing environmental laws related to forest, water, and land are hardly enforced.

Current state of the core site of Cusseque

- The main road Huambo / Bié-Chitembo-Menongue was tarred in 2010. Only a few secondary earth tracks penetrate into the hinterland.
- Rural settlements cluster along the main road. There is neither electricity nor drinking water provided in the villages.
- Traditional slash-and-burn agriculture is the main economic activity. Cassava flour, charcoal and bushmeat are sold along the roadside.
- Agriculture, charcoal making, and honey production have reached the limits of sustainable land-use practices. Hunting already overstresses the resilience of the wildlife resources. Fire aggravates the pressure on the ecosystems.
- Water quality in the Cusseque River and its main tributaries is locally still considered good.
- The core site currently presents a mosaic of pristine natural landscapes and of seminatural agricultural systems.

areas. In the valleys frost may occur on 30 or more nights per year, and temperatures may fall as low as -7°C . The occurrence of frost limits the dry-season production of sensitive crop species on the fringes of the peatlands.

The core site of Cusseque is situated in the Município of Chitembo, the latter with a population of 68,581 inhabitants (census 2014) and a population density of 3.6 inhabitants per km^2 . Few rural settlements exist in the core site along the main road to Menongue. At Cusseque natural fertility is high and is a dominant driver of population growth. Both internal migration towards the urban centres and in-migration by new relatives to the communities are common. The urban hubs, like Menongue, Chitembo, Kuito, and, further away, Huambo are undergoing rapid growth.

The main road Huambo / Bié-Chitembo-Menongue has been tarred since 2010. There are no second-

ry tarred roads in the area, and few secondary earth tracks. There is no electricity provided in the villages. The cellphone network already covers most of the villages along the main road. The next rural hospital is in Chitembo. Primary schools are accessible from the villages in the core site. Water for domestic consumption and use is taken from the rivers. There are no boreholes for domestic water supply; neither are there any water treatment facilities. The few small shops at the core site mainly serve local demands. Manufacturing trade is almost nonexistent.

The 2012 socio-economic survey at the Cacuchi site revealed an average annual per capita income of € 206. The Gini coefficient of the annual per capita income was 0.59. Only one out of 236 sample households had access to safe drinking water. Of the sample, 49 % had no formal education and only 2 % had finished secondary school. These data seem to describe the socio-



Fig. 38: Irrigation infrastructure in the Longa Rice scheme, Angola (photo: M. Finckh).



Fig. 39: Slash and burn farming in Cusseque, Angola (photo: S. Domptail).

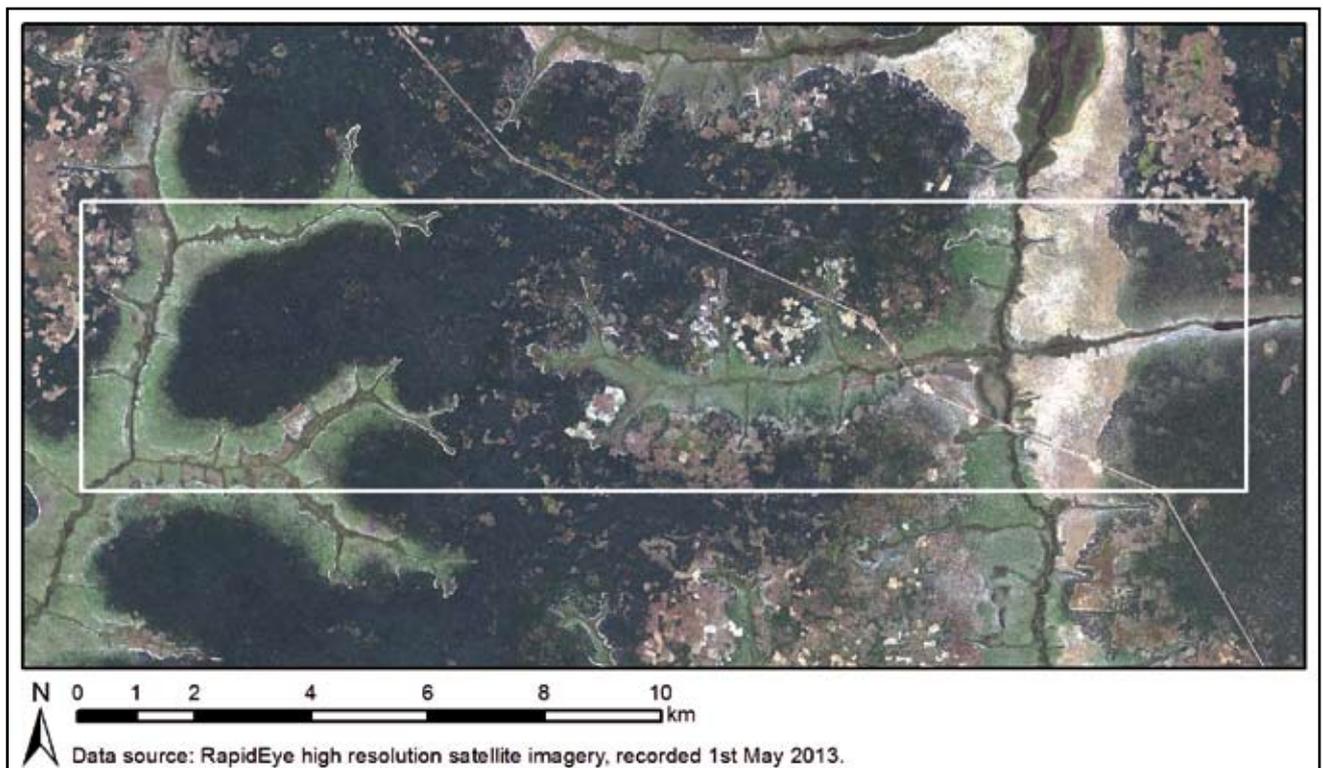


Fig. 40: Overview of the core site of Cusseque. White line depicting the extent of the core site.

economic conditions at the Cusseque site and other rural communities in southern Bié reasonably well.

Traditional slash-and-burn agriculture is the main economic activity at the core site. The community land is designated state land. Local farmers hold no formal land rights. Nevertheless, customary law has been effective in allocating land and avoiding conflict within the community. Between 1998 and 2008 ca. 4 km² of forest were cleared for agriculture and charcoal production. Between 2008 and 2011 a further 3.5 km² were converted in this area. Clearings cluster along streets and around settlements, and mainly impact upon forests.

Some rather localized conversions of wet grasslands are taking place for horticultural activities (fig. 44). Good rainfall conditions and existing land resources still allow for stable yields (in spite of inadequate soil fertility management, pest control, and post-harvest management). Households generally reach food sufficiency and are able to sell a crop surplus at the market. Due to perceived natural resource abundance, households follow homogeneous livelihood strategies and do not yet feel the pressure to adapt to rising resource scarcities.

Commercialization of local products (esp. cassava flour and charcoal) in order to sell to urban markets occurs



Fig. 41: Rainy season, Cusseque River, Angola (photo: M. Finckh).

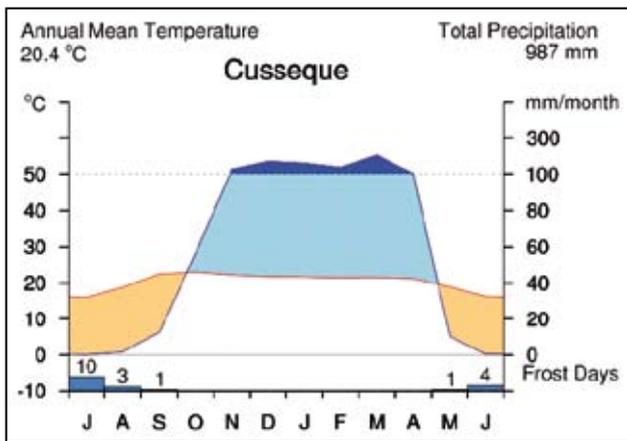


Fig. 42: Walter-Lieth climate diagram of Cussequ for the period 1971 – 2000 (Weber 2013b).



Fig. 43: Market for local products (photo: M. Pröpper).

along the roadside. A growing market in Chitembo leads to an increase in cash cropping and commercialization of natural resources. There are also an increasing number of outsiders who intend to plant cash crops in the core site. In combination with population growth this exerts a growing pressure upon the environment.

Water quality in the Cussequ River and its main tributaries is locally still considered good enough for domestic use, including as drinking water. Currently there are no water shortages in the dry season, and the base flow of the major tributaries is always high enough to meet domestic demands. Microbial water safety, however, does not comply with Angolan or international sanitary standards for drinking water quality. There are only diminutive amounts of water offtake required to supply the domestic demands of the villages. Small irrigation schemes at the village level are currently being implemented or planned. Larger agricultural development of the grasslands and wetlands (which currently act as filters for the water bodies) would, however, quickly put the water quality at risk.

Currently there is no notable tourism and little cattle husbandry at Cussequ. Neither irrigated industrial agriculture nor commercial ranching currently exist in the area. The Municipality of Chitembo encourages and subsidizes collective small-scale irrigation schemes at the village level in the currently unused grasslands in order to improve the production of dry-season crops like potatoes, sweet potatoes, tomatoes, onions, etc. In this program a small tract of grasslands along the Río Sovi has been ploughed by tractor since September 2013.

Timber is mostly exploited for domestic use in the villages. There are only a few signs of valuable timber exploitation for commercialization in the recent past. Charcoal is being produced at several spots for commercialization along the roadside; however the intensity of charcoal production is still low in this area, in comparison with the areas along the main road in southeast direction. Honey production is of widespread importance, and production levels are stable. Hunting is intensively pursued. Bushmeat commercialization occurs along the main road, and bicycles and motorcycles are



Fig. 44: Horticulture in Cacuchi, Angola (photo: S. Domptail).

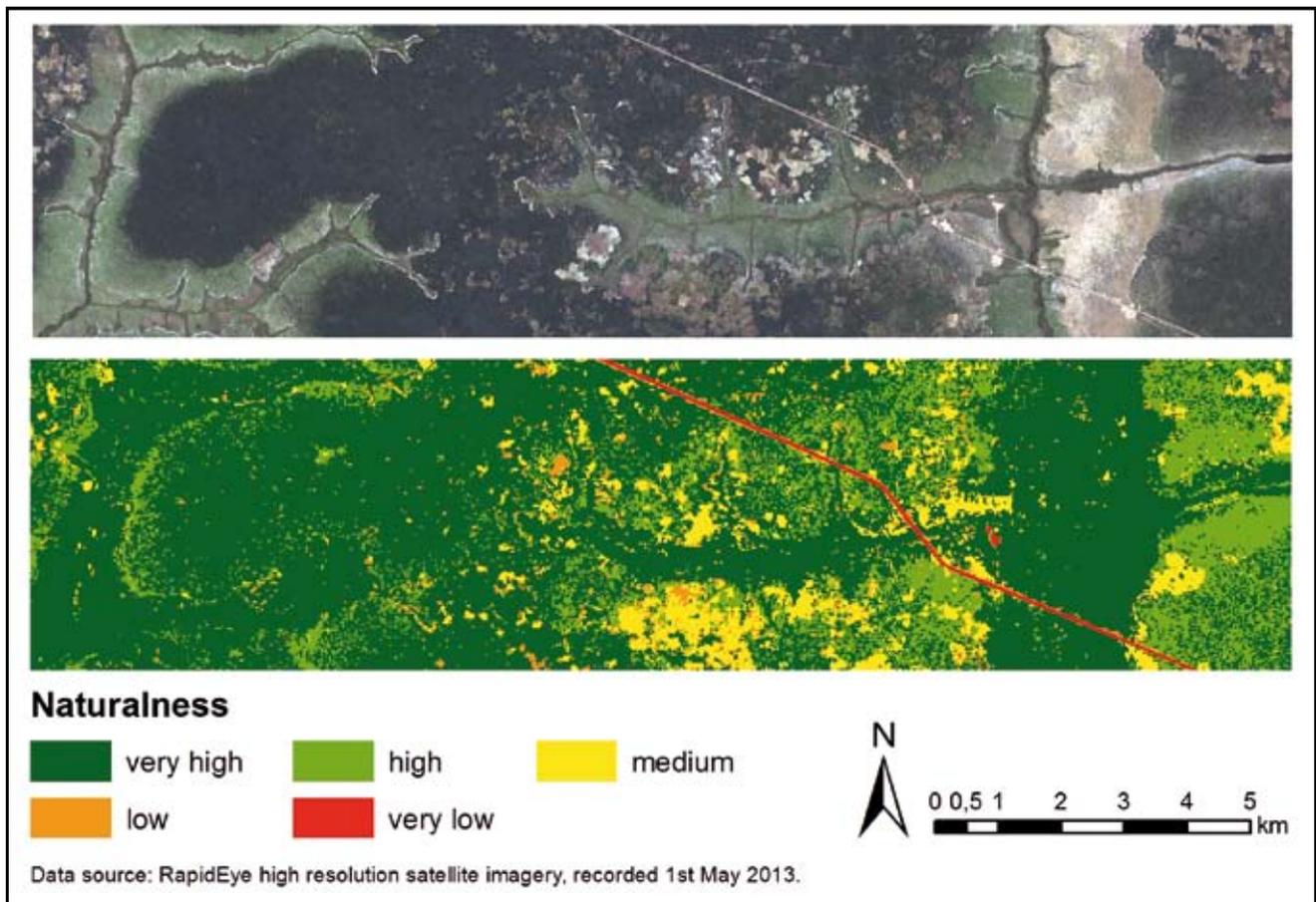


Fig. 45: Degree of naturalness in five classes from very high (natural) to very low (non-natural) at the core site of Cusseque. Red lines and areas depict mainly roads and homesteads; yellow areas mainly smallholder agricultural land. For better understanding an aerial image of the core site is added.

used to penetrate far into the hinterland. The hunting pressure has reduced the game populations considerably since 2007.

Permanent settlements are located mostly along the tarred road, which interrupts the ecosystem connec-

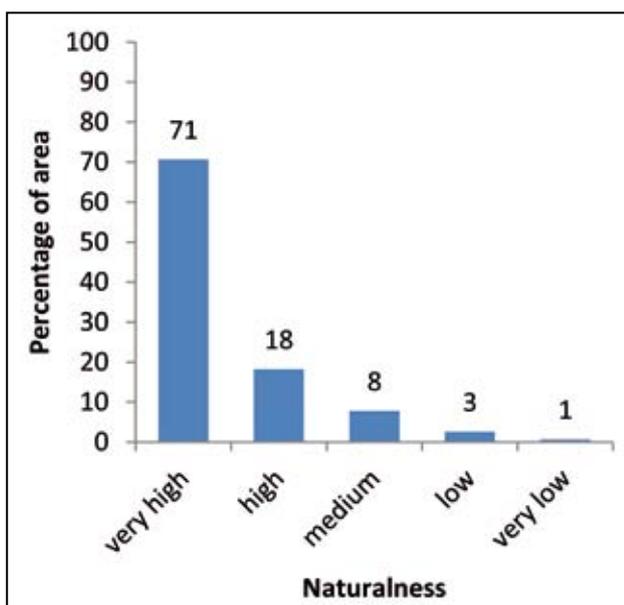


Fig. 46: Percentage of area of the five naturalness classes from very high (natural) to very low (non-natural) at Cusseque core site.

tivity to some degree. The main impact of the road, however, is the opening-up for commercialization of a wider range of natural products (from bushmeat to charcoal), which affects landscape integrity (fig. 45 and 46) and ecosystem functioning for quite some distance into the hinterland (the actual distance depending on the product; e.g. charcoal 1–2 km, bushmeat 10–15 km). Already under the current low population density, agriculture, charcoal making, and honey production have reached the limits of sustainable land-use practices. Other forest uses like hunting already over stress the resilience of the natural resources (e.g. several species of game have disappeared). Fire aggravates the pressure on the ecosystems. Woodland fires mostly spread in August and September from the burned fields into the surrounding woodlands and fallows. Grassland fires are set mainly earlier in the dry season to improve grazing for domestic animals and to facilitate hunting. However, the grasslands along the main rivers and the forests in the hinterland of the Cusseque area are still mostly pristine. The natural peatlands are locally used for horticulture; however, their overall condition is still good, again especially in the area further away from settlements in the western part of the core site. Currently there are no designated conservation areas in the Cusseque core site.

3.2 The socio-ecological system at Mashare

The middle ranges of the Okavango River where the two Namibian Kavango regions (East and West) are opposed by the southern edges of the Angolan Kuando Kubango region are characterized by a woodland savannah.

The **climate** in the Namibian Kavango region and the TFO Mashare research site is characterized by semi-arid conditions with a rainy season during the austral summer and a dry period from May to September. Between 1971 and 2000, the annual mean rainfall was determined to be 571 mm (Weber 2013). Between 1950 and 2009, the annual rainfall in Mashare showed a high inter-annual variability without any obvious trend. Mashare has an annual mean temperature of 22.3 °C; October and July are the hottest and the coldest months, with average mean temperatures of 26.2 °C and 16.2 °C respectively (period 1971–2000). The long-term annual mean temperature shows a moderate interannual variability with an increase in temperature since the late 1970s (Weber 2013).

The **population** of the two Kavangos is currently 222,500 people, living in an area of 48,742 km². The population of the regions is largely concentrated along the riverside, which is overpopulated, and there is strong competition for the remaining resources. This competition, and the resulting **resource pressure**, has long driven people to migrate to the hinterland. Migration to these areas depends on infrastructure, water availability, and land rights/leasehold policies. At the core site of

Mashare it is rather probable that natural fertility will remain high and continue to be a dominant driver of population growth. Internal migration towards the urban centres occurs, especially of the younger generation seeking a better school education or looking for a job. However, in-migration of new relatives to the communities is also rather common.

At present, in comparison to all other regions of Namibia the Kavangos have high indices of **poverty and underdevelopment** (Namibia Statistics Agency 2012), as the main livelihood strategy for a major part of this population is small-scale rainfed semi-permanent cultivation with a high land scarcity and advanced levels of household impoverishment. In the Mashare research area the 2012 socio-economic survey at the core site revealed an average annual per capita income (including subsistence income) of € 406. The Gini coefficient of the annual per capita income (including subsistence income) was a very high 0.76. 38 % of the households had access to safe drinking water. 34 % of the sample had no formal education. Only 13 % had finished secondary school.

Meanwhile national and regional governments push strongly towards the socioeconomic development of the regions. In general Namibia follows a mixed **development policy**, and there is a strong emphasis on improving education. On the other hand, private and public large-scale agricultural projects as well as tourist operations are encouraged. Currently the national and regional economic strategy leans strongly towards economic growth through market promotion and **intensified agricultural projects**. One example is intensively



The core site of Mashare

Current national and regional framework

- National economic strategy leans strongly towards economic growth through market promotion and considerable external investment.
- Agricultural intensification and irrigation farming is encouraged.
- Urban hubs like Rundu and Nkurenkuru/Katwitwi undergo rapid development.
- Existing environmental laws related to forest, water, and land are hardly enforced.

Current state of the core site of Mashare

- Rural settlements cluster along the main roads. There is little electricity provided in the villages.
- Traditional subsistence agriculture is the main livelihood strategy for a major part of the population with a high land scarcity and advanced levels of household impoverishment.
- Agriculture along the river has reached the limits of sustainable land-use practices. Hunting already overstresses the resilience of the wildlife resources. Fire aggravates the pressure on the ecosystems.
- Existing environmental laws related to forest, water, and land are inconsequently enforced, except in cases of severe pollution and degradation.
- Water quality along the Namibian Kavango River still considered to be pristine with local and inter-annual variations, but measurements are still far below drinking water limits (Namibian Standards).
- Regarding the integrity of the landscape, Mashare at present constitutes the core site with the strongest human-generated landscape alterations.

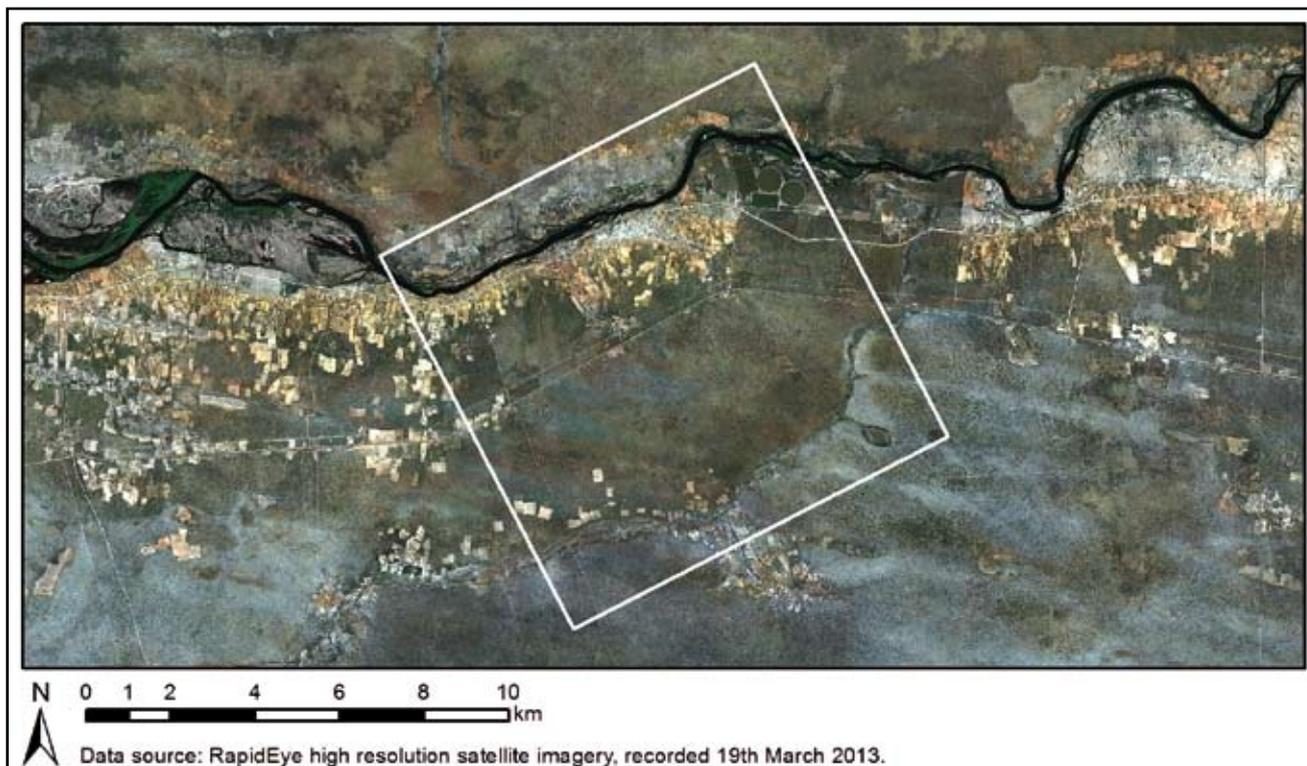


Fig. 47: Overview of the core site of Mashare. White line depicting the extent of the core site.

cultivated green-scheme products strongly influenced by external actors/interest groups, which grow both in number and in area covered. On the one hand, low-cost smallholder-oriented agricultural strategies such as the use of fertilizer or tractor-hiring schemes are promoted and subsidized both by the government and by development organizations. However, these punctual activities cannot be described as a sustainable vision for the large rural population who are dependent on agriculture and are excluded from the green-scheme benefits.

Due to rural-urban migration and high population growth rates the current rate of **urbanization** is high, and is predicted to average around 3.5 % over the next 15 years. Rundu has grown from a small settlement in 1970 to a town of 63,431 inhabitants in 2011, and continues to grow rapidly. The town is faced with the

challenge of adapting to this growth with formalizations of land titles, building of infrastructure (roads, sewerage, waste disposal, electricity etc.). Migration is a result of the pull factors of urban settlements – such as perceived job opportunities, and better infrastructure and housing – in addition to ‘push factors’ from rural areas, such as shortage of land, declining returns from agriculture, poor health care and poor education. The growth and expansion of urban areas is causing an unprecedented level of localized depletion of natural resources, discharge of unprocessed wastes into the environment, and massive demands for urban services. Municipalities in the two Kavango regions are already challenged to keep pace with the demand for basic services such as housing, roads, piped water, sanitation, and waste disposal. Provision of health and education services and facilities also lags behind urban population growth. One result is that the environment has become hazardous to human health through the rapid spread of waterborne and respiratory diseases such as bilharzia (Mendelsohn and el Obeid 2003), a lack of health facilities, low levels of education and employment opportunities, and hence a reduced ability to afford improvements to living conditions (UNEP Report).

Urban hubs like Rundu and increasingly also Nkurenkuru and Katwitwi are also experiencing rapid development of their commercial sectors, advertising, and trading in all sorts of modern consumer goods. Such imports by global corporate actors require cash payments. The advertising industry is especially busy inciting new desires and markets. Regional political

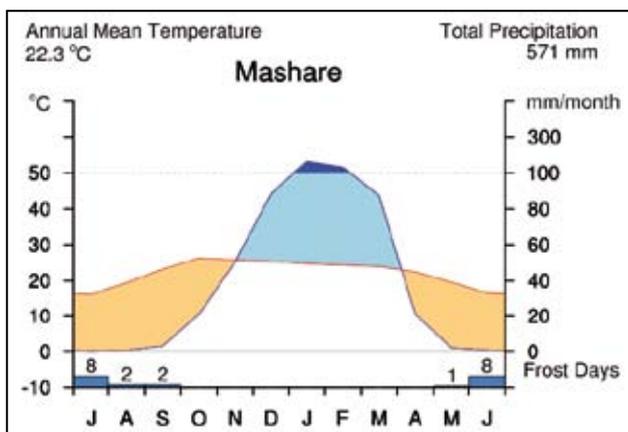


Fig. 48: Walter-Lieth climate diagram of Mashare for the period 1971 – 2000 (Weber 2013c).



Fig. 49: The Kavango River at Rundu, Namibia (photo: L. Schmidt).



Fig. 50: Dry Woodland in Kavango, Namibia (photo: A. Gröngroft).

and legislative bodies clearly facilitate investments and the creation of such new markets. Urban cash-based markets have an impact on the rural peripheries as new incentives emerge, and to some extent even natural resources are being commodified (fig. 51). Shops and cash-based transactions increasingly play a role in rural contexts like Mashare as subsistent land users become consumers – however, interviews from this field show that this trend does not develop without meeting some resistance. Farmers perceive cash-based markets (labour/ jobs, trade) and the commercialization of their land-use as only one possible option. A considerable fraction of farmers are clearly interested in working towards a sustainable future for farming, which would require investments in training, education, access to land, and other measures to secure sufficient yields for the rural population.

The small-scale economic traffic across the river, which was considerably organized, and usually transported by boat, and the unilateral attempts by the Angolan side to establish a pontoon bridge have been stopped due to the fact that their ecological and economic costs for the Namibian side were not negotiated beforehand (fig. 52).

At the current stage there are no serious **governmental or institutional efforts to secure smallholder land rights** or to increase rural yields – a ‚push factor‘ for the rural population. In general the whole of Kavango has experienced continuous population growth over the last decades, and Rundu is the second largest town in Namibia, after Windhoek. This trend might remain stable due to the expansion of infrastructure towards Angola and the increasing trade in tourism.

Over the last decades Namibia has placed great emphasis on **integrating environmental concerns into its legal framework** and there is a strong policy and legal framework for sustainable natural resource management amongst all basin states. In the Namibian Kavango region, land is also held under customary land rights. Customary laws related to natural resource management exist. In Namibia customary law is recognized by statutory law, and as such is also enforceable by the statutory executive system. Nevertheless, there is a high risk that development policies will conflict and result in uncoordinated developments that are prone to be economically and environmentally unsustainable in the long run. A critical shortcoming is



Fig. 51: Commodification of natural resources: Mokoros on sale for tourists in order to generate cash for the consumption of modern goods (photos: M. Finckh & M. Pröpper).



Fig. 52: Cross-border traffic and trade (photo: A. Gröngröft).

the insufficient sectoral integration of environmental policies (Malzbender et al. 2010, Setlhogile and Arntzen 2012). The legislations make provisions for environmental impact assessments (EIAs) and in particular in Namibia the procedures are clearly specified and enforced. Nevertheless, the scope of such assessments is limited and can only be based on the best available information. There are critical limitations on environmental and social information (OKACOM 2011, Setlhogile and Arntzen 2012, Jürgens 2014). As a result policy- and other decision-makers have to decide on the basis of poor predictions of the potential consequences of their actions.

Existing **environmental laws** related to forest, water, and land are inconsequently enforced, except in cases of severe pollution and degradation. The society perceives other aspects of social life to be of higher priority. Fines and punishments are too low to prevent resource-degrading activities such as illegal logging. Efforts are made to ensure compliance with forestry and fishery laws, but the monitoring authorities responsible are overstrained by having to patrol the large area. This creates insecurity and reduces incentives to manage the land sustainably. Traditional authorities play an important role in the enforcement of customary laws regarding natural resources, and compliance with customary law would make a strong contribution to sustainable resource management.

The community land is designated state land. Local farmers hold no formal land rights, and oppose government attempts to formalize land tenure. **Customary law** has been effective in allocating land and avoiding conflict within the community. Customary law has its limitations, however, which become apparent as soon as more powerful external players become interested in accessing land. With the growing demand for land and the need to enhance commercial operations, the go-



Fig. 53: Informal selling of timber (photo: M. Pröpper).

vernment is under pressure to confiscate land, forcing people with various types of formal and customary (informal) land rights to resettle elsewhere. The Communal Land Reform Act specifies that in such cases compensation has to be paid and that all customary and statutory land rights must be acknowledged. As such the farmers are at least legally well protected against land grabbing. The traditional authority system is generally able to allocate and protect land rights. Since traditional authority structures are not built on the notion of a separation of powers, statutory organs are often suspicious and rather try to curtail the powers of traditional authorities.

Tourist activities play a minor economic role in the Namibian Kavangos. However, the movement of wildlife is strongly impeded by the system of veterinary fences running through northern Namibia. A network of tarred main roads links the major urban nodes, and secondary roads are still mainly gravel or earth roads, with partially restricted usability in the rainy season. There are airports in Rundu and Calai. Electricity is available in the main centres as well as in the bigger settlements, especially along the main roads.

The **area of effectively conserved land** is about 6 % of the Namibian FORA.

The Mashare core site itself is not located within a protected area, but there are some community forests and communal conservancies in the area surrounding it. We find major hotspots of urban transformation close to Rundu, and agricultural transformation along the densely populated Namibian south rim of the Kavango. Between 1990 and 2000 approximately 12 km² of woodlands were converted to arable land or streets. Moreover, new irrigated fields were established in that period near the river. Even though the area of Rundu increased during that period, settlements within the core site show only a few changes.



Fig. 54: Fields of dryland agriculture (Mahango) and Conservation agriculture (photos: A. Gröngröft).

Most areas experience **fires** regularly. As fires are mostly man-made, the burning seasonality corresponds to the agricultural practices in the different seasons. Wild-fires start in this area once the vegetation is dry enough (June) and gain in frequency and intensity as the dry season progresses, peaking in August and ending in October with the first rains. The fire maps show that the woodland areas burn regularly. Intensively used areas with high population densities are not affected by fires. This is true for the city of Rundu, situated in the western part of the map, as well as for the villages of the core site along the Okavango River.

Regarding **agriculture** we find two dominant systems: **Small-scale, rainfed semi-permanent subsistence cultivation; and irrigated industrial agriculture**. The actual **area under irrigation** covers a 2,200 ha in the Namibian Kavangos. There are only small parts of the core site which are covered with industrial agriculture.

The small-scale cultivation system is characterized by land scarcity and reduced levels of soil fertility, which restrict cultivation mainly to low-yielding pearl millet (which delivers reliable harvests only in years of good rainfall). Tradable food surpluses are very rare. In the last decade, the speed of impoverishment processes has increased due to a breakdown of the cattle economy, which was caused by overgrazing of communal pastures. This resulted in a lack of oxen for ploughing as non-ox-owning households often need to spend most of their cash resources on hiring oxen, which are available only after ox owners have ploughed their own fields. Due to the small time window available for ploughing (depending on rainfall), non-ox-owning households often do not manage to plough & plant their entire fields, or even a single field, at all. Thus, their total harvest is reduced. These processes result in an ongoing stratification of households in Mashare; the majority are affected by degrading household re-

sources (reduced soil fertility and deteriorating forest resources due to overgrazing), while a minority of households benefit from slowly increasing cash-market integration (specialization & commercialization). However, the failure of old production practices has led to the training of 72 farmers to adopt the new & more labour-intensive production system of **Conservation Agriculture**.

Some of the local population own **cattle**, but due to the degradation along the river, larger herds are mainly found in the drier hinterland. Ranching is also supposed to play a role on the so-called **‘small-scale’ hinterland leasehold farms**. However, export-oriented cattle ranching is mainly found south of the veterinary fence. The positioning of ‘small-scale’ hinterland leasehold farms north of the **veterinary fence** thus hampers connections with EU and international markets. It is unclear to what degree these hinterland leasehold farms on communal lands are **1) productive units, and 2) generating benefits for the wider population**. It has to be asked whether these farms are not a step towards the privatization of land through local and national elites. Such farms cover a very significant fraction of the total land area of the regions in question.

Foot-and-mouth disease does not break out often, probably due to the very low numbers of wild animals remaining in the area. When the disease is found in cattle further to the east, where wild animals are more abundant, then the control of movement of animals and their products between veterinary zones is tightened, and cattle may be vaccinated more frequently.

Regarding the **integrity of the landscape**, Mashare at present constitutes the core site with the strongest human-generated landscape alterations (fig. 55 and 56). Two roads dissect the site from west to east – the old gravel road following the rim of the recent Okavango floodplain, and the new tarred road running ca. 3 km

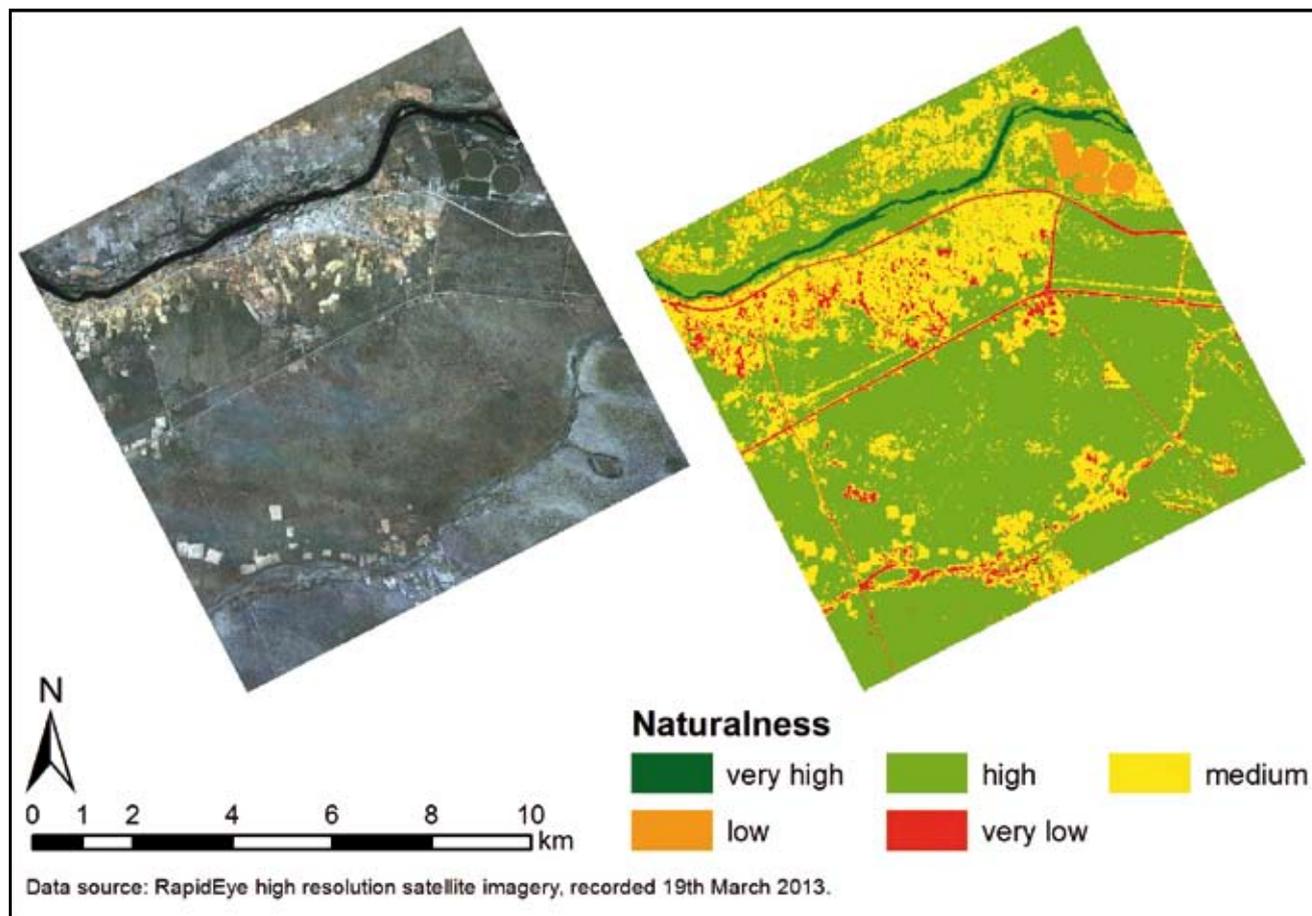


Fig. 55: Degree of naturalness in five classes from very high (natural) to very low (non-natural) at the core site of Mashare. Red lines and areas depict mainly roads and homesteads; yellow areas mainly smallholder agricultural land. For better understanding an aerial image of the core site is added.

within the Kalahari Dune hinterland, with several vertical shortcuts between them, and with sand pads extending southwards into the hinterland. A mostly continuous sequence of rural communities extends along those two main roads, transforming most of

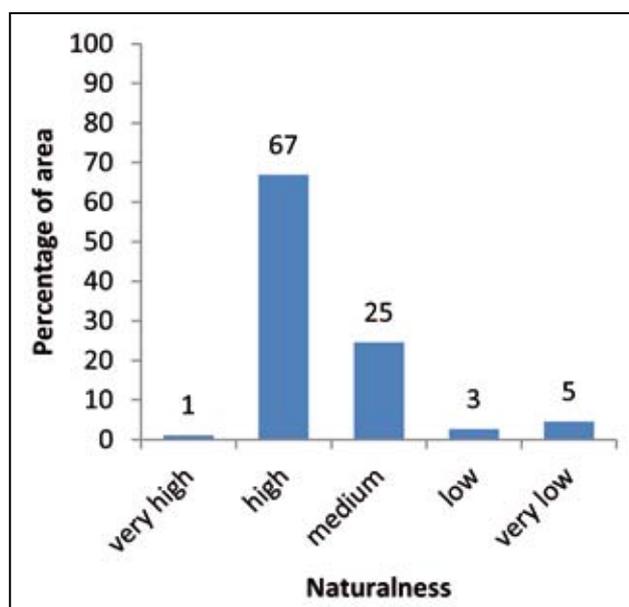


Fig. 56: Percentage of area of the five naturalness classes from very high (natural) to very low (non-natural) at Mashare core site.

the original old floodplains into semi-natural agricultural landscapes of rather intensive transformation due to smallholder activities, with mosaics of small fields, fallows, homesteads, hedges, remaining trees and shrubs, etc. A small fringe displaying the beginnings of periurban dynamics is currently developing along the tarred road, with small shops and shebeens. The only part with larger tracts of near-natural ecosystems on the old floodplains is within the limits of the MITC/MADI complex. In the north-western part of the core sites are several irrigation fields used for modern industrial irrigation agriculture, with correspondingly disturbed biotic communities and natural ecosystem processes.

The Kalahari Dune hinterland south of the tarred road is less populated, with settlements almost exclusively following the course of the ephemeral river systems. Although this area is less populated, agricultural activities do take place, with many fallows and active fields on the Kalahari sand dunes. The overall landscape integrity in the hinterland is therefore higher; however, the impacts of forms of land-use such as wood extraction, hunting, and cattle grazing extend far beyond the southern limits of the core site. The recent floodplain of the Okavango is very small in the core site; the original gallery forests on the Na-



Fig. 57: Rural household in Mashare, Namibia (photo: H. Seidel).



Fig. 58: View from Mashare, Namibia to the Angolan side across the river (photo: L. Schmidt).

mibian side of the river have been mostly cut down, and reed beds are intensively harvested for thatching on both sides of the river. However, the river course still has mainly intact structures and flood dynamics. Ecosystem connectivity is considerably interrupted by the above mentioned roads and by the fences around the MITC/MADI complex. Biotic communities lack most of their larger herbivores and top predators on the Namibian side.

The core site includes a small section of the Angolan side of the river. Settlements are sparse there; however, fields already extend all over the most fertile parts of the old floodplains there, currently indicating the beginnings of a transformation process toward agricultural landscapes. However, many of these agricultural activities seem to be associated with communities from the Namibian side of the river, so the landscape transformation is less pronounced than on the southern rim. The northern hinterland on the Angolan side still shows fairly intact and natural landscapes, including some emblematic elements of the natural biotic communities (e. g. elephants passing through).

3.3 The socio-ecological system at Seronga

The **climate** at Seronga is characterized by semi-arid conditions, with a rainy season during the austral summer and a dry period from May to September. Between 1971 and 2000, the mean annual precipitation was about 478 mm (Weber 2013). The annual rainfall in Seronga showed a high interannual variability without any significant trend between 1950 and 2009. The mean annual temperature is 23.2 °C. November and July are the hottest and the coldest months, with mean average temperatures of 27.1 °C and 16.5 °C respectively (period 1971–2000). The long-term annual mean temperature shows a moderate interannual variability, with an increase in temperature since the late 1970s (Weber 2013).

The small town of Seronga (and the TFO core site of Seronga) is situated at the south-eastern edge of the Okavango Panhandle at the confluence with the delta. The area is composed of relatively intact natural wetlands and Kalahari Sandveld. The development of Seronga was supported by landscape characteristics, as a major channel within the floodplains meets a broad belt of relatively fertile soils in the Sandveld there. Human settlements are lined up along the slope between wetlands and Sandveld. The gravel road from Shakawe to Seronga follows the same line along the eastern rim of the panhandle. All these factors contribute to **high landscape integrity** (fig. 63 and 64).

The area is only moderately affected by bush fires. Within the core study area of 100 km² around Seronga more than 90 % of that study area are still in a relatively natural state. The natural fauna of the area still shows fairly intact trophic chains, with large herbivores (e. g. elephants, buffalo, hippopotamus) and top predators (e. g. lions). The small town of Seronga is located in the buffer zone just outside the core zone of the UNESCO World Heritage Site of the Okavango Delta. A portion of the floodplains used by the community falls within the core site area, and this portion is also classified as a Ramsar wetland of international importance. Moreover, parts of the community lands belong to a Wildlife Management Area. Nevertheless, in terms of ecosystem functioning, the large-scale movements of migrating animals are restrained by the Northern Buffalo Fence and the Caprivi Fence, trapping the animals between the fences and the panhandle (fig. 28).

Along the road the ecosystem connectivity is partly interrupted by the linear development of settlements. This leads to strong human-wildlife conflicts in the dry season, as elephants are forced to pass through fields and close to settlements in order to get to the wetlands for water (see below).



The core site of Seronga

Current national and regional framework

- National economic strategy leans strongly towards economic growth through market promotion and considerable external investment.
- Enforcement of wildlife and fishery laws is strict, while existing environmental laws related to forest, water, and land are inconsequently enforced. Traditional authorities play a marginal role in natural resource management.

Current state of the core site of Seronga

- Traditional agriculture is the main economic activity.
- There are strong human-wildlife conflicts.
- Fire aggravates the pressure on the ecosystems.
- The quality of the drinking water provided by a pipe system is low.
- The core site currently presents a mosaic of pristine natural woodlands in the Kalahari Sandveld hinterland, of seminatural agricultural systems along the main road and of intact natural wetlands along the panhandle.

The only major urban hub in the delta area is Maun, with a population about 60,000 people. Seronga is part of the North-West District of Botswana, with a population of approximately 152,000 people. The administrative centre of Shakawe, at the north-western end of the Panhandle, plays a major role in migration, trade, exchange and supply. It can be reached from Seronga via a gravel road and a public ferry boat (fig. 65). Increasingly, agriculture is spreading along the edges of the gravel road. Simultaneously, there is also an increasing concentration of the **population** in Seronga, which offers more and more comfort due to improving public infrastructure (schools, a hospital, police, land administration, a water supply system, cell phone coverage) as

well as market development (represented by e. g. a small supermarket). Electricity is provided by a decentralized generator, but only a few households can afford to get connected to the power lines. Seronga is loosely connected with Maun through infrequent air traffic.

Along the panhandle communities have permanent access to the open **water** in the streams of the wetlands. Seronga pumps water from a central borehole and distributes it through a pipe system. However, the infrastructure is in a poor state and the quality of drinking water is low. Poorer people therefore still rely on the river water or scattered public hand-pumps while wealthier households have installed wells on their compounds. Human water extraction is only for personal consump-

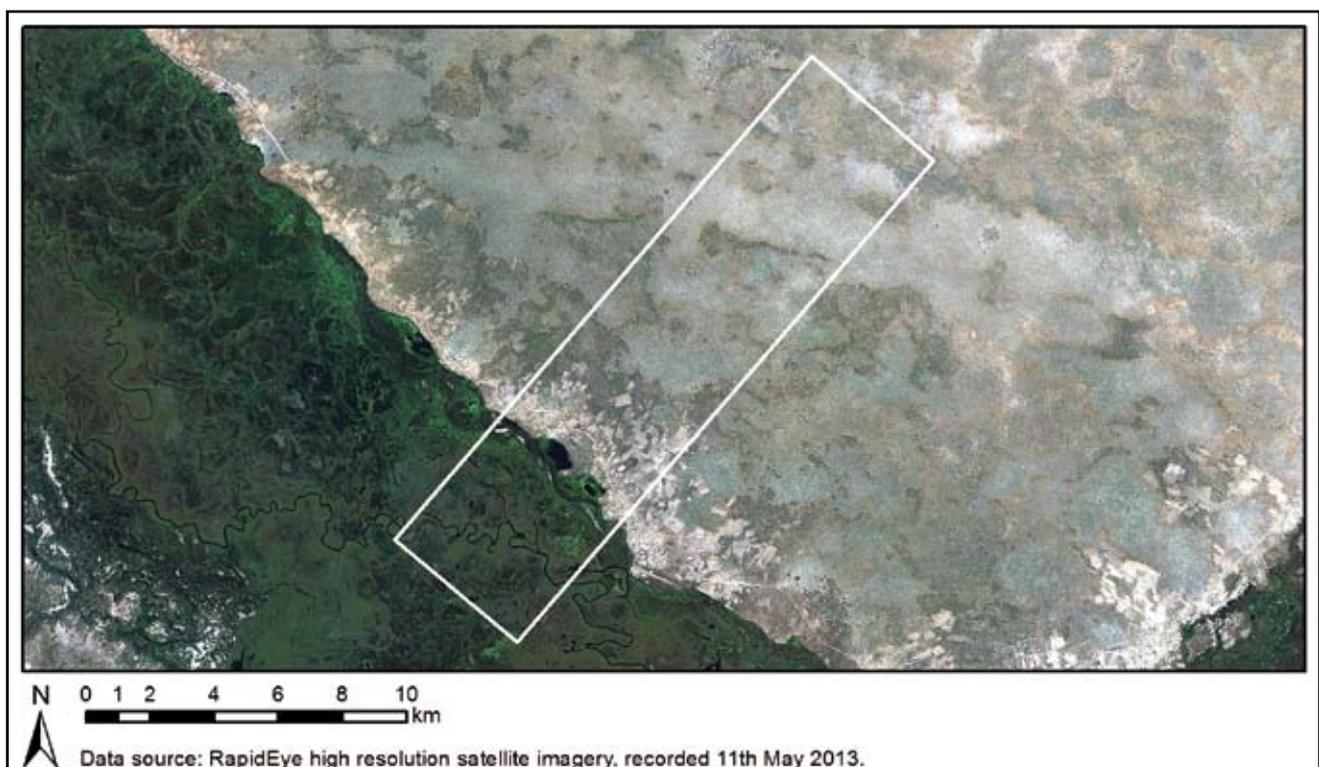


Fig. 59: Overview of the core site of Seronga. White line depicting the extent of the core site.

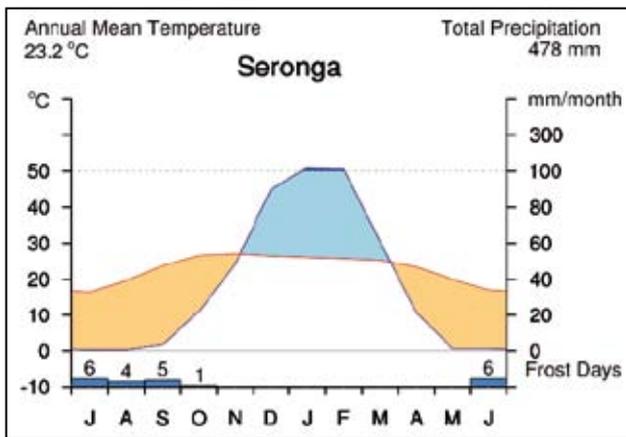


Fig. 60: Walter-Lieth climate diagram of Seronga for the period 1971–2000 (Weber 2013d).

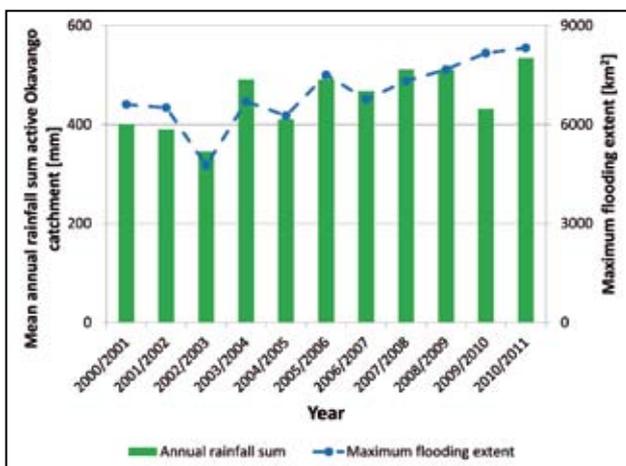


Fig. 61: Mean annual rainfall sum of the active Okavango Catchment and maximum flooding extent for the observation period from 2000 to 2011.

tion, and the total volume extracted is low. Along the border of the wetlands small amounts of water are used for the irrigation of small-scale horticulture (fig. 66).

Seronga has approximately 950 households and nearly 3,000 inhabitants. According to the preliminary results of the 2011 census, the population growth rate was 1.9 (Census 2011). In the region as a whole, as in Seronga itself, natural fertility is still high, and will most likely continue to be the dominant driver of population growth. However, due to its remote position internal migration towards the urban centres is and will remain a strong dynamic, especially for the young. Re-migration by relatives to the communities is also common.

The TFO 2012 socio-economic survey at the core site revealed an average annual per capita **income** (including subsistence income) of € 756. The Gini coefficient of the annual per capita income (including subsistence income) was very high (0.82) indicating a very unequal income distribution. Of the households, 74 % had access to safe drinking water. 31 % of the population had no formal education, while 28 % had finished secondary school.

Botswana follows a mixed **development policy**. On the one hand, low-cost smallholder-oriented agricultural innovations such as the use of fertilizers or tractor-hiring schemes are promoted and subsidized both by the government and by development organizations. On the other hand, commercial mining projects as well as tourist operations are encouraged.

Overall, there is a strong policy and legal framework for sustainable **natural resource management** in Botswana (Malzbender et al. 2010). The Community Based Natural Resources Management Policy (CBNRM 2007) includes the objective of balancing nature conservation with livelihood improvement. Nevertheless, there is a high risk that development policies will conflict and result in uncoordinated developments that prove to be economically and environmentally unsustainable in the long run. A critical shortcoming is the insufficient sectoral integration of environmental policies at both district and national level (Malzbender et al. 2010, Setlhogile and Arntzen 2012). The District Development Plan (DDP 7) for Ngamiland makes provision in particular for the development of settlements and new wildlife concessions, but also includes plans to establish large-scale agricultural projects (Setlhogile and Arntzen 2012). Input subsidies are an important policy instrument for smallholder agricultural development (Setlhogile and Arntzen 2012). There are critical limitations on environmental and social information, a point which is also highlighted in Botswana's Vision 2016 (OKACOM 2011, Setlhogile and Arntzen 2012, Jürgens 2014). As a result, policy- and other decision-makers have to decide on the basis of poor predictions of consequences of actions. This is one reason why many ecosystem services are insufficiently taken into account when planning land- and resource-use. There are efforts being made to increase decision-makers' knowledge about the multidimensional consequences of resource-use decisions (OKACOM 2011, Jürgens 2014), but the country faces serious capacity constraints.

There is a very effective and strict enforcement of wildlife and fishery laws. **Environmental laws** related to forest, water, and land are unclear however, and consequently enforced, with the exception of cases of severe pollution and degradation. For these resources, fines and punishments are too low to prevent resource-degrading activities. Traditional authorities have lost much of their power and play a rather marginal role in natural resource management.

The community land is designated state land. Local farmers hold formal **land rights**, and land is allocated by the land board. The mechanism is effective in preventing more powerful external players from illegally accessing land. Nevertheless, with the growing demand for land and the need to enhance commercial operations including mining, the government is under pressure to encourage

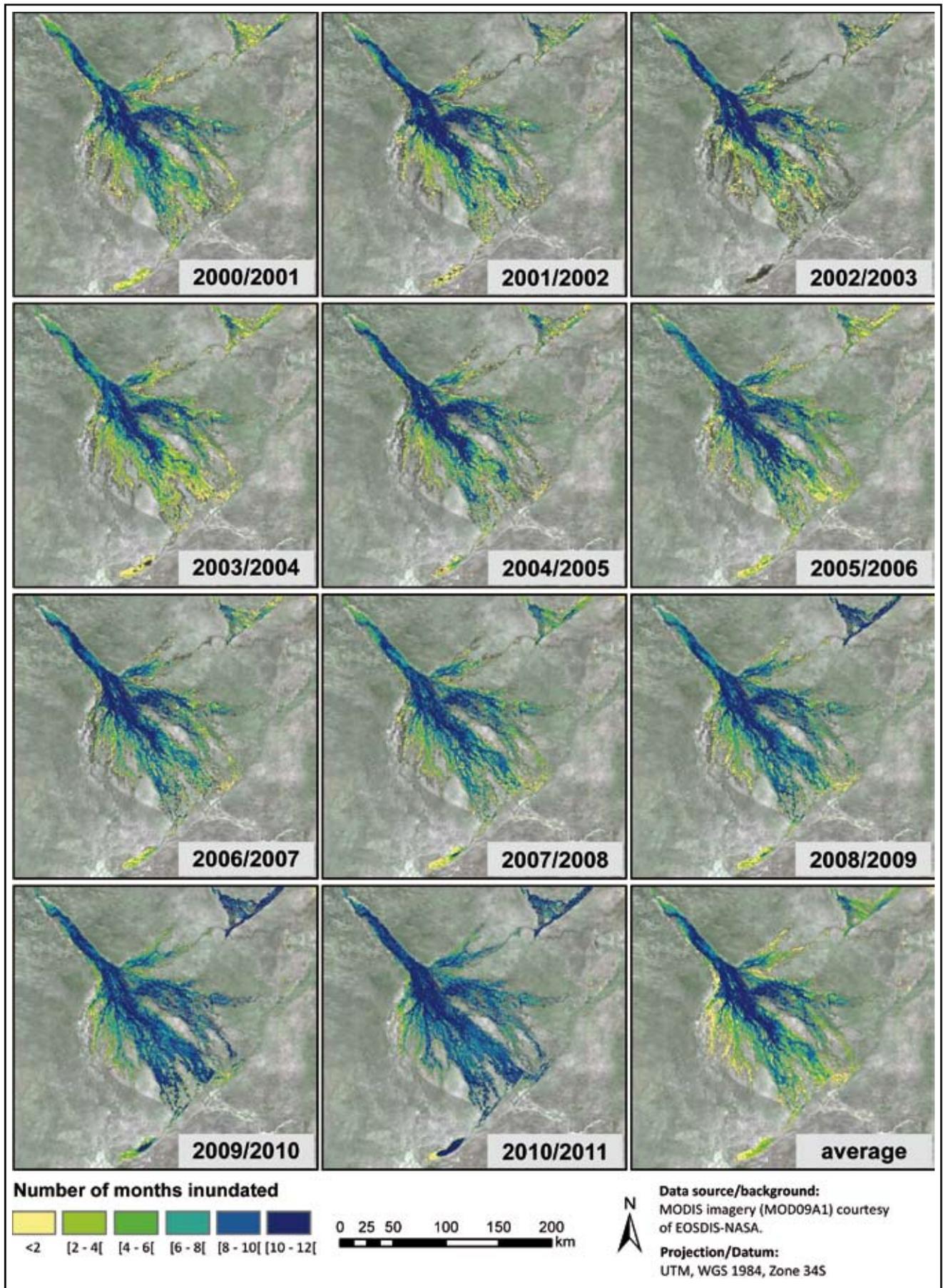


Fig. 62: Estimated number of months inundated within the Okavango Panhandle and Catchment covering the observation period from 2000 to 2011. The dataset is based on 8-day reflectance data of the MODIS sensor (MOD09A1).

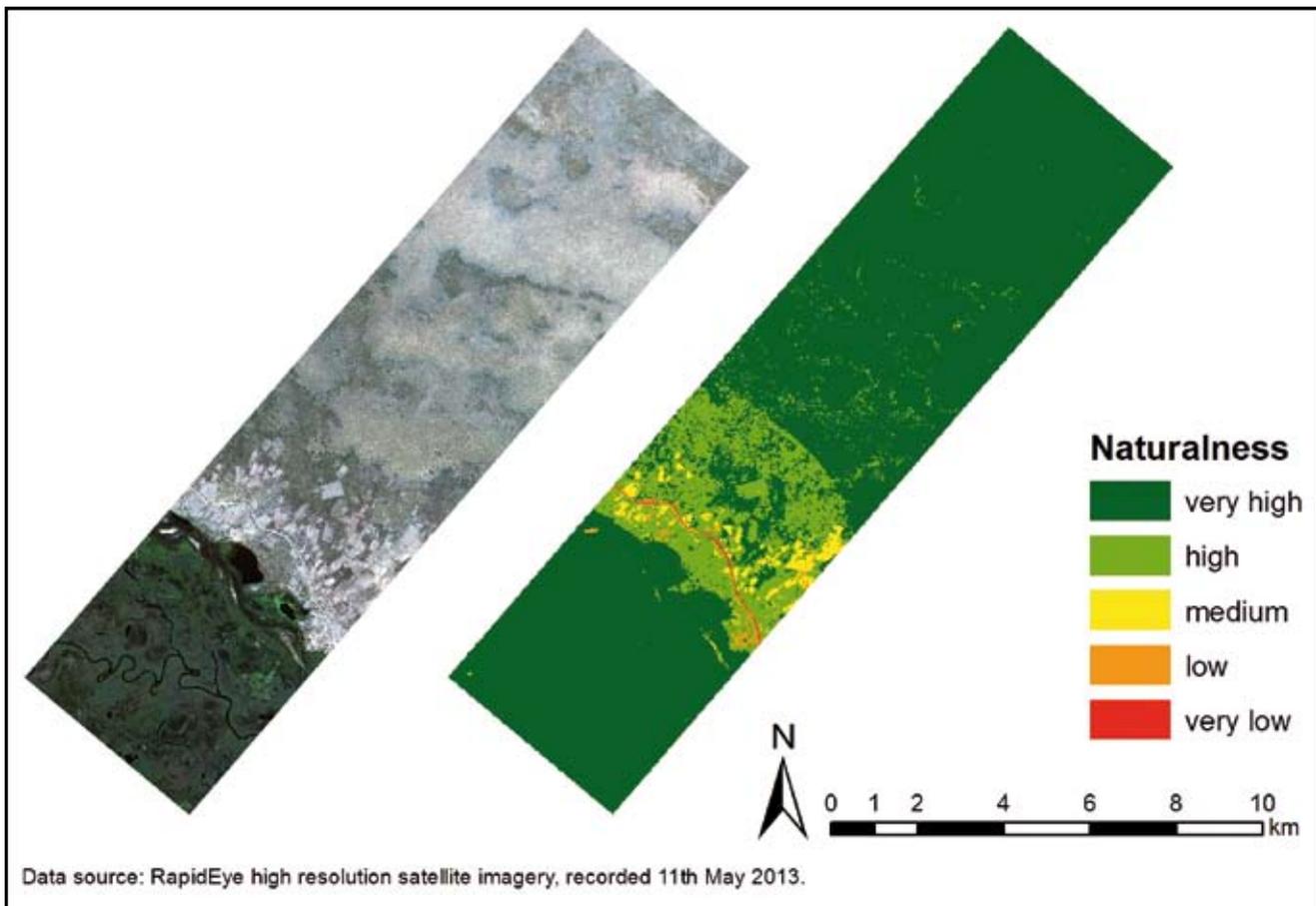


Fig. 63: Degree of naturalness in five classes from very high (natural) to very low (non-natural) at the core site of Seronga. Red lines and areas depict mainly roads and homesteads; yellow areas mainly smallholder agricultural land. For better understanding an aerial image of the core site is added.

people to move their homesteads and fields. In such cases compensation has to be paid. As such, the farmers are relatively well protected against land grabbing.

The town of Seronga is becoming increasingly involved in **cash markets**, and at least some people have become increasingly preoccupied with the acquisition of consumer goods. Households display a wide variety of modern goods which are to a great extent imported from global and regional markets. Cash income is strongly based on employment (mainly public, but also in the private tourism sector) and compared to the other TFO core sites Seronga offers a higher institutional density and thus more labour opportunities. As such there is less pressure to commodify natural resources than in less developed places.

Along the panhandle the communities practice a semi-permanent **cultivation** system with high importance of natural resource-use for their livelihoods. The road to Seronga constitutes an axis of transformation of Sandveld woodlands into a patchy agricultural mosaic of smallholder fields, fallows, and degraded shrublands. People live and make their fields close to the road. The clearing for fields concentrates in areas with mixed Mopane woodlands. These Mopane stands have darker and more fertile sandy soils than the *Terminalia* woodlands. Therefore, despite relative overall land abundance, farming concentrates around Seronga, and

the transformation is limited to an area less than four kilometres from the river into the dry hinterland. Only cattle-grazing extends farther into the Sandveld without major impacts on the ecosystems of the hinterland. However, the traditional land-use pattern of fields in

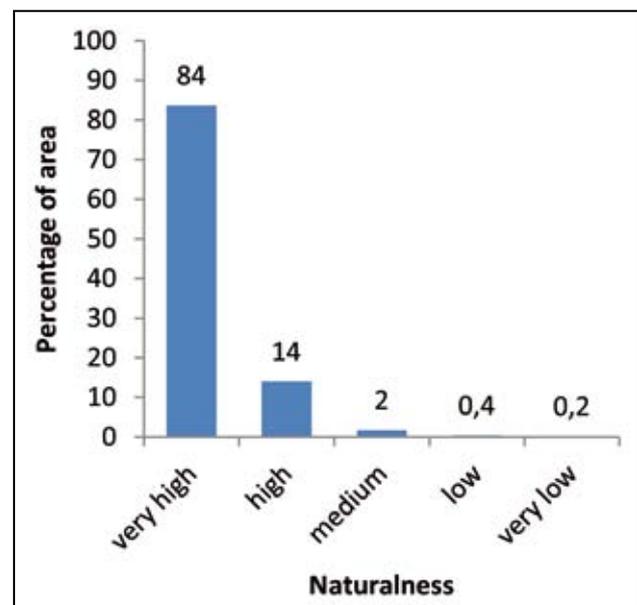


Fig. 64: Percentage of area of the five naturalness classes from very high (natural) to very low (non-natural) at Seronga core site.



Fig. 65: Ferry and gravel road to reach Seronga from Shakawe (photos: S. Domp tail & L. Schmidt).

the close vicinity of settlements and cattle posts in remote areas is increasingly dissolving. The cattle stocks are stable. During the wet season, grazing areas extend far into the hinterland. All year round the wetlands are used as pastures.

Low crop yields are additionally aggravated by crop losses due to wildlife and livestock damage. Thus, farming becomes less attractive as soon as alternative sources of income become available. Within the study area of 100 km², ca. 5 % of the land is used for cultivation. Currently, there is no area under intensive irrigation close to Seronga.



Fig. 66: Irrigated small-scale horticulture in Seronga, Botswana (photo: A. Gröngroft).

Livestock management is largely based on communal pasture management. The community pastures are adjacent to the Okavango and Kwando Wildlife Management Areas. This increases the risk of disease outbreaks (e.g. of foot-and-mouth disease) though this rarely happens thanks to careful monitoring and established annual vaccination campaigns run by the government. Nevertheless, the classification as a high-risk area is the reason why Seronga is placed within a restricted area from which the export of livestock products to major regional and global markets is strongly hampered. Three veterinary control fences are in place to the south of Seronga, running from east to west.

Compared to other parts of the delta there are less **tourism** activities around Seronga. A campsite is run on a cooperative basis by community tourist guides. It also has poorly maintained cottages. The camp is visited only sporadically by independent tourists and a few overland trucks. The nearby Xau Mokoro station facilitates boat trips in the north-western part of the delta. There is also a private tourism operator offering houseboat trips into the delta. The majority of tourism is organized in the form of fly-in / fly-out Mokoro-tours organized by external Safari companies. Most of the local employees in the tourism sector have low-skill jobs and are poorly paid. However, the Seronga community benefits from tourism through concession fees paid to the Okavango Community Trust.

Currently there are no **mining** operations going on in the Seronga area.

TFO's interview-based **ecosystem service** assessment revealed that the community harvests large amounts of thatch grass and reeds for roofing (512 and 129 tons per annum respectively). In addition, wood / timber is used for construction and cooking, mostly being extracted in the areas close to the road and near the village. People catch and consume fish frequently, with a total annual extraction of approximately 11 tons. Medical plants, nuts, roots, and the famous 'Mopane worms' complement the local diet.

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Chapter 4

Key findings and Recommendations

Within this chapter we present key findings of the inter-disciplinary research. Each key finding characterizes aspects of the socio-ecological system with varying degrees of spatial as well as temporal relevance. Some have specific relevance for small areas within the catchment, e. g. for the riparian woodlands in the delta; others analyze the whole basin or even larger areas. The findings are grouped in the chapters **Climate & climate change**; **Water use, availability & management**; **Conservation and management of living natural re-**

sources and their ecosystem services; **Agriculture & Food security**; and **Society and Governance**. Based on the findings and the analysis of the system for each chapter, integrative recommendations for stakeholders operating at different scales within the catchment are presented. These recommendations have been prepared by the scientists working within the project, with the general vision of promoting a long-term sustainable development of the basin while conserving the beauty and uniqueness of the natural system.

4.1 Climate & Climate Change

C1) The Basin is expected to become warmer, especially in Southern Angola, Namibia and the Delta (appr. 1.5 to 2.5 °C in the period 2016–2045).

Climate change scenarios are of uppermost interest, because the potential change of the climate in the Okavango River Basin may affect all components of the hydrological cycle, and thus the lives of the people living this region. To generate high-resolution climate projections, regional climate models are used to down-scale simulations (i. e. calculating the climate data at higher spatial and temporal resolution) created by global circulation models. Climate projections, however, contain various uncertainties which have to be considered and estimated. The uncertainty originating from climate models can be estimated by applying different global circulation models and regional climate models. In long-term climate change projections, however, the largest portion of uncertainty is assigned to the hu-

man contribution to climate change, which is a result of unknown global developments in technology, economies, lifestyle and policy. This uncertainty can be tackled using different emission scenarios covering a wide range of possible future anthropogenic emissions. In the TFO project, the new Representative Concentrations Pathways (RCPs) are considered, which contain a possible moderate (RCP4.5) and a high (RCP8.5) anthropogenic emission scenario (Moss et al. 2010). Finally, the uncertainty resulting from the climate variability can be reduced by considering the mean value of a meteorological variable over a sufficiently long period of time, e. g. 30 years. In the scenario-building process, only the high-emission scenario (RCP8.5) was considered, since for the

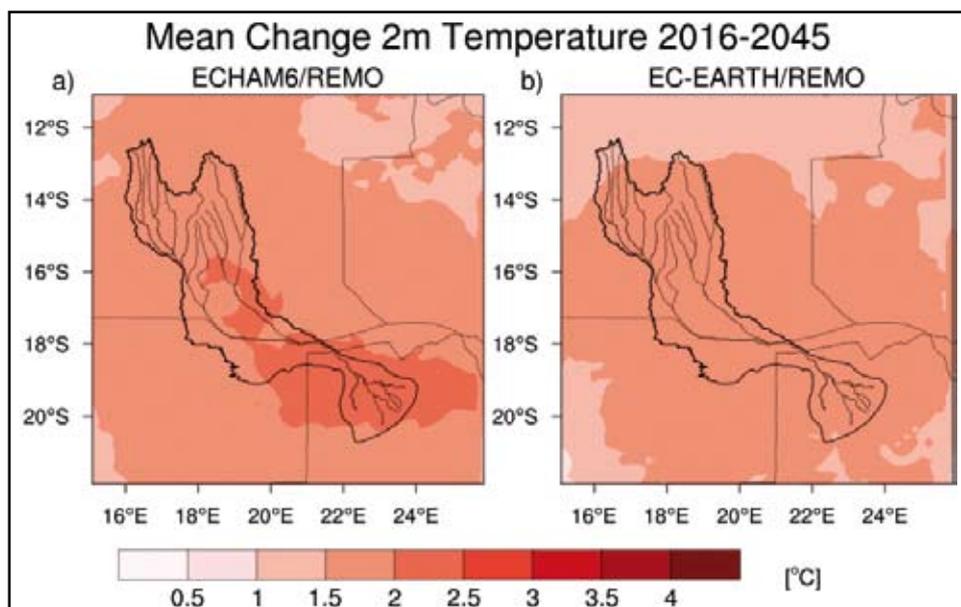


Fig. 67: Mean change in 2 m air temperature for the period 2016–2045 based on two models (a: ECHAM6/REMO, b: EC-EARTH/REMO).

near future the emission pathway of RCP8.5 is similar to the former Special Report on Emissions Scenarios (SRES) A1B. Thus, the results can be compared with the SRES scenarios used in other research projects.

In detail, subproject 01 generated climate change projections at a high spatial resolution for the Okavango River Basin. The regional climate change projections were dynamically downscaled with the regional climate model REMO (Jacob 2001) using data from the global circulation models ECHAM6 (Stevens et al. 2015) and EC-EARTH (Hazeleger et al. 2010). To obtain the high spatial resolution of 25 x 25 km² of the regional climate change projections, a double nesting method was applied (i. e. initially, the climate data were downscaled

to a spatial resolution of 50 x 50 km² and subsequently again, to a spatial resolution of 25 x 25 km²).

The mean air temperature at a height of 2 m from ground level was analyzed for the near-future 2016–2045 (with the core year 2030), and compared to the reference period 1971–2000. The possible temperature change is indicated by a range (minimum and maximum value), which expresses the uncertainty resulting from the use of two different global models as input for the regional climate model. Fig. 67 indicates the changes, which vary between 1.5 and 2.5 °C.

Link to data and further readings: A detailed analysis of climate change projections is available in OBIS.

C2) The annual rainfall tends to decrease in the whole basin and the duration of the rainy season tends to shorten with up to 20 days in the Angolan Highlands (in period 2016–2045).

Background information for the climate change projection approach of the TFO project is given above.

The annual rainfall and the duration of the rainy season were analyzed for the near-future period 2016–2045 (with the core year 2030) and compared to the reference period 1971–2000. The duration of the rainy season was calculated based on the definition by Liebmann et al. (2012), which allows an objective determination of the duration of the wet season for each year and each grid cell. When summarizing the daily rainfall in a year minus the mean daily rainfall of all years, the onset of the rainy season is the day for which the cumulative curve is at its minimum.

The possible changes of both variables are indicated by a range (minimum and maximum value), which expresses

the uncertainty resulting from the use of two different global models as input for the regional climate model.

Fig. 68 shows the change in mean rainfall for the whole basin calculated with two global models as input. Both global model inputs indicate a decrease in rainfall especially for the upper part of the catchment, whereas for the delta the change varies between zero and -100 mm a⁻¹.

The duration of the rainy season (fig. 69) tends to decrease by up to 20 days in the Angolan highlands. For the other parts of the catchment, the models simulate no clear tendency for the duration.

Link to data and further readings: A detailed analysis of climate change projections is available in OBIS.

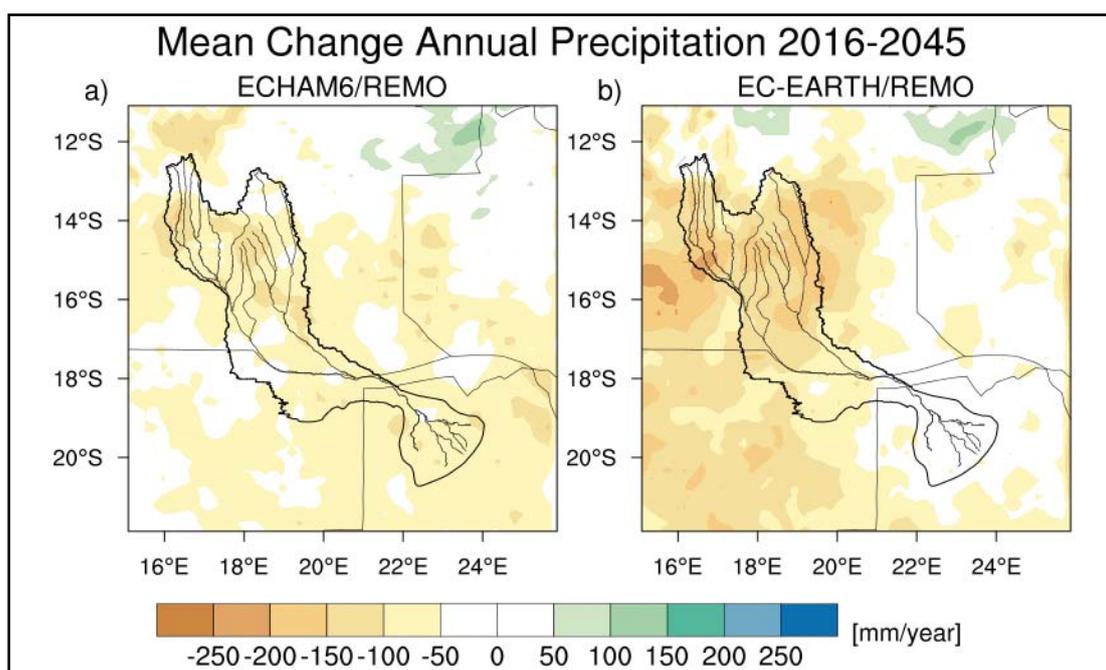


Fig. 68: Mean change in annual precipitation for the period 2016–2045 based on two models (a: ECHAM6/REMO, b: EC-EARTH/REMO).

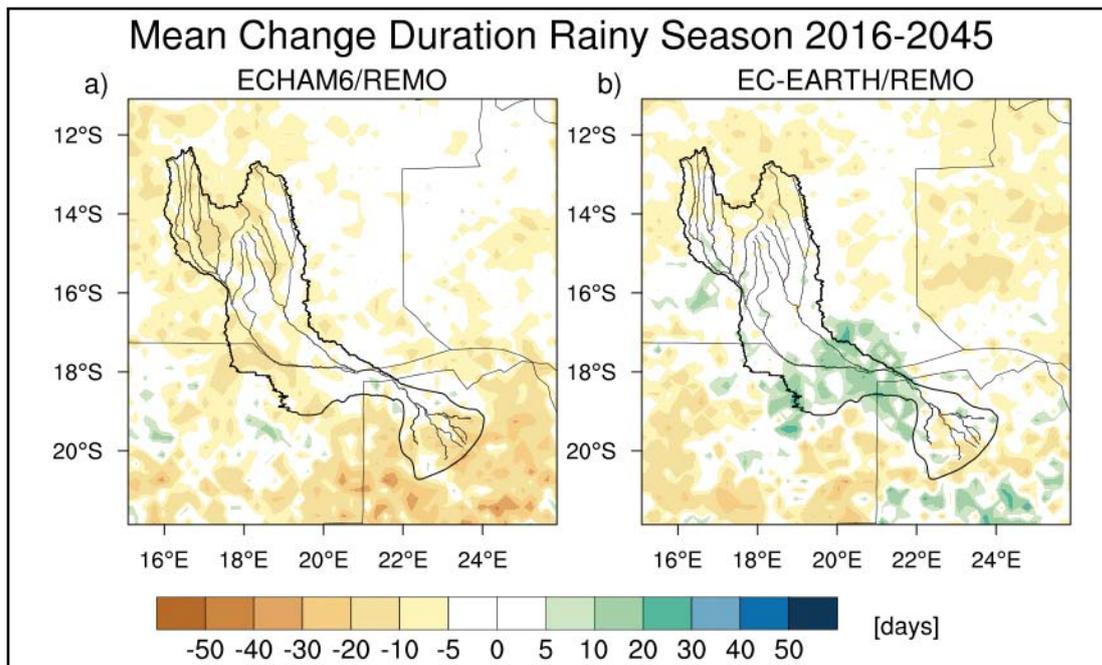


Fig. 69: Mean change in the duration of the rainy season for the period 2016-2045 based on two models (a: ECHAM6/REMO, b: EC-EARTH/REMO).

C3) Climate change is likely to lead to a shift of areas suitable for crop cultivation.

Recent studies say that in many areas around the world, a substantial amount of crop yield variability can be explained by climate variation (Ray et al. 2015). In the Okavango Basin, a large percentage of the population is dependent on rainfed subsistence agriculture, while the arid climate conditions and relatively unproductive soils place major constraints on the suitability of the land for crop growth. In the future, additional pressure on the cultivation of certain crops may occur if precipitation falls below their tolerance limits due to climate change.

To investigate the corresponding shifts in suitable zones for the five main crops grown in the basin (maize, pearl millet, sorghum, cassava and cow pea) a GIS-based analysis (Weinzierl and Heider 2015) was performed. It links the regionalized TFO climate scenarios for the end of the century (2071–2100, Weinzierl et al. 2013) with water tolerance levels from the Ecocrop database (FAO 2015), shown in tab. 5. The recent climatic suitability was derived from ERA-Interim/REMO reanalysis data

(Jacob 2001) and both a medium-low (RCP4.5) and a worst-case (RCP8.5) emission scenario, which are identical to those used by the IPCC, illustrate the possible future situation.

Also, the dominant soil type was obtained from the SOTERSAF database (Dijkshoorn and van Engelen 2003) and included in the approach. The soil types were rated according to their suitability for agricultural use without additional irrigation or fertilization based on FAO 2006, and fuzzified to values between 0 and 1. The two fuzzified datasets on precipitation and soil were then combined using an 'AND Intersection' algorithm with the min-operator. The output dataset is thereby assigned the lowest cell value from the two different inputs. This means that if in one cell cultivation is not possible at all because of one of the factors, the output will be 0. When one of the factors is optimal, the other factor determines the overall suitability. Or in other words, the agricultural potential can be only as high as the worst constraining factor at a certain location.

Tab. 5: Annual water requirements (mm) (FAO 2015) of the five main crops of the Okavango catchment.

Crop	absolute min	optimal min	optimal max	absolute max
Maize	400	600	1200	1800
Pearl Millet	200	400	900	1700
Sorghum	300	400	600	700
Cassava	500	1000	1500	5000
Cow Pea	300	500	1500	4100

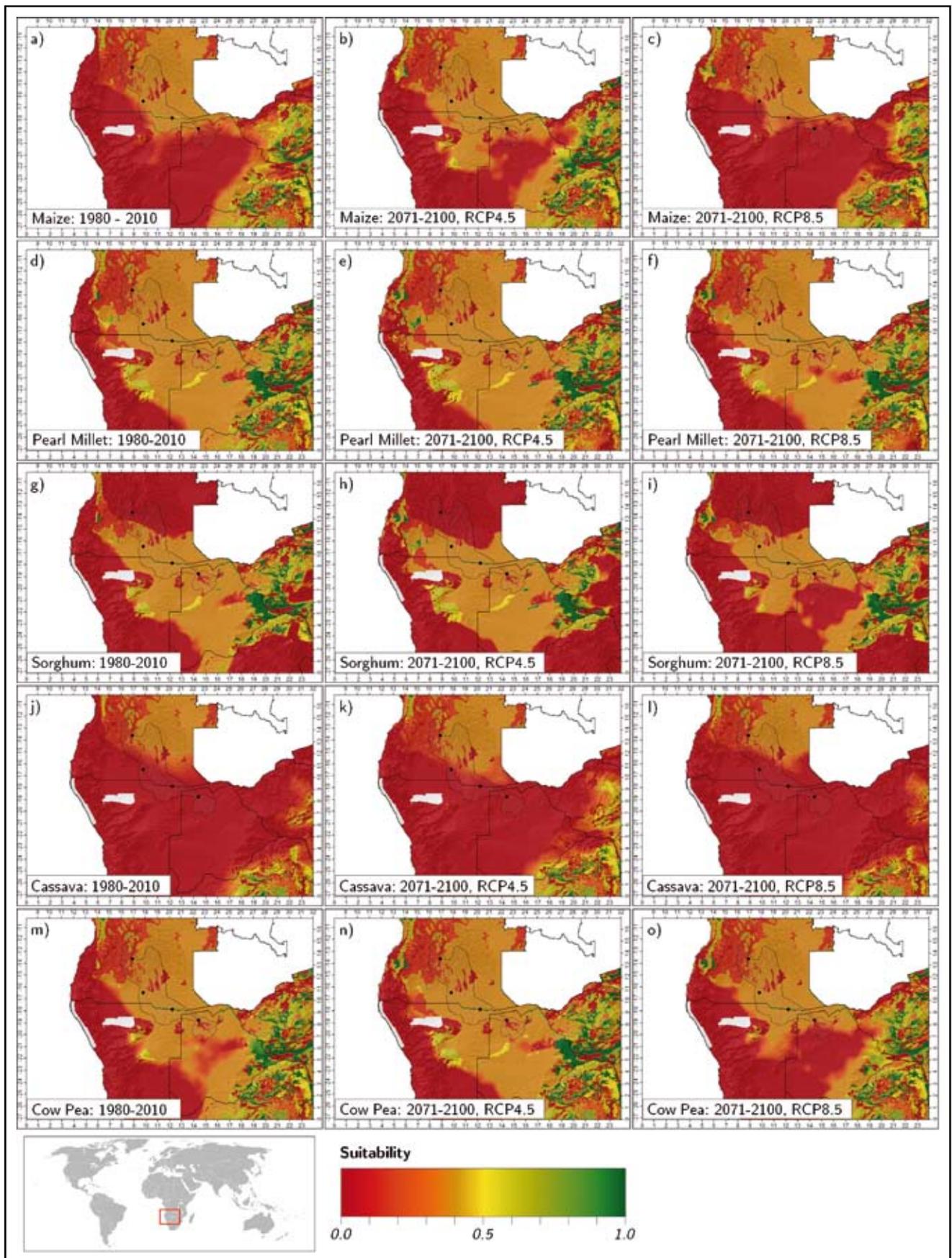


Fig. 70: Natural suitability for the five main crops derived from precipitation reanalysis (left column) and two climate model scenarios (middle and right column). The FORA is outlined grey and the four TFO core sites are marked black.



Fig. 71: Morning fog in the Cusseque valley (May 30th 2011) illustrating the accumulation of cold air in the valleys of the Angolan Highlands (photo: M. Finckh).

The results are compiled in fig. 70. They show that in the northern and central part of the catchment, poor soils are the limiting factor for farming, while especially to the south, precipitation poses the main restriction. Due to the prevalence of the sandy Arenosols, even optimal water provision only leads to a medium suitability in the major part of the basin.

Our data suggest that south of the catchment and in parts of the delta region, maize is not suitable at present. Under the RCP4.5 scenario, a slight increase in precipitation might enable cultivation in northeastern Namibia and parts of Botswana. RCP8.5 suggests a northwards shift of the suitable zone and therefore a decline in yields in the southern half of the catchment. As pearl millet is relatively drought-resistant, it can be grown in most parts of the study area except the extremely arid desert areas. Until the end of the 21st century, the climatic potential for growing pearl millet will most likely remain moderate under both emission scenarios. Today, sorghum is suitable for widespread areas in the center of the study region. Under RCP4.5 only slight changes are projected, while under RCP8.5 especially central Botswana is affected by a decrease in mean precipitation. Cassava is at present only grown in the very northern part of the catchment. While the mid-range projection shows a slight increase in suitable area, the

worst-case scenario shows no major changes compared to the present state. The current suitability for cow pea is moderate in most parts of the study area. RCP4.5 suggests a slight increase along the Namibian-Angolan border and in the center of Botswana. The same regions are affected negatively in the RCP8.5 scenario. To sum up, pearl millet is the most suitable crop in most parts of the study area under both scenarios due to its drought-resistance. The mid-range-scenario potentially slightly expands the suitable zone for maize and cow pea. Under the high-emission scenario especially maize, sorghum, and cow pea may be affected by precipitation declines.

At the TFO core sites, the current farming systems and crops were assessed within the project and confirm the results for the present state. Since the analysis assumes that no irrigation or fertilization is taking place, there may also be regions classified as 'unsuitable' where a cultivation is in fact taking place in reality. The results are therefore not to be mistaken for an exact portrayal of the actual situation. They are however an approximation of the merely natural preconditions and their development in the future.

Link to data and further readings: Details regarding the climate data can be found on DVD B. Soil raw data can be retrieved from OBIS.

C4) In the valleys of the Angolan highlands the growth of tropical crops is limited by frosts in the dry season.

The Angolan Highlands can be described as a gentle, rolling landscape with valleys, slopes, and elevated areas alternating in a regular pattern. Miombo forests cover the hill tracts and top slopes, while mid- and foot slopes are covered by grasses and dwarf shrubs, and the valley bottoms are covered by peatlands.

This specific topography is the reason for a site specific microclimate. Clear skies during night time in the dry season from May to September facilitate loss of heat by thermal radiation, resulting in accumulation of cold

air close to the soil surface. As cold air is heavier than warm air, cold air flows downwards and accumulates in the valleys (fig. 71). Microclimatic measurements in the Cusseque core site have shown that the valleys and valley bottoms are frequently subject to frost, with temperature dropping to several degrees below 0 °C (Revermann and Finckh 2013, Finckh et al., in press). Between the end of May and mid-September 2012 to 2014 we recorded up to 44 frost nights per year in the valleys, reaching an absolute minimum temperature of -7.5 °C. In contrast,

in the forested areas, frost was recorded only on a few occasions throughout the year (fig. 72).

Frosts are always of short duration, restricted to the night time, and reach the lowest temperature just before sunrise. Due to this short duration, soils support a balanced temperature regime and soil temperature at 10 cm always remained over 10 °C throughout the year in all areas.

Rainfed agriculture of maize and cassava during the rainy season is not affected by frost, as frost occurrence

is limited to the dry season only. Frost-sensitive perennial crops such as bananas or mangos are not frequently cultivated. However, there are several opportunities to diversify agriculture by using frost-tolerant varieties of crops or selection of sites with reduced frost risks.

Link to data and further readings: Time series of microclimate logger data can be found on OBIS.

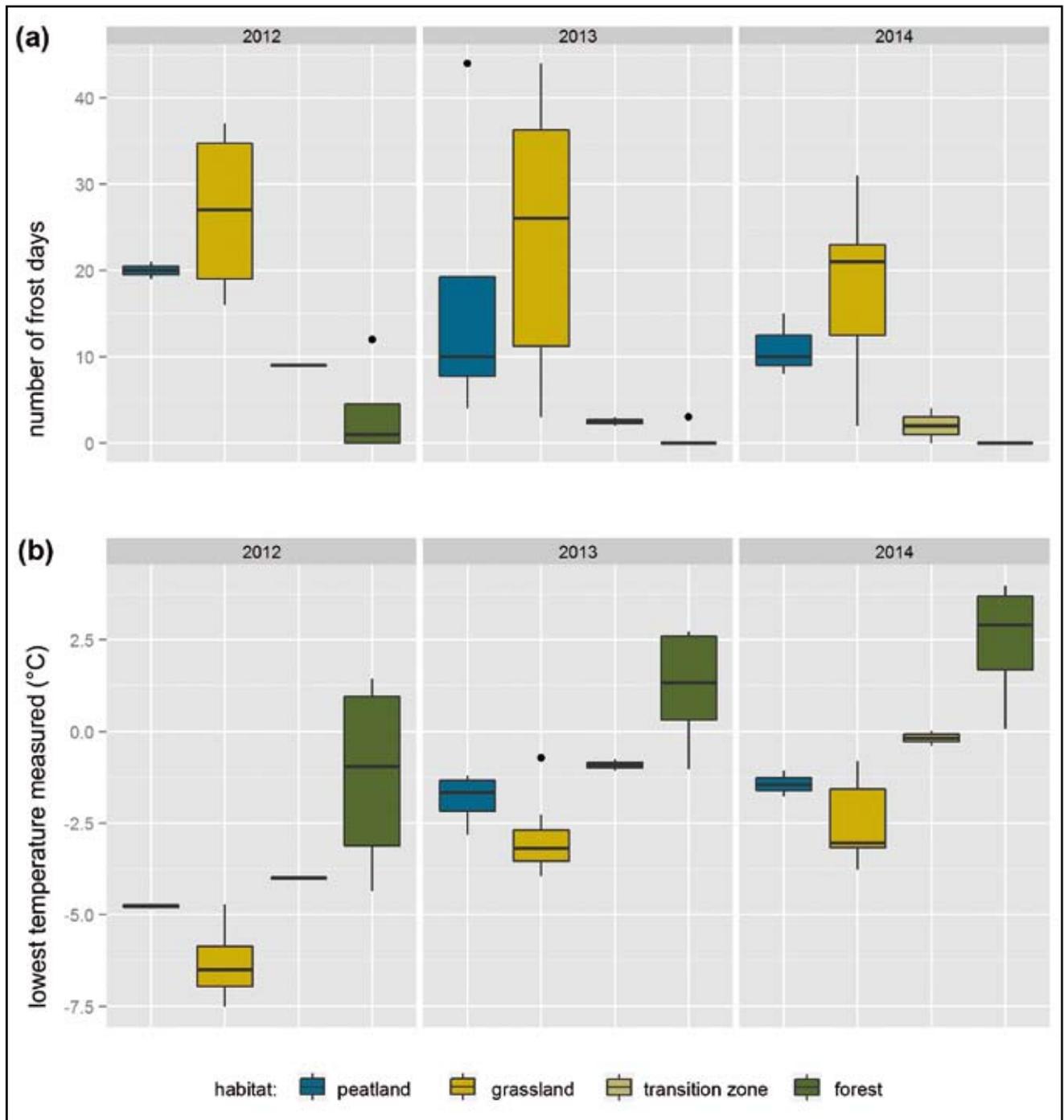


Fig. 72: Variation in the annual number of frost days (upper graph) and the absolute minimum temperature (lower graph) in different habitat types (peatland, geoxylic grassland, forest-grassland ecotone, forest). Temperature was automatically measured with varying number of micro-climate loggers (2012: 11, 2013: 21, 2014: 16). (Finckh et al., in press).

C5) In the woodland biomass and the soils substantial amounts of carbon are stored, which are transferred to the atmosphere at woodland conversion.

With regard to climate change, carbon stocks and their below- and above-ground pools serve as storage for greenhouse gases, and have several additional important ecosystem functions.

Soil carbon enhances several soil functions that are related to fertility:

- It provides nutrients and prevents them from leaching by acting as binding companion for ions that would otherwise be washed out by rainwater.
- It is responsible for the medium-term storage and release of nitrogen that is provided during the decay processes of organic material via fungi, bacteria and termites.
- It plays a major role in aggregating soil particles and thus protects soil from wind- and water erosion, and enhances water availability by keeping the water in the rooting zone.

Above-ground biomass carbon corresponds to the climate gradient and decreases from north to south. This trend is less pronounced in soil carbon stocks. However, the highest measures of soil carbon stocks are found on the northernmost site, Cusseque. The soil carbon stocks are always higher than those of the above-ground woody biomass. During woodland conversion to farmland, the main part of carbon released to the atmosphere as CO₂ comes from the burning of the woody biomass. This

effect is greatest in Cusseque, where the above-ground biomass carbon is the highest of all core sites (fig. 74).

Additionally, significant losses of soil carbon stocks occur under long-term agricultural land use. This effect could be shown for the Namibian core site, where soil carbon stocks are significantly lower in acres than in woodlands. Loss of soil carbon stock (0–100 cm depth) varies between landscape units in the range of -11 to -39 % of initial values (3.5–21.2 t ha⁻¹). For the Angolan sites the effect is not visible due to a shorter period since slash-and-burn first took place. Since bush-fires and cutting of wood produce a high quantity of dead wood which decomposes and is thus brought back into the soil, soil carbon stocks can be even higher on freshly cleared fields (fig. 73).

In total the conversion of woodlands to long-term agricultural cropland leads to a carbon release of 50–63 t ha⁻¹ in the Miombo woodlands, 25–33 t ha⁻¹ in Angolan *Baikiaea* woodlands, and 10–24 t ha⁻¹ in the dry woodlands of Northern Namibia and Botswana. The conversion of woodlands into farmland releases the largest amounts of carbon, whereas conversion due to other land-use practices releases less carbon.

Link to data and further readings: Soil raw data can be retrieved in OBIS; for detailed results on the soil carbon stock see Appendix.

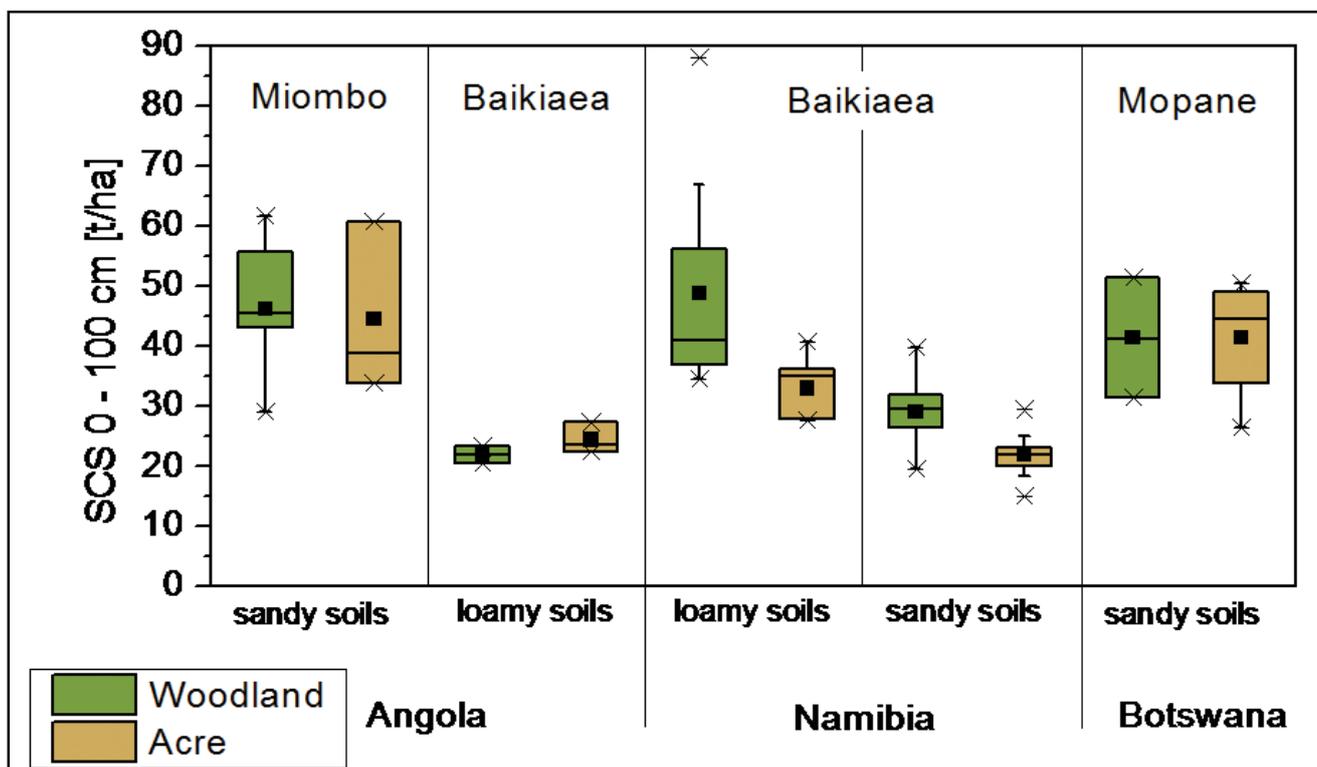


Fig. 73: Soil carbon stocks (SCS) in different woodland types (Miombo in core site Cusseque, *Baikiaea* in core sites Caiundo and Mashare, Mopane in core site Seronga) and in corresponding farmland. Consider that agricultural use took place for different periods (short period since woodland conversion in Angola, long-term cultivation in Namibia and Botswana).

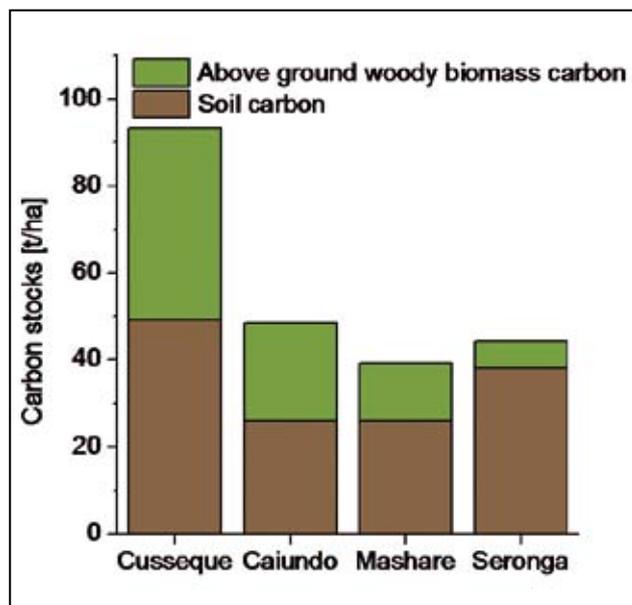


Fig. 74: Carbon stocks in woodlands of the four core sites.

RECOMMENDATIONS

The adaptation to climate change in all sectors of natural resource use is a general necessity for all countries involved. Based on the downscaled climate change projections and the integration of two global scenarios, the knowledge about possible future changes of the climate within the Okavango Basin has now been substantially improved. These data have already been used to project water flows in the river system, and should be used by other future planning.

A relevant contribution that can be made by all the countries to mitigate climate change lies in the issue of woodland conservation and sustainable forest management. By avoiding woodland conversion and subsequent rainfed agriculture, a carbon release of 10–63 t can be prevented for each hectare, depending on the area within the catchment. To generate financial incentives for the avoidance of woodland conversion, the mechanisms of the multi-lateral UNFCCC agreement on climate change as defined in REDD+ should be applied.

4.2 Water use, availability & management

W1) Water flow is generated in the Angolan highlands. Here, peatlands stabilize water quality and buffer peak flows.

Hydrological assessment and upstream-downstream analysis lead to the conclusion that most of the runoff generation takes place in the Angolan highlands. Runoff contribution is essential to keep the flow of the Cubango and Cuito rivers stable. The movement of water received during intense rainfall is slowed down by peat soils through infiltration and retention in the soil matrix. Rainfall patterns in the northern part of the Okavango

catchment can reach up to 1,300 mm a⁻¹ and therefore generate essential parts of river runoff delivered towards the delta in Botswana. 95 % of the river runoff is generated during the rainy season.

The influence of peatlands on hydrological behaviour ranges from the buffering function in flood events and peak flows, and during the rainy season, to essential base-flow runoff contribution in the dry season

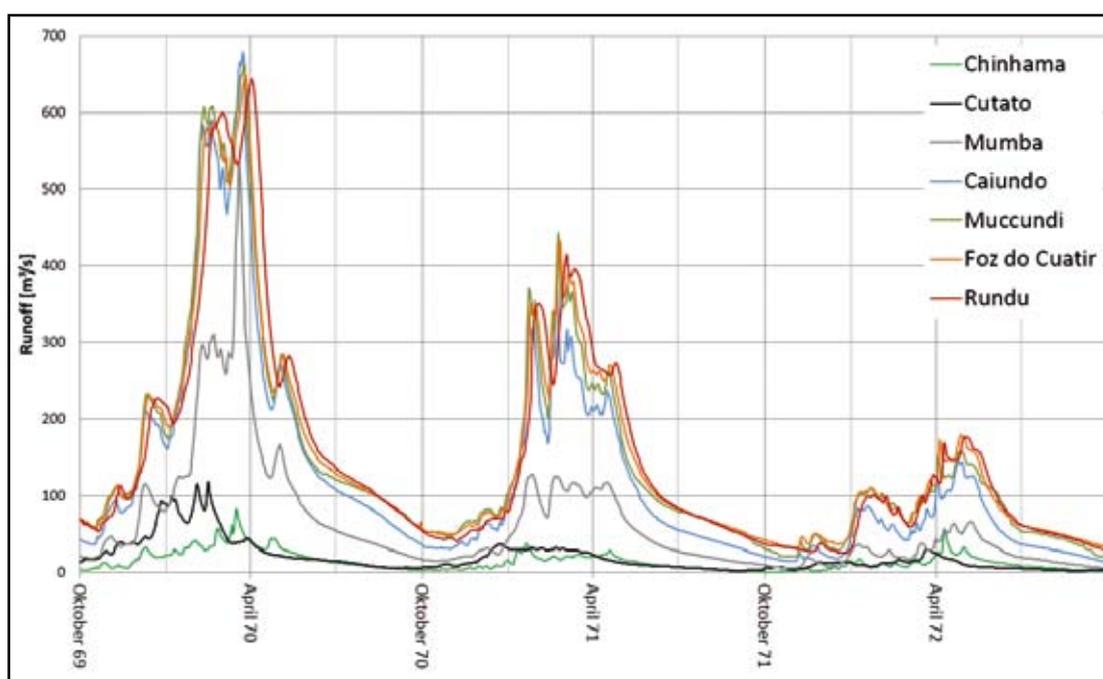


Fig. 75: Upstream-downstream analysis in the Cubango System.



Fig. 76: Peatlands in the Angolan highlands (core site Cusseque). Regular structures indicate former use for vegetable gardening (photo: A. Gröngroft).

(Mitch and Gosselink 2000). The pristine peatlands in the northern part of the Okavango catchment (fig. 76) are essential to providing peak flow buffering and base-flow contribution to keep the flow pattern stable, as the Cubango river has a high variability in discharge delivered to downstream areas, ranging from less than $50 \text{ m}^3/\text{s}$ (dry season low-flow runoff [MNQ]) in the dry season up to $250 \text{ m}^3/\text{s}$ (rainy-season runoff [MHQ]) in flood conditions.

Fig. 75 shows the runoff generation in an upstream-downstream analysis within the Cubango catchment. The headwater catchments of the Cubango system (sta-

tions Chinhama, Cutato, and Mumba) deliver different amounts of runoff to the station of Caiundo. Due to the local conditions, at station Cutato within each season the runoff starts comparatively early. After Caiundo, and down to Rundu, the flow pattern and discharge amounts at all stations are almost equal, which indicates that in this section a combined output of the upstream catchments takes place.

Link to data and further readings: Discharge data from several stations can be obtained through OBIS or, if restricted, via Global Runoff Data Center (GRDC), Koblenz, Germany.

W2) The broad wetlands along the Cuito stabilize water flow and thus safeguard minimal flow to the delta in the dry season.

The geomorphological settings in the Cuito catchment, with (in contrast to the Cubango catchment) deep Kalahari sands instead of underlying Precambrian metamorphic rocks, has led to the creation of a very broad riverbed. The sand deposits are more affected by water-induced fluvial erosion and allow the river and its tributaries to meander along the entire riverbed, especially downstream of Cuito Cuanavale. The catchment size of the Cuito river ($57,000 \text{ km}^2$) is only half the size of the Cubango river catchment ($108,000 \text{ km}^2$). Despite this, the flow length of the Cuito is almost 75 %

of that of the Cubango River. This indicates the strong meandering of the Cuito river in the broad riverbed. The wide areas in between the river meanders of the Cuito are covered in part with peaty wetlands, which are either permanently or periodically flooded and predominantly covered with grass vegetation. The comparison between the floodplain/swamp area along the stream network of the Cubango and the Cuito rivers revealed that the Cuito has more than twice the area of floodplains and swamps along its riverbed than the Cubango (Baumberg et al. 2014).



Fig. 77: Cuito River close to Nankova with extended wetlands in the background (photo: M. Finckh).

The wetlands along the rivers (fig. 77) have several hydrological functions. Firstly, with rising water levels during flood events, wetlands and the sandy hinterland display increased water content and raised groundwater level, and thus reduce the runoff in the riverbed. With the falling river water level after flood events, and especially in the dry season, these wetlands feed back the stored water and are thus the main driver of base-flow contribution towards the Okavango Delta. The retention function results in a smoothed hydrograph with longer but flatter rising and falling limbs. Additionally, the wetlands significantly contribute to the quality of

the flowing water, as substantial amounts of nutrients are stored in the wetland's soils and vegetation; however, with regard to the Okavango catchment this function has not yet been studied. In comparison with the flow pattern of the Cubango, the Cuito delivers essential base-flow to the delta during the dry season from May to September (fig. 78).

Link to data and further readings: Discharge Data from several Stations can be obtained through OBIS or, if restricted, via Global Runoff Data Center (GRDC), Koblenz, Germany.

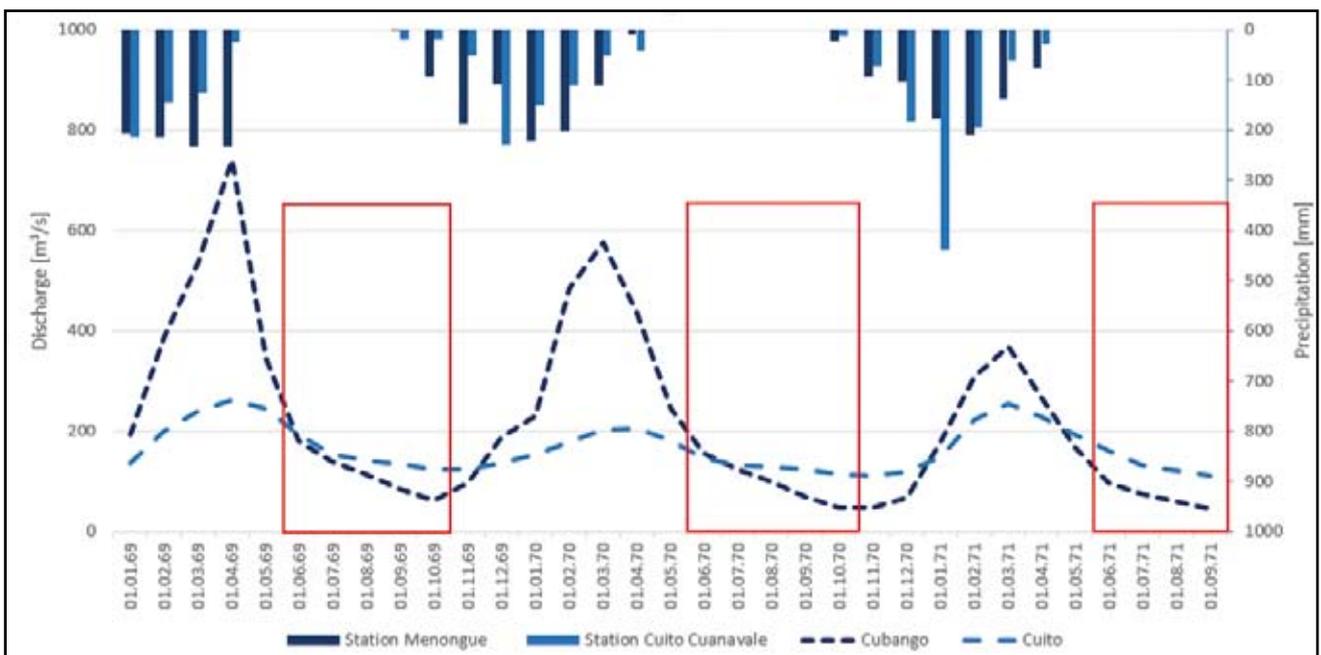


Fig. 78: Rainfall runoff pattern from the main tributaries of the Okavango River.

W3) The flow regime is influenced by damming for hydropower, irrigation (esp. green schemes), and other abstractions. Woodland conversion enhances total water flows.

The current flow regime of the main tributaries, and therefore the integral flow regime of the Okavango River, can be described as a flood pulse system. During the rainy season flood peaks deliver an essential amount of water to the delta. The influence of damming the river flow is obvious. Damming and/or the implementation of reservoirs in the riverbed leads to buffered runoff generation. As such, flood pulses are buffered in their intensity and extended in duration.

At the moment water abstraction is not influencing the flow pattern because the amount of water which is extracted by large green schemes, especially in Namibia, is rather small compared to the amount of water in the river. As the Namibian Kavango region is expected to be a hotspot of intensive agricultural production with intensive irrigation usage, the current status seems to be balanced, as the abstraction before the confluence of the Cubango and Cuito is only 1.2 % of the mean minimum water flow (MNQ), and downstream of the confluence only 1 % of the mean minimum water flow. Future changes will extend green-scheme facilities and irrigation usage, which will lead to a total abstraction of 3.6 % from the MNQ upstream of the confluence at Dirico, and 7 % of the MNQ downstream of the confluence (Liebenberg 2009, Helmschrot et al. 2014).

Integrated hydrological modelling has been combined with future predictions of land-use changes which led to the integration of possible deforestation areas in the northern catchment area. The simulation of local water balances using soil properties and vegetation characteris-

tics of the core sites gives quantitative data on the effect of woodland conversion in areas for crop production on runoff generation. For the Miombo forests of the upper catchment, the specific mean annual runoff of the forest is about 270 mm; after conversion to traditional fields the runoff doubles to about 540 mm. For the *Baikiaea* woodlands of Northern Namibia almost no runoff occurs, as the natural vegetation is able to take up all water stored in the soil. However, after conversion to agricultural land use, the groundwater recharge increases even under the semi-arid conditions to 110 to 180 mm a⁻¹ depending on the soil's water storage capacity. After integration of these data in the computer-based river-discharge model, it becomes clear that ongoing deforestation will lead to an increased runoff in general. If the shift in runoff generation produces higher peak flows or even enlarged base flow depends on the distribution of the areas of woodland conversion. The analysis of changes in water flow, linked to deforestation, was calculated to an increase by average of 7.5 % in the Cuito system (varying from +1 % to +10 % per month) and 5.9 % in the Cubango system (varying from 17 % to -5 %). These values are based on the reduction of 30 % of forested areas in the Cuito catchment (8,300 km²) and Cubango catchment (10,200 km²).

Link to data and further readings: Discharge Data from several Stations can be obtained through OBIS or, if restricted, via Global Runoff Data Center (GRDC), Koblenz, Germany, EPSMO Literature/Reports Database.

W4) In the current state, the water in the Okavango river system is of good water quality.

The Okavango River water quality appears to be pristine at the moment, as only relatively low pollution through human activities takes place. There are currently few to no commercial industries of note, and any impact from several agricultural projects is considered low. Currently these are readily absorbed and diluted in the large and diverse river system (OKACOM 2010). The natural buffering function of floodplains and riparian areas regulates nutrient load in the river (Trewby 2003). Applying South African standards for phosphate concentration (less than 0.1 mg/l) these limits are currently not exceeded; moreover, an attenuation of phosphorus loads can be observed (Vushe et al. 2014). Nitrogen concentrations are still low, with inner annual fluctuations. Long-term observations have indicated that the total nitrogen concentration in the Okavango has decreased and that up to 2012 the nitrogen concentration in the river water never exceeded Namibian limits for excellent water quality standards (Vushe 2014).

In the Namibian section along the river, the bigger settlements (Rundu, Nkurenkuru) appear to have minimal effect on the water quality, compared to large agricultural schemes. Still, measurements have shown that the river system is able to naturally attenuate nutrient loads before the water enters Botswana. All current studies indicate that there is intra-annual variation in phosphorus and nitrogen loads, the range of the loads in the Okavango River varying from very low to undetectable (OKAKOM 2010, Andersson 2006, Trewby 2003).

Link to data and further readings: Discharge Data from several Stations can be obtained through OBIS or, if restricted, via Global Runoff Data Center (GRDC), Koblenz, Germany; EPSMO Database and Reports [<http://epsmo.iwlearn.org/publications/files>].

W5) Based on MODIS imagery improved automated techniques to monitor flood extent areas in the delta have been developed.

In water-scarce regions such as the southern African countries, knowledge about the spatial extent and the temporal patterns of floods is an important tool in order to develop and improve hydrologic models. These models may assist researchers in understanding the hydrological and ecological dynamics. They can also be used in making predictions of incoming floods which are valued by both the flood recession farmers and the tourism industries. In the Okavango Delta, a few remote-sensing studies covering the spatial and temporal changes of floods over a long period of time have been done by McCarthy et al. (2003) and Wolski and Murray-Hudson (2006). These studies used platforms that were of high spatial resolution but low temporal resolution. Therefore this study used the MODIS dataset, which is more advantageous because of its high temporal frequency measurements and medium spatial resolution (Chen et al. 2013; Feng et al. 2012).

A method based on bimodality of the red band pixel values was used in classification of the images. The method classified the pixels into inundated or non-inundated based on thresholding of the red band. Pixels or Digital Number (DN) values below the threshold were classified as inundated, while those with DNs above were classified as non-inundated. This method relies on the difference in reflectance between water bodies and dry or vegetated soil, with the former having low reflectance, while the latter displays higher reflectance values. The thresholding approach is conceptually simple, but in the Okavango Delta there are two factors affecting the ability to determine the spectral threshold in an objective way. Firstly, water bodies in the Okavango Delta are usually covered by aquatic vegetation of various densities, which causes spectral overlap between dry, and wet but vegetated land. Secondly, the spatial scale and complexity of geomorphological units (floodplains and islands) is smaller than that of the MODIS pixels. This can result in the spectral response of individual pixels being a mixture of responses from wet and dry land. In practice,

these effects manifest in the overlap of the reflectance (or simply DN) histograms of a scene that contains similar number of wet and dry pixels.

The method is applied in such a way that the DN threshold is determined separately for each image using an objective formula, as a function of season and inundation extent (Pricope 2013, Wolski *pers. comm.*). In the process of development of the method (Murray-Hudson et al. (2014a), Wolski *pers. comm.*), various MODIS bands, band combinations and products (NDVI, EVI etc.) were tried, and MOD09Q1 band 1 turned out to provide the best discrimination between inundated and non-inundated areas.

Additionally, in the method used, the MOD11A2 images were used to further distinguish between fire scars and flooded areas. Fire scars, similarly to inundated areas, exhibit low reflectance in the visible part of the spectrum, and thus can be confused for the latter when classification is done using the method described above. However, unlike the inundated areas, fire scars are characterized by high surface temperature, which offers the opportunity to distinguish fire scars from inundated areas. The method has been verified against Landsat-derived inundation maps generated for Wolski and Murray-Hudson (2006).

After classification, the number of pixels that represent inundated area was converted into inundated area within the scene in square kilometers, by multiplying it by 0.0625 (one pixel of 250 m by 250 m is 1/16th or 0.0625 of 1 km²).

The inter-annual inundation extent for the period 2001 to 2012 was at its maximum during the years 2010 and 2011 (fig. 79), at approximately 10,300 km². This means that MODIS returns an accuracy of ~87 % in mapping the inundation extent of the delta. Seasonally, monthly minimum inundation extents were observed in January-December (summer) for most of years except in 2001 and 2002 and monthly maximum extents occurred in September for most of the years (winter).

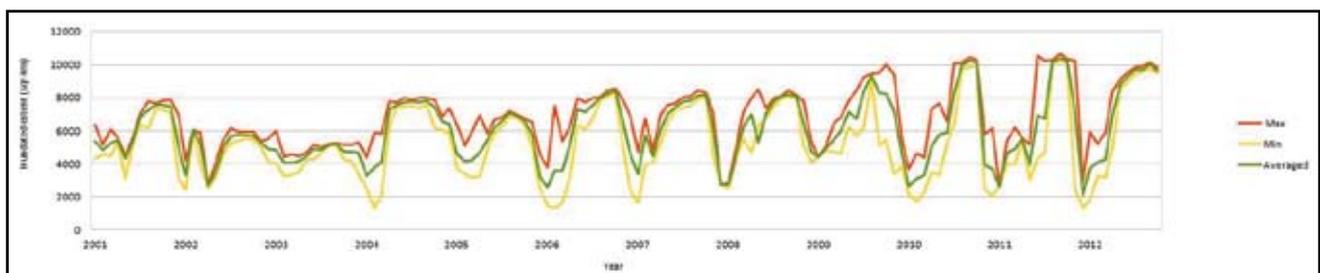


Fig. 79: Inundation extent for the Okavango Delta derived from MODIS images for the period 2001 to 2012. The max and min in the legend represent the maximum and minimum inundation extent in the classified images for a given month. The averaged represent the mean of the 3 or 4 scenes analysed in each month. The maximum and minimum areas do not represent actual variation of inundation, but rather reflect errors arising from classification due to presence of clouds and image artefacts (e. g. effects arising due to merging raw data from two different satellite overpasses etc.). Note that maximum and minimum values are very similar during the cloudless dry period (May-August), but large differences occur during the rainy season (November-April).

W6) Annual flow rates to the delta are much more impacted by land-use changes than by climate change.

Climate change scenarios up to 2030 indicate that only minor changes in the flow pattern will affect the amount of water reaching the Panhandle and the delta. Computer simulations with calibrated hydrological models using current land-use distribution have shown that the impacts of climate change affect the headwater catchments in different ways. Trend analysis of the modelled results show that more water will be contributed by the Cubango and less water will come from the Cuito, but in total, only a small amount of water will be missing at the entrance of the Panhandle at Mohembo compared to current measurements. This is contrasted by possible changes in land use. Implementation of expanded agro-industrial schemes, using large amounts of river water for irrigation, will primarily affect regional flow patterns, and indirectly also the flow pattern of the entire downstream river system. Planned schemes in the Namibian Kavango region will abstract a maximum of 27 m³/s (7 % of the mean minimum flow) before entering Botswana. Several large schemes are proposed in the

Angolan part of the headwater catchments, leading the subsequent abstraction rates to strongly affect the flow of small tributaries. For example, in the Cuelel catchment a scheme is proposed to abstract 120 m³/s, which exceeds water flow even in the high-flood period. In the neighboring catchment of the Cuelebe, a planned scheme could abstract 12 m³/s, which equals 75 % of the mean minimal flow in the river. Keeping in mind that both of these catchments contribute to the Cubango system, which is characterized by a high variability in flow pattern, this might affect low-flow conditions tremendously, especially in the border zone of Angola and Namibia before the confluence with the Cuito River. Therefore, the conversion to agro-industrial land use will affect the flow pattern more than climate change.

Link to data and further readings: Discharge Data from several Stations can be obtained through OBIS or, if restricted, via Global Runoff Data Center (GRDC), Koblenz, Germany.

W7) Increasing peak flows will affect the settlements and villages, as their location is adapted only to current flow regime.

The height of peak flows depends on the rainfall distribution in the catchment and the water storage characteristics of the individual landscape elements. Changes in land use (woodland conversion, establishment of large-scale irrigation schemes, expansion of urban areas) and climate are likely to increase peak flows in the future. The locations of current settlements are adapted to the current flow situation, thus keeping damage during peak flow situations to a minimum. With water levels exceeding the current peaks, damage to housing, infrastructure, and tourism facilities is very likely to occur. Additionally, cropping activities around many villages concentrate on the more nutritious soils of former floodplains situated only slightly above the current peak-flow height. The possible amount of damage to all these values cannot be foreseen; however as the lives of

the local people are well adapted to the current flow situation, it has to be regarded as potentially very severe.

The recent floodplains are natural retention areas, into which the river expands during flood events. Variations of water-level measurements in Rundu show ranges from 3.2 metres minimum up to 8.9 metres in high-flood conditions. The peak-flow level may increase due to future changes in climate and land use. At the onset of a flow peak the rise in water level occurs very quickly. Fig. 80 shows a water-level gauge at the Kavango (MADI, core site Mashare), where within eight days the water level rose more than one metre.

Link to data and further readings: Discharge Data from several Stations can be obtained through OBIS or, if restricted, via Global Runoff Data Center (GRDC), Koblenz, Germany.



Fig. 80: Rising water level of the Kavango near Mashare (MADI) - left from March 12th, 2012 and right from March 23rd, 2012 (photos: H. Göhmann).

RECOMMENDATIONS

With the current climate and gauging measurement network (including the six gauging stations revitalized within the TFO project) it is possible to assess the impact of climate- and land-use changes at the basin scale. However, for a more detailed analysis at sub-basin level, the hydro-meteorological measurement network within the Okavango River Basin should be extended to represent regional processes at a higher level of detail.

The hydrological assessment and the integrated modeling approach led to a fundamental systems description of the two main tributaries of the Okavango River, covering more than 80 % of its catchment area. These two systems (i. e. the Cubango and Cuito River sub-basins) are fundamentally different in their dominant hydrological processes and their intra annual/seasonal contribution to the Okavango Delta inflow. The evaluation of these differences shows that the Cubango system is highly variable and contributes essential discharge volumes to the delta in the rainy season. At the same time, the base-flow-dominated Cuito contributes essential runoff in the dry season. These differences between the Cubango and Cuito sub-systems should be taken into account in catchment management planning.

The water quality of the Okavango River can be quantified to be of high quality at the moment, as it has been throughout the last decades since the first measurements started. Several studies along the lower part of

the Cubango/Okavango showed intra-annual fluctuations of nutrient loads at a very low level. The average loads of total Nitrogen and Phosphorus do not exceed drinking-water limits at the moment. In order to safeguard the high water quality of the Okavango River, transboundary water management and fine-grained water-quality monitoring should be built up to control intensive agricultural activities and other potential sources of water pollution.

The model-based analysis of changing climate (RCP8.5 CO₂ emission scenario) and land use (deforestation) up to the year 2030 showed that land-use change has a higher potential to have an impact on runoff regeneration than climate change. Great attention should be paid to large-scale land-use changes.

To support basin-wide water management and planning activities in the Okavango River Basin, data repositories and information systems like the Okavango Basin Information System (OBIS) provide a substantial functionality for data storage, management, analysis, and visualization for a large variety of users. A centralized data- and information management platform is an essential requirement to facilitate transboundary integrated water-resources management and decision-making, and to provide a platform for data and knowledge exchange across different scientific disciplines and stakeholders.

4.3 Conservation and management of living natural resources and their ecosystem services

N1) Currently the landscape and the vegetation in the Okavango Basin in large areas is still mostly intact and close to natural, while the fauna and especially larger wildlife is strongly degraded. Slash & burn agriculture, road constructions, agro-industrial intensification, and continued hunting for bushmeat drive the conversion, fragmentation, and degradation of the natural ecosystems.

Fig. 81 shows the naturalness of the basin classified into five categories from dark green (very high naturalness) to dark red (very low naturalness). The overall picture still shows predominantly shades of green; the overall state of the basin is still very good (fig. 82). The lighter shades of green in the central part of the basin reflect the fire impacts there, in the southern part of the basin they reflect intensive pastoral use by cattle and interrupted migration pathways for wildlife by veterinary fences.

The map reflects several development trends which start to endanger the integrity of landscapes and ecosystems in the Okavango Basin. In more densely populated areas smallholder agriculture rapidly converts natural forests and woodlands into agricultural fields. Conversions from natural vegetation (in green) into semi-natural low-intensity agricultural systems are strongest in the western part of the Angolan highlands,

in a strip along the Namibian Kavango, and around the larger urban centres.

Low naturalness in the Okavango area is mainly related to agro-industrial irrigation schemes such as at the Longa River in Angola and along the Kavango River in Namibia. These schemes lead to complete landscape transformations, but are spatially limited (and are therefore not visible in the landscape integrity map at FORA scale, fig. 81). However, they increase rapidly and are located in areas along the rivers which also have a high value for smallholder agriculture, tourism, and conservation, and consequently conflicts are inevitable.

Low to very low naturalness is currently mostly restricted to the main urban centres (Chitembo, Menongue, Cuchi, Rundu, Maun). They represent nodes of development which not only transform the area they occupy, but which also transform their surroundings. Furthermore, urban

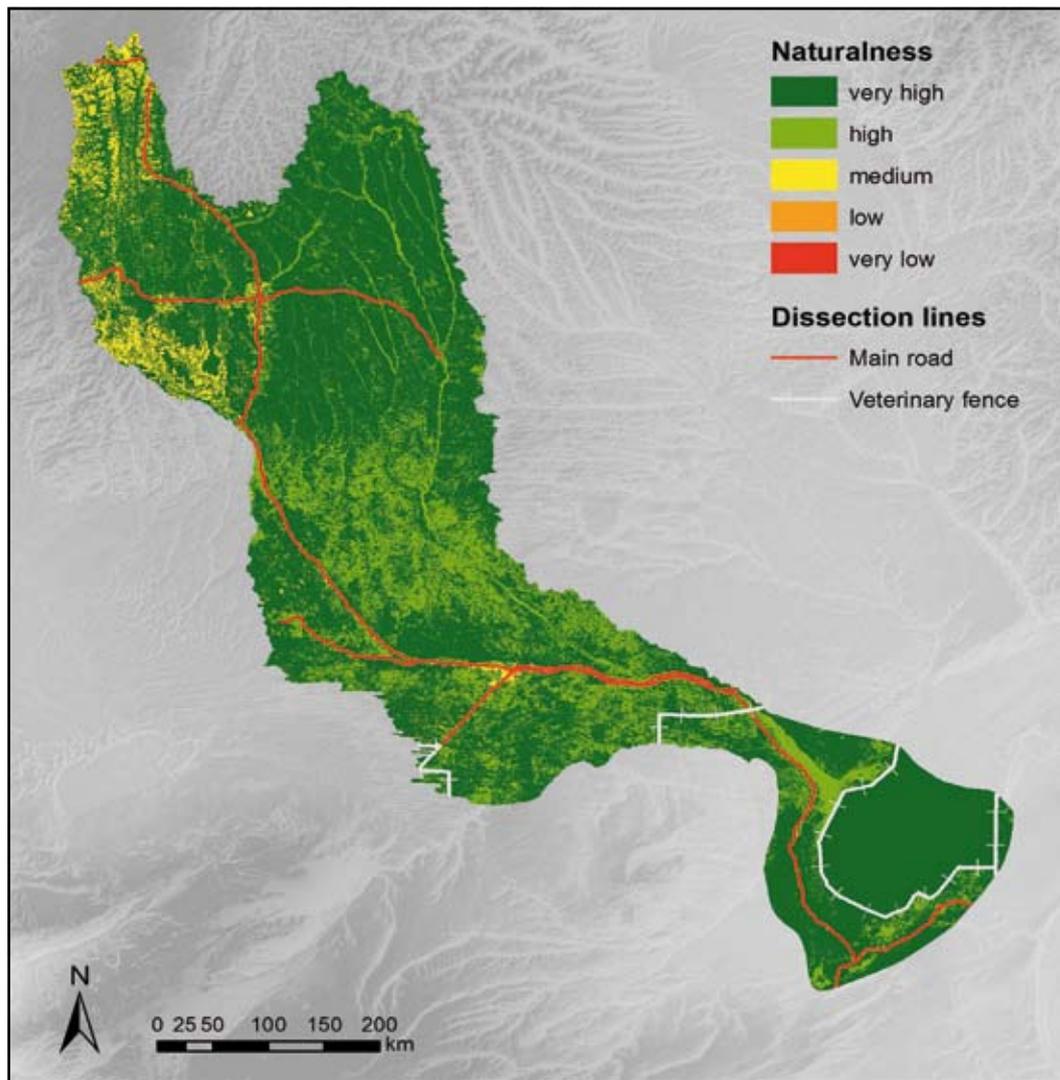


Fig. 81: Map of the naturalness of the vegetation in the Okavango catchment.

demands and lifestyles reach out along the main roads, creating new demands and encouraging exploitation and commodification of natural ecosystems and resources.

Finally, the roads with their associated belts of land use, as well as the system of veterinary fences, create significant barriers which fragment the ecosystems of the basin and interrupt wildlife migration patterns.

Based on the studies of the TFO project, the vegetation units and their floristic composition are now better

known (Revermann and Finckh 2013) and mapped (Stellmes et al. 2013). The ecological and economic value and the vulnerability and irreplaceability of these vegetation units are different. Based on the combination of these parameters and their spatial distribution TFO will shortly provide a robust basis for systematic conservation planning.

Link to data and further readings: Wallenfang (2013).



Fig. 82: Pristine floodplain of the Longa River (photo: M. Finckh).

N2) The highlands of the Bié Plateau feature a very high biological diversity, an important number of rare or endemic plant and animal species, and fragile highland ecosystems. These biological features are observed in several of the major vegetation units of the area. The species composition differs almost completely from the central and southern part of the basin.

Fig. 83 shows the modelled plant species density per 1,000 m² for the terrestrial vegetation units of the Okavango Basin (excluding the wetlands) (Revermann et al., in prep.). The map shows a gradient of increasing species richness from the hinterland of the Okavango Delta to the Angolan highlands. The data for the core site level confirm this north-south gradient (at this scale including the peatlands) (fig. 86). Mean plant species density in Cusseque is about twice as high as in Caiundo, and more than three times higher than in the woodlands of Seronga.

Furthermore, we find an almost complete species turnover between the savannah and woodland ecosystems in the

southern part of the Okavango Basin and the Angolan highlands. While the flora of the southern part of the Basin includes mostly species which are widespread in the savannahs of southern Africa, the flora of the Angolan highlands includes many species which are endemic to specific ecosystem types of the Zambebian floristic region. This makes the highlands extremely valuable for global biodiversity conservation, as many of these species are not included in the larger conservation areas in or adjacent to the south-central parts of the Okavango Basin.

The species turnover between the Angolan highlands and the woodlands and savannahs in the central part

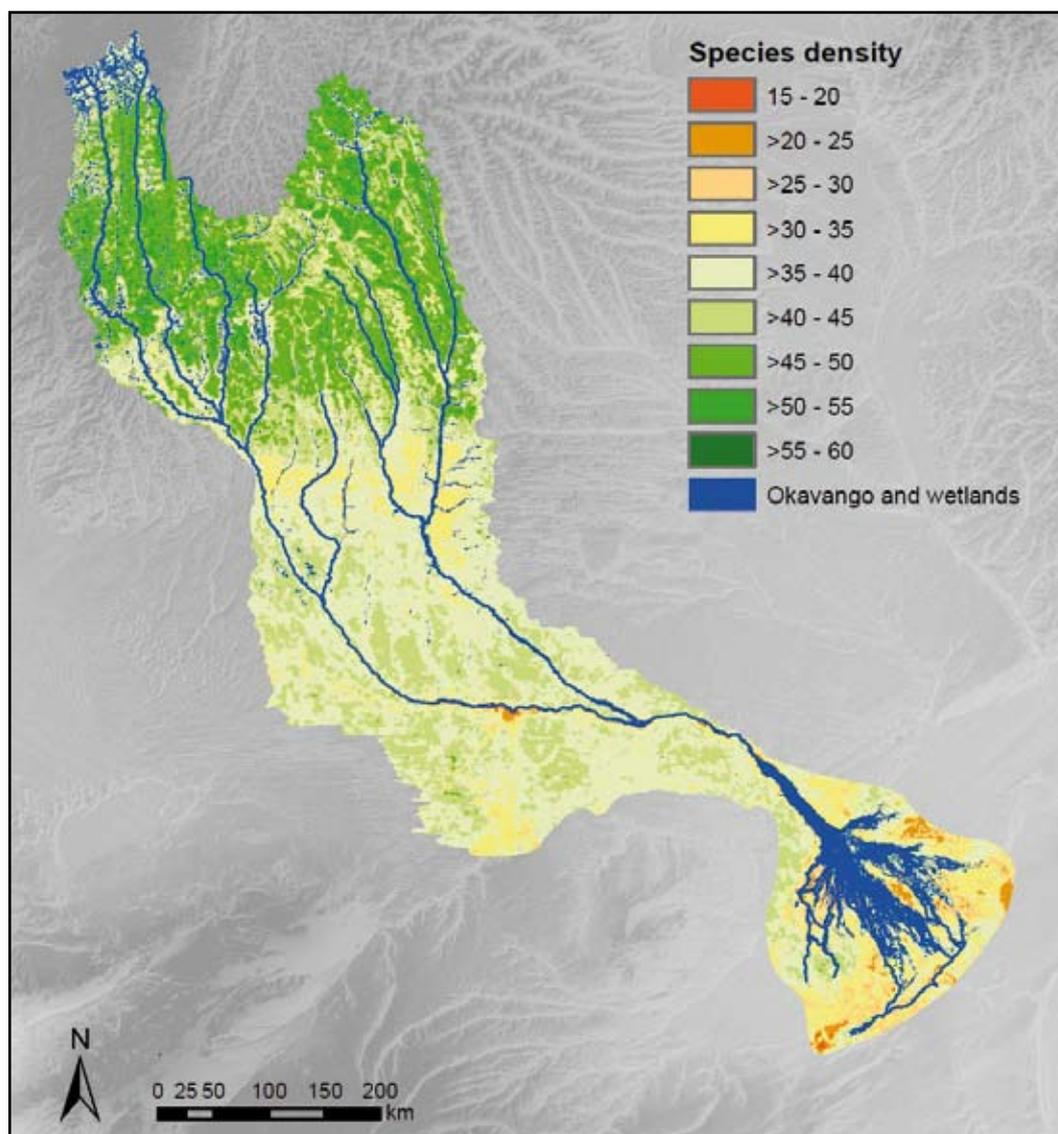


Fig. 83: Modelled plant species density of the Okavango Basin based on a statistical model using plot-based vegetation data (plot size 20 m x 50 m, n = 999) and as predictor variables phenological metrics of a MODIS time series analysis and topographic attributes derived from the global digital elevation model SRTM.



Fig. 84: Spectacled Weaver, a characteristic bird species of the woodland savannahs of southern Africa (photo: M. Finckh).



Fig. 85: Many orchid species are restricted to the Zambezi-an Floristic Region (photo: M. Finckh).

of the Basin is not only true for the flora, but also for the avifauna and probably for other faunistic groups, too. Bird censuses of the forest- and woodland avifauna in Cusseque, Caiundo, and Seronga showed strong differences between the three sites, and a shift from a

more central African forest avifauna towards a southern African savannah avifauna (Richter 2013, Wendefeuer, in prep.).

Link to data and further readings: Stellmes et al. (2013).

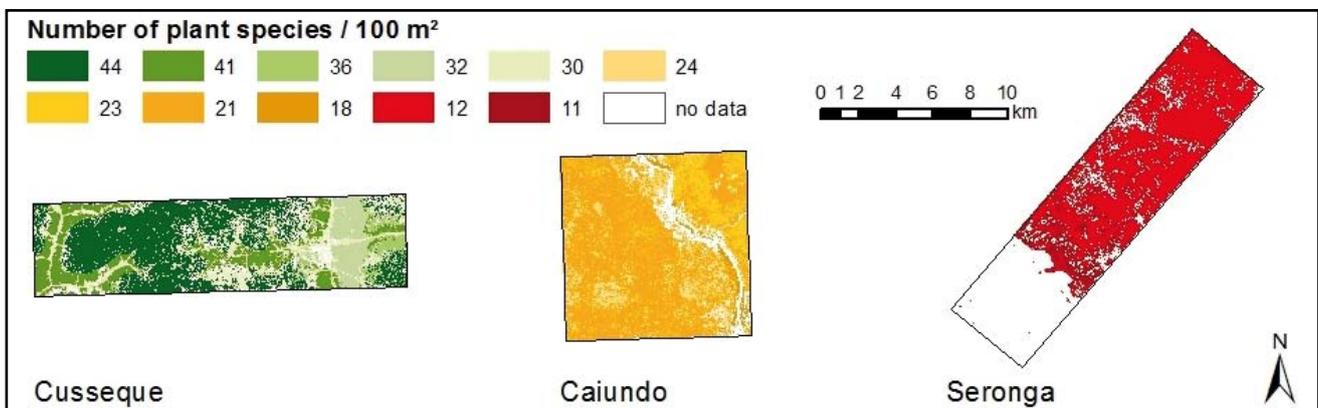


Fig. 86: Comparison of spatial patterns of species density between the core sites of Cusseque, Caiundo, and Seronga.

N3) Forests in the Angolan highlands provide manifold goods for local users, such as timber, fruits, medicine, honey, and charcoal. The shift from local use of goods towards trade and marketization (commodification) changes the balance between different options for use of the forests, and leads to important trade-offs between incompatible options of use.

The Miombo forests in the Angolan highlands provide a multitude of different goods to local stakeholders, among which are timber, bark, honey, wild fruits, medical plants, and bushmeat. Traditionally, those goods were harvested in quantities which corresponded to the domestic demands of the rural households.

The emerging demand for cash to buy modern consumer goods causes dramatic changes in extraction patterns, especially along the main roads, which allow for the goods to be sent towards the urban centres of Angola. People

with an entrepreneurial spirit started to use the forests on a large scale for charcoal production, clearing the landscape along the roads for a distance up to 1–2 km (Schneibel et al. 2013) away from the roads at both sides, and to expand hunting for bushmeat (strongly affecting ecosystem functioning) up to 15 km into the hinterland. This kind of market-driven exploitation has a much higher intensity and spatial demand than former local uses, and thus has direct impacts on ongoing traditional and less destructive or less intensive uses of forest goods.



Fig. 87: Beehives are placed in the canopy of larger trees (photo: M. Finckh).



Fig. 88: Closed Miombo forests dominated by *Cryptosepalum exfoliatum* ssp. *taxoides* provide a high nectar production (photo: M. Finckh).

A good example of the incompatibility of uses is the trade-off between charcoal and timber extraction on the one hand with honey production on the other. Honey is the most emblematic forest product among the Chokwe people in southern Bié and Moxico (see TFO participatory film ‚Honey‘). All households consume honey (Baptista 2013) and most households have some member or relative who produces honey. Beehives are placed in the canopy of forest trees (fig. 87) and African honey bees collect nectar from flowering trees, especially from the larger *Leguminosae* family. Trees from this family (e. g. the genera *Brachystegia*, *Julbernardia*, *Cryptosepalum*,

Erythrophleum, *Bobgunnia*, and *Pterocarpus*) dominate the Miombo forests and produce most of the nectar collected by the bees (fig. 88). Thus, clearing the forest for charcoal production and subsequent agricultural use or fallow directly reduces the nectar (and honey) production at the landscape level. At the community level, the destruction of forests for the commodification of charcoal (or timber) benefits a few charcoal (or timber) producers and traders, but negatively affects the vast majority of rural livelihoods.

N4) It takes the timber species kiaat more than 90 years to reach the minimum harvest size of 45 cm diameter.

Kiaat (*Pterocarpus angolensis*) is one of the most important timber trees of southern Africa because of its attractive and stable hardwood, which is mainly used for furniture and decking (Groome et al. 1957). It is

intensively harvested, and concerns are raised about the future of this species. Limited information is available about kiaat's growth rate, which is required to determine sustainable harvest. Some growth studies have been



Fig. 89: Stem disc of *Pterocarpus angolensis* (kiaat) obtained from the study by Moses (2013) (photo: P. Nichol).



Fig. 90: Increment boring of *Pterocarpus angolensis* (kiaat) near Kanovlei forestry research station, Otjozondjupa, Namibia (photo: V. de Cauwer).



Fig. 92: *Pterocarpus angolensis* (kiaat) (photo: V. de Cauwer).

mental conditions. In the last decades, models have been developed that allow the derivation of the potential distribution of a species, with species observations and environmental data in GIS format. These models are called species distribution models (SDM) or species habitat models. The current and future distribution of kiaat was modelled with the SDM Maxent. The model showed that the distribution of kiaat is mainly influenced by summer rainfall, minimum temperature in winter, temperature seasonality, and by its preference for well-drained soils.

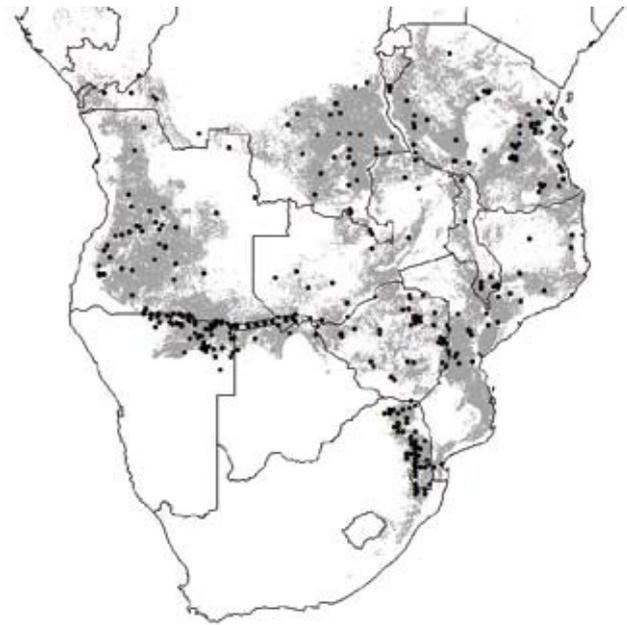


Fig. 93: Distribution range of kiaat modelled with Maxent and with indication of species observations (occurrences) used.

The projection for the year 2080 showed that global climate changes may decrease the species' distribution area by up to 50 %, mainly because of lower summer rainfall (fig. 94). Namibia and Botswana are most exposed to this potential trend, and the species' existence is even threatened there. On the other hand, the species' occurrence is predicted to increase in Zambia.

Africa is one of the most vulnerable continents to climate change, and forest managers need to consider its potential effects on this important timber species

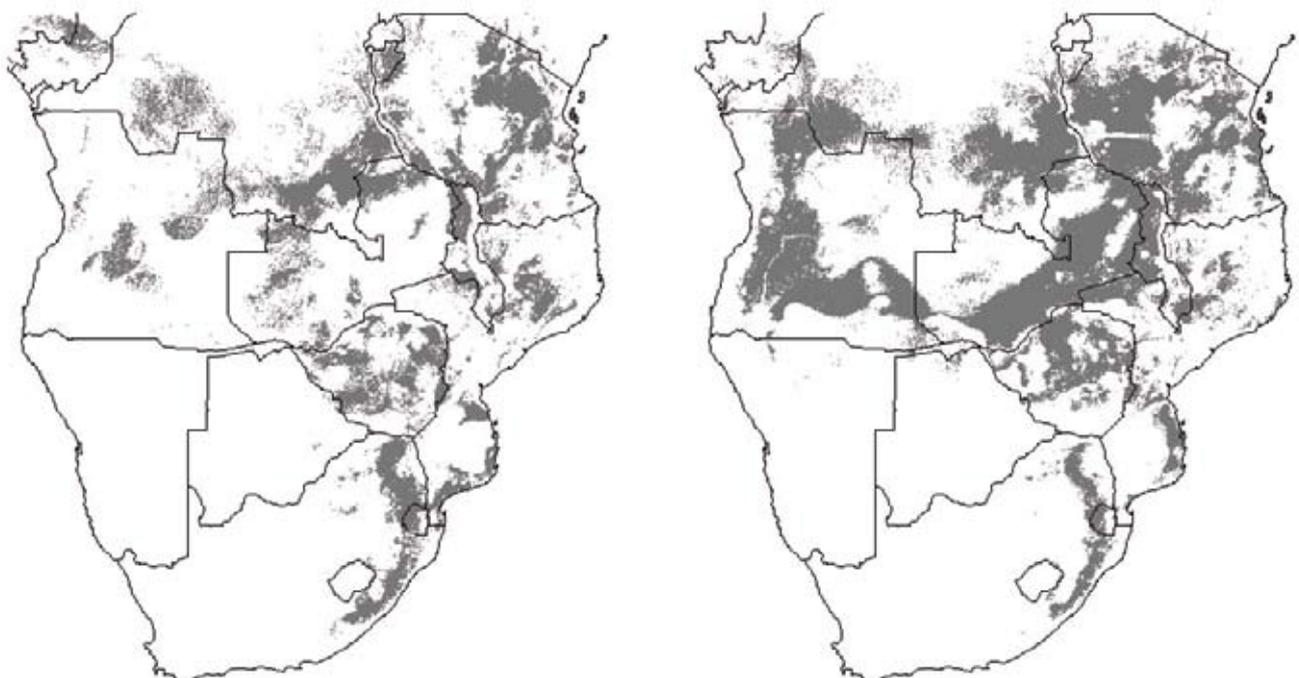


Fig. 94: Future (2080) distribution scenarios for *Pterocarpus angolensis*. At left is the scenario using emission data from emission scenario A2a (worst-case) and at right from emission scenario B1 (best-case).

in combination with all other short-term threats to southern Africa's woodlands. The distribution models created can assist in assessing the conservation status of the species on a regional scale and identify suitable areas for regeneration trials, controlled fire experiments, or forest inventories. The future models can point out the

regions where the species is most sensitive to climate change, and thereby contribute to detect early signs of climate change in the field.

Link to data and further readings: De Cauwer (2014), De Cauwer et al. (2014).

N6) Kiaat (*Pterocarpus angolensis*) represents less than 14 % of available wood volume in the dry woodlands. Forestry management interventions offer a perspective for future land use of dry woodlands.

The south-western Miombo woodlands near Caiundo and Mashare are open *Burkea* forests, also known as Zambezian *Baikiaea* forests (Burke 2002; Timberlake and Chidumayo 2011) (fig. 95). Little is known about these woodlands, especially their exact extent, composition, sustainable harvest rates, and wood production potential (Baptista 2014; Graz 2004; Strohbach 2013). The project aimed to assess the latter by building upon forest inventory data gathered by the Namibian Directorate of Forestry (DoF) for the Kavango regions of Namibia (Kamwi 2003; Kanime 2003; Kanime and Kakondo 2003; Kanime and Laamanen 2002; Muhoko and Kamwi 2014). On the Angolan side, only information from colonial times is available (Baptista 2014; Coelho 1967).

Wood volume and biomass was assessed and compared for several study areas with varying rainfall and manage-

ment regimes (fig. 95). The Caiundo site had the highest rainfall and Ncaute the lowest (tab. 7). Most of the study areas are situated on communal land, with Ncaute managed as a community forest, while Hamoye is a state forest reserve. The Namibian Forest Inventory methodology was used, whereby all woody species with a minimum diameter at breast height (DBH, at 1.3 m high) are measured (Burke et al. 2001). Random sampling along transects was used instead of systematic grid sampling.

The inventory results are shown in tab. 7 and 8. The main cause of tree damage is fire for all sites. Basal area is indicated in both tables as it gives a very good indication of available wood volume; it is the sum of the cross-sectional areas of all tree stems at breast height, per hectare. Calculation of wood volume or biomass requires a generalization of stem or tree shape through equations,

Tab. 7: Study areas for which forest inventories were performed, with general site characteristics, number of sample plots and forest inventory results per study site. Damage is indicated in classes from 0 to 4, with 1 = mild and 2 = moderate damage.

Study area	Caiundo	Nkurenkuru & Cuangar	Mashare	Hamoye	Ncaute	Grand Total
Amount of samples	24	28	62	49	33	196
Annual rainfall (mm)	704	595	574	554	552	
Tree coverage (%)	32	27	24	32	18	
Shrub coverage (%)	40	37	29	11	15	
Human Damage	1,0	1,4	1,1	0,2	0,1	
Fire Damage	2,1	1,9	1,6	1,8	1,6	
Min. temperature coldest month (°C)	6,2	7,4	5,9	6,0	6,0	
Temperature seasonality (°C)	31	31	35	35	35	
Fire frequency 1991–2004 (%)	NA	16	14	21	20	
Fire frequency 2001–2012 (%)	27	14	4	11	7	
Stems per ha	191	209	202	180	111	181
Small stems per ha (5–25 cm DBH)	76	71	81	71	80	76
Basal area (m ² /ha)	7,6	7,5	5,3	7,2	3,4	6,0
Bole volume (m ³ /ha)	19,4	19,6	12,3	19,5	10,4	15,7
Total wood volume (m ³ /ha)	68,0	69,5	44,8	66,6	30,0	54,1
Wood biomass (ton/ha)	55,8	54,8	38,2	53,1	22,0	43,7

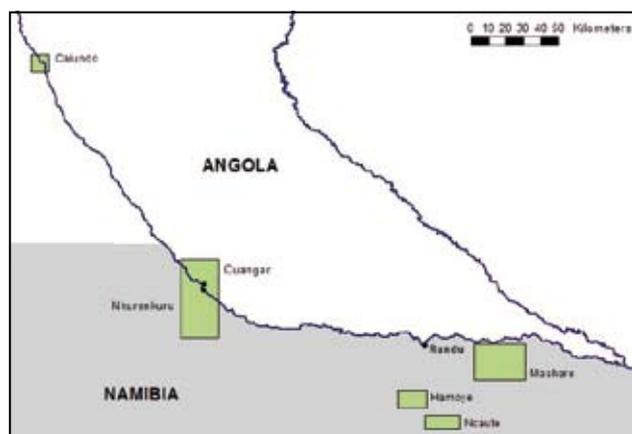


Fig. 95: Study areas with forest inventories.

and is therefore more prone to error. Several equations were used for the results in tab. 7 and 8: bole volume was calculated as the volume of a cylinder with height taken as the potential saw log or pole length measured during field work; DoF equations were used for the total wood volume up to branches of 10 cm in top diameter (Kanime and Laamanen 2002); and the formula of Chidumayo was used to calculate the dry weight of above-ground wood biomass of stems and branches up to a top diameter of 5 cm (2014).

Only 19 % of the average bole volume in the woodlands is of Kiaat (*Pterocarpus angolensis*), the main species harvested for timber wood. It represents even a lower percentage (14 %) of the total wood volume. Kiaat is mainly harvested in order to to saw planks from the logs, and total revenues could increase significantly if there was a bigger market for other parts of the tree (Moses 2013). The species with the highest bole volume is *Burkea africana*, a species that is hardly utilized, not even as firewood.

Bole volume is less than a third (29 %) of the total wood volume. The tree with the highest total wood volume and biomass is Manketti (*Schinziophyton rautanenii*). It is the most dominant tree in Caiundo and Mashare because of its basal area, although it has lower stem numbers than other tree species, such as *Combretum collinum* and Kiaat. The study sites with the lowest biomass and timber wood volume were the sites with younger forest, where at least 80 % of the trees had a DBH of 25 cm or less. Wood biomass values are higher than those calculated earlier for Kavango (20.6–21.6 t/ha) (Chakanga 2000; Muhoko and Kamwi 2014) and other areas in southern Africa with mean rainfall of 500–600 mm (16.3–19.7 t/ha) (Rutherford 1979; Werger and Bruggen 2012).

Link to data and further readings: Baptista (2014), De Ruytter (2015), Kabajani (2013).

Tab. 8: Forest inventory results for the most common tree species (Baiplu = *Baikiaea plurijuga*, Burafr = *Burkea africana*, Comcol = *Combretum collinum*, Diaeng = *Dialium engleranum*, Eryafr = *Erythrophleum africanum*, Guicol = *Guibourtia coleosperma*, Pteang = *Pterocarpus angolensis*, Schrau = *Schinziophyton rautanenii*, Terser = *Terminalia sericea*).

	Baiplu	Burafr	Comcol	Diaeng	Eryafr	Guicol	Pteang	Schrau	Terser
Study area	% of basal area per study area								
Caiundo	5	10	7	4	9	4	10	32	2
Nkurenkuru & Cuangar	14	10	6	0	2	4	29	26	3
Mashare	12	14	7	1	2	11	9	23	6
Hamoye	17	21	2	10	0	10	11	18	2
Ncaute	0	48	0	6	0	8	15	10	1
Stems per ha	15	33	17	12	3	6	17	9	17
Basal area (m²/ha)	0,70	1,09	0,28	0,27	0,13	0,49	0,85	1,34	0,19
Timber wood volume (m³/ha)	1,9	3,4	0,6	0,7	0,3	1,1	3,0	3,1	0,3
Total wood volume (m³/ha)	7,1	10,2	1,9	2,4	1,3	4,7	7,5	13,5	1,1
Wood biomass (ton/ha)	5,4	6,8	1,5	1,6	0,9	4,1	5,9	12,8	1,0

N7) Riparian woodland in the delta accounts for approx. 27 % of evapotranspiration while occupying only 7 % of the area.

In arid and semi-arid areas, transpiration by phreatophytes is a principal groundwater sink and a significant component of wetland water budgets. Understanding and accurately quantifying evapotranspiration (ET) is necessary for water resources management, especially when facing an uncertain climatic future. In the tro-

pical Okavango Delta, transpiration by trees (fig. 96) is an important process partly responsible for maintaining the basin as a freshwater environment rather than a saline one. ET, which consumes about 96 % of the total water input from terrestrial landforms of the delta, fringed by riparian woodlands, is one of the main areas



Fig. 96: Riparian woodland species in the upper Delta (photo: A. Lubinda).

contributing to uncertainty in current hydrologic modelling in the delta. However, ET measurements have historically been difficult to make, and hence ET tends to have been calculated as the remainder term from the water balance. Ignoring model uncertainty undermines the value of a model for its use in the decision-making process (Cathey 2011). The objective of this study was therefore to acquire quantitative estimates of water fluxes through the major woody riparian species in the Okavango Delta, and thus to contribute to the ability to model eco-hydrological change.

Using the compensation heat pulse velocity method, sap flow measurements, which are widely used in eco-physiological field studies, were used in this study to estimate tree transpiration, from common species, in the distal, mid and upper delta during low, medium, and high water levels. Work by Tsheboeng et al. (2013, unpublished) informed the choice of common species. Eight different species were studied in total. One individual of each species was studied per site except in Maun, where four individuals of the same species, of different sizes, were investigated. Two pairs of probes were inserted per tree. A line heater was inserted radially into the stem with a thermocouple probe below and above the heater. The upstream probe was located 5 mm away from the heater and the downstream probe 10 mm away. A heat pulse was fired every 30 minutes and cross-

over times, t_z , recorded. t_z is the time delay in seconds for temperatures between the two probes to become equal. From the t_z values raw heat pulse velocity was calculated using the equation: $V_z = (x_d + x_u)/2t_z$, where V_z is the raw heat pulse velocity, x_d and x_u are distances upstream and downstream of the heater. Wound corrections were made using constants as outlined by Swanson and Whitfield (1981). The constants were used to calculate corrected heat pulse velocity using the formula: $V_c = a + bV + cV^2$, where V_c is the corrected heat pulse velocity, a , b and c are constants and V is the raw heat pulse velocity. Sap flow velocity, which is the speed of sap within the lumens, was then derived from the heat pulse velocity. The sap velocity was multiplied by the sap wood area to give the total flow within the stem. Initially sap flow was recorded for five consecutive days and after establishing that there were no major variations in sap flow between days this was reduced to three days. A CR1000 Campbell data logger was used to record data.

The distal and mid-delta sites behaved similarly in terms of the seasonal variation of sap flow; the trends were similar but the rate of transpiration different. In November–December 2012, sap flow was generally lower than in July–August 2012 in these two sites. November–December corresponds to a period of low water level and July–August to high water level in both

these areas. Our results show higher sap flow during high water levels (July/August 2012) than during low water levels (November/December 2012). This might possibly mean that since shallow groundwater is more available during high water levels, trees don't need to expend a lot of energy in pumping the water, hence high sap flow. July-August is midwinter in Botswana, and November–December is early summer (Botswana Meteorological Services). Normally it is expected that sap flow would be higher in summer when temperatures are high than in winter when temperatures are cool. In Botswana the climate is sub-tropical, with rainfall occurring in summer. This therefore means that rainfall might have been a significant factor influencing declines in sap flow, by creating conditions that do not favour transpiration. Rainfall generally lowers air temperatures and increases relative humidity, resulting in trees transpiring less water than when temperatures are high and the air dry.

In the upper delta July–August 2012 was medium water level, November–December 2012 low water level, and February–April 2013 high water level. From our

results the higher the water level the lower the sap flow in this part of the delta. During the periods November–December 2012 and February–April 2013 there was abundant surface water but sap flow recorded in both seasons was lower than in November–December 2012 when it was dry. With abundant water available it would be expected that there would be no limit to sap flow. Our study trees in the upper Delta are just on the edge of the main channel. Large bodies of water alter microclimatic conditions by reducing air temperature within the river channel, resulting in lower evaporative demand (O'Grady et al. 2006). During high and medium water levels water was not only confined to the channel but also spilled onto the islands. This means that the microclimatic conditions in the islands may also have been altered by the presence of surface water.

ET from the whole delta (with riparian woodland covering an area of 1,190 km²) was estimated to be 4.06 million m³/year. This is equivalent to 27 % of the total annual input into the delta.

Link to data and further readings: Lubinda (2014).

N8) In the delta the riparian woodland composition is driven by hydrology. Some riparian species show stable populations structure while others show unstable population structure.

In Botswana there is a policy framework designed to conserve and protect the Okavango Delta. These policies include the National Conservation Strategy (Matiza and Chabwela 1992), the Botswana National Wetlands Policy and Strategy of 1999, and the Okavango Delta Management Plan, which between them attempt to engage the public as active participants in wetland management through the utilization of their indigenous knowledge and local institutions (Jansen and Madzwamuse 2003). The Okavango Delta is also a declared Ramsar site, a wetland of international importance, and a UNESCO World Heritage Site. Despite these efforts to conserve the delta's biodiver-

sity and ecology, the threats of deforestation, climate change, and invasion by alien species persist, and as human populations around the periphery of the delta grow, these damaging activities increase. An additional threat is increasingly posed by a large and rapidly growing population of African elephant, *Loxodonta africana* (Natural Resources and People 2007). Given the critical ecological function of the riparian woodlands, little can be done to ensure the sustainability of the delta and its ecosystem processes and services without better knowledge of the current status and trends of tree populations. The information can also be used in modelling the possible future of the Okavango Delta



Fig. 97: Elephant damage in the Okavango Delta influences riparian tree population size structure distribution (photo: K. Thito).



Fig. 98: Fire in the Okavango Delta also influences riparian tree population size structure distribution (photo: K. Thito).

in the context of vegetation resources utilization, climate change, and basin development.

If the tree species are to be used sustainably their ecology, and the ecological consequences of that use, have to be understood (Naiman et al. 1993). The aim of this study was to investigate the spatial variation in the population structure of selected riparian tree species in the Okavango Delta. Variation of riparian tree species population structure was studied in sites selected along hydrological (flooding) gradients. Flooding has been found to be the overriding factor influencing the vegetation ecology of the Okavango Delta (Ellery et al. 1993). The effects of other influences, for example those of elephants (fig. 97) and fire (fig. 98), were inferred based on field observations. Previous research, however, indicates that fire, though frequent in floodplains, does not often enter the riparian woodland, probably due to a lack of fuel in the lower canopy layers (Heinl et al. 2007).

The population structure of riparian tree species was studied in randomly selected 20 x 50 m plots. In each plot the stem circumference (>15 cm) of tree individuals (Sop et al. 2011) was measured at 1.3 m above ground. For multi-stemmed trees, circumferences of the stems were summed up (Sop et al. 2011). The diameter at breast height (DBH) for individual trees was computed from the circumference. A total of 75 plots were sampled. Tree species from each study site were categorized into 8 DBH classes, namely 0–10, 10–20, 20–30, 30–40, 40–50, 50–60, 60–70 and >70 cm. The method for inferring recruitment status of different

plant species followed Shackleton et al. (1993). Recruitment status of each species was determined by analyzing the slope of a linear regression of DBH size classes. DBH midpoint (m_i) was used as the independent variable while the density of individuals (N_i) in each DBH class was used as the dependent variable. N_i was transformed by $\ln(N_i + 1)$ since some classes had zero individuals. The regression was then done using $\ln(N_i + 1)$ and $\ln(m_i)$. Negative slopes indicated ongoing recruitment, with more individuals in smaller size classes than in larger size classes, while positive slopes indicated little recruitment or possibly episodic recruitment (Helm and Witkowski 2012).

Some riparian species show stable population structure, while others show unstable population structure. *Croton megalobotrys* showed a stable size-class distribution (SCD) pattern in Boro, Santawani and Vumbura, while it showed an unstable bell-shaped distribution pattern in Moremi. *Philenoptera violacea* showed an unstable population structure in Boro and Santawani while it showed a stable population structure in Vumbura. *Diospyros mespiliformis* showed an unstable population structure in Boro, Seronga and Vumbura. *Acacia nigrescens* showed an unstable population structure in Boro and Santawani and a stable population structure in Seronga. The differences in species population structure across different sites is partly influenced by the spatial variation in the Okavango Delta hydrology.

Link to data and further readings: Tsheboeng and Murray-Hudson (2013).

N9) The high fire frequency in large parts of the Okavango Basin hinders the regeneration of forests and woodlands, especially if the fire return period is less than five years.

Open woodlands and savannah landscapes burn easily in the dry season, due to the high fuel load accumulated through dried biomasses of grasses and dry shrubs. Young trees need at least a five-year period without fire disturbance to become robust and tall enough to survive the fires and to have the chance to grow up into an adult tree. There is plenty of evidence that a fire return period of less than five years captures tree regeneration in the sapling stage. This process is commonly referred to as 'regeneration bottleneck' or 'fire trap' (Sankaran et al. 2004; Bond and Keeley 2005).

Based on the MODIS burned area product MCD45A we mapped the fire for each year between 2000 and 2013 and calculated the fire return period for the Okavango Basin.

Fig. 99 shows the longest fire return period during the observation period. For all areas presented in reddish colours there was no sequence of more than five years without fire during the observation period which would have allowed for the regeneration of trees. In other

words, for more than a decade there was almost no regrowth of wood and timber resources in large parts of the central Okavango Basin.

Still more worrying are the observations gained from a closer look at the processes in the northern part of the basin. In its natural state, more than 70 % of the southern slopes of the Bié Plateau are covered by closed forests. Closed Miombo forests maintain a more humid microclimate than grasslands, and in combination with lower fuel load in the understory withstand ignition and thus are fire-resistant, according to Archibald et al. (2009). However, once forests are opened up by slash-and-burn agriculture or charcoal production, tall grasses and shrubby regrowth start to colonize the areas and they become vulnerable to ignition. Once the area of fire-resistant landcover types drops below 40 %, fires can spread rapidly through entire landscapes (Archibald et al. 2009, Hennenberg et al. 2006). This seems already to be the case in parts of the Bié Plateau.

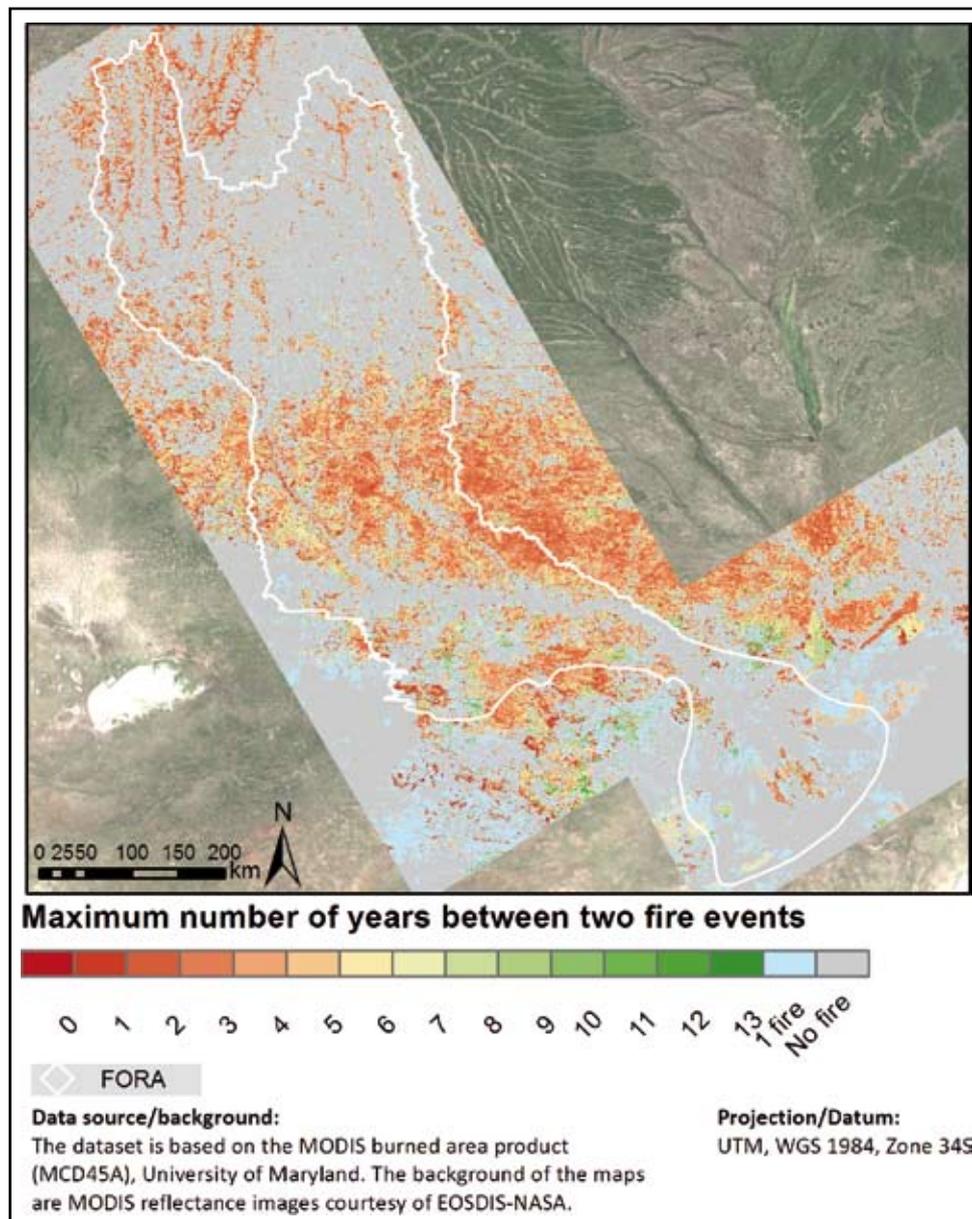


Fig. 99: Map showing maximal number of years between two fire events.

Fig. 99 shows that areas under exploitation pressure for charcoal or agriculture start to behave like grasslands; they switch from non-flammable to flammable and burn easily in the dry season. Fig. 100 shows former fields and charcoal plots at the core site of Cusseque 20 years after harvest still not having completely recovered. This means that under the current fire regime, forest regeneration after exploitation is dramatically compromised in the Miombo forests of Bié and Moxico. The interaction between exploitation and fires enhances the pressure on the remaining wood and timber resources in the Okavango Basin. Under the current fire regimes, forestry ceases to be sustainable, and instead becomes devastating.

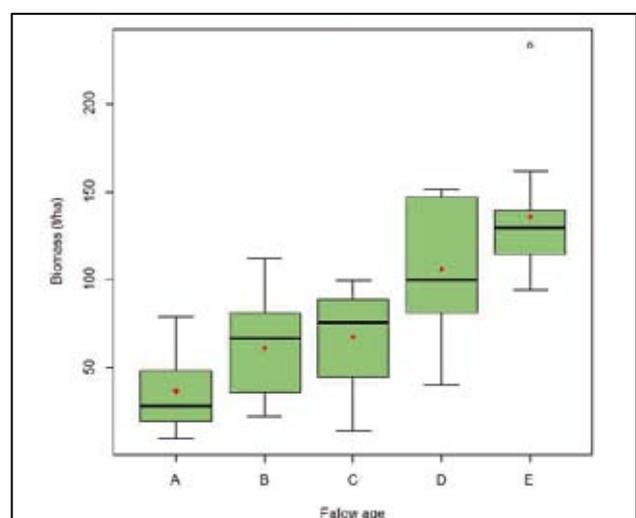


Fig. 100: Woody biomass of charcoal parcels in t/ha at different time spans after exploitation. A (fallow ca. 8 yrs), B (charcoal plots ca. 8 yrs), C (fallow ca. 14 yrs), D (fallow ca. 20 yrs), E (closed stands).

N10) Roads are axes of transformation leading to loss and degradation of forests and woodlands.

Loss of forests and woodlands by complete removal or selective extraction threatens the long-term provision of ecosystem services and of functions related to these ecosystems. Such processes have been shown to be related to infrastructure and settlement areas in different parts of the world (Rudel et al. 2009). We investigated the presence of similar effects in different locations within The Future Okavango Research Area by analyzing time series of Landsat-TM, -ETM+ and -OLI images. We combined different image classification approaches, such as ISODATA cluster analyses and Support Vector Machine classification (Pal and Mather 2005) to map major land-use and land-cover types for different time steps between 1984 and 2014. Comparing these maps (fig. 101) through time established that the conversion of forests and woodlands to areas used for small-scale

agriculture was by far the dominant process during the observation period. This is added to by the selective extraction of trees for timber use or charcoal production; however, the latter processes can only be detected at the medium resolution of Landsat data if they affect larger areas. For the test areas, conversion rates of the mentioned processes were quantified for different periods.

The resulting change maps were combined with geospatial information to address the question of spatial determinants of woodland decline. We analyzed the spatial gradient of the loss of forests and woodlands in relation to roads, settlements and rivers. Buffer zones of 2 km width were calculated around these target features, and for each zone woodland loss was quantified. As a result, we can clearly confirm that especially roads and settlements are major agents of change. The boundary of intact wood-

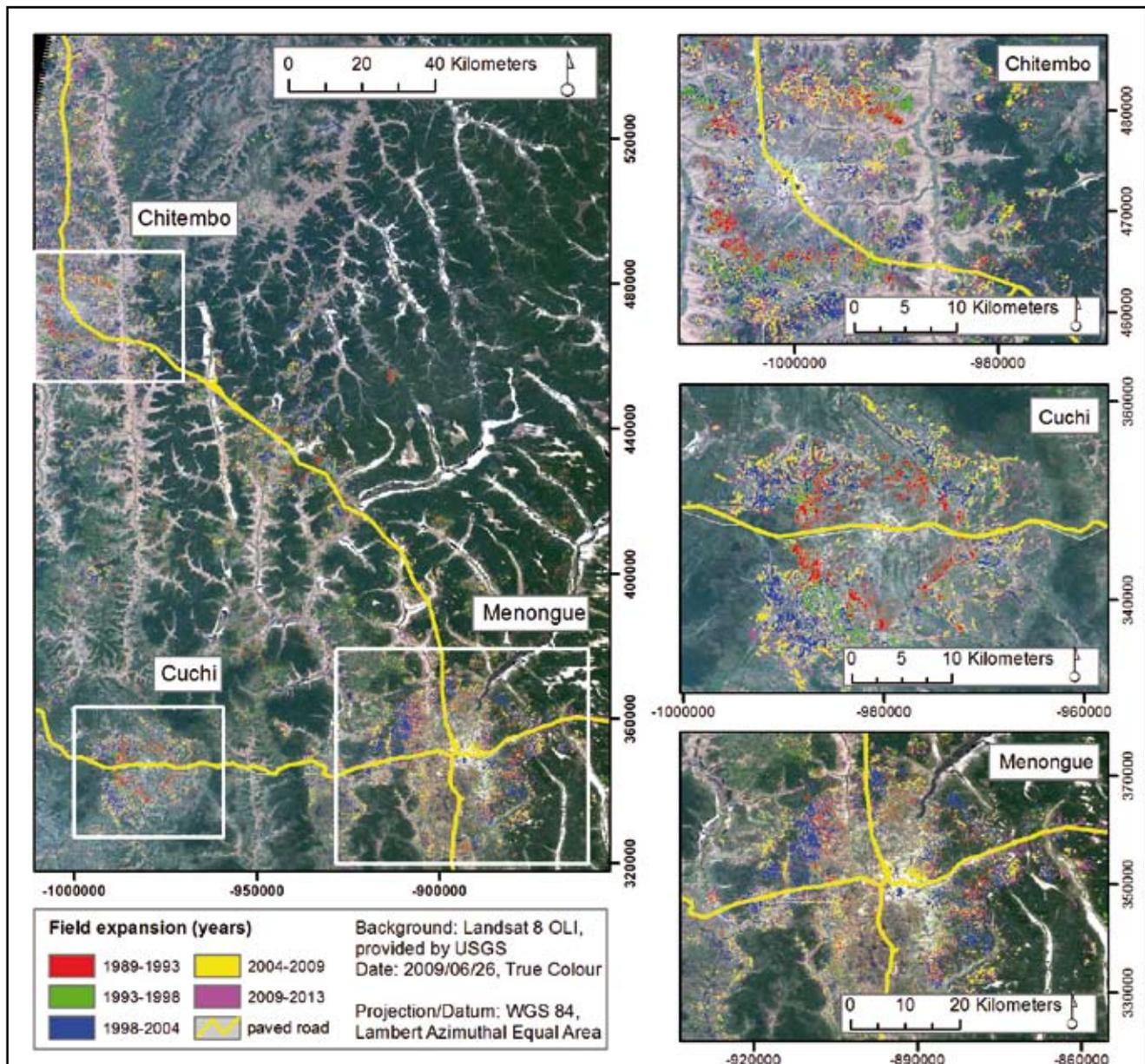


Fig. 101: Map of field expansion from 1989–2013 with additional close-up for the three cities of Chitembo, Cuchi, and Menongue.

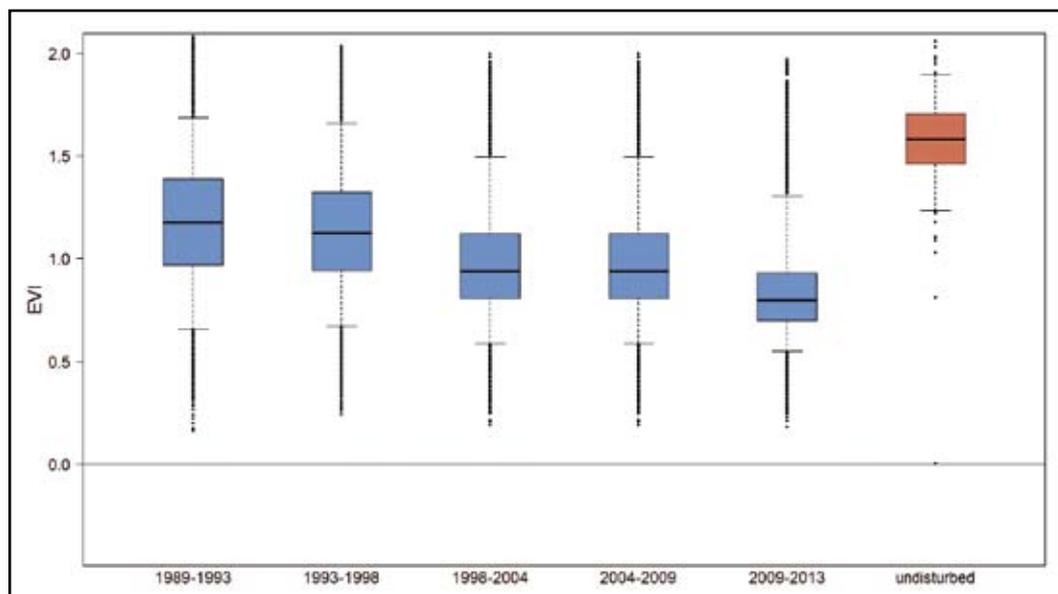


Fig. 102: Vegetation index (EVI) distribution for the five time intervals (blue) of woodland clearing and subsequent fallow in comparison to randomly selected EVI values in undisturbed forest areas (red) for the year 2013. The whiskers show the 95 % confidence interval, the outliers are shown as points.

lands was shown to move away from settlements with time, in particular where settlements experienced strong growth (e.g. urban centers such as Rundu/Namibia or Menongue/Angola). The same effect was visible in relation to roads, even if no larger settlements were located close by. Roads promote easier access to natural resources and increase the connectivity between locations of resource availability and market commodification.

To evaluate the long-term effect of using timber resources, we analyzed regrowth dynamics on fallow fields in the Angolan test area. We calculated the Enhanced Vegetation Index (EVI, Huete et al. 2002), a proxy for biomass, and traced its development for different

fields that were taken out of use during the observation period, and compared this development to undisturbed Miombo woodlands. Our results show (fig. 102) that even after a fallow period of ~20 years the biomass, as expressed by the vegetation index, has not returned to its theoretical maximum corresponding to the pre-clearing situation. This is in line with findings by Chidumayo (2013) based on field experiments in similar vegetation zones.

Link to data and further readings: Land use/cover and change maps for core sites: OBIS. Details on measurements and results: Röder et al. (2015), Schneibel et al. (2013).

N11) Land users experience high incentives to clear woodland for cropping due to the tradeoff between the options of cropping and maintaining forest land. The low economic benefit of woodland products for local communities reduces the local valuation of woodlands.

Decisions to convert land from forest to fields are influenced by a number of ecological, socio-economic, and institutional factors and their interactions. Deforestation and degradation in sub-Saharan Africa are mainly driven by small-scale agricultural expansion (De Fries et al. 2010; Fischer 2010; Hosonuma et al. 2012; Rudel 2013). Small-scale subsistence farming lacking input-based soil conservation measures causes soil degradation and low land productivity. However, in open-access settings this degraded land can be replaced by clearing forest for fields.

Land allocation in the Kavango regions for subsistence agriculture is managed under customary law, which is effective in preventing non-community members from accessing the community land or resources. Nevertheless, traditional authorities generally do not prevent the clearing of forest for fields and the expansion of fields, but as-

sign designated areas for farming. The Communal Land Reform Act of 2002 established Land Boards as a control mechanism for customary land administration, increasing transaction costs for land allocations. The intended effect of these boards – that of restricting the accelerating deforestation in the Kavango region and encouraging investments in land improvements – is yet to be seen. At the time of our research, communities are opposed to the law, as farmers feel that the rule is not adapted to their farming system.

In order to gain a better understanding of the clearing decisions of local farmers we conducted a livelihood analysis in 31 randomly selected rural villages with 618 households in the Kavango region. The estimation of the communities' income composition gives evidence that households are largely dependent on various direct natu-

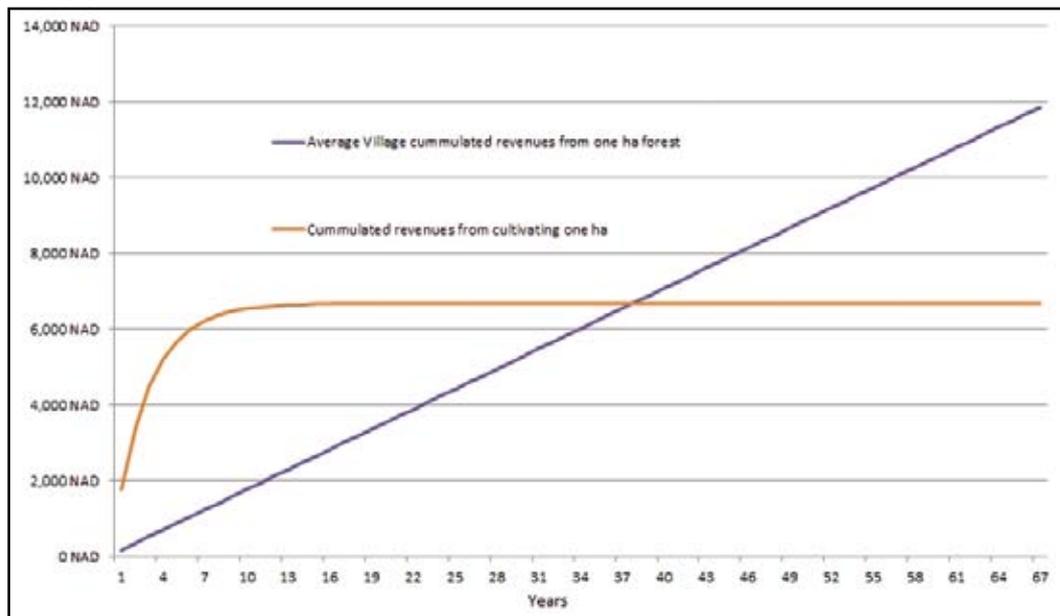


Fig. 103: Break Even Point of Cumulative Benefits (per ha).

ral resource uses and on agricultural production. Income from business or employment is an exception. To compare the direct benefits of the two different land uses, forest and cropping, we valued the natural resources people collect in the forest and the crop harvests from their fields on the basis of local exchange prices. The valuation indicates that the direct use value of forest resources for local users in a year is clearly more than twice as high as the harvest value of the crops.

Considering that forest land uses are competing with crop fields, and the harvest value of crops is generated on a field with a few hectares while the value of forest resources is collected by a community member over a much larger area, we need to compare the respective values per hectare of field and forest area. Remarkably, forest resources constitute more than 50 % of total household income, as compared to 22 % from harvested crops; however, the value per hectare of forest resources is less than one fifth of the harvest value of crops per hectare.

In the long term perspective, and accounting for decreasing soil fertility and productivity, we analyze the cumulative benefits from one ha of crop production and forest use (fig. 103). The cumulative benefits from forest use exceed the cumulative benefits from cropping one field no earlier than after 38 years. Assuming even slightly lower discount rates of local farmers' preferences for future benefits or slightly higher productivity values may result

in a break-even point which is beyond the life expectancy of the Kavango population.

The analysis demonstrates that in the short term, cropping is more profitable than forest land uses for the individual. This clearly indicates that there are strong individual short-term incentives to clear the forest for fields as long as people suffer from insufficient incentives to adopt expensive soil conservation methods to increase productivity and are able to replace easily degraded fields.

Accounting also for the forests' long-term, non-use values and the regulating services forest ecosystems provide, as well as benefits enjoyed on a global scale (e.g. carbon sequestration), it is likely that the overall benefits of the forest exceed the benefits of the agricultural use of the land. Nevertheless, the question remains as to how such benefits can influence incentives for local resource users in their clearing decisions.

Conversion of forest land for fields poses a severe threat for rural livelihoods and the integrity of ecosystems in the long run. To reduce deforestation speed and improve soil conservation and soil fertility, it is crucial to enhance individual incentives. Thus, investments in soil fertility can be seen as a public benefit, responsibility for which should not only lie with the individual farmer.

Link to data and further readings: Data can be made available on request by Lawrence Brown, brown@staff.uni-marburg.de.

RECOMMENDATIONS

An integrated and systematic conservation and land-use planning concept is urgently needed across the whole basin. As a robust foundation for any science-based response to the impacts of climate and other en-

vironmental change on forests, savannahs, woodlands, and grasslands and their organismic diversity, the establishment of long-term monitoring plots is recommended. Additionally, the adaptive capacity and the

sustainability of species of high ecological or economic value should be analyzed in detail. In seeking to integrate the findings of the TFO project, the following points should be considered for strategic conservation and management plans:

- There is an urgent need to identify priority areas for nature reserves and national parks based on the improved scientific knowledge, especially in Angola.
- To secure the suitability and connectivity of the different ecosystems for rare and endangered organisms, and especially for migrating animals, including elephant, zebra, buffalo, and a variety of other larger ungulates requires a spatially explicit integrated management plan for both conservation areas and economic development areas.
- The multiple functions of wetlands for the extraction of ecosystem goods, for the protection of species, and for the buffering of water flows should be integrated into management plans, also considering their role as a lifeline for the dry hinterlands.
- The role of woodlands in providing a significant contribution to people's subsistence incomes as well as the protection of water flows and the stabilization of the climate must be recognized.
- There is a need to plan the road infrastructure so as to avoid further fragmentation of intact forest areas.

There is also a general need to change stakeholders' perceptions of the forests and woodlands from the idea that they are an infinite and less valuable area to a view that regards them as a limited resource that offers high income opportunities. In the ecosystems with deep and nutrient-poor Kalahari sands and restricted rainfall, trees in the woodland vegetation are able to make use of deeper water resources for biomass production, whereas crop growth is substantially limited by both soil fertility and water availability. This difference defines a trade-off between the values generated by woodland compared to the values generated by crop production.

This change in perception should form the basis for conservation and land-use planning concepts. Destructive use of forests for the commodification of forest goods strongly affects a multitude of other uses which are important for the day-to-day subsistence of the poorer rural households. Natural resource management should strictly restrict destructive uses, and only issue exploitation permits with the associated obligation that the permit-holders enable forest regrowth within a short time span.

In detail, specific management concepts for the sustainable use of forests based on optimized and adapted practices should be developed for the different zones of the basin. Here the following points should be integrated:

- In the Miombo forests, charcoal production will probably remain one option for forest use; however, it must be restricted to defined charcoal-production zones. Charcoal trade towards urban centers should be controlled and limited. Alternative sustainable energy sources need to be promoted.
- For the *Burkea* woodlands in Namibia and southern Angola the use of the newly derived age-diameter relation as a tool for sustainable forest management is recommended. Here, woody biomass and tree bole volume can easily reach values of 50 ton/ha and 19 m³/ha respectively. Timber revenues can be improved through forest-management interventions focusing on Kiat and Zambesian teak. However wood use should encompass more than just sawn timber to improve total revenues, as indicated by Moses (2013).
- As one part of a climate adaptation strategy, **in vitro** multiplication of high-quality kiat individuals currently growing in the Otjozondjupa Region of Namibia should be considered. There specimens are found at the lowest annual rainfall of the species' range, and cultivated saplings can be planted in the still-wetter areas further North.
- In the delta, riparian woodland species are exposed to vulnerable site conditions (water, fire, grazing), which have already led to unstable tree populations. Suitable measures should be intensified to protect these ecosystems as a whole. Conditions and processes allowing and controlling the regeneration of riparian woodland should be further studied and monitored. Protective measures at the local scale should have a strong focus on outreach to engage communities and prioritize advocacy, rather than regulation.
- In the neighbourhoods of crop production areas, forest harvesting practices like coppicing or use of leaf litter may provide an opportunity to improve nutrient supplies on the arable lands.

The TFO project has compiled precise maps that show the high frequency of bush fires in large parts of the basin. Important differences were observed regarding the frequency, duration, and spatial extent of fires in the different parts of the catchment. The present application of bush fire kills animals, leads to a loss in nutrients (especially nitrogen) from the soil, and reduces the regeneration potential of woodlands. The frequency of human-induced fires should be reduced, especially on fallows and clearcuts in the first five years after the ceasing of cultivation. Grasslands should only be burnt early in the dry season when the risk of spreading into woodlands is still small. Burning should never be allowed in hot and windy weather conditions. A training and awareness campaign regarding the short-term and long-term effects of fires should be initiated.

For parts of South-East Angola wildlife-based tourism is a new and challenging income opportunity, and not only for areas within KAZA. As was shown for Botswana and Namibia, the number and diversity of large wildlife species is a prerequisite for tourism, together with

landscape beauty. Therefore, enforced hunting regulations and the establishment of corridors for wildlife migrations are necessary to set the frame conditions for the expansion of larger wildlife, and thus income generation from high-end tourism.

4.4 Agriculture & Food security

A1) Smallholder subsistence forms of agriculture are the dominant farming systems in the Okavango Basin. They are currently on a pathway towards impoverishment and natural resource degradation. Smallholders need assistance to achieve sustainability.

Smallholder farming systems in the Okavango Basin are in a process of ongoing change due to decreasing land availability per person and the impacts of various global processes. Under the current cropping systems, limited land availability results in soil degradation and reduced yields (see results key findings A 4 & A10). This may cause households to fall into a poverty trap, a vicious cycle of resource degradation and impoverishment from which they are unable to escape on their own, as they cannot make the investments needed for the adoption of improved farming practices (see Barret 2008).

The following trends can be observed: Households adapt to decreasing land availability with different degrees of success. This results in an increasing social stratification of rural communities into **i)** a minority of relatively wealthy smallholders who manage to cope with reduced access to land and benefit from increasing cash availability; and **ii)** a majority of smallholders who struggle under conditions of soil degradation and are in danger of falling into a poverty trap. This stratification leads to an increasingly skewed distribution of access to and use of natural resources, because intensified and possibly exploitative natural resource use by the wealthier smallholders may further endanger the livelihood base of the poorer ones and thus quicken their impoverishment process. This skewed distribution can already be

observed in areas of high population density (esp. in Mashare and to a lesser extent also in Seronga core site), but not yet in the upper catchment, with its low population density and thus higher land availability (Cusseque core site). But even here, commodification of natural resources (e. g. forest use for charcoal production) and the establishment of large-scale agricultural schemes are likely to reduce land availability in the near future.

In order to avoid a rural impoverishment process and to meet the food needs of the growing population, there is need for a sustainable intensification of smallholder production (see next key finding). Yet, inducing subsistence smallholders to voluntarily adopt these practices is a complex challenge: In practice, this occurs only when low and erratic yields pose a threat to smallholder families' survival (see key finding A3 and Scherr and Hazell 1994). But if degradation dynamics occur at a fast pace, smallholders may already have fallen into a poverty trap and thus depend on external assistance to manage this shift. This poverty trap seems to already be affecting some poorer households in Mashare core site, but not yet in the other core sites.

Link to data and further readings: See factsheets 'The people' in Oldeland et al. (2013) for a detailed analysis of livelihood stratification in the core sites. A detailed discussion of outcomes is given in Kowalski (in prep.).

A2) Applying the three indicators land-, labour-, and energy efficiency to evaluate the sustainability of cropping systems forms a basis upon which to design successful measures towards sustainable intensification.

Several highly differentiated farming systems coexist in the different agro-ecological zones of the Okavango River Basin. These include traditional systems such as **(1)** slash-and-burn agriculture in a shifting cultivation system (core site Cusseque), and **(2)** semi-permanent cropping systems where fields are used for decades and are slowly enlarged by converting forest lands. Both are characterized by land clearance and fallow as the main fertility management measures. Parallel, input-based systems are developing, such as **(3)** semi-permanent systems with inputs (currently low amounts of inorganic fertilizers – 20 kg/ha – and manure – 4-5 t/ha) and **(4)** conservation agriculture, with large amounts of manure (15 t/ha) on carefully prepared seed beds in usually small cropping areas.

We compared the four farming systems with regard to their sustainability using three efficiency indicators. **Land efficiency** refers to the output of harvest obtained per unit of land under cultivation. It is of particular interest to policy-makers, as agricultural production goals are often used to evaluate the agricultural sector. **Labour efficiency** assesses the outputs of harvest per unit labour invested, and is of particular interest to the land user, as it is the prime limiting factor of production. Finally, **energy efficiency**, or the EROI (energy return on investment), shows how much energy needs to be invested in the agricultural system, as compared to how much energy, in terms of food, is produced by the agricultural system. It indicates whether an agricultural system makes sense in

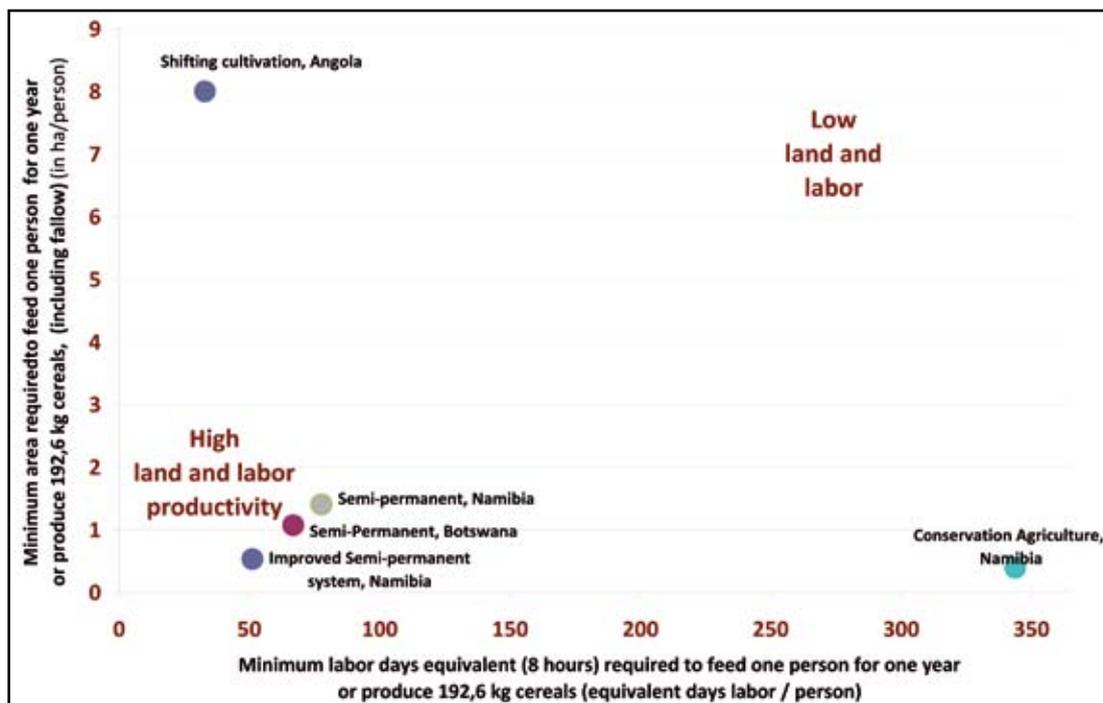


Fig. 104: Comparison of the main smallholder systems of the ORB and their characteristics.

the long term. For successful cropping systems the EROI should exceed 5 : 1.

The cropping systems investigated in TFO differ widely in regard to their various land, labour and energy efficiencies (see fig. 104 and tab. 9). At the two extremes, one finds shifting cultivation (Cusseque core site, Angola), characterized by both high land- and labour productivity, yet depending on land availability for its implementation (depending on fallow length, 2.6 to 12 ha are required to feed one person, or 33 labour-day equivalents) and on the other end, Conservation Agriculture (Mashare core site, Namibia), which has a high land productivity (high yield per ha) but is very labour-intensive and requires 344 labour-day equivalents to produce enough food for one person. However, Conservation Agriculture may be competitive for households with no assets (draft power, manure) or on highly degraded soils (see next key finding). In between, the semi-permanent cultivation system in Botswana is more labour- and land-efficient than its counterpart in Namibia, as soils are cur-

rently less degraded in Seronga than in Mashare. The best combined labour- and land productivity is achieved with the adoption of the improved semi-permanent system in Namibia, with the use of small amounts of inputs (fig. 104). However, the energy efficiency of the improved system is currently low. The causes of this low energy efficiency may be complex, and may include, among others: (i) use of fertilizers, which have a very high energy content; (ii) poor soils, not able to respond properly to inputs without prior regeneration measures; (iii) unsuitable inputs with regard to soil needs, such as in cases where micronutrients are more limiting. Importantly, all semi-permanent systems are characterized by an EROI lower than 5 : 1, which confirms the theory of Ruthenberg (1971) that semi-permanent systems are only transitory systems between shifting cultivation and other sustainable intensified systems.

Link to data and further readings: A detailed discussion of these findings is given in Kowalski (forthcoming).

Tab. 9: A comparison of various efficiencies of the farming systems analyzed within the FORA (for conservation agriculture, only manure inputs were considered).

	Traditional (low-input) Agriculture		Improved systems		
	ANGOLA	BOTSWANA	NAMIBIA		
	Shifting cultivation	Semi-permanent	Semi-permanent	Semi-permanent with manure & fertilizer	Conservation Agriculture
Energy return of inputs (cereal harvest obtained in kilocalories / invested input of human & animal labor and fertilizer & manure in kilocalories)	14.9	4.2	3.4	0.7	0.8

A3) Subsistence smallholders judge cropping practices according to land- & labour productivity and the trade-offs between them. For the adoption of intensified sustainable cropping practices locally adapted solutions are required.

Due to the ongoing soil degradation in traditional farming systems of the Okavango Basin, a shift towards sustainable farming practices is needed (see results key findings A1 and A10). Existing technical solutions focus on increasing land-productivity (yield/ha), thus responding to the upcoming threat of land scarcity as a consequence of both increased land conversion linked to population increase, and soil degradation. Thus, high land-productivity is important for establishing sustainable cropping systems in the future. Often, measures to increase land-productivity include techniques that rely on increased and/or more efficient use of field inputs. Improved techniques that were analyzed by TFO cover various forms of Conservation Agriculture (CA), using manure, mulch and other biomass as additional inputs in the production system, as well as inoculation of crops with nitrogen-fixing bacteria. Compared to traditional farming methods, these techniques are associated with immensely increased labour requirements (up to +1500 %/ha).

Our results confirm the theory of Boserup (1965), that subsistence farmers usually favour systems with high labour-productivity (yield/working hour), where the goal is to produce sufficient food for the family with minimal effort. It is unlikely that farmers in these systems will voluntarily invest additional labour to reach a higher productivity per unit of land unless harvests obtained through the traditional labour-extensive system drop to such a level that families struggle to produce sufficient food (Boserup 1965, Scherr and Hazell 1994). Such a drop would result from soil degradation due to insufficient nutrient inputs in the traditional labour-extensive system (see key finding A10). In some cases, however, the seasonal distribution of labour-needs of a certain practice may be more important than its total labour-demand. The high seasonality of tropical, sedentary agriculture often leads to periods of high labour-needs in the beginning of the growing season, esp. for ploughing (see Ruthenberg 1971). In Mashare and Seronga, for example, the short time window available for ploughing is determined by rainfalls at the beginning of the rainy season, and access to oxen during this period may restrict the size of the cultivated area in a specific year. CA can offer a solution for households without oxen, as here soil

preparation can be undertaken in the dry season, when there are only a few tasks competing for time.

Our research shows that the different TFO core sites face different incentives to embrace a shift from labour- to land-productivity. In the Mashare core site, natural soil fertility varies substantially between the old floodplains and Murambas on the one hand side and the deep Kalahari sands on the other. While most areas of higher fertility have been cultivated for many decades, an increasing proportion of households are nowadays forced to crop on the low-fertility Kalahari sands. This results in low and erratic harvests which do not cover the needs of all households (HH); very few crops are sold (if at all; only 33 % of HH sell crops) and HHs often depend on drought-relief aid (30 % of HHs). Combined with a lack of oxen, this critical situation has induced some farmers to experiment with Conservation Agriculture (CA) practices. As a comparison, in the Cusseque core site, the traditional slash-and-burn cropping system currently suffices for the population to cover the food needs of the households. In fact, about 20 % of the crops produced are sold as (seasonal) surplus, and all households have sufficient crop surplus for sale. Thus, there is little incentive for subsistence farmers in Cusseque to voluntarily change towards a system with a higher land-productivity. Currently, there is limited scientific knowledge about which factors may induce such a shift of smallholders in the currently food-sufficient regions. Our results regarding the role of labour in farming systems suggest that it seems unlikely that CA will be voluntarily adopted by smallholders of these regions due to its very high labour demand. The generation of cash through an increase in cash cropping has been mentioned in the literature as being among incentives that may foster investment in land-productivity. However, the production and marketing of cash crops is dependent on prior access to cash, and may benefit only richer households while poorer ones remain trapped in a degradation cycle (see result key finding A1 and Barrett 2008).

Link to data and further readings: Qualitative interview data are not available due to confidentiality agreements. The discussion of outcomes is given in Kowalski (forthcoming).

A4) Due to the sandy and humus-poor character of most soils, natural soil fertility is rather low, restricting potential yields to <600 kg ha⁻¹. The yields are predominantly nitrogen-controlled.

The soil atlas of Africa gives an overview of the distribution of different soil types on a scale of 1 : 3,000,000 (Jones et al. 2013). For the Okavango Basin, the map shows a very wide distribution of Arenosols, which are soils composed solely of sands. Also to be found are

some areas of Podzols in the middle reaches, and Ferralsols in restricted parts of the Angolan highlands, as well as soils influenced by the rivers. Our much more detailed investigations about the soil properties at the four core sites revealed a substantially higher diversity of

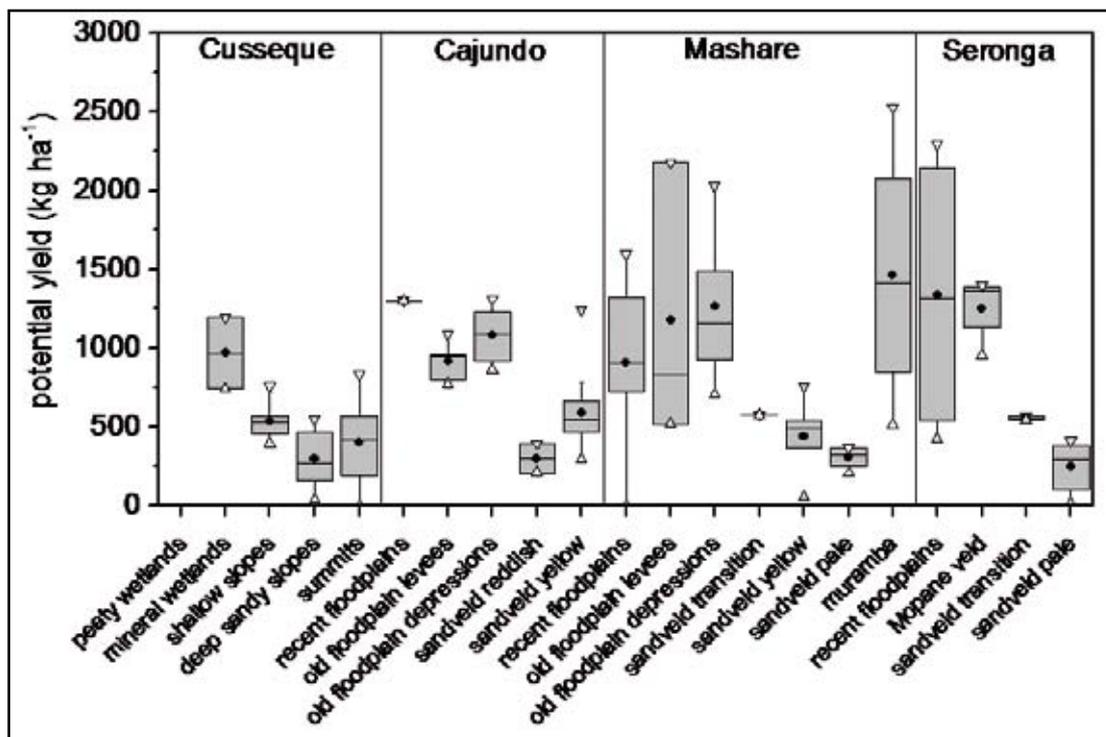


Fig. 105: Potential yields (Maize) estimated from soil pH, organic substances and nutrient concentrations for all studied landscape units in the pristine state.

different soils. Especially soils in the recent floodplains and on floodplains of earlier formation along the rivers have different properties, often much better suited to agricultural land use. The same is true for some interdunal stripes within the Kalahari duneveld and overwashed sands along the Panhandle. And, also in the Angolan highlands, the soil properties may be influenced by the weathered bedrock. Nevertheless, deep sandy soils dominate the landscape in Cusseque (63%), Cajundo (81%), Mashare (78% of the analysed 100 km², respectively) and Seronga (67% of the sandveld area).

For the soils of all landscape units we measured the acidity, the amounts of organic carbon and the contents of the macronutrients nitrogen, potassium, and phosphorus. Based on these measured values we could estimate potential yields using the QUEFTS model (see chapter Methodology), which assumes sufficient water supply and a good crop management practice.

In fig. 105 the results of the potential yield estimates are shown for all landscape units studied. The given values represent the pristine condition of the soils; areas with cropping activities or fallows are excluded. Yields could not be estimated for the peatlands of the Cusseque area,

as there the organic carbon concentrations are beyond the limit of the model. The recent floodplains of all studied sites, and the wetlands in the upper catchment, are not suitable for crop production due to regular flooding or saturated moisture conditions. Thus enlarged values for potential crop production cannot be realized. Preferred landscape units for crop production are the old floodplains in Cajundo and Mashare, the dry river beds (Muramba) in the Namibian Kavango regions, and the Mopane veld in Seronga. Here, based on the natural fertility, potential yields of 800 to 1,200 kg Maize ha⁻¹ can be realized. However, these units cover only small parts of the landscape. The units with vast extension – slopes and summits in Cusseque and the different coloured sandveld in Cajundo, Mashare, and Seronga, all being dominated by sand – exhibit only very low natural fertility, here expressed in the potential yields. The mean potential maize yields in these landscape units vary between 250 and 600 kg maize ha⁻¹. The estimation of the yield potential shows that especially nitrogen is deficient, and at some places also phosphorus.

Link to data and further readings: Soil raw data can be retrieved in OBIS.

A5) Land use influences soil physical and chemical properties in Seronga, Botswana. However, cropped land and fallow land did not differ significantly in nutrient levels.

In the Okavango Panhandle region, in Seronga, land-use systems include tourism, and pastoral and arable farming. However, crop production is the main land-use system, as the other forms are limited by market and outbreak of animal diseases (Große et al. 2013).

The soils are cultivated despite the low cation exchange capacity (<5 meq/100 g soil) associated with high sand content (>85%) of the soils (Starring 1978). This has led to reduced crop yields, probably as a result of low nutrient levels due to leaching by seasonal rainfall and

lack of nutrient replenishment. Thus, shifting cultivation is common, which involves abandonment of crop fields and clearing of virgin soils under grassland or woodland (*Colophospermum mopane*, *Ximenia americana*, *Dichrostachys cinerea* and *Terminalia sericea*). This practice could be driven by the low crop yields and / or subsidies given to the farmers through ISPAAD. It is nevertheless unsustainable as it is done without prior knowledge of nutrient status and may lead to loss of biodiversity and further deterioration of soil fertility. Despite the significance of arable agriculture in the region, few studies have assessed soil nutrient dynamics in the Okavango area (Bonyongo and Mubyana 2004; Krah et al. 2004; Krah et al. 2006; Tsheboeng et al. 2014). These studies have focused on the effects of flooding on soil nutrients and nutrient budgets in the Okavango Delta. However, Mubyana-John and Masamba (2014), assessed soil microbial biomass carbon, nitrogen, and sulphur for the different land uses in Seronga. The study only assessed surface soils (0–10 cm) and did not consider seasonal variations. There is thus insufficient knowledge of soil nutrient dynamics in the Okavango region and of the impact of land use on soil properties.

Land-use systems such as cropping and grazing influence soil properties by the direct adding or exporting of nutrients and the shifting of the water balance compared to the pristine areas. Expansion and intensification

of land use may negatively impact both soil and water quality due to overexploitation without conservation measures put into place (Buck et al. 2004). Information on soil physico-chemical properties as governed by land-use systems at the local level is necessary in order to determine soil productivity and appropriate management activities for sustainable land use (Tsehaye and Mohammed 2013). This study therefore assessed soil nutrient status in the different land-use systems and soil profiles of Seronga, in the Okavango Delta's Panhandle region, which will contribute to sustainable land use. Both chemical (soil pH, EC, soil organic matter, macronutrients and micronutrients) and physical (particle size distribution and moisture content) properties of the soil were assessed under the different land-use systems and soil profiles of Seronga using standard methods (Lindsay and Norvell 1978; Thomas 1982, Ben-Dor and Banin 1989; Anderson and Ingram 1993; Thomas 1982).

Seronga soils are acidic to neutral (pH CaCl₂ 3.8–6.7) with very low moisture content (<6 %) and electrical conductivity (<1 mS/cm). The soils contained high sand (>90 %) and low clay content (0.4 % to 2.8 %). The clay content increased with depth. The highest (0.78 %) and lowest (0.32 %) soil organic matter content was recorded in tall mopane woodland at the onset of rains and in the dry season, respectively. Soil organic matter content was highest in the soil surface (0–10 cm).



Fig. 106: Dark-coloured soils with higher pH and organic carbon content are preferred for crop production (here *Sorghum*) (photo: L. Landschreiber).



Fig. 107: Light-coloured soils with low pH and carbon content in *Terminalia* woodlands are unsuitable for crop production (photo: J. Luther-Mosebach).

However, isolated instances of migration to the lower horizons were observed. Soil total nitrogen (N) was very low (<0.03 %) in all the different land use systems at the onset of rains and in the dry seasons. However, total N increased at the peak of rains; with highest in grassland (0.37 %), *Ximenia* woodland (0.39 %) and *Dichrostachys* woodland (0.36 %). Soil total N was highest at the soil surface and decreased with depth. Soil total phosphorous (P) was below detectable limit (<0.1 mg/kg) at the onset of the rains and in the dry season in all the different land-use systems and soil profiles. At the peak of the rains, total P was high in grassland (70 mg/kg) and in tall mopane woodland (80 mg/kg). Total P did not differ significantly with soil depth. Available P ranged from 22 mg/kg in grassland at the peak of the rains to 2 mg/kg in *Terminalia* woodland during the dry season. Available P decreased with increase in soil depth. Generally very low levels (<0.01 %) of total sulphur (S) were recorded in the different land-use systems and soil profiles. However, total S differed significantly among the land-use systems. Basic cations varied significantly among the land-use systems but did not differ within the soil profiles except at the peak of the rains in *Ximenia* woodland. The micronutrients (i. e. copper, iron, manganese and zinc) differed greatly among the different land use systems and soil depth. Soil copper (0.2 mg/kg) and zinc

(<0.8 mg/kg) were below the established critical levels, showing deficiency in the different land-use systems.

Overall, the results indicated that Seronga soils have very low soil organic matter and macronutrients content. However, significant differences in soil chemical contents exist among the land-use systems and soil profiles. Grassland had significantly higher soil organic matter content, total N, P, and available P, whereas woodland *Terminalia* contained very low nutrient levels except for DTPA-extractable soil Fe. Generally, apart from *Terminalia*, woodlands retained high concentrations of nutrients when compared to cropped and fallow land. Cropped land and fallow land did not differ significantly in soil organic matter, total N, P, S, available P, basic cations or micronutrient cations, suggesting no justification for shifting cultivation. Even though grassland and woodlands contained high nutrient levels as compared to cultivated land uses, cultivation may accelerate loss of organic matter resulting in reduced CEC, thus, management should be focused on increasing organic matter in cultivated fields instead of on cultivation of new areas, as the latter may further reduce soil fertility.

Link to data and further readings: Data can be retrieved in OBIS.

A6) Under traditional agriculture, crops are unable to use the rainwater efficiently, as their growth is controlled by the low soil fertility. Thus even under restricted water conditions (Mashare, Seronga) evaporative water loss is high.

Under dryland agriculture conditions the amount of plant-available water throughout the wet season is crucial for plant growth and thus crop production. Part of the rainfall is lost directly from plant surfaces, through evaporation from the bare soil, through run-off, or due to deep drainage and only the remaining part is taken up by roots and thus feeds into plant growth. Here, we regard the total amount of water transpired in the growing season by the crop in relation to potential transpiration

as given by densely covered grass vegetation as the **water use efficiency (WUE)**. High WUE means that the crop is able to use the perhaps restricted soil moisture well, whereas low values indicate that large amounts of water are lost without promoting crop growth.

The WUE has been quantified based on the following data:

- Hydraulic properties of typical soils measured at undisturbed samples of the three core sites, Cusseque, Mashare, and Seronga.
- Modelled climate data of the core sites, 30 year period (representing 1980–2010)
- Leaf area indices measured with SunScan Canopy Analysis System by Delta-T **in situ** at characteristic land-use variants, including maize and pearl millet, under dryland conditions in various development stages as well as under irrigation.
- Plant rooting distribution and depth: data from Allen (1998) in combination with own field survey data for natural vegetation and crops.

These data were fed into the SWAP model (Kroes et al. 2008) with which the soil water balance has been calculated assuming defined vegetation characteristics on a daily basis for 30 different soil- and land use va-



Fig. 108: Typical view of a pearl millet field on deep Kalahari sands, Mashare, March 2011 (photo: A. Gröngöft).

Tab. 10: Precipitation, mean transpiration of maize and grasslands, and calculated water use efficiency.

Core site	Landscape unit	Mean precipitation (mm a ⁻¹)	Mean transpiration Maize (mm a ⁻¹)	Mean transpiration grass (mm a ⁻¹)	Water use efficiency (%)
Cusseque	Summits	945	114	600	19
Mashare	Old floodplains	581	162	449	36
	Kalahari sandveld	581	159	425	37
Seronga	Old floodplains	570	158	406	38

riants. The advantage of the modelling approach is the possibility of generating knowledge for a long period under different environmental settings. However, not all conditions and processes are covered in the model; for instance the fact that dry spells within the growing season may lead to a breakdown of the vegetation, and that weeds in between the crops need additional water. Also, knowledge about root distribution within the woodlands is sparse.

A typical view of a pearl millet field at the end of the growing season (March) is given in fig. 108. The low density of millet plants is characteristic, also leading to low yields (Groengroeft et al. 2013). Under those or comparable conditions, the mean transpiration of maize over a period of 30 years is given in tab. 10.

For the dryland sites in Namibia and Botswana, of the mean annual precipitation of nearly 600 mm only 160 mm are used by the field crops. The availability of water is much higher in Cusseque, based on the subtropical climate conditions not controlling plant growth. Unproductive water losses occur through evaporation (about 270–320 mm a⁻¹ under maize dryland conditions, and 60–150 mm a⁻¹ under natural grass- or woodlands) and through recharge to the groundwater (about 500–550 mm a⁻¹ under maize dryland conditions, and 230–270 mm a⁻¹ under natural grass- or

woodlands). The high proportion of loss due to evaporation is directly linked to the density of plants, and thus the leaf area index is used as input variable for the modelling. The WUE could be substantial higher if no other factors restricted crop growth.

Based on the measured organic carbon and macronutrient supplies of the soils in the core sites, the potential yields of maize have been calculated (QUEFTS model). The calculations revealed that potential annual yields are restricted to 320 to 680 kg ha⁻¹ of grain for Mashare (Kalahari sandveld) and Seronga, respectively, if no fertilizer is applied. The yields are limited by the low nitrogen content of the soil.

Combining the above information, it is evident that at all study-site yields could be substantially increased even with small amounts of nitrogen fertilization. This is practiced by the local farmers in Mashare using the Conservation Agriculture approach, where nitrogen is added from cattle dung. The subsequent denser plant coverage on the fields reduces evaporation and improves the WUE.

Link to data and further readings: Soil raw data can be retrieved in OBIS; detailed results of the soil water balances see Landschreiber (forthcoming).

A7) Active microbial communities mediate nutrient release and recovery potential. They are affiliated with soil type, land-use type, and water availability, and are especially adapted to high temperatures.

The major nutrients carbon, nitrogen, and phosphorus form the molecular basis of functional life on Earth. Microorganisms account for a similar biomass on Earth as that of all animals and plants together. Therefore, microorganisms are an important reservoir of carbon, nitrogen and phosphorus.

Besides their role as a nutrient reservoir, soil microorganisms are the key players in the biochemical cycling of carbon, nitrogen, and phosphorus, as they directly affect the degradation of complex soil organic matter, and nutrient release from manure and crop residues, and thereby the soil fertility and recovery potential. Microorganisms initialize the breakdown of soil organic

matter by the secretion of so-called exoenzymes. After the degradation of complex organic compounds, smaller compounds are transported into the bacterial cells, further transformed and finally provided to the soil community including plants.

However, knowledge about the environmental drivers influencing and affecting the biochemical cycles, the microbial community – and thereby the nutrient content – is scarce, especially for subtropical savannah soils.

Within the TFO project, we have examined the soil microbial community in Cusseque/Angola, Mashare/Namibia, and Seronga/Botswana under different environmental

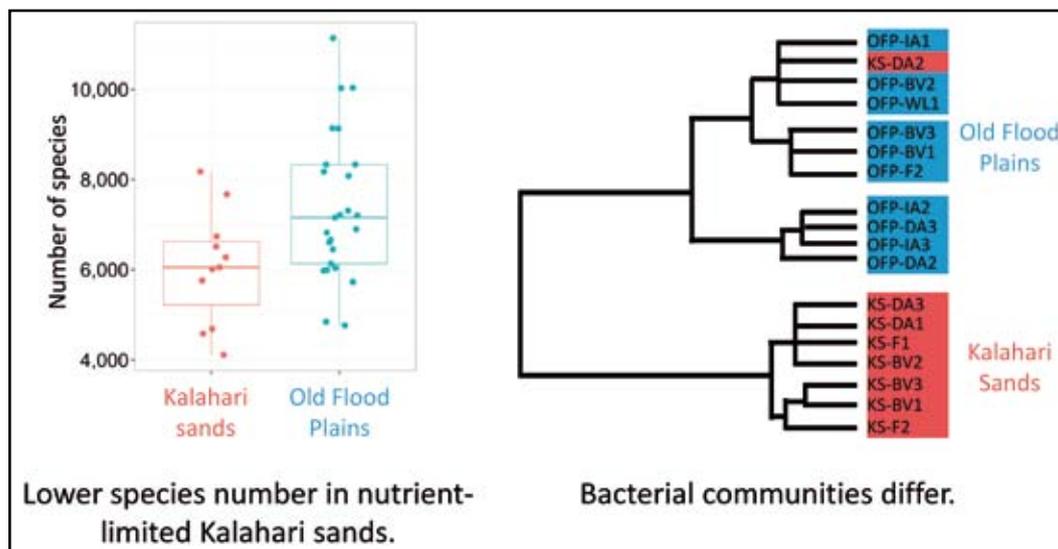


Fig. 109: Influence of soil type on bacterial diversity in subtropical savannah soils.

parameters such as water availability, sampling time point, land use type, and soil type to identify the main environmental parameters affecting the active soil microbial community and therefore the biogeochemical cycles.

The analyses of bacterial high-throughput sequences deriving from subtropical savannah soils showed that the diversity of the soil microbial community is dependent on the prevailing soil type and land use type. Soils richer in nutrients, like the old flood plain soils of the Okavango River, display higher cell numbers and higher diversity values than those poorer in nutrients, like the Kalahari Sand soils. This may also affect the biochemical cycles (fig. 109). In addition, the land use type clearly affected the composition and the activities of the bacterial community as well. While bacterial cell numbers and diversity, as well as gene activity related to nitrogen cycling, are highest in pristine woodland and bushveld savannah soils, these numbers decrease with increasing anthropogenic impact on the soils, reaching comparable lowest values in the agriculturally used fields. A major activity in the microbial nitrogen cycling in these soils is nitrification, the conversion of ammonia to nitrate. This may contribute to N losses, because this form of nitrogen is easily washed out in sandy soils.

Comparative analyses of soils sampled after the rainy season with the same soils collected after the dry season confirmed that the active microbial community in subtropical savannah soils changes with the seasonal varying water availability in soils. During drought, mainly bacteria which are adapted to the hot and dry conditions in

the subtropical savannah soils show activity, while the overall microbial diversity decreases due to water stress. Adaptations include the formation of resistant forms like spores. As a result the activity of the soil microbial community, and thereby the microbial-mediated nutrient release, is also decreased during dry periods, as mostly only the well-adapted microorganisms survive these extreme conditions.

The phylum *Acidobacteria* is widespread in different soil habitats, where they can constitute up to 70 % of the active microbial community, although only a few representatives of this phylum have been validly described. Especially subdivision 4 and 6 *Acidobacteria* are thought to play an important role in the nutrient cycling and nutrient recovery process of subtropical savannah soils. Attempts to isolate subdivision 4 and 6 *Acidobacteria* and their further physiological characterization showed that these *Acidobacteria* have the potential to affect nutrient cycling. *Aridibacter famidurans* and *Aridibacter kavangonensis* were isolated from Namibian soils during the TFO project, and participate in the nitrogen cycle as they synthesize nitrogen-degrading exoenzymes. In addition, these newly isolated *Acidobacteria* strains might be well adapted to the hot and dry conditions in the subtropical savannah soils, as they are able to display a thickened cell wall to protect cells from desiccation and allow their further participation in the nutrient cycle of subtropical savannah soils.

Link to data and further readings: Whitman et al. 1998; Huber et al. 2014.

A8) Symbiotic nitrogen supply may be enhanced by inoculant application, which increases cowpea yields.

Under dryland agricultural conditions in the area studied, yields of the smallholders' farmers are commonly low and mostly nitrogen-limited. As fertilizers are not applied in traditional cropping systems, soil fertility used to decline

with the duration of cropping (see key finding A4). Nitrogen is unique among the other essential nutrients because N_2 from the atmosphere can be fixed by biological nitrogen fixation (BNF) into an utilizable form. This pro-

cess is exclusively carried out by specific microbes (prokaryotes) that possess the enzyme nitrogenase. Some plants live in symbiosis with these microbes by forming root nodules that deliver nitrogen to the plant and indirectly enhance the nitrogen content of the soil. The potential to improve the nitrogen supply of crops can be employed by using plants of the family *Fabaceae*; however, the success depends on the intensity of effective nodules. The studies within the TFO project revealed:

- a) Pulses or grain legumes as protein-rich food and for improvement of soil nitrogen are present: Local protein-rich pulses with the potential to improve soil fertility and yields are: in the Mashare area, cowpea (*Vigna unguiculata*), Bambara groundnut (*Vigna subterranea*), peanuts (*Arachis hypogaea*); and in the Cusseque area, also common bean (*Phaseolus vulgaris*). However, nodulation with effective nodules was often found to be poor in the Namibian Kavango area and Cusseque. Here, inoculant technology of the seeds with symbiotic bacteria, which is commonly used in other countries to improve nodulation and thus nitrogen fixation of pulses, is seen as a future possibility.
- b) Novel species of climate-adapted symbiotic bacteria for root-nodule symbiosis are to be applied: Adapted bacteria may be especially relevant for the Okavango region with its harsh climate, high temperatures, and dry seasons. From our screening of nodules of local pulses, we isolated a wide range of nodule symbionts (Grönemeyer et al. 2014a) belonging mostly to the genus *Bradyrhizobium*. Several putative novel species could be characterized, which were different in Namibia and Angola; the Namibian isolates shared an exceptionally high temperature tolerance, but none of the isolates showed considerable adaptation to drought (Grönemeyer et al. 2014b). The temperature tolerance may provide an advantage to the bacteria to help it to survive in soils and perform well in symbioses even at high soil temperatures.



Fig. 110: Improved nitrogen status (green colour) of cowpea after inoculation with *Bradyrhizobium* in N-free pot cultures (photo: B. Reinhold-Hurek).

- c) Namibian Type Culture Collection of Microorganisms as a bioresource started: The relevant strains have been deposited for future teaching and biotechnology uses at the newly founded Namibian Type Culture Collection of Microorganisms (NTCCM) centre at UNAM, Windhoek, Curator Prof. Percy Chimwamurombe.
- d) Yield increases using cowpea with inoculant technology confirmed: In pot experiments, the most competitive and effective strains have been identified for cowpea in Namibia and Angola (fig. 110). First field experiments with peat-based *Bradyrhizobium* inoculant in Mashare (MITC and MADI) showed promising results. Yield increases can be obtained, especially when low doses of phosphate fertilizer (2 kg of P per ha) are applied. Pilot experiments at Mashare showed 120–180 % increased bean yield with rhizobial inoculant in phosphate-fertilized plots; in comparison to plants not treated with P or bacteria, yield increases as high as 130–380 % were obtained.

Link to data and further readings: Grönemeyer et al. 2013; Grönemeyer et al. 2014.

A9) Fertilization and irrigation may counteract the negative effect of tilling on microbial activity and nutrient recovery.

Subtropical savannah soils as found in Cusseque/Angola, Mashare/Namibia, and Seronga/Botswana are often nutrient-limited. Especially low amounts of the major nutrients carbon, nitrogen, and phosphorus limit the biomass production, and thereby also the crop yields of these soils.

As shown in key finding A7, microorganisms play an important role in the global biogeochemical cycles, and are able to sustain soil fertility. Microorganisms initialize the breakdown of soil organic matter by the secretion of exoenzymes to degrade complex organic compounds from plant and animal residues and mediate the release of ammonium and nitrate from complex nitrogen compounds by ammonification and nitrification. Ammoni-

um and nitrate are the preferred nitrogen compounds which can be taken up by plants and the soil community in order to form biomass and thereby crops. Therefore, nutrient recovery potential in soils is directly affiliated with the activity and the population size of the soil microbial community.

However, the conversion of pristine land to agriculturally used fields, and especially the process of tilling, dramatically affects the soil microbial community. Tilling destroys the microhabitats of microorganisms, and so changes the diversity and activity patterns of the soil microbial community and nutrient recovery potential. The removal of crops, the lack of added manure or crop residues, and the decreased nutrient cycling by micro-

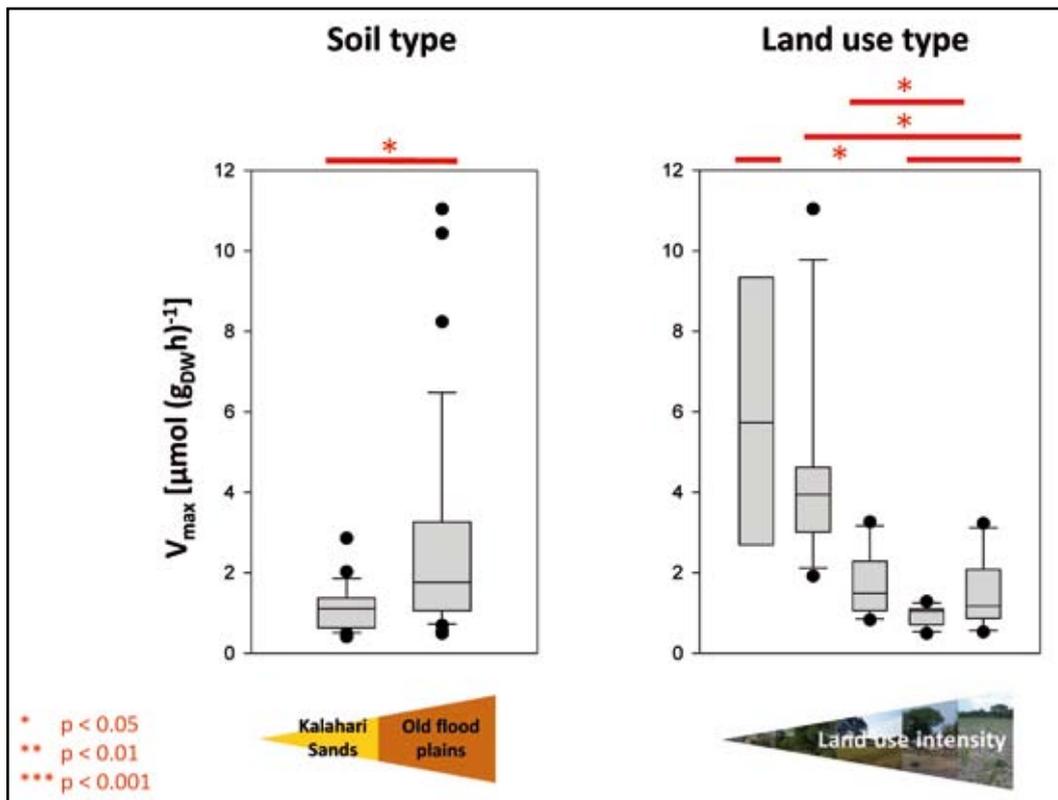


Fig. 111: Degradation potential of complex organic compounds in subtropical savannah soils.

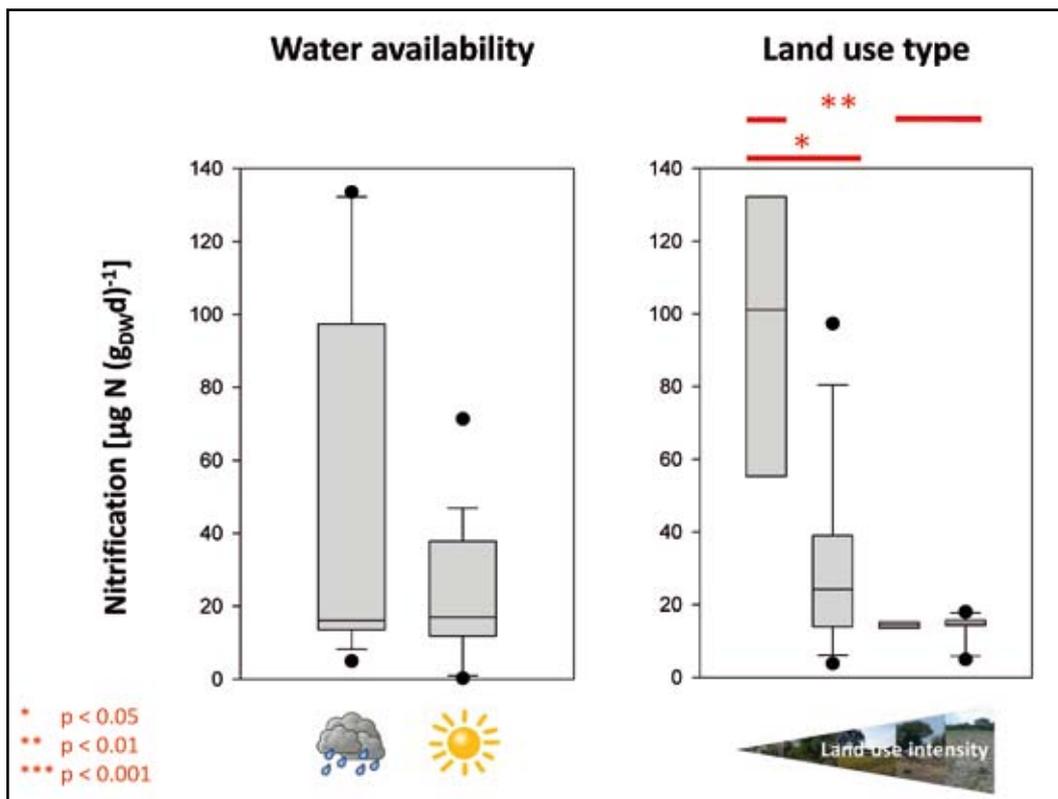


Fig. 112: Nitrogen transformation rates determined in Namibian soils.

organisms result in a dramatic decrease of fertility in agriculturally used soils of the inherently low-fertility subtropical savannahs.

The determination of the activity of four different exoenzymes and ammonification and nitrification rates in

subtropical savannah soils confirmed that the degradation potential of complex compounds and nitrogen transformation rates, as well as the gene activities of the responsible microbes, are indeed dependent on the land use type and water availability. In pristine woodland and bushveld savannah, soils with a low anthropogenic

impact were found to have higher degradation and nitrogen transformation rates than soils in the agriculturally used fields with a high anthropogenic impact.

To counteract the negative anthropogenic effect on the microbial activity and nutrient extraction by harvests in agriculturally used fields, nutrients like carbon, nitrogen, and phosphorus, and water have to be provided from external sources to the soil's microbial com-

munity, or rather to agricultural crops. The addition of manure or crop residues and a regular irrigation of the fields will sustain the remaining microorganisms so they can degrade complex organic compounds and release the important nitrogen compounds ammonium and nitrate from organic material, and therefore sustain soil fertility.

A10) Under current cropping systems, a decline in land availability leads to a depletion of soil fertility.

The current traditional cropping systems in the mid- and lower basin are fairly recent, and on the basis of interviews with local traditional authorities can be traced to the 1920s at earliest in Mashare, and to the 1990s in Seronga (when cropping replaced livestock keeping or fishing as the main livelihood strategy). These cropping systems were often established by migrants coming from the wetter Northern part of the basin (Angola) where, due to the abundance of land, shifting cultivation is practised successfully and results in reliable and sufficient yields per cultivated area. The mid- and lower basin offers only marginal conditions for cultivation, where erratic rainfalls induce a high risk of harvest failure, strongly limiting the ability of farmers to experiment and improve the system.

As a result, the current rather young traditional systems of the mid- and lower basin continue to depend mainly on fallow as their prime fertility management measure. The other management practices in these systems are insufficient for the regeneration of soil fertility. This means that the fertility of soils depends on the availability of land. However, several factors limit the availability of land: **(i)** rising rural population density, **(ii)** limited availability of fertile soils (in Cajundo, Mashare and Seronga) and **(iii)** monopolization of rural land via a few capitalizing entrepreneurs from both the urban centers and rural communities (spatial expansion of cash cropping). In all our study areas, the soil fertility of dominant parts of the landscape is very low (see key finding A4). Especially in the land-scarce mid-river areas of the basin (e. g. Mashare), farmers are increasingly forced to convert these areas for crop production. This is symptomatic for fallowing-systems where insufficient land is available for fertility management. If no additional fertility-management measures are introduced, widespread soil degradation in the form of nutrient losses will occur. Consequently, farmers are trapped in a



Fig. 113: Soil profile on an acre at core site Mashare – deep, sandy, humus- and nutrient-depleted (photo: A. Gröngröft).

cycle of poverty and resource degradation, and lack the knowledge and financial means necessary to break the degradation cycle. Thus, acute investment in agricultural knowledge systems adapted for these areas is needed. This requires government support, and the governments will need to invest in smallholder agriculture.

Link to data and further readings: Qualitative interview data are not available due to confidentiality agreements. The discussion of outcomes is given in Kowalski (forthcoming).

A11) Land degradation risk is highest in three areas of the FORA: West of the core site of Cusseque, around Rundu, and around Maun.

Land degradation has been a challenge for pastoralists and farmers for centuries, and according to several studies Africa is among the areas most affected. The FAO defines land degradation as the reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for the beneficia-

ries of these' (Kellner et al. 2011). In this definition The term covers a wide range of processes that potentially have a negative effect on the present land cover. While the exact causes, extent, and severity of land degradation are still contested, the degradation process usually begins with the removal of natural vegetation, and is exacerbating

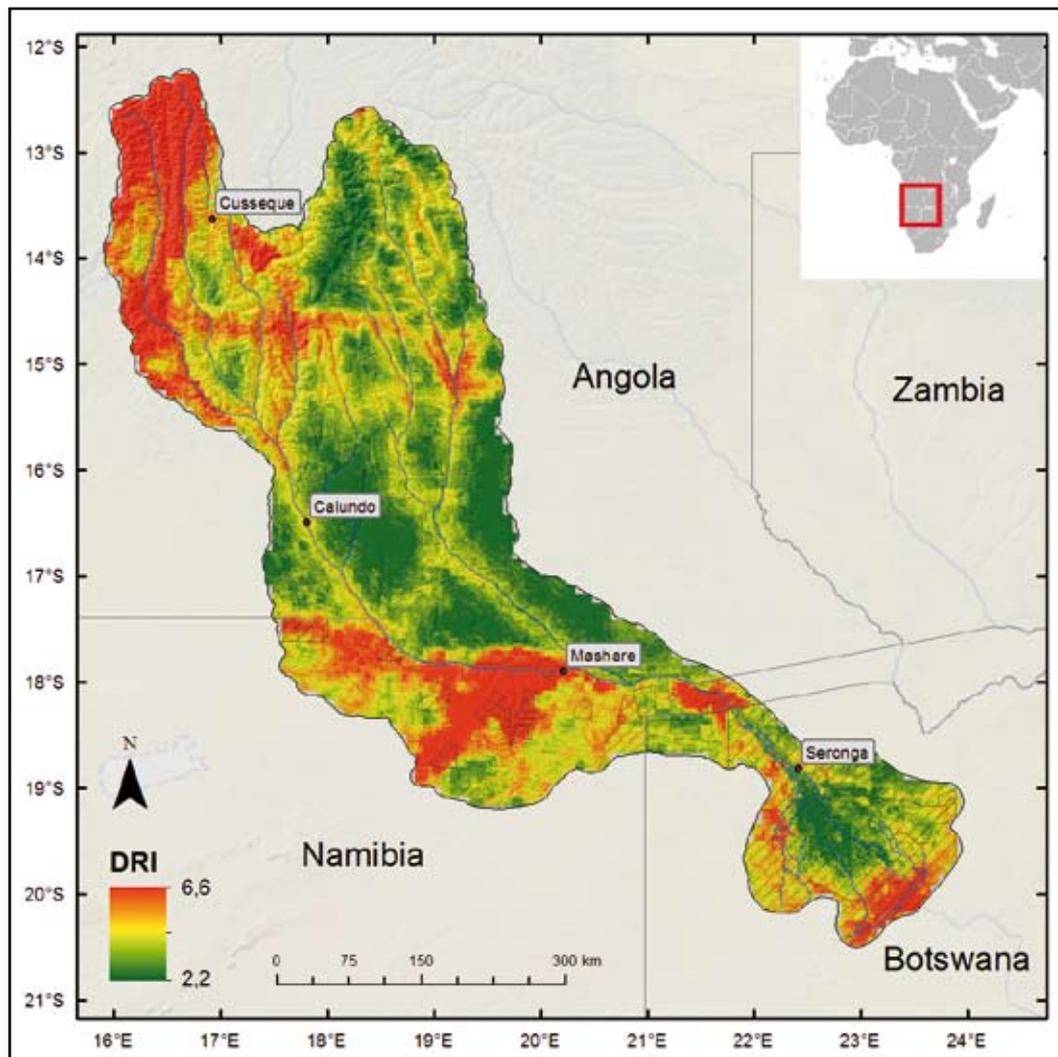


Fig. 114: Map of the Degradation Risk Index (DRI) for the FORA. Red areas comprise a high land degradation risk. Protected areas are drawn hatched.

ted by unsustainable land management practices such as deforestation, land transformation, extraction of water from the rivers, overgrazing, and overexploitation of the ecosystems. In the arid region of the Okavango Basin, it is reinforced by disadvantageous climate conditions such as high temperatures and low and erratic rainfall, as well as socioeconomic transformation processes such as population growth and changing consumption patterns. The complex interaction of all these factors may lead to a number of negative effects, including the damaging of ecosystems, biodiversity loss, declining productivity and agricultural yields or even the complete loss of cropland, land-use conflicts, and outmigration.

To evaluate the spatial distribution of land degradation risk in the Okavango basin, a GIS-based assessment (Weinzierl et al. 2015) of the commonly associated risk factors was undertaken. In the study, remote-sensing data were combined with regionalized climate simulations (Weinzierl et al. 2013) as well as socioeconomic and soil data. A high-resolution overview at the catchment scale is provided for decision-makers and stakeholders by identifying priority intervention areas where a long-term

decline in ecosystem functions and land productivity is most likely to occur. The approach combines 19 risk factors into seven individual ratings for topography, land cover, soil, demography, infrastructure, livestock pressure, and climate. The soil, infrastructure, livestock and demographic ratings show a very unequal distribution of risk with large, relatively clear-cut zones, whereas the land-cover rating reveals details on a smaller scale without a clear spatial trend. The topography and climate ratings show a definite north-south gradient across the catchment, which is also represented by the four core sites.

The seven ratings were weighted and combined into an integrated degradation risk index (DRI). The resulting map illustrated in fig. 114 shows that the overall land degradation risk is quite heterogeneously distributed in the basin. DRI values are lowest in the middle reaches of the river and the north-eastern part of the catchment, where neither of the individual ratings is above average. An area with high DRI can be found in the north-western part of the catchment, in the Angolan highlands of the province of Bié. Another area of high DRI is found around Rundu and along the river on both sides of the

Namibian-Angolan border. A third area can be identified around Maun at the southern outskirts of the delta. However, since it has been proclaimed a UNESCO World Heritage Site, the delta is subject to protection and management requirements that might mitigate degradation processes.

The four core sites also perform very unequally in the study: While Cusseque itself lies in an area of medium DRI, most of its surroundings append to the high-risk category. This is mainly due to the relatively high density of livestock in the area (Robinson et al. 2007) accompanied by a slightly negative NDVI trend and high relief energy. Another reason is the high accessibility from the direction of Huambo, an important hub in central Angola and the country's second biggest city. The surroundings of Caiundo show quite a low degradation risk despite a clearly negative NDVI trend. This may be due to the very low population and livestock density as well as the comparatively low accessibility. The core site of Mashare lies in a definite hot-spot comprising almost all the areas around the local center Rundu in the Kavango

RECOMMENDATIONS

Crop production by smallholders is and will likely remain the backbone of rural livelihoods within the Okavango Basin. However, cropping practices which are based on a the soil's natural fertility, and which thus depend on the potential to shift and expand the arable land into pristine areas, produce insufficient yields. Growing populations and increasing demands for cash income are additional push factors for a spatially expansive agriculture that is encroaching upon pristine habitats. A major aim for an agricultural reform and awareness campaign should therefore be to increase yields on existing dryland plots with alternative technologies (e. g. conservation agriculture including (organic) fertilization, evaporation control, improved seeds, agro-forestry). Such a shift in development paradigms is necessary due to the need to improve livelihoods for the growing rural population facing the low fertility of the majority of soils, the harsh climatic situation, the restricted possibilities for extracting surface water or groundwater for irrigation, and in consideration of the high value of woodlands. Integrated programs to further develop smallholder-oriented and locally adapted agro-ecological production systems should incorporate:

- **Identification of priority areas for agricultural use:** An identification of the areas with the highest suitability for crop production should be discussed with local communities, the relevant state authorities, and other stakeholders. In case of conflicts with communities' land rights or conservation goals (e. g. Seronga and the rim of the eastern Panhandle) a participatory strategic management-planning process is

recommended. Intersectoral integration can help to provide harmonized (dis-)incentives.

East region. Rundu has become Namibia's second largest city and developed into a hub for commercial activities and tourism. Its high accessibility through the national highways 8 and 10 as well as the Trans-Caprivi Highway, along with widespread livestock rearing and unfavorable climatic conditions, contribute towards the high rating. The core site of Seronga is located at the Panhandle in an area with low to moderate DRI compared to the western and southern parts of the delta. Major factors for this result are the low population density in the vicinity, as well as more favorable soil properties and topography.

While the utilized approach is suitable for providing an overview of degradation risk in the study area, the classification process turned out to be a crucial procedure that must be based on expert knowledge and/or statistical methods to yield reasonable results, and should be standardized for further research.

Link to data and further readings: Details regarding the climate data can be found on DVD B. Soil raw data can be retrieved from OBIS.

- **Direct and indirect support:** For many rural farmers the capacity to invest in improvement of farming practice is limited. Additional support measures should be put into action within the priority areas for agricultural use in order to improve yields and income. Support should include training and empowerment for agricultural extension service officers, and the respective improved extension services for farmers. Additionally, access opportunities for small-scale financial credits (e. g. microcredit systems for farmers) should be considered. For the priority areas, the local infrastructure, as a prerequisite for the access to markets, should be improved and maintained.
- **Research and development activities:** As improved and locally adapted farming systems have to be tested before application, agronomic field research incorporating the existing institutions like MADi and MITC should be strongly intensified. Research should include **i)** small-scale and water-saving irrigation techniques, **ii)** horticulture (home gardening) concepts focusing on vegetables and fruit trees, **iii)** pest management even in post-harvest times, **iv)** use and improved production of manure and organic residues, **v)** application of pulses like cowpea with bacterial inoculant technology, **vi)** development of pest-resistant varieties, and **vii)** combined agro-forestry systems. For the implementation of test sites, cooperation with volunteering farmers from the local villages is recommended. The analysis of farming systems needs to relate the productivity of the fields to the inputs of labour and finances.

- **Conservation agricultural (CA) approaches:** The promotion of CA farming techniques in the Kavango region by partners of the TFO project was successful; however, the participating farmers need further support in order to allow full establishment of this approach. All future research should include the CA farming system as a key option for sustainable land use in land-restricted areas.
- **Training of smallholders:** Following assessment of the local suitability, the implementation of improved agro-ecological production systems has to be implemented by training of volunteer farmers in the villages. As the training of farmers in CA practices within TFO has demonstrated, this step requires frequent contact and backstopping with the farmers. The training may be organized by adequately trained agricultural extension services or by contracted NGOs.
- **Ownership and responsibility for the fields:** Current customary and statutory land-tenure systems in all three countries provide secure land rights to farmers. Smallholders' land rights are only placed under pressure when powerful players try to acquire land. Institutions, innovations, and therefore also government support are needed to mitigate these threats. It is not clear whether a stronger formalization and privatization of land rights would decrease or increase the risk of smallholders becoming victims of land grabbing.
- **Livestock keeping:** The keeping of larger livestock, especially cattle, plays a major role in the traditional socio-ecological system. In improved agro-ecological farming systems too, the livestock may be important in terms of milk- and meat production, for ploughing and for the deliverance of nutrient-rich manure. However, with the increasing rural population, the concentration of arable lands on priority areas, and the use of woodlands for timber and other products, the livestock density may have to be reduced. Frequent livestock censuses should be used to control the development of numbers of animals in the villages of the basin. Institutions that guarantee fair and equitable access to cattle are needed. These institutions should allow for improved communal grazing management, and regularly reassess optimal communal cattle densities.
- **Monitoring:** To monitor the development of the agricultural sector in the communal areas, a continuous survey of agricultural indicators is recommended (e. g. spatial distribution of production systems, livestock densities, yields, quality of products land).

4.5 Society and Governance

S1) Natural resources are collected by 98 % of the households for the purposes of building, energy, food, medicine - and are increasingly sold for cash income. Within villages households making the most of the commercialization of natural resources are often endowed with more assets (knowledge, skills, transport possibilities, access to cash).

Natural resources continue to play a very important role in the livelihoods of households in the Okavango River Basin. In the TFO core sites of Cusseque, Mashare and Seronga, natural resources are collected by the greater majority of the households (above 98 %) for the purposes of building, energy, food, medicine, and others. In Mashare and Seronga the use of natural resources is more widespread than the practice of agriculture or cattle-keeping. Beyond the evident traditional dependence of households on natural material for their livelihoods, the collection of natural food resources has a positive energy return on investment (EROI; see tab. 11). This activity seems to be worthwhile for households even though real surpluses can only be generated by activities with an EROI higher than 5. However, the collection of natural foods, hunting and fishing are perceived by the local population as fun activities, while agriculture is considered a burden-related labour. These incentives will induce households to make use of these natural re-

sources as long as they have access to them and they are available. If this use is for household consumption only, it seems unlikely that over-harvesting will take place.

In the village of Caulolo (core site Cusseque), half of the natural resources collected are sold on the roadside. Most households engage in selling natural resources, thereby generating cash income. However, a smaller number of households sell natural resources as commercial goods in Mashare and Seronga (66 %, 12.5 % respectively). Livelihood analyses in the core sites show that a few households even rely on the retail of natural resources as one of their main livelihood strategy in Mashare and Seronga (5 % and 3.5 % respectively).

In addition, we found that specific items play a particularly important role in each of the core site societies, and these tend to have high EROIs. In Cusseque, extraction of honey, a traditional ecosystem good for the Tchokwe, amounts to 23 t and plays an important role

Tab. 11: Energy return on investment of different uses of natural resource for food.

	Seronga	Caulolo – Cusseque
Cropping	4.2	10.7
Fishing	114	1.7
Hunting	Not practised	6.3
Cattle (only meat and milk consumed)	2.4	Very little, no data
Gathering (veld food)	1.1	5.5
Honey	Not practised	25.5

in cash-income generation (11.5 t or 50 % of harvest). Charcoal extractions have developed and increased exponentially from 2012 to 2013 as well. Both activities are concentrated among a minority of households. In Mashare, the trade of thatch grass is already of high importance for 7 % of households, and fish is increasingly becoming a commercial good (with sales in Rundu). In Seronga, fish is a major contributor to food security, with 120 kg fish consumed per person per year for the whole population. However, grazing grass (consumed by livestock) is by far the most important ecosystem good, and is extracted from the environment to the extent of 18 thousand tons (!) per year. Yet, only 42 % of the households own cattle.

Our findings point to an uneven use of natural resources and ecosystem goods for commercial purposes among rural households in our investigation sites. Households making the most of the commercialization of natural resources are often endowed with more assets

(knowledge, skills, transport possibilities, access to cash) which enable them to capitalize and make a greater use of natural resources than they would do for home consumption only. For households that have access to the market, the retail of natural resources can be a springboard to a 'modern' industrial lifestyle. In parallel, there is a rising need for the sustainable management of these resources to mitigate the growing inequity and to preserve biodiversity.

Link to data and further readings: See factsheets 'The people' in Oldeland et al. (2013) for an overview of livelihood strategies (and the importance of natural resources within each of these strategies) in the core sites of Mashare and Seronga and in the Angolan community of Cacuchi. Data concerning the Angolan site of Caulolo are available on demand. Detailed results appear in two Masters theses (Holden 2015 – to appear, for the study on Caulolo; and Eigner 2012, for the study on Seronga) available on the TFO website under publications.

S2) People living in the Okavango Basin highlight the importance of a clean and healthy river. Even compared to better (or higher) economic development outcomes, the water quality and quantity was given priority, in particular downstream in the basin.

Water is the most essential resource in the Okavango Basin (e. g. RoN 2004, RoB 2010). Critical upstream-downstream interactions are linked to the impacts of development on water quality and quantity. The communities residing along the Okavango Basin depend on water for their livelihoods, and it is crucial for economic development of the riparian countries. In the near future, population growth, economic growth, and increasing urbanization will increase all three countries' demands for water, and all countries consider the Okavango Basin as an important water source (Kgathi et al. 2006). There are plans to use increasing amounts of water for irrigation, build dams and hydropower plants, and extract water to satisfy the needs of urban centres (Kgathi et al. 2006, King and Brown 2009, RoB 2010, OKACOM 2011, RoB 2013). At the same time, the growing ecotourism in the basin strongly depends on the quality and quantity of the Okavango water (Turton et al. 2003).

As such it is not surprising that in TFO stakeholder workshops, the quality and quantity of water from the Okavango was addressed as a major issue of concern, as well as the challenge of properly addressing this problem and finding improved management solutions. Particularly in Botswana, shortage of potable water in the delta was considered problematic, while stakeholders in Namibia rather addressed the challenge of capitalizing on the water. This indicates that there are perceived trade-offs between economic development and conservation of the water resources.

The Future Okavango project studied the trade-off perceptions of people living in three settlements in Angola, Namibia, and Botswana and in the largest town in the Kavango Region in Namibia. The results of a study on people's preferences for alternative development scenarios (fig. 115) provide evidence that a healthy river is considered very important all along the basin. Good river water quality and quantity is of greatest concern in



Fig. 115: Illustration of one of the presented development scenarios.

downstream Seronga/Botswana and the urban centre of Rundu in Namibia. Interestingly, people both in Seronga and Rundu are least dependent on the river for their water consumption. Here, the public water infrastructure is much better developed compared to the other sites. At the same time, downstream Seronga citizens benefit more than those in other communities from eco-tourism in the Okavango Delta. They also feel more vulnerable to developments further upstream. In con-

trast, people at the Angolan research site have a more balanced perception regarding different development outcomes. After decades of civil war they are at least as concerned about employment opportunities and public infrastructure as they are about water.

Link to data and further readings: A journal publication on this topic is forthcoming. Data can be made available on request by T. Falk.

S3) As tourists value the Okavango delta mainly for its landscape, which is based on water dynamics, the continuing water flow from the Angolan highlands is crucial for the Botswana tourism sector.

Preferences of tourists visiting the Okavango Delta were assessed with regard to the Okavango Delta's following three attributes: **i)** landscape, **ii)** wildlife species and **iii)** management of community tourism enterprises in the Delta. The data obtained in tourist interviews was analyzed using a multinomial logit model which provided the tourists' marginal willingness-to-pay for each of these attributes. Marginal willingness-to-pay is defined as the value that a person is willing to pay for an extra unit of a commodity, not its total value. A higher mar-

ginal willingness-to-pay indicates that tourists care more about a certain attribute than about an attribute with a lower marginal WTO.

These results (tab. 12) show that tourists are in favour of the current management of community-owned enterprises (they are in joint venture with private safari companies) and are not willing to contribute financially to a change of their management – indicated by a negative marginal willingness to pay (BWP -53). However, tourists stated that they are willing to contribute to the conservation of the landscape of the Okavango Delta (BWP 340 per person) and of wildlife species (BWP 266 per person). That tourists showed the greatest marginal willingness to pay for the landscape indicates that tourists value the landscape of the Delta itself more than the wildlife species that live there. As the landscape of the Okavango Delta is sustained by water from the Angolan highlands, the continuing water flow from the Angolan highlands is crucial for the Botswana tourism sector.

Link to data and further readings: Detailed results will appear in a Master thesis Matlhola 2015 (in prep.).

Tab. 12: Results from the multinomial logit model concerning the marginal willingness-to-pay of tourists in the Okavango basin for three aspects that are relevant for tourism in the delta.

Variable	Marginal WTP (BWP / Botsw. Pula)
Management	-53
Landscape	340
Wildlife	266

S4) Differences in perception about the land-use system of the ORB and in priorities for land use shape the stakeholder landscape. A discussion around the underlying values is necessary to achieve sustainable land-use planning and development.

River basin land-use management in a transboundary setting involves a large number of actors from different countries, active at various scales (local, regional, national, basin) and with specific sectorial backgrounds. We investigated how this diversity of actors is at the source of myriad different perceptions about

the land-use system in the ORB, and what the consequences of the co-existence of these perceptions have on management of land use and potential conflicts. Data consist of the responses to 80 interviews with stakeholders from the whole basin (fig. 116), analyzed with content analysis.

Based on stakeholders' perceptions of the land-use system in the basin, we identified 6 stakeholder profiles (Fischer and Young 2007) – the investor; the coordinator; the conservationist; the resource- or land user; the civil servant; and the expert. The profiles prioritize specific criteria (e.g. conservation, equity, economic development, empowerment, investment in knowledge systems) affecting land use, and are correlated with the country, sector, and scale characterizing a given stakeholder (also see Hein et al. 2006). The main difference lies in the idea of development that different stakeholders embrace. More specifically, the development process that stakeholders at the national scale have in mind for the people – namely a quick transition to a cash market and industrial economy – does not correspond to the one the people have for themselves. Regional-scale actors accept the transition rather fatalistically, but are frustrated by the lack of tools, support, and empowerment they face to guide the people through this transition. This results in a mosaic of potential (5) and latent (4) conflicts (Yasmi et al. 2006) in the following 4 domains: use of agricultural and natural areas; governance; social issues; and transboundary cooperation. At the centre of all conflict landscapes we find weak governance, where corruption, bureaucracy, and lack of institutional capacity and sense of commitment can be seen as the underlying cause of many of the issues at stake. The conflicts involve stakeholders operating at specific scales and within specific sectors. The most severe inter-scale conflicts concern the actual management of agricultural and natural areas, where decisions taken at the national scale are perceived as favouring conservation or agro-industrial projects, imposing restrictions on traditional subsistence activities of the riparian communities at the local scale. The most generally perceived inter-sectorial conflict involves mainly the

55) Households in Namibia as well as in Botswana suffer from low incentives to invest in education due to poor labour-market integration and high costs of education. Land-allocation institutions worsen deterrence in the Namibian Kavango, while in Botswana the emphasis on potential land users' qualifications encourages investments in education.

The Socio-Economic Baseline Survey (SEBS) undertaken by TFO, as well as data from the 'Core welfare survey' 2009/2010 (Government of Botswana 2013) and the 'Household income and expenditure survey' 2009/2010 (RoN 2013) show that average education levels are higher in Seronga (Ngamiland in general) than in Mashare (the Namibian Kavango) while both subregions suffer from high drop-out rates in junior and senior secondary education.

Thus, the question arises as to how school-enrollment rates can be improved in both regions. In addition, the factors driving the difference in education levels between both regions need to be identified. These questions have been addressed by institutional economic models (Azebaze et al. 2015, Azebaze 2015).

Both regions have a similar schooling system and comparable levels of costs associated with school attendance.

Scales	Countries			Total
	Angola	Namibia	Botswana	
Basin	2	4	4	10
National	8 (7)	6	5	19 (18)
District/region /province	12 (10)	12 (10)	9 (8)	33 (28)
Local	11 (9)	8 (6)	9	28 (24)
Total	33 (28)	30 (26)	27 (26)	90 (80)

Source: own. Numbers indicate the total number of valid interviews. The number of interviews transcribed and used in the study is indicated between brackets

Fig. 116: Interviews across scale and country. Numbers indicate the total number of valid interviews. The numbers in parentheses indicate the interviews that were successfully transcribed and used for this study (80 in total).

agriculture, tourism, water, and lands ministries/sectors around the issue of weak implementation and/or absence of policies and regulations. These perceptions are linked with values about what is good or bad for the society and why, which stakeholders have developed personally in the context of their shaping environment (social relationships, political and/or personal interests and knowledge and value systems).

Link to data and further readings: Qualitative interview data are anonymous and cannot be made available to the public due to our agreement with the interviewed stakeholders. Related findings include the ranking by importance by the stakeholders of 12 ecosystem services: data are published in Domptail and Mundi (2013). More detailed results of this finding can be read in a Master thesis (Tello 2015 – to appear, on TFO's website under publications).

Therefore, the difference in school attendance must be caused by other factors. One possible explanation relates to the land-allocation institutions in both countries. In the Namibian Kavango the allocation of land rights for residential, grazing, and subsistence cultivation purposes is performed by traditional authorities. Application for land-use rights is a simple process for people living in the community. The traditional authority in most cases approves requests by local applicants, taking other villagers' interests into account. In contrast, for people not belonging to the particular settlement, customary law follows a complex registration procedure. In the same style, the customary inheritance system in Namibia is still strongly influenced by the community-focused rights-to-avail principle. Under customary law, land rights can only be inherited by people who were already living on the land when the rightful owner passed away. Relatives who were

not living at the place of the deceased are considered outsiders. Thus, access to land is a closed-shop issue within villages, where costs of entry and exit are high.

In comparison to Namibia, Botswana has made more radical changes in its land administration. It was the explicit objective of the Tribal Land Act of 1968 to move the powers of land administration from traditional authorities to land boards (Kalabamu 2000). These are impersonal structures which free up land administration from social networks and community ties. Their main duties are to allocate, change, and cancel land rights for residential, grazing, cropping and business purposes. Any transfer of land through gift, inheritance or exchange has to be authorized by the land board. The same rules of land allocation apply to transfers within a village or even within a family as they do to village outsiders. Applications for gaining access to land are evaluated based on the applicant's personal land-use record, which includes the number and type of land plots the person already owns as well as proof of land-use abilities. However, while the more formalized system has the advantage of a higher level of transparency compared to the Namibian system, it comes at a cost in terms of accessibility. The process is rule-based and therefore connected to administrative effort; in addition, the next land board is not as close as the traditional authority in charge would be.

S6) Cooperation norms within communities in Seronga and Mashare are strong, and people respond to both customary and statutory law in natural resource management.

Communities in the Okavango Basin collectively manage and use natural resources. The success of cooperation and collective action in natural resource management strongly depends on social norms and a governance framework which includes institutions of different origin, and customary and statutory law.

Southern Africa has a long history of legal pluralism and constitutionalism, where customary and statutory laws coexist. Meanwhile, in Botswana and Namibia formal laws control and limit the capacity of traditional authorities to enforce customary laws. In particular, state authorities transferred powers of land administration from traditional authorities to land boards through the Tribal Land Act of 1968 in Botswana and the Communal Land Reform Act of 2002 in Namibia (Mapaure 2010). These policies are justified with reference to a strong criticism of traditional authorities not meeting modern democratic expectations (Cousins 2002).

These features of the land-allocation mechanism result in different incentives to invest in education: In a system that is based on formal qualifications schooling has a higher value than in a system that puts higher emphasis on personal relations. In addition, the consequences of increased mobility associated with higher levels of education are smaller in Botswana's system than in Namibia, as children who have left the village to enter the formal labour market are able to return more easily.

The difference in the land-allocation mechanisms also has consequences for the development of soil productivity: It is relevant due to the subsistence-based agricultural practices. Whenever a field is losing its fertility, a new field is cleared. Upholding this pattern is much easier under the Kavango land-allocation system than it is in Botswana. The high cost of bureaucracy associated with the land-transfer mechanism in Botswana provides incentives for land holders to invest in maintaining the fertility of their fields. Consequently, the technology for enhancing long-term soil fertility is more readily developed and accepted in Botswana.

Link to data and further readings: Access TFO Socio-Economic Baseline Survey (2011) – Household dataset via OBIS.

Nevertheless, traditional authorities are well accepted and supported in their communities (Hinz 2003; Oomen 2006) and play an important role (Hinz 2000, Falk 2008), fulfilling far-reaching functions and resolving conflicts (RoN 2002a). Their legitimacy and efficiency depend on the values and morals of their respective communities (Hinz 2003; Oomen 2006).

In order to develop a better understanding of cooperation norms in the communities and of the acceptance of different governance structures, we conducted a public good experiment which involved playing a simple game representing a real-life situation that embodied a social dilemma in a collectively managed community project in Mashare, in Namibia, and Seronga, in Botswana. In the game the community can yield higher benefits if all community members agree to cooperate by contributing a part of their endowment for the common goal than if each individual engages in the activity entirely for her/his own private interest.

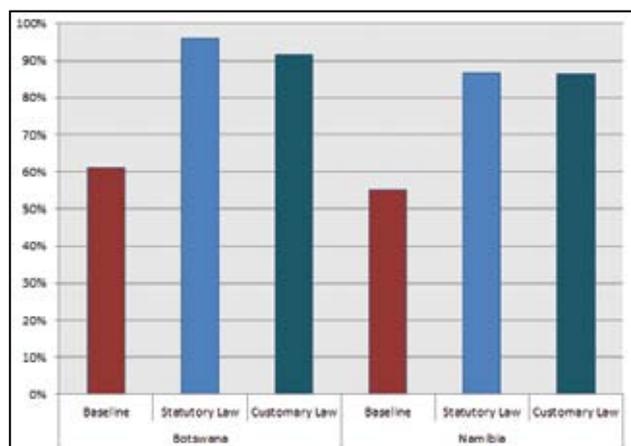


Fig. 117: Average contributions in the public good game.

Our results (fig. 117) give evidence of a strong cooperation norm as people in Seronga contribute more than 61 % of their endowment, compared to 55 % in Mashare. To analyze whether people are more likely to follow an identical rule either enforced by customary law or statutory law we introduced a rule to the game demanding full contribution to the community project. The rule is enforced by customary law for one part of the community and by statutory law for the other part, with a monetary punishment for members who decide not to follow the rule. People equally responded to both customary and statutory laws by increasing their contributions and following the rule in the management of the community project. These results indicate that an identical rule is equally accepted regardless of its origin. One can argue that the fear of punishment accounts for the increase in cooperation. Our findings do not give evidence of how effective the two bodies of law are compared to each other in real life, as we would need to consider that customary and statutory laws are based on different mechanisms and frameworks.

The support of traditional leaders is at least partly also the result of costly and weak provision of institutional services by existing state structures in rural communities (Oomen 2006). If the state, as management authority over communal land, does not have the financial or human resources to control and satisfactorily enforce national laws (Campbell et al. 2002) communities often rely more strongly on their traditional leaders to perform institutional functions (Corbett and Jones 2000; Team 2003).

Considering the limits of the ability of the state authority to ensure legal justice, to monitor and enforce statutory law, well accepted, visible, and accessible traditional authorities with specific local knowledge and located in within the communities (Oomen 2006; Hangula 1995) can still play an important role in providing institutional services.

Link to data and further readings: Data can be made available by L. Brown.

57) Local land users experience material and immaterial values of nature in everyday activities.

Stakeholders in the Okavango Basin value nature both for material (e. g. food, timber) and immaterial (e. g. belonging, religious) ecosystem services. Those services are typically not experienced in separate places and at separate times (e. g. work and leisure), but simultaneously, e. g. while fishing (fig. 118). Thus, changing land use and economic activities will not only change the material services attached to them but also the immaterial services provided during those activities or in those places (Baptista 2013, Pröpper and Haupts 2014, Rieprich and Schnegg 2015, Schnegg et al. 2014).

Link to data and further readings: A report of SP06 containing key findings, abstracts of all publications and links to the sources can be found in the appendix.

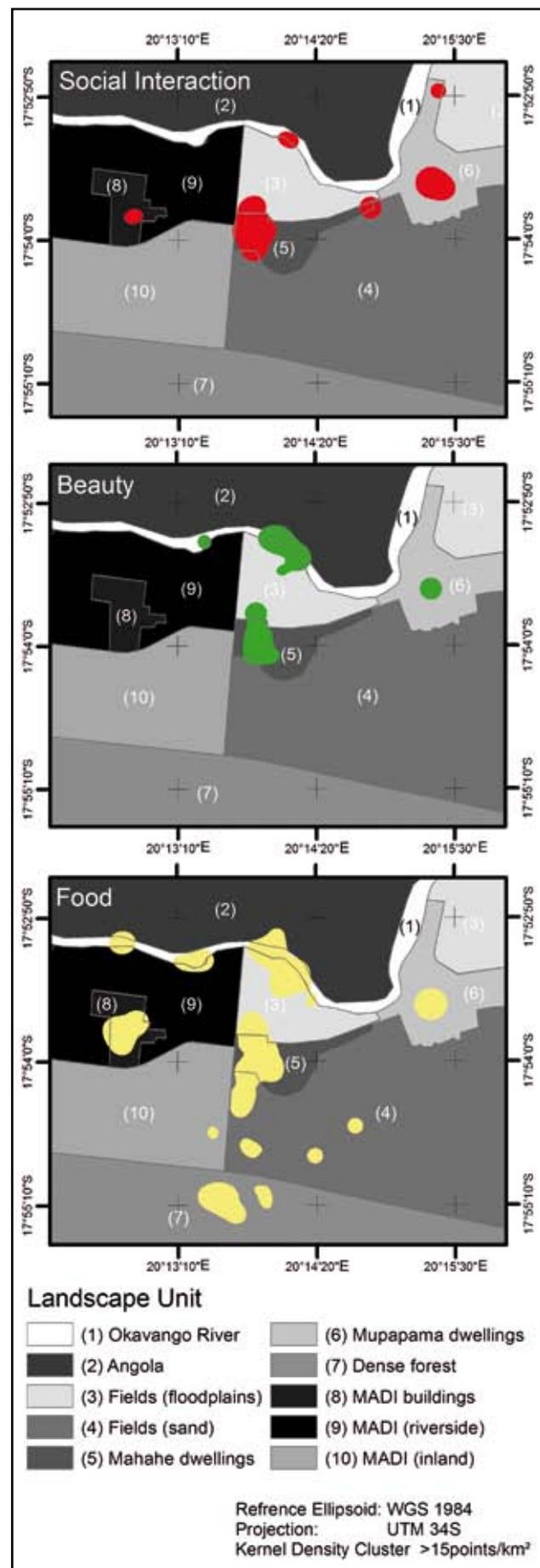


Fig. 118: Kernel density clusters for social interaction (red), beauty (green), and food services (yellow) in Mashare, Northern Namibia (scale 1 : 100,000; cell size 50 m, search radius 300 m).

S8) Under global transformations people and households increasingly face trade-offs between goods from nature and goods from other sources. This affects their valuations, livelihood strategies, and also their consumptive behaviour with regard to their main form of capital – natural resources.

People in the Okavango Basin perceive their lives as being shaped by poverty, lack of jobs and deficits regarding development (electricity, health, education), and as part of a world that seems to be transforming towards ‚modernity‘ with increased levels of consumption of things and services that are coming from ‚outside‘ (‚non-ecosystem-services‘). Our interviews have shown that many people perceive a need and even feel a desire to become part of ‚modernity‘ and ‚progress‘ (Baptista forthcoming, Pröpper et al. 2013, Pröpper in prep). In a setup that was formerly dominated by subsistence, cash-incomes have now become enor-



Fig. 119: Bundles of grass piled up alongside a Kavango road for trade (photo: A. Gröngroft).



Fig. 120: A group of people harvesting timber illegally for commodification (photo: M. Pröpper).

S9) Environmental rules and laws are insufficiently enforced.

TFO's governance analyses confirm that both statutory and customary authorities feel responsible for regulating natural resource management throughout the Okavango Basin (Kgathi et al. 2011, Röder et al. 2015). In particular, Namibia has a well-developed

and very progressive system of environmental laws (Falk 2008). In addition, there are also very sophisticated customary laws with regard to natural resources (Hinz 2010). Nevertheless, it has also been observed that the effectiveness of different rules and

ously important. Cash is suddenly needed for all sorts of purposes (school fees, water fees, electricity, health, communication) including to meet new desires for consumer goods (artificial hair, cell phones, air-time, modern food, TVs etc.). That means that people have started revaluing their own lives with reference to those who have been successful in adapting to modernity (Herold et al. 2013, Pröpper et al. 2013). Envy and jealousy and increasing social stratification (the drifting apart of rich and poor), the splitting up of families, and the ongoing individualization especially among the youth, are some of the consequences of this process (ibid.). Another is the widespread occurrence of the phenomenon of witchcraft, impacting on all sorts of intra-familiar, intra-village and general social and economic decisions (Pröpper 2010).

In sum, what happens is that people revalue some modern items and practices, e. g. the practice of subsistence agriculture, which young people prefer not to undertake any more (Pröpper in prep.). They overvalue things that they do not have. By the same token they tend to undervalue many of their natural resources (Pröpper and Haupts 2014, Pröpper 2015). These things and services from nature are often being used and sold without even knowing their exact value; e. g. planks of timber, wild medicine, thatch grass (Pröpper 2015). This whole process is driven by changing global structures and the advance of capitalism, and by an economic model that so far seems to be the main paradigm for environmental political decision-making. It is certainly enforced by dysfunctional regional and local institutions and authorities whose performance clearly differs between the three countries (Udelsmann, Rodrigues and Russo in prep.) and who, in short, do not perform effectively in the service of their citizens (Röder et al. 2015). For example the regulation of water (Green Schemes) and of land (hinterland farms) – which are common properties – is not being undertaken to the benefit of the majority of the people.

Link to data and further readings: A report of SP06 containing key findings, abstracts of all publications, and links to the sources can be found in the appendix.

laws related to natural resource management varies greatly. While the regulation of land access functions relatively well, the coordination of logging, grazing, grass cutting, fishing, water pollution, and hunting is rather ineffective (Pröpper 2009). In a situation of ecological and socio-economic challenges it is often certain experimental and free-riding personality types who tend to decouple individual choice from problem awareness and the social control-setting (Pröpper and Vollan 2013). As a result, at least partially, resources are extracted and managed in an unsustainable way (Falk 2008).

On the one hand, insufficient enforcement results from a lack of capacity among lower-level authorities (Cardenas et al. 2000). Trials in courts, imprisonment, and the collection of fines are expensive. Nature conservation has not yet come to be of the highest priority for most enforcement providers. Keeping the police and courts busy with the investigation of illegal logging or fishing prevents them from following up on capital crimes. Line ministries are insufficiently staffed with field guards (Pröpper 2009). In 2003, five law enforcers of the Directorate of Forestry/Ministry of Agriculture, Water and Forests had to control an area of almost 50,000 km² of relatively inaccessible land. Traditional authorities on the other hand have



Fig. 121: Freshly cut tree trunks in the forest (photo: M. Pröpper).

been increasingly weakened in their capacity to regulate natural resource management. Nevertheless, the wide community is still largely following customary law as far as it is in line with their deeply rooted cultural norms and beliefs. If this is the case they are also prepared to use social sanctions to ensure compliance (Falk 2012, Pröpper and Vollan 2013).

Link to data and further readings: Falk (2008), Falk et al. (2012), Kgathi et al. (2011), Pröpper (2009), Pröpper and Vollan (2013), Röder et al. (2015).

S10) *There is a need to develop more effective and inclusive water- and land-related policies and strategies for the sustainable use of water and natural resources of the basin. The inclusion of local stakeholders in this process would strengthen the role and function of transnational institutions.*

Focusing on governance with respect to water and natural resources in the Okavango Basin, the research leading to this key finding relied on earlier research that revealed weaknesses in national water law and in the laws governing natural resources in Namibia (see cited literature). The political anthropological field work (e. g. interviews) of the TFO project (conducted along the border between Namibia and Angola on both sides of the river) produced a very complex picture with regard to the use and management of water and the natural resources related to the Kavango River, of which the following two aspects are to be highlighted:

The answers of traditional leaders, government employees, farmers, harvesters of natural resources, and herbalists to questions about access to water, the rules to protect water and other natural resources, the role and function of governmental water management, the role and function of traditional leaders, and the working of water committees showed not only a wide-spread awareness about the need to develop more effective policies and strategies for the sustainable use of water and natural resources of the basin, but also indicated the potential ability of the people to engage themselves in those policies and strategies.

Since October 2013, meetings at village level were held on both sides of the Kavango River to discuss problems with respect to the use of the river, its waters, and natural resources. These transborder activities sought to establish commonly applied rules to protect the Kavango River and its resources. The activities were carried out in the understanding that the Kavango River was ‚our river‘ in the interests of which ‚we‘ were called upon to act so that the river, its water, and its resources would be better protected than they had hitherto been. A catalogue of 16 rules was established, distributed to the villages concerned, and discussed. The rules provide for the control of traffic on the river and the harvesting of its natural resources. To what extent it is possible for the rules agreed upon in principle to be implemented remains an open question. The transborder consultations under the traditional leadership from both sides of the river continue, and are certainly a challenge to the national (Namibian and Angolan) policies, but also to international arrangements, such as OKACOM.

S11) Societies in villages are in a transition from a homogeneous agrarian to a more connected but increasingly unequal state.

Not only agricultural systems, but societies as a whole seem to undergo a transition from an agrarian society (with a strong hunter-gatherer component in Seronga) to a connected society making use of modern (i. e. mainly fossil) energy sources and materials, exchanging goods on the cash market and thus entering the industrial stage. This change seems to be sudden when it happens (e. g. in Cusseque, with the tarred road connection and the rise of charcoal production) or latent and waiting for an impulse (e. g. in Seronga, where isolation due to a bad road connection and weak property rights currently maintains a farming system which is highly energy-inefficient; see key finding A2). These changes also affect the livelihood strategies of households.

While in Cusseque households' livelihood strategies and wealth are currently still rather homogeneous and sustainable (without considering the rise of charcoal production in 2014), in Mashare and Seronga, where soils are poor and in part degraded, current traditional rainfed farming brings low and erratic harvests. Here, access to any resource (cash income, natural resources, oxen for draft power) is of key importance for keeping oneself out of poverty. Yet in these villages, 22 % of households (both in Seronga & Mashare) depend almost exclusively on cropping (mostly without draft power) and only some complementary foraging for their survival. In both villages, a new group of non-farmers is emerging, in which one can find both the 'employed upper-class people' and the 'very poor' – the latter with almost no access to any livelihood option. This points to a diversification of livelihood strategies which can be seen as an indicator for the increased scarcity of resources in these areas. It also supports the theory that households may be caught in poverty traps in degraded ecosystems, and we observe the stratifi-

cation of households (rich vs. poor) within villages (See Ruthenberg 1971, Barret 2008). In both sites, we also found households whose livelihood strategies rely strongly on natural resources resale. Cash and assets obtained from off-farm (temporary) employment (S1) could fuel this tendency by increasing the harvest capacity of households or individuals. Households combining livestock (cattle) and cropping are far less widespread than commonly assumed, as they constitute only around 35 % of the total.

While growing market integration offers a chance for households to integrate themselves into the modern cash and consumption society, it is also a threat to some households in a context of unequal access to cash and draft assets, and of increasing scarcity of land and natural resources. Households compete to deal with these challenges with varying degrees of success – some benefit, some suffer from increasing scarcity. If not mitigated by appropriate institutions, this process may be self-reinforcing and lead to a growing gap between the rural rich and poor (by allowing successful households to further intensify their resource use while reducing the available natural resource base that poorer households are dependent upon; see also key finding A 1).

Link to data and further readings: Kowalski et al. (2013), Domptail et al. (2013), Grosse et al. (2013), Pröpper et al. (2013).

RECOMMENDATIONS

Ecosystems and social systems in the Okavango Basin are interwoven in very complex ways. People certainly do have economic relationships with the wider biotic world (extracting food, fodder or fibres) but also have perceptive, bodily, emotional and spiritual connections with the landscape (senses of home, beauty, belonging, sociality etc.). All these factors shape their values and may influence their decisions and actions with regard to ecosystem services. Furthermore, these interactions have to be seen as embedded in a globalizing world that rapidly transforms, and which demands similarly rapid adaptations to these changes.

Thus, a responsible and social governance policy is faced with the challenge of identifying value-based decisions and frame conditions under which the extraction of

goods, and the conversion and the destruction of ecosystems can be mitigated while taking into account the holistic nature of human valuation and environmental action. Based on these premises we can offer the following recommendations:

- **Policy answer to globalization:** The significant and rapid advance of modernity comes along with **1)** a transformation of formerly cashless land-use systems based on subsistence towards cash-markets, and **2)** unprecedented levels of consumption of all sorts of new global goods requiring the input of all sorts of natural resources. This process requires a political mitigation or intervention. Decision-makers should take into account the material and immaterial values of existing ecological and socio-cultural systems. The

advance of markets and investors purchasing land and natural resources or importing commodities offers short-term monetary opportunities, but also poses threats. We have emphasized the many and potentially costly processes of cash-driven commodification (charcoal, thatch, timber, honey). Development should not be considered only as driven by economic and cash-market-based values and incentives, but also in terms of the continuous functioning of social-cultural systems and the ecosystem. However, local land users must also be challenged to think and act about their natural resources and accept their responsibility to apply sustainable farming and extraction methods, to ask for appropriate prices for their products, and demand decent services from their political and traditional leaders.

- **Diversification and stratification of livelihoods:** Policy supporting rural development should acknowledge the diversification of household livelihood strategies and the issue of (in)equity and social stratification within villages, in terms of wealth as well as the use of and access to agricultural assets and natural resources. One consequence of the diversity of livelihood strategies among rural households is that a focus only on agricultural development alone – crucially important as it is – will be insufficient (see above). Additionally policies should secure more livelihood options (e.g. the regulation of casual labour, labour opportunities in the agro-industrial sector). Importantly, there may be interactions between livelihood options which may affect the outcomes of policies in unexpected ways, e.g. the fact that access to cash may increase the collection of natural resources. Thus, holistic approaches for rural development and natural resource use are required for policy design.
- **Institutional change and incentives:** Traditional and modern rules regulating the access to and the harvesting of natural resources need to be harmonized and strengthened. Institutional change is required in particular where new market opportunities encourage the commercialization of natural resources. This situation represents both an opportunity and a risk. Commercialization of communal resources might lead to unsustainable extraction rates by a few at the cost of the community. At the same time some new market incentives and sustainable income options can reduce incentives for land transformations if, for instance, the income from managed forests is increased. As these are new challenges, both customary and statutory law must respond to such dynamics and develop regulations which ensure sustainable resource use and protect the resource rights of all community members without removing useful incentives and motivations.
- **Education and land allocation:** Education and training are of the utmost importance. A land allocation system that requires formal abilities has shown to increase the motivation to invest in education. Therefore embedding formal qualifications into customary land allocation mechanisms could provide additional incentives to invest in education. Such transformations should, however, be based on a consensus within communities as they may discriminate the poor. Incentives following from land-allocation mechanisms should be taken into account when designing innovation-enhancing programs. The introduction of a grant system to support schooling can facilitate innovations and reduce dependency on low productive subsistence agriculture.
- **National service and education institutions:** The performance of agricultural extension services and other statutory land-user education and awareness-raising tools is poor. It has to be significantly improved and broadened to cover issues such as sustainable consumption and sustainable intensification, especially taking into account the complexity of land-use decision-making e.g. by planning a long-term agrarian reform.
- **Relation between traditional and national laws:** Taking into account that it is especially costly for the states to provide institutional services in rural areas, the harmonizing of customary and statutory law can be an effective means to monitor and enforce natural resource laws. In particular in the context of community-based natural resource management programs such as community forests or conservancies, by-laws should be developed in an open and participatory way. By-laws which are more strongly based on deep-rooted norms can be enforced at very low cost by the community itself. A consequent subsidiary enforcement system is recommended. Within defined frames, communities should be given authority to determine and enforce their own laws. In cases when norms and social sanctions are insufficient to ensure environmental law compliance, the state should reliably step in. Awareness-raising, ownership, and knowledge transfer should play an additional role in the whole process.
- **Conflict management on land use:** Priorities for land-use management and related perceptions of stakeholders of the land use in the Okavango River Basin are country-, scale- and sector-specific. These differences may hinder the development of a shared vision for land use, and thereby also the implementation of successful land-use management, by creating conflicts. In particular, it is necessary to recognize in each conflict what values are at stake (e.g. ‚smallholder agriculture is a motor of rural development‘ vs. ‚urban employment is the motor

of rural development, while smallholder agriculture only a means of keeping people out of poverty for the time being') and what scales are involved, in order to establish inter-scale, international and inter-sectorial communication towards a solution. This can be done by creating/facilitating a dialogue among stakeholders around these values, rather than around applied land-use decisions (e.g. how much funding should be dedicated to smallholder agricultural improvement) because land-use decisions follow from values stakeholders attach to given development options.

- **Trans-national cooperation:** Compared to other river commissions in southern Africa, the Permanent Okavango River Basin Water Commission (**OKACOM**) is showing poor performance indicators. It has a weak mandate and does not fulfill its envisioned advisory role. Committed state-based funding, independent of donor support, and a stronger mandate are needed to promote coordinated and environmentally sustainable regional water-resources development, while addressing the legitimate social and economic needs of each of the riparian states. At the same time more local transnational cooperation can be observed with communities negotiating customary natural resource management laws across borders. The inclusion of local stakeholders in trans-border negotiations which aim at the protection of water and natural resources on both sides of the river can potentially strengthen the role and function of OKAKOM.

The key findings and recommendations have been compiled by an interdisciplinary team (see below). The data on which they are based were provided by the TFO-consortium listed in detail in Chapter 8.

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Chapter 5

Trends of possible future development

5.1 Genesis, logic and definitions of scenarios

Scenarios can be defined as ‚plausible and often simplified descriptions of how the future may unfold based on a coherent and internally consistent set of assumptions about key driving forces, their relationships, and their implications‘ (Henrichs et al. 2010). Importantly, the aim of scenarios is not to make predictions or forecasts, but to investigate possible futures, and at best cover a broad array of possible futures in order to prepare decision-making.

The scenario exercises in TFO aim to generate knowledge² that contributes to the preparation of decisions about land- and water management in the catchment. Scenario-building in TFO was used to synthesize data, as it used common questions regarding land-use, ecosystem services, and well-being at the local and catchment scale to organize research data and to provide answers. Another objective was to **communicate research data** to stakeholders in a format that fosters the **building of opinions** about what type of land-use stakeholder's desire in the future, and why.

For this purpose, the scenario building was carried out as an interdisciplinary exercise, within a team of 26 researchers drawn from all TFO subprojects, disciplines, and countries. Our approach follows that adopted by the Millennium Ecosystem Assessment (2005). It comprises several steps, including (1) the definition of the scope, aims, and scales of the scenarios; (2) a system analysis for identifying key variables and drivers affecting land- and resource-use in the Okavango Catchment; (3) the identification of critical drivers in terms of impact and uncertainty; (4) deciding on the scenario logic; (5) the drafting of the scenario storylines, and (6) the evaluation of the impact of these storylines on the ecosystem services and well-being in the basin.

Since the scenarios address possible developments in land- and resource-use in the Okavango Catchment they consider the transboundary context in which the river flows from Angola via Namibia to Botswana as well as the interactions and relationships between the local and larger scales, in order to understand how decisions made at a given scales may impact other scales. Therefore, we adopted a multi-scale approach in which the analysis is carried out both at the catchment scale and the local scale – i. e. at the three TFO core sites Cusseque, Mashare, and Seronga.

The scenarios at both scales address the focal question: **How will land-use, ecosystem services and well-being change between now and 2030?** We opted for the development of exploratory scenarios, which use the present situation as a starting point and explore how the future may develop under different sets of assumptions. The scenarios were not developed during a participatory exercise, but rather as a scientific output of the TFO research project, with the aim of achieving high consistency between the analyses of the local and basin scales. However, stakeholder knowledge was included where the identification of key variables and drivers of land and resource-use was concerned: Ninety face-to-face interviews were carried out in all three countries at the local, regional, national and catchment scales (fig. 122). This published information was integrated into the system analysis (Domptail and Mundy 2013). The data documented perceived drivers and key variables, land, resource-use, and wellbeing variables, visions, and knowledge about land-use-related projects and plans.

In a subsequent step, the key drivers of the system were identified by ensuring that all variables affecting the ecosystem services analyzed by TFO were considered and that all important drivers were pinpointed. The variables were described thoroughly in an interdisciplinary effort (see ‚List of Variables‘ in the annex). The interaction between these variables was evaluated using an impact matrix which enabled the classification of four categories of variables: **active**, **ambivalent**, **passive**, and **buffer** variables. Thus, we could structure the land-use system and identify the variables that will most likely have the strongest influence on land-use in the catchment, and thus on the provision of ESS, until 2030: progression of



Fig. 122: Face to face Interviews at the local scale (Seronga, Botswana): ranking of key ecosystem services (photo: S. Domptail).

² Socially robust knowledge is ‚shared by all stakeholders; integrates scientific and practitioners‘ knowledge, is understood and recognized by both parties and also can be used in the process of decision-making in complex situations‘.

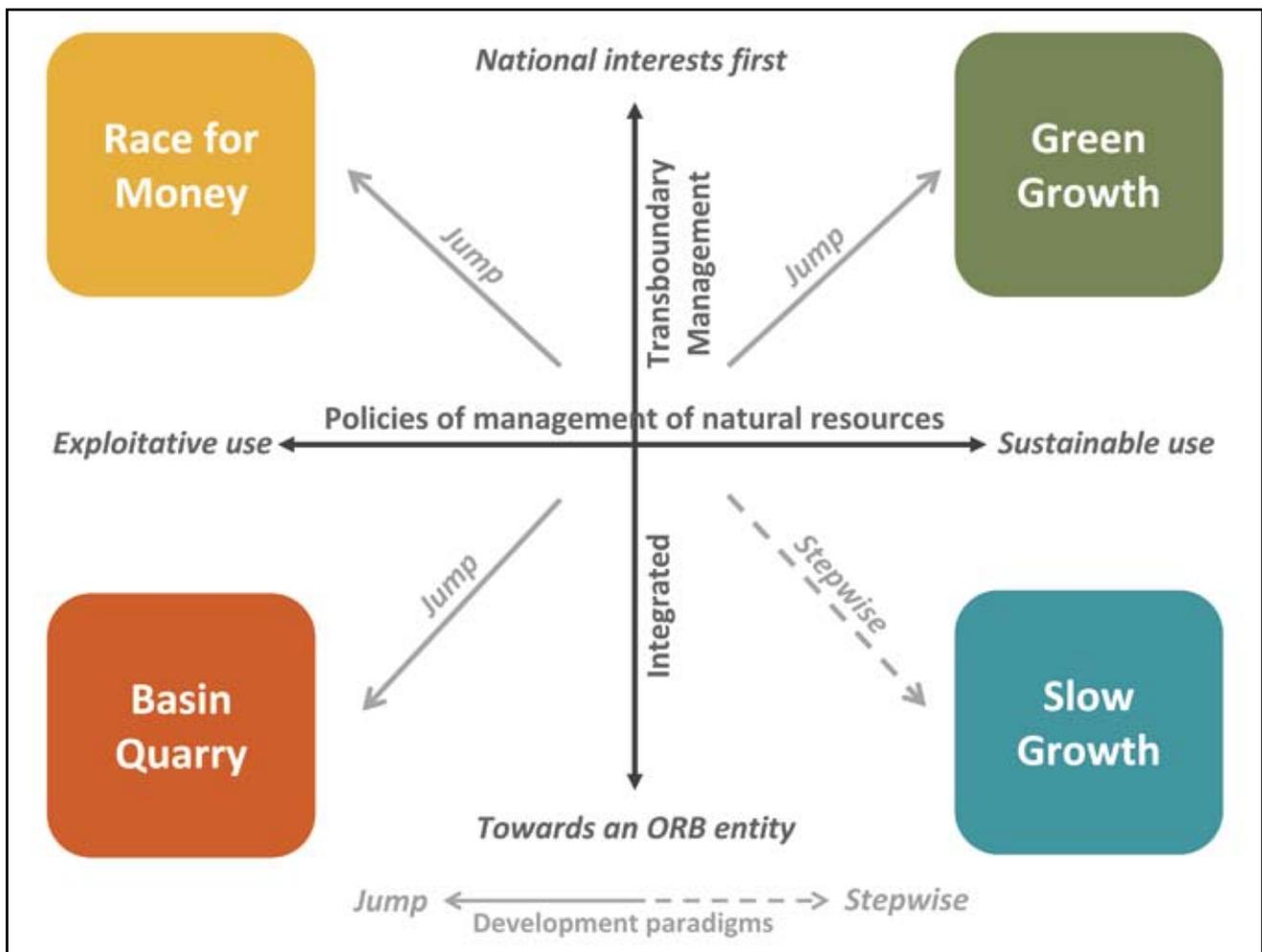


Fig. 123: TFO-scenario logic.

the cash economy; development paradigms; policies of management of natural resources; population growth; area under irrigated industrial agriculture; integrated transboundary management; and urbanization.

Exploratory scenarios follow a certain **scenario logic**. This means that key driving forces of the system whose future development is highly uncertain are combined to define different pathways into the future – which can then be described. Combining two key drivers,

each represented, for simplicity's sake, as a binary variable, as axes in a grid would result in four different pathways to be described. Thus the key variables **integrated transboundary management** (describing whether the basin is or is not managed as an economic and ecological entity, prioritized to national interests), and **policies of natural resources management** (describing whether a sustainable or exploitative management of natural resources is or is not applied by the govern-

Tab. 13: Assignment of the third key variable, development paradigms.

<p>Scenario 1: Race for Money</p> <ul style="list-style-type: none"> • National interest first • Exploitative management of natural resources • Jump into the future (unidimensional growth-oriented policies with a focus on innovations mainly in the industrial and commercial agricultural sectors) 	<p>Scenario 2: Green Growth</p> <ul style="list-style-type: none"> • National interest first • Sustainable management of natural resources • Jump into the future
<p>Scenario 3: Basin Quarry</p> <ul style="list-style-type: none"> • Integrated transboundary management • Exploitative management of natural resources • Jump into the future 	<p>Scenario 4: Slow Growth</p> <ul style="list-style-type: none"> • Integrated transboundary management • Sustainable management of natural resources • Stepwise improvement of current situation (multidimensional poverty alleviation policies with a focus on people's current activities and expertise)

Tab. 14: Essential features of the four TFO-scenarios.

Scenario	Essential Features
1 Race for Money	No collaboration between the three countries exists. Rather, there is a fierce competition within the region to become a player in the global economy. Natural resources are mainly seen as the economic basis for development. Agro-industrial agriculture is strongly supported; smallholders will be marginalized. This will lead to lower productivity of smallholders, an increase in poverty, urbanization, and a selling-out of nature.
2 Green Growth	Each country follows its own national interests and relies on its share of the basin as a source of resources. In contrast to scenario 1, there is an increasing awareness and drive to produce, trade and export national products in a sustainable manner. Since the focus is on strong economic growth options, investments are primarily made in modern land-use practices (e. g. large-scale organic production schemes, certified commercial logging, hydropower stations). Smallholders persist in rural poverty and partially migrate towards urban centres.
3 Basin Quarry	The Okavango Basin is perceived as an economic and ecological entity. In order to promote regional economic growth, the countries preferentially exchange and market produced resources. Jointly developed land-use plans assign respective zones for agricultural, pastoral, tourism and forestry use. Since the focus is on industrialization and marketization, natural resources are increasingly exploited. Smallholders, too, are encouraged to intensify, mechanize and commercialize agricultural production.
4 Slow Growth	As in scenario 3, there is strong cooperation between the basin countries, and the basin is managed as an economic and ecological entity. A coordinated land-use plan has been developed based on comparative ecological advantages; trade between the countries is encouraged. But notions of sustainability have fundamentally changed the values and lifestyles of society. Although markets are the main economic mechanism, social, cultural and environmental values are equally important. The countries mainly promote innovations strongly linked to small-scale agricultural production.

ments) were chosen as main driving forces of the four scenario storylines (fig. 123).

Of course, a socio-ecological system that is part of global and local transformation processes at multiple scales cannot be comprehensively described using only two variables. However, the addition of any further dimensions would increase the number of possible combinations of variables, and so the future scenarios to be combined and described. This is simply not feasible, and more to the point, it would not increase the clarity of the analysis for the stakeholders/political decision-makers. Consequently, TFO proceeded in the following manner: A third, highly active and uncertain key variable, called **development paradigms** (describing whether either unidimensional growth-oriented policies or multidimensional poverty alleviation strategies are followed by the governments) was assigned unevenly (3:1) to the four scenarios, as is shown in tab. 13.

The essential features of the four scenarios are then summarized in tab. 14.

5.2 Trends of possible future developments for the Okavango Catchment

According to the logic described above, four possible alternative future storylines for the Okavango Basin have been developed.

The challenges the three countries will have to face in 2030 will include the still-high population growth resulting from both natural population growth and migration into the basin. This will be accompanied by increased urbanization, especially for the regional centres Chitembo, Caiundo, Menongue, Rundu and Maun, Shakawe, Katwitwi).

Another challenge is related to climate change: Since the climate models project less precipitation and higher temperatures causing increased evaporation from the Okavango Basin, the water availability will presumably decrease during the period from 2016 to 2046.

i The Okavango Catchment – Race for Money

Main characteristics of the *Race for Money* scenario storyline:

- Fierce competition within the region; no collaboration between the three countries exists.
- Natural resources as the economic basis for development; weakened monitoring and enforcement of the respective regulations.
- Investments in large-scale agro-industrial schemes, infrastructure, and mining.
- Traditional agricultural livelihoods will be marginalized, resulting in even lower productivity.
- Increase in poverty, urbanization, and a selling-out of nature.
- Depletion of natural resources, first noticeable with regard to water quantity and quality.

5.2.1 Scenario 1: *Race for Money*

Within this scenario we assume that **collaboration** between the three countries **is abandoned** in favour of a fierce competition within the region to become a player in the global economy. Each country tries to **exploit its national resources** to a maximum. In order to achieve this, existing environmental laws related to forest, water, and land are hardly enforced, and traditional authorities are not supported in the monitoring and enforcement of customary environmental laws. OKACOM has an increasingly weak mandate and its recommendations are largely ignored in the national policy-making. There is no regulation, transboundary water management, or agreement between Angola, Botswana or Namibia regarding the maximum amount of water which can be extracted from the rivers in the headwater region of the Okavango Basin.

Natural resources are mainly viewed as the economic basis for **development**. Depending on their respective natural resources, the three countries set different priorities: Angola aims at the development of national well-

being and wealth through modernization of the country in important sectors including infrastructure and agriculture; Namibia expands irrigation agriculture and meat production for national food supply and export markets, and Botswana continues its mining, tourism, and ranching activities.

By 2030, several **dam projects** in Angola are in the planning phase or have been realized to produce hydro-power and to store water for irrigation. Large-scale **irrigation agriculture** plots have been established, specializing in rice and citrus fruits. Foreign investors have leased large areas of arable land to produce cash crops (fig. 124). Compensations for communal land-use are based on market prices. For development aims, part of the compensation will be in the form of local education and training centres, or boreholes for arable land in the hinterland. As an additional source of income, high-end tourism will be developed in the KAZA area along the Cuito. Constraints are the still slow improvement of the traffic across borders, and the associated customs procedures.



Fig. 124: Longa rice scheme in Angola. Only one of many in 2030? (photo: M. Finckh).



Fig. 125: The breadbasket of Namibia: Irrigation scheme in the Kavango Region (photo: A. Grönröft).

In **Namibia**, large parts of the river terraces and lands adjacent to streams are transformed into agro-industrial irrigation schemes, especially in the middle catchment. The aim of the national government is for this area to become the **breadbasket** of Namibia. Therefore not only maize and wheat but also fruits and vegetables are produced, to allow the country to become more independent of imports (fig. 125). Cattle farms also try to intensify production. Since the climate models project less precipitation and higher temperatures causing higher evaporation from the FORA for the period 2016–2045, the water availability will presumably decrease until the year 2030. Taking into account the additional water extraction within the headwater catchments, the volume of water available downstream will decrease. The southern hinterlands of the Namibian Kavangos north of the veterinary fence – originally communal lands – will have been completely leased out to financially potent elites, and will be used for intensified cattle farming. As agro-industrial schemes expand on favourable soils (river terraces etc.) **smallholders migrate** for subsistence agriculture to marginal lands in the hinterland of roads and rivers, causing large-scale transformation of natural woodlands and forests.

In **Botswana**, mining is still considered one of the major economic pillars. New **mines** are established to the west (Shakawe) and east of the Panhandle, causing migration due to job opportunities as well as the development of power supply and roads in this area. **Cattle**-farming expands on the west rim of the Panhandle, and the eastern rim is zoned for wildlife-based tourism. High-end **tourism** activities continue in the delta area. Locations of tourism concessions shift slightly northwards, due to increasing drought risk and ecosystem degradation in the southern part of the delta. Major conflicts arise when, due to water abstraction upstream, less water arrives in the Panhandle, and the main economic activities of the Botswana part of the FORA will be jeopardized (fig. 126).



Fig. 126: The development of high-end tourism in the delta is dependent on a reliable seasonal flooding and a pristine environment (photo: S. Domptail).

The influx of consumer goods strongly increases in response to the growing internal demands. **Cash demand** greatly increases among the (currently subsistence-based) rural population, increasing the pressure to exploit the remaining natural resources in communal and public areas.

National policies mainly focus on promoting **technological innovations** to strengthen national economic development (hydropower, modern agricultural techniques, and infrastructure) and on supporting the respective state's connectivity to international markets (infrastructure improvement, information technology, wholesale markets). Correspondingly, the education policy strongly focuses on supporting higher education, especially in urban centres. There, a small but notable middle class has developed.

Due to the policy-makers' focus on the formal sector, no policies have been put into place with the aim of assisting smallholders. Rather, **smallholders** are seen as an obstacle to economic growth, and certainly not as part of any growth strategy. Due to the competition with agro-industrial agriculture the subsistence farmers are driven from the more productive land to the hinterland, where yields are lower. Under such conditions traditional agricultural livelihoods remain under strong pressure, with related consequences such as low productivity, poverty, **urbanization**, and commodification of nature. By 2030 we find a strong increase of urban poor living in squatter settlements around the major urban centres. Rural and, due to migration, also urban poverty levels are rising, and with them there is an increase in associated problems such as social tensions. Altogether, social inequality has increased.

Unmitigated urbanization is leading to a clearly visible spatial expansion and the related problems of localized **depletion of natural resources**, discharge of unprocessed wastes into the environment, massive demands for urban services, and an increase in the

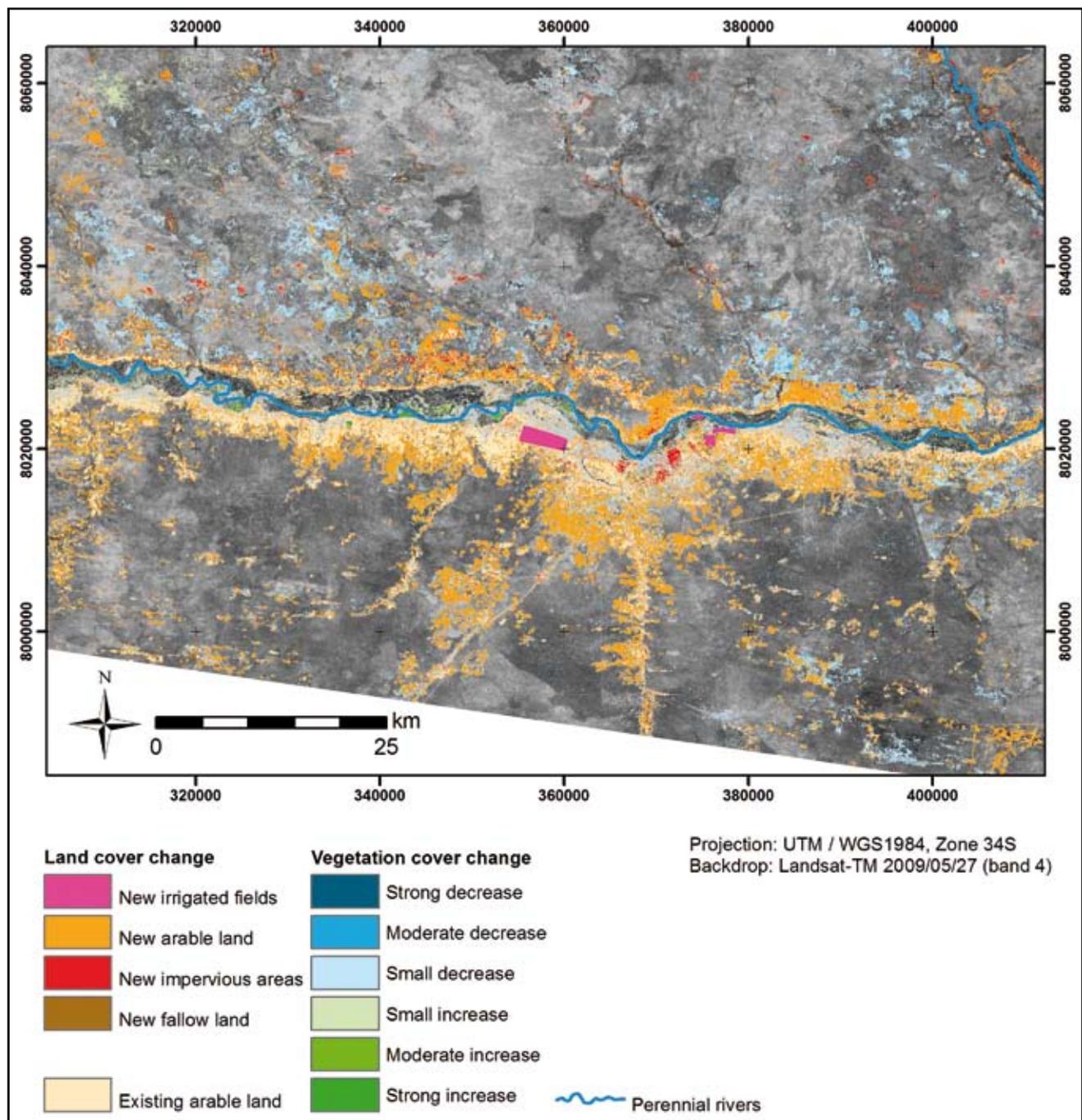


Fig. 127: Major land-use / cover conversions and modifications (irrespective of previous land-use / land cover type) for Northern Namibia/Southern Angola (including the Mashare core area). Major conversions are signified with discrete colors, modifications of savanna ecosystems are shown in graduated colors representing decreasing (blue color tones) or increasing (green color tones) vegetation cover. Stable areas are illustrated by a Landsat backdrop image in greyscale.

hazardousness of the environment in urban areas (fig. 127 and 128).

Rising population densities in marginal areas lead to high levels of natural resource degradation. Due to the lower and even more unpredictable yield, the rural poor are dependent on natural resources: the general intensification of wood extraction in communal woodlands causes a strong degradation of the remaining woodland ecosystems. Charcoal extraction leads to near-complete destruction of Miombo forests in the northern part of the catchment. Roads constitute axes for charcoal commercialization. Poaching and bush-meat trade in An-

gola remain at unsustainable levels. Game is mostly exterminated outside of the protected areas. Overfishing and unsustainable fishing techniques reduce fish stocks already affected by decreasing quality of riverine habitats and disturbed river dynamics.

The economic development achieved is to the detriment of the natural resources. Especially the greatly reduced water availability due to water abstraction, together with the expected decrease in precipitation due to climate change, sooner or later leads to national as well as political conflicts between the three countries.

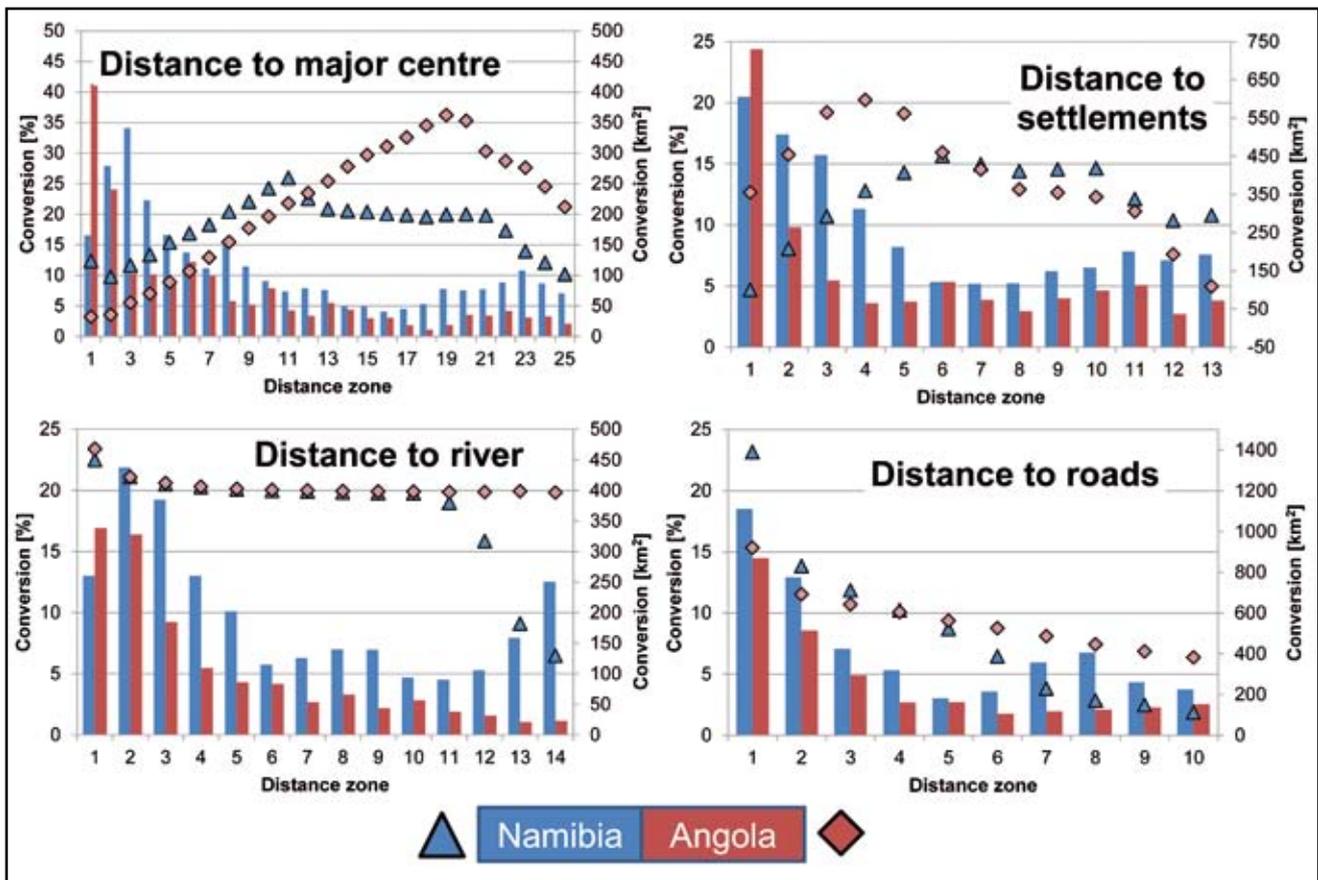


Fig. 128: Conversion of savanna to arable land for Northern Namibia/Southern Angola (including the Mashare core area) as a function of distance to the respective driving factor. Bars represent percentage of changed area within the respective distance zone; symbols show overall area (in km²). Shown are zones starting from the lowest to the first zone whose total area is below 100 km² for any of the countries.

5.2.2 Scenario 2: Green Growth

In this scenario, the three basin countries pursue their respective national interests and rely on their individual shares of the basin as a source of resources. National policies of the three countries target development with sustainable resource-use, taking into account the whole range of benefits from natural resources for both present and future generations on the local and national scales. However, they do not give any special attention to particular externalities on the catchment scale (esp. water use). OKACOM has an increasingly weak mandate. It has no funds for independent activities and its recommendations are largely ignored in national policy-making. Policy-makers make considerable efforts to increase their knowledge about the multidimensional consequences of resource-use decisions. The states give higher priority to the monitoring and enforcement of statutory and customary environmental laws. Fines and punishments are increased, and have a deterrent effect on resource-degrading activities such as illegal logging.

There is an increasing awareness of the necessity to produce, trade and export national products in a sustainable manner. But the focus is on **strong economic growth options**: All three states share the policy paradigm that

to combat poverty and promote development, economic growth, industrialization, and marketization are essential. They therefore invest in and support **modern land-use practices under consideration of ecological externalities**. Concerning agricultural innovations, environmentally friendly technological solutions (e. g. drip irrigation) are applied with a focus on high-price bio-products for export markets and national high-end ecotourism (e. g. large-scale organic production schemes, conservancies). Forest management and hydropower developments (e. g. certified commercial logging, building of dams) are decided upon, taking into account the whole range of environmental impacts at national scale (e. g. sustainable forestry oriented towards high timber quality rather than exploitation licences; small dams rather than large dams, etc.). Energy and mining investments are subject to strong EIAs. Water extraction from the Okavango does not take into account the interests of the downriver neighbours, but avoids excessive water extraction in order not to harm the green image of the export products.

Accordingly, the education policy focuses on supporting **higher education** to meet the qualified labour demands of the export sector. New job opportunities in the rural areas are created by eco-tourism and large-scale organic production schemes, as well as certified commercial

i The Okavango Catchment – Green Growth

Main characteristics of the *Green Growth* scenario storyline:

- Focus on own national interests and the use of each nation's share of the basin as a source of resources.
- Increasing awareness of the need to produce, trade and export national products in a sustainable manner.
- Strong economic growth options: Investments primarily in large-scale but sustainable land-use practices (e. g. large-scale organic production schemes, certified commercial logging, hydropower stations).
- Smallholders persist in rural poverty and partially migrate towards urban centres; overall, inequality increases.
- High competition for eco-tourists; highly diversified tourist activities.
- Natural resources protected as the basis for the economic development.

logging businesses. However, the number of new jobs in these sectors does not meet the high demand for jobs requiring little formal qualification in the rural areas.

Since the large-scale organic farms are predominantly situated within a band along the river, the remaining smallholders' access to river resources is restricted. As a consequence **smallholders** persist in rural poverty and partially migrate towards urban centres. Together with a still-high natural fertility the urban population is growing strongly, and belts of poor squatter settlements form around the major cities. Countries and regions acknowledge the need to mitigate **urbanization**, waste production, river pollution, and resource commodification, but are not able to keep up with the growing population. The tertiary sector in the cities is growing. However, the labour demand is higher for qualified staff than for rural migrants without formal qualification. Overall, inequality is increasing. The national governments try to maintain the social peace by providing baseline services in urban education and health sectors, and with subsidies for staple foods.

The three countries develop their **tourism** sectors individually and strengthen their national profiles. The national actors apply aggressive marketing strategies, creating intense competition for tourists. Tourism development is strongly driven by the aim to create maximum income with as little ecological impact as possible. The

diversity of tourism activities caters for trophy-hunting, photographic tourism, adventure tourism, angling, and cultural and educational tourism, with an eco-friendly and community-based orientation. Border crossing for tourists remains complicated, especially into Angola.

Even though conservation is considered important, no transboundary managed **conservation** areas such as KAZA are in place (KAZA). In Angola parks are established and poaching is punished. Large herbivores and predators are protected in order to foster tourism. High-end ecotourism develops along the Cuito River. In Namibia parks are maintained as they were in 2015, because the region is envisaged as the breadbasket of the nation. In Botswana too, parks are maintained as they were in 2015 in order to maintain ecotourism, which is fostered by the nomination of the delta as a UNESCO World Heritage Site.

Infrastructure development follows national business demands under consideration of environmental criteria. By 2030, Angola has caught up in its infrastructure development in terms of transport, roads, and water and energy supply, as well as communication. In Botswana the ferry in Shakawe has been replaced with a bridge, and new roads east of the Panhandle have been constructed, so villages there are now better connected and supplied. In Namibia, roads are built in order for tourists to reach the Kaudom park.



Fig. 129: The National Fresh Produce Business Hub at Rundu, Namibia. A future trading center for the export of bio-products? (photo: L. Schmidt).



Fig. 130: High-end tourism in Lubango, Angola (photo: L. Schmidt).



Fig. 131: Paving the way: tarred roads by 2030? (photo: L. Schmidt).

Sustainable forestry is promoted through the cancellation of traditional land-use rights of local communities (e. g. hunting, timber use, pasture, etc.). Natural resources outside of protected areas are sustainably managed by long-term-oriented enterprises, and deforestation decreases. New forest clearance by smallholders is suppressed (as non-sustainable) by the governments.

5.2.3 Scenario 3: *Basin Quarry*

The underlying logic of this scenario is the idea that the three basin countries come to the conclusion that **increased economic collaboration** and distributed **resource exploitation** might be the best way to maximize the economic growth potential, and thus added value, of the region for all three partners. A strongly determining factor is the paradigmatic view, shared by all three states, that to combat poverty and promote development **economic growth**, industrialization and marketization, as well as shared/distributed resource exploitation, are necessary. While the three countries remain autonomous, the basin serves as a source of resources for transboundary needs and interests. The

basin is thus perceived and managed as an economic and ecological entity (prioritized above national interests) and the countries preferentially exchange and market produced resources.

Cooperation within the basin is driven by comparative economic advantages achieved in productivity zones which are targeted to generate more income per country. A regional forum of the three countries within SADC has emerged. Integrated transboundary economic management includes a **land-use planning process** that identifies spatially optimal areas for making best use of comparative advantages (e. g. tourism in Botswana; meat in Botswana and Namibia; forestry and crop production in Namibia and Angola; and hydropower in Angola). OKACOM is relegated to the role of an environmental monitoring agency with little enforcement potential.

Stakeholders and policy-makers mainly take into account direct-use benefits from natural resources for present generations on the local, national and catchment scales. Likewise, people make no significant efforts to increase their knowledge about the multidimensional consequences of such resource-use decisions.



The Okavango Catchment – Basin Quarry

Main characteristics of the *Basin Quarry* scenario storyline:

- The Okavango Basin is perceived as an economic and ecological entity; produced resources are preferentially exchanged and marketed between the countries.
- Jointly developed land-use plans assign spatial optimal zones for agricultural, pastoral, tourism and forestry use.
- The focus is on industrialization and marketization; natural resources are increasingly exploited.
- This applies particularly to water abstraction in the upper parts of the basin leading to a significant decrease in water reaching the panhandle.
- Smallholders, too, are encouraged to intensify, mechanize and commercialize agricultural production.
- Cash demand greatly increases, increasing the pressure on natural resources.
- Unmitigated urbanization leads to the discharge of unprocessed wastes and related environmental problems.
- Mass tourist activities are concentrated in selected zones.



Fig. 132: Tarred roads connecting people and places along the Okavango River (photo M. Pröpper).

Under such a development, favouring **open internal borders and markets** (e. g. goods, labour, tourists), improved and aligned customs practices are in place – with all expectable implementation problems. No special attention is being given to putting up trade barriers against market incentives that promote exploitative NRM. In all three countries, existing environmental laws related to forest, water, and land are still hardly enforced, with the exception of cases of severe pollution and degradation.

There have been strong investments in **transboundary infrastructure** such as tarred roads, bridges, tracks, and professionally operated border points and customs services. Water abstraction and water use are primarily realized by run-of-the-river (Namibia) and conventional (Cubango and Cuito tributaries) hydropower schemes. The hydropower potential is developed to its fullest.

The favouring of cash markets, paid labour, and industrialized production systems has led to a significant structural change in the formerly subsistence-based agricultural systems. **Smallholders** are encouraged with strong (dis-)incentives to intensify, mechanize and commercialize agricultural production. The countries effectively enforce the jointly developed land-use plans. The zones for agricultural, pastoral, tourism and forestry use are strictly monitored. Environmental laws related in particular to extractive uses of forest products, water, and wildlife are, however, barely enforced.

As agro-industrial schemes expand on favourable soils (river terraces etc.) smallholders have to migrate to marginal lands in the hinterland of roads and rivers to pursue agriculture. Outside of restricted zones traditional agricultural livelihoods are further marginalized and remain under strong pressure, with related consequences such as low productivity, poverty, urbanization, and commodification of nature. Together with the installation of hydropower schemes in Angola the expansion of agricultural irrigation schemes in Angola and Namibia will lead to a decrease in water reaching the panhandle.



Fig. 133: Smallholder in the marginal hinterland of Kavango, Namibia (photo: H. Seidel).

Therefore, the decreased inflow into the Okavango Delta will affect the Delta area.

The influx of consumer goods is strongly promoted in response to the growing internal demands. **Cash demand** increases greatly among the (currently subsistence-based) rural population, increasing the pressure to exploit the remaining natural resources in communal and public areas.

The poor interplay between customary and statutory **land rights** makes communities more prone to becoming victims of land grabbing and relocation by powerful players, which reduces their incentives to engage in sustainable land management. This approach also leads to a growing inequity in rural areas, with a few wealthy farm businesses starting to cultivate more and more land for the goal of profit maximization.

Another aspect is the increasing **urbanization**, since an unmitigated urbanization rate of 3.5 % has led to a clearly visible spatial expansion and the same problems as pointed out in the previous scenario related to localized depletion of natural resources, discharge of unprocessed wastes into the environment, massive demands for urban services, and an increase in the hazardousness of the environment in urban areas.

The three countries cooperate in **tourism-related activities** and try to maximize profits from the tourist sector. To avoid conflicts with other uses of land, tourist activities are concentrated within selected zones (the delta, selected parks and game reserves). Tourism products are more diversified, and increasingly allow for mass tourism. Transborder traffic of tourists is simplified (visa & customs regulations). This approach also creates new jobs for a small share of local residents who live in the designated zones. New tourism concepts have been developed within the basin to maximize tourist numbers. The concept of transboundary management of wildlife is adhered to for profit maximization.



Fig. 134: The Okavango Delta in its pristine condition (photo: S. Dompatil).

5.2.4 Scenario 4: *Slow Growth*

The underlying logic of this scenario is that there is **strong cooperation** between the basin countries, and the basin is managed as an economic and ecological entity (prioritized before national interests). OKA-COM has been given a strong mandate. It carries out monitoring and assessment activities and its recommendations are seriously taken into account in the national policy-making.

Another important assumption is that **notions of sustainability** fundamentally change the values and lifestyles of society. Although markets are the main economic mechanism, social, cultural and environmental values are equally important. Stakeholders make considerable efforts to increase their knowledge about the multidimensional consequences of resource-use decisions. Any economic activities, and especially agricultural innovations, forest management, and hydropower developments, are decided upon taking into account the whole



The Okavango Catchment – Slow Growth

Main characteristics of the *Slow Growth* scenario storyline:

- Notions of sustainability have fundamentally changed the values and lifestyles of society. However, this development pathway has followed a slower economic growth trajectory, as the strategy of a ‘jump’ into a future of exploitative profit maximization (as described in other scenarios) could not be pursued. There is a strong cooperation between the basin countries, and the basin is managed as an economic and ecological entity.
- A coordinated land-use plan has been developed based on comparative ecological advantages; trade between the countries is encouraged.
- Conscious political decisions to mitigate the advance of global market consumerism/ market integration with its negative effects such as commodification of natural resources and waste production.
- OKAKOM facilitates a coordinated land-use plan and monitors water quality and flows, soil degradation, and biodiversity.
- The countries mainly promote innovations strongly linked to small-scale agricultural production.
- High-end ecotourism is concentrated in jointly selected zones; the local population is strongly integrated into tourism concepts.



Fig. 135: Trainings in Conservation Agriculture in Mashare, Namibia (photos: A. Gröngroft & H. Seidel).

range of benefits from natural resources for present & future generations on the local, national, catchment, and global scales. This also includes conscious political decisions to mitigate the advance of global market consumerism/market integration with its negative effects like commodification of natural resources and waste production. To foster and support such sustainable development, international donors provide technical and financial assistance. This **international aid** is coordinated between the countries.

Since the basin serves as a source of resources for transboundary needs and interests, OKACOM faci-

litates a coordinated **land-use planning** process. Zoning takes into account comparative economic and ecological advantages and encourages trade between the countries: **Tourism** in Botswana; meat in Botswana and Namibia; forestry and crop production in Namibia and Angola, and hydropower in Angola. The development of the Kavango Zambezi Conservation area is strongly linked to the strategic planning process of OKACOM.

OKACOM monitors climate, soil degradation, water quality and flows, and biodiversity in order to inform sustainable national natural **resource management** policy-making and implementation. The states give higher priority to the monitoring and enforcement of statutory and customary environmental laws. Fines and punishments are increased and have a deterrent effect on resource-degrading activities such as illegal logging.

The countries mainly promote innovations strongly linked to **small-scale agricultural** production. The underlying idea is that it has to be expected that a large number of people will live, at least in the medium term, from smallholder agriculture, and a fair approach to development must therefore improve their living conditions. More specifically, the education policy focuses on **basic education**. Smallholder farmers receive training in adapted and sustainable resource-use practices such as drip irrigation, conservation agriculture, community forest management, community-based rangeland and livestock management, or community based tourism. This kind of training can be offered to a large number of people. The interventions lead to an increase in productivity without diminishing the natural resource base. The use of biodiversity is a major asset in the development model.

Existing or newly established fields of large-scale agricultural production schemes will have to comply with the strict environmental requirements. This refers in particular to **water abstraction**, but also applies to soil- and water quality and other natural resource-uses.



Fig. 136: Mokoro trips into the Okavango Delta: Sustainable tourism concepts integrating the local population (photo: S. Domptail).



Fig. 137: Will the ferry between Rundu, Namibia und Calai, Angola soon be replaced by a bridge? (photo: H. Göhmann).

Since the development paradigm focuses on rural-based livelihoods, for a larger population **urbanization** is rather moderate. Nevertheless, the regional centres (Chitembo, Caiundo, Menongue, Rundu and Maun, Shakawe, Katwitwi) see an increase in their populations. More villages grow as they bundle new small and medium enterprises thanks to new economic opportunities. Some of them have become towns.

Nevertheless, urbanization policies avoid and mitigate localized depletion of natural resources, increased demand for energy, water, and transport, and the discharge of unprocessed waste.

In this scenario the three countries jointly develop and implement guidelines to promote high-end **ecotourism** generating maximum income with the lowest possible ecological impact. Tourism is concentrated in jointly selected zones, especially around national parks. Tourism products are diversified (photographic tourism, trophy-hunting, adventure tourism, angling, cultural and educational tourism) in order to generate maximum income from natural habitats and therefore increasing incentives to preserve them. The local population is strongly integrated into tourism concepts.

Thus, the majority of the rural households do not need to harvest **natural resources** to generate more cash because of the increased opportunities to generate income from agriculture and tourism, and the actively stimulated entrepreneurship and processing of goods.

To facilitate trade between the three countries and with neighbouring countries and to support better connectedness, the **infrastructure** is improved considerably. This includes a bridge near Rundu and additional border posts to enhance more frequent transitions between the countries. More storage capacities for agricultural products are built near the towns and bigger villages of the three countries, as are open markets to facilitate the sale of small-scale agricultural products. The use of renewable energy supply is supported.

5.3 Trends of possible future developments for Cusseque

According to the scenario logic described above, four storylines for the core site of Cusseque have been developed.

5.3.1 Future developments for all scenarios

For the period between 2016 and 2045, the models project a warmer and drier climate. The annual precipitation is expected to decrease by 50 to 150 mm and the rainy season may become shorter by up to 20 days. The annual mean temperature is projected to increase by 1.5–2 °C, and the minimum and maximum temperatures in the wet season are expected to increase by 1–1.5 °C and 1–2 °C, respectively.

At the core site natural fertility has remained high and is a prominent driver of population growth. The existing settlements have grown together, joined by small craft and repair shops serving agricultural demands, overland trade (timber, charcoal, cassava flour, etc.), and commercialization of local products and crafts. A small rural market has developed at the roadside. The urban hubs like Menongue, Chitembo, and, further away, Huambo and Kuito have experienced ongoing rapid growth, which influences other variables (e. g. cash demands, domestic energy demands).

Commercial ranching is still without relevance. The Cusseque area has remained an area without major cattle production.



Fig. 138: Women in Cusseque (photo: M. Finckh).

5.3.2 Scenario 1: *Race for Money*

Major development trends

Within this scenario we assume that the collaboration between the three countries was abandoned in favour of fierce competition within the region to become a player in the global economy. The massive expansion of the commercial sector based on the rebuilding of infrastructure and considerable external investment continues. Export-oriented irrigation agriculture of rice, corn, soy-bean, and citrus fruits expands on fertile soils. Menongue and Chitembo experience a rapid development of the commercial sector, advertising and trading all sorts of modern consumer goods. Regional political and legislative bodies clearly facilitate investments and the creation of such new markets. Urban cash-based markets have had a massive impact on the rural peripheries, and in particular the commodification of charcoal has progressed.

Effects on the core site of Cusseque

Enhanced transboundary commerce and improved road infrastructure put pressure on land resources in the southern parts of Bié. Settlements along the main road spread in the Cusseque area. Secondary earth roads and tracks expand into the hinterland of the core site, e. g from Chingueia to the upper Cusseque valley and from Satchijamba to Soma Cuanza. Boreholes for domestic water consumption are drilled in the villages, because the water quality of the Cusseque River has declined strongly due to irrigation agriculture upriver and wastewater from the settlements along the main

road. Electrification extends to the villages along the main road. Cell phone coverage extends to all villages along the main road.

Large-scale agricultural investments are actively encouraged. Investors acquire land for irrigation schemes on the sandy plains along the Cusseque River. Local farmers are encouraged to join contract-farming schemes or to work on commercial farms. Stronger actors in the local communities with access to capital or subsidies intensify the agricultural use of their fields using tractors and fertilizers and thereby enhance their yields. However, the majority of the farmers are not able to improve their household income. Semi-permanent cultivation with a strong focus on cash cropping predominates. The productivity of smallholder agriculture is decreasing. Poverty persists in the core site, and social inequity is increasing. Poor members of the communities expand the current slash-and-burn agriculture further into the hinterland. Conflicts arise between traditional authorities who aim at preserving collective land and households who want to utilize/exploit it for personal cash income generation.

Internal migration towards the urban centres is very common. However, there is also some ongoing re-migration by people to the communities, which function as a repository.

There are critical shortcomings in the sectoral integration of environmental policies. Provincial authorities allow large-scale land conversion for agricultural investments. The monitoring of environmental regulations is not given high priority. Only severe cases of pollution and degradation are taken to court. Trade of natural re-



The core site of Cusseque – Race for Money

Scenario settings:

- National interests: encourage large scale investments and create new markets.
- Weak monitoring and enforcement of environmental regulations.

Main characteristics of the *Race for Money* scenario storyline for Angola:

- Export-oriented irrigation agriculture of rice, corn, soya, and citrus fruits expands on fertile soils.
- Massive expansion of the commercial sector based on infrastructure development and external investment.

Main characteristics of the *Race for Money* scenario storyline for the core site of Cusseque:

- Secondary earth roads and tracks expand into the hinterland.
- Investors acquire land for irrigation schemes on the sandy plains along the Cusseque River.
- The majority of the farmers are not able to improve their household income; poverty persists in the core site; social inequity is increasing.
- Charcoal production has exhausted its own resources; forests have largely been replaced by smallholder agriculture and commercial plantations.
- The integrity of the landscape has been severely damaged; the exploitative use of land has destroyed the potential for future touristic development.
- The rivers lose their drinking-water quality due to pollution and water extraction.

sources like charcoal, timber and bushmeat is **de facto** not regulated. As the area of pristine land has shrunk severely, the intensity of resource extraction in the remaining natural areas has grown considerably. Charcoal production has exhausted its own resources and shifted eastwards into Moxico. Miombo forests have largely been replaced by smallholder agriculture and plantations with fast-growing *Eucalyptus* and *Pinus* species. Remaining timber production from natural forests is scarcely enough to satisfy the local demand of the settlements at the core site. Honey production has dropped severely due to the reduction of Miombo forests.

The fire regime remains more or less the same as it was in 2015, with the exception of the larger agricultural schemes in the Cusseque floodplain, which utilize controlled burning at the beginning of the dry season. The landscape integrity is strongly reduced; the formerly pristine grasslands in the valleys have been transformed into fields and fragmented. Forests have become fragmented and degraded by slash-and-burn agriculture, charcoal

production, and forest plantations. Agro-industrial infrastructure (e. g silos and hangars) and tracks further alter the landscape. Larger fauna have disappeared almost completely due to habitat losses and hunting. Endemic and sensitive species have gone altogether.

Tourism remains nonexistent in the Cusseque area, since no land was dedicated to conservation. The exploitative use of land has destroyed the potential for future touristic activities.

Due to irrigation offtake, flow of the Cusseque and Sovi River decrease by 30 % (rainy season) to 50 % of their current base flow in the dry season. The agricultural use of peatlands has destroyed both their physical buffering functions and their chemical filtering functions. The main streams are strongly affected by domestic wastewater and nutrient and pesticide input from the irrigation schemes, the river water has lost its former drinking-water quality. The spread of the settlements along the roadside causes increasing sanitary problems, especially with regard to safe drinking water.

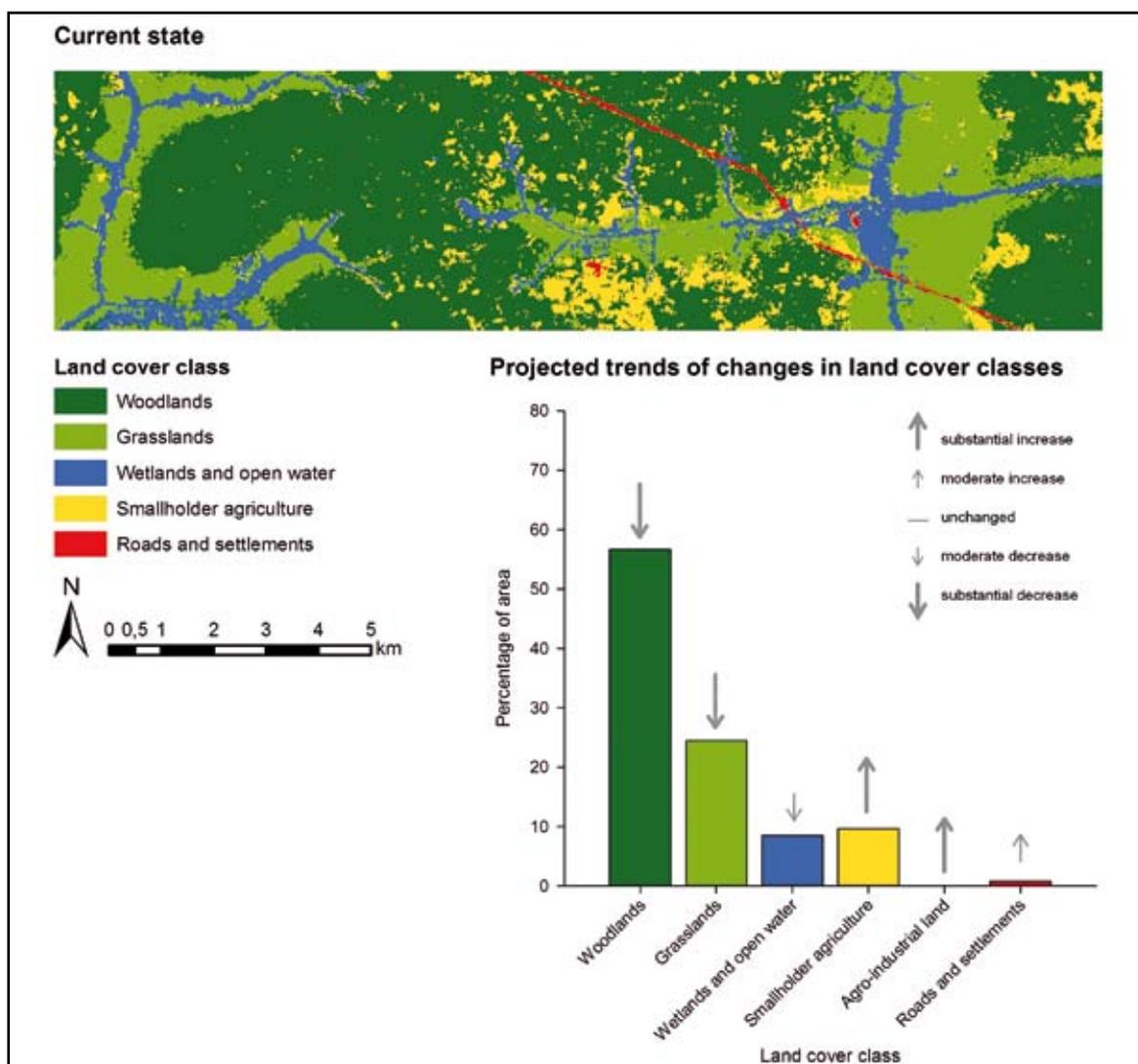


Fig. 139: The map depicts the simplified land cover classes of the core site of Cusseque at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Race for Money'. Note: The arrows indicate a relative change in their respective land cover class only.

5.3.3 Scenario 2: Green Growth

Major development trends

The Green Growth scenario depicts a future in which collaboration between the three countries is abandoned in favour of national optimization of natural resource management. Angola shares the opinion that to combat poverty and promote development economic growth, industrialization and marketization are essential. The national and regional governments actively attract investors by offering subsidies, credit, and tax reductions.

There is an increasing awareness in Bié of the necessity to produce, trade, and export agricultural and silvicultural products in a sustainable manner. But the focus is on strong economic growth options, and therefore the province invests in and supports modern land-use practices under consideration of ecological externalities. Concerning agricultural innovations, environmentally friendly technology (e. g. drip irrigation) is applied with an emphasis on high-price organic products for export markets, and on national high-end eco-tourism. Large-scale investments in 'green' investment schemes are actively encouraged, and investors acquire land for commercial but sustainable agricultural and forestry enterprises. Organic-label and fair trade certification is promoted.

The effects on the core site of Cusseque

Enhanced transboundary commerce and improved road infrastructure open new opportunities for land-use in the southern parts of Bié. Secondary earth roads and tracks expand into the hinterland of the core site, e. g. from Chingueia to the upper Cusseque valley and from Satchijamba to Soma Cuanza. These secondary roads provide access to the forest concessions in the hinterland. Boreholes for domestic water, electrification and cell phone coverage extend to all villages along the main road, in order to attract people to live permanently there all year round.

An irrigation scheme for the organic production of horticultural products is established on the sandy plains along the Cusseque River. Local farmers are encouraged to join cooperatives or to work on commercial farms. Stronger actors in the local communities with access to capital or subsidies intensify the agricultural use. They use conservation agriculture approaches with tractors and organic fertilizers and enhances their yields. Semi-permanent cultivation with a strong focus on cash cropping prevails among smallholders. The expansion of fields in the hinterland is restricted by forest management concessions for sustainable timber and charcoal production. Smallholders are therefore forced to stay on their current fields, suffering from decreasing soil fertility. Poverty persists in the core site, because the majority



The core site of Cusseque – Green Growth

Scenario settings:

- National policies target development on the basis of sustainable resource-use.
- Improvement of the monitoring and enforcement of environmental regulations.

Main characteristics of the *Green Growth* scenario storyline for Angola:

- The national and regional governments actively attract investors. Large-scale investments in 'green' investment schemes are actively encouraged.
- The province encourages modern land-use practices under consideration of ecological externalities.

Main characteristics of the *Green Growth* scenario storyline at the core site of Cusseque:

- Secondary earth roads and tracks expand into the hinterland.
- An irrigation scheme for the organic horticultural products is established along the Cusseque River.
- Forest concessions for sustainable timber and charcoal production dominate the hinterland; the expansion of fields in the hinterland is restricted.
- Local farmers are encouraged to join cooperatives or to work on commercial farms.
- Poverty persists in the core site; social inequality is increasing.
- Customary land rights are partly taken away by state authorities. Large tracts of communal land are being given to agricultural and silvicultural investors.
- Forest concessionaires restrict smallholders' access for hunting or honey production; game resources partly recover under this *de facto* protection.
- Farm-based tourism develops slowly; the sustainable land-use maintains the potential for further touristic development in some areas.
- Water quality is locally affected by pollution; the main streams lose their former drinking-water quality.

of the farmers are not able to improve their household income. Therefore social inequality is increasing.

As certified commercial logging and organic farming facilities spread in the Angolan highlands, potential drivers of smallholder market integration (such as tourist lodges, hotels, and supermarkets in the urban centres) purchase mainly from these certified producers. The market for smallholders is therefore mostly restricted to open markets in nearby urban centres, rural communities, or roadside sales. As a result of rising population densities, this market continues to grow. However, smallholder market integration will remain limited.

Customary land rights are partly taken away by state authorities. Transfers of land from communities to individuals and organizations intending large-scale commercial land-use does not depend on the approval of traditional authorities and community members. Compensations are based on governmental regulations. On the remaining communal land, traditional authorities are empowered to enforce natural resource-related customary law.

Migration towards the urban centres takes place. However due to the increased national efforts to support and improve rural livelihoods and labour opportunities e. g. in tourism, there are still many people living in rural communities, and re-migration to these communities is rather common.

Better knowledge about interactions between land-use and ecosystem functions is available at institutional levels. On this basis, the local administration pushes investments in innovative land-use schemes, taking into account ecological concerns. Large tracts of communal land are being given to agricultural and silvicultural investors. Significant efforts are made to improve the monitoring and enforcement of environmental regulations. Standardized procedures for environmental impact assessments, resource extraction, and pollution control are carried out by specialized staff, particularly on commercial farms and forest concessions. On the local level, traditional leaders are pushed to enforce the laws restricting unsustainable resource management.

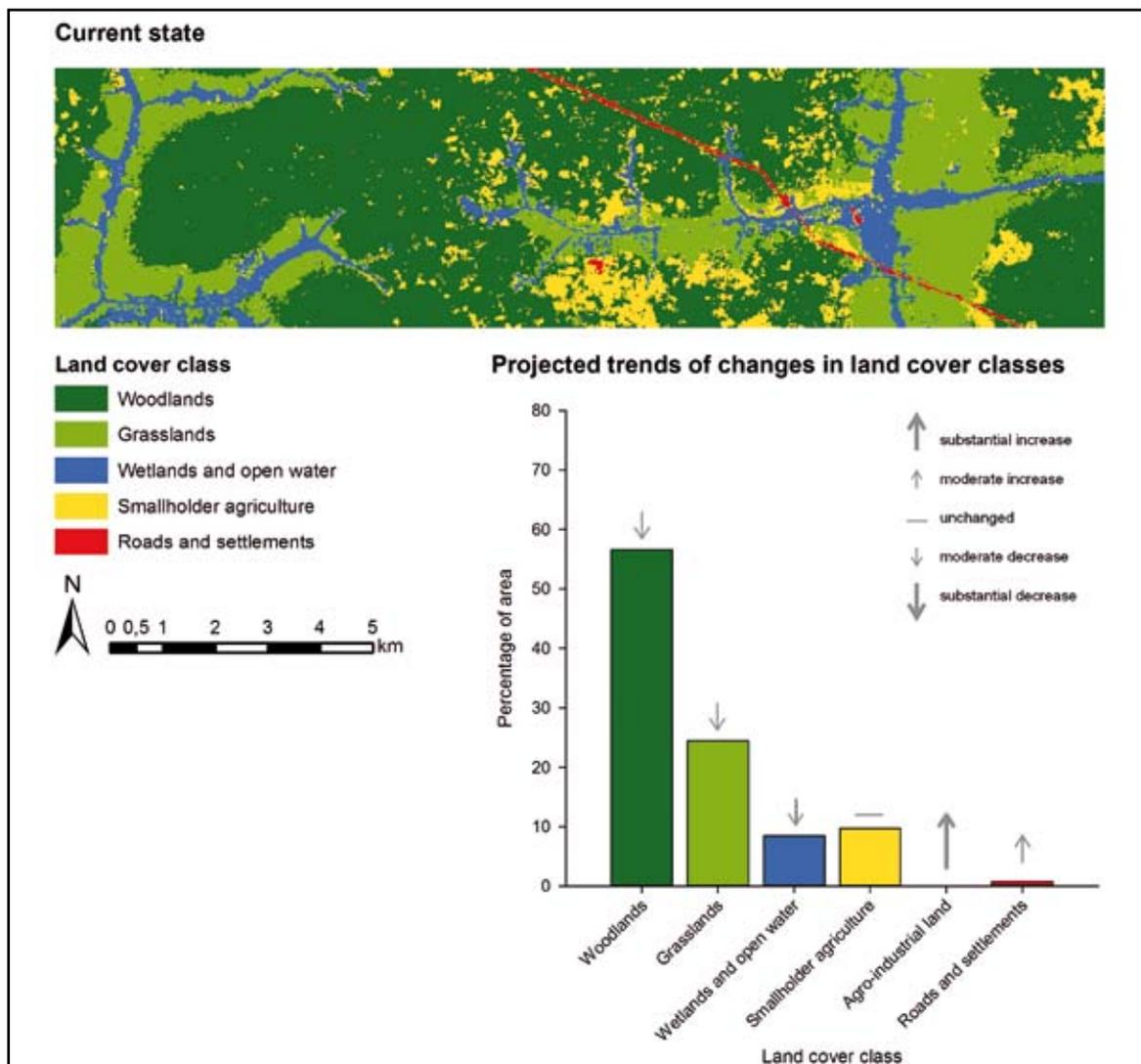


Fig. 140: The map depicts the simplified land cover classes of the core site of Cusseque at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Green Growth'. Note: The arrows indicate a relative change in their respective land cover class only.

As large tracts of the hinterland have been given to forest enterprises, access to these tracts of land (and thus the intensity of extraction of non-timber products) is limited. Control of charcoal production has shifted to enterprises. Forest concessionaires restrict smallholders' access to their concessions for hunting or honey production. Timber production from natural Miombo forests is increasing, but oriented towards urban markets. Game resources partly recover under this **de facto** protection. In the remaining tracts of collectively owned land, the area of natural vegetation has shrunk markedly, and the intensity of resources extraction in those few remaining natural areas under communal control has grown correspondingly. However, national guidelines and institutions reduce the massive commodification of timber and charcoal.

The fire regime has changed significantly. Forest concessionaires apply strict post-harvest fire control and a general fire management protocol, with controlled burning on fire breaks at the beginning of the dry season. Forests in the hinterland are managed according to the paradigms of sustainable forestry. The frequency and intensity of fires is declining, and limitations on the use of bark along with systematic management improve the quantity and quality of forest regrowth. Exploitation of mature forest tracts, on the other hand, opens current tracts of dense Miombo forest.

Parts of the sandy grasslands along the Cusseque River have been converted into horticultural schemes for the organic production of vegetables. The landscape integri-

ty is considerably reduced; the formerly coherent grasslands in the valleys are becoming fragmented due to the conversion of selected sectors into fields. Large forests are becoming fragmented by forest tracks. Endemic and sensitive grassland species disappear in the surroundings of the transformed grasslands. Agro-industrial infrastructure (e. g. silos and hangars) and tracks further alter the landscape. However, wetlands and grasslands adjacent to water courses are conserved against agricultural expansion in order to protect the water quality. Settlements remain located along the main road.

Farm-based tourism develops slowly in the Cusseque area. The sustainable land-use maintains the potential for future touristic activities in some areas.

The extraction of water from the Cusseque and Sovi River increases. Flow decreases by 10 % (rainy season) to 20 % (dry season). Water quality is locally affected by domestic waste water, reduced flow, and nutrient input from the horticultural irrigation schemes. The river water in the main streams loses its former drinking-water quality.

5.3.4 Scenario 3: *Basin Quarry*

Major development trends

In this scenario we assume that the three countries have developed a close economic collaboration and distributed the exploitation of shared resources between them in order to maximize the economic growth for all three countries.



The core site of Cusseque – Basin Quarry

Scenario settings:

- Increased economic collaboration between the three basin countries.
- The basin serves as a source of optimized resource exploitation.
- Integrated transboundary management.

Main characteristics of the *Basin Quarry* scenario storyline for Angola:

- Massive expansion of the commercial sector, based on infrastructure development and external investment.
- Angola supports intensive land-use practices without consideration of ecological externalities. Agroindustrial projects are actively encouraged by offering subsidies, credit, and tax reductions.
- Provincial authorities allow large-scale conversion of natural land for agricultural uses. Export-oriented plantation agriculture of rice, corn, soybean, and citrus fruits expands on fertile soils. *Eucalyptus* and *Pinus* plantations are encouraged.

Main characteristics of the *Basin Quarry* scenario storyline at the core site of Cusseque:

- Secondary earth roads and tracks expand into the hinterland.
- Investors establish irrigation schemes along the Cusseque River.
- Heterogeneous farming systems develop enhancing social inequality; poverty persists in the core site; social stratification and growing inequity cause considerable strain within the communities.
- Extraction of natural resources has grown considerably; charcoal production has exhausted its own resources.
- Landscapes are fragmented and degraded by agriculture, charcoal production, and forest plantations; exploitative land-use has destroyed the potential for future touristic developments.
- Most water courses lose their former drinking-water quality.

Angola shares the vision that to combat poverty and promote economic growth, industrialization and marketization are essential. The massive expansion of the commercial sector, based on the rebuilding of infrastructure and considerable external investment, continues. The province supports intensive land-use practices without major consideration of ecological externalities. Large agricultural projects are actively encouraged. The national and provincial governments deliberately attract investors by offering subsidies, credit, and tax reductions. Export-oriented irrigation agriculture of rice, corn, soy-bean, and citrus fruits expands on fertile soils. Menongue and Chitembo experience rapid development of their commercial sectors, advertising and trading all sorts of modern consumer goods. Urban cash-based markets have a massive impact on the rural peripheries, and in particular the commodification of charcoal has progressed.

The province of Bié follows a development model based on the production, trade and export of agricultural and silvicultural products. The emphasis is on strong eco-

nomical growth options. Concerning innovations, conventional agro-industrial approaches are encouraged. Provincial authorities allow large-scale conversion of natural land for agricultural uses. Fast-growing *Eucalyptus* and *Pinus* plantations are encouraged on degraded agricultural soils. Additional forest plantations directly replace native forests. The legislative provisions for environmental impact assessments (EIAs) remain unclear and unspecific. There is little effort made to increase the general knowledge of the multidimensional consequences of resource-use decisions.

The effects on the core site of Cusseque

Improved and aligned customs practices and improved road infrastructure allow for enhanced transboundary commerce. This puts pressure on land resources in the southern parts of Bié. Its location, on the main road from central Angola to Namibia with strongly increased international traffic, allows for greatly improved opportunities

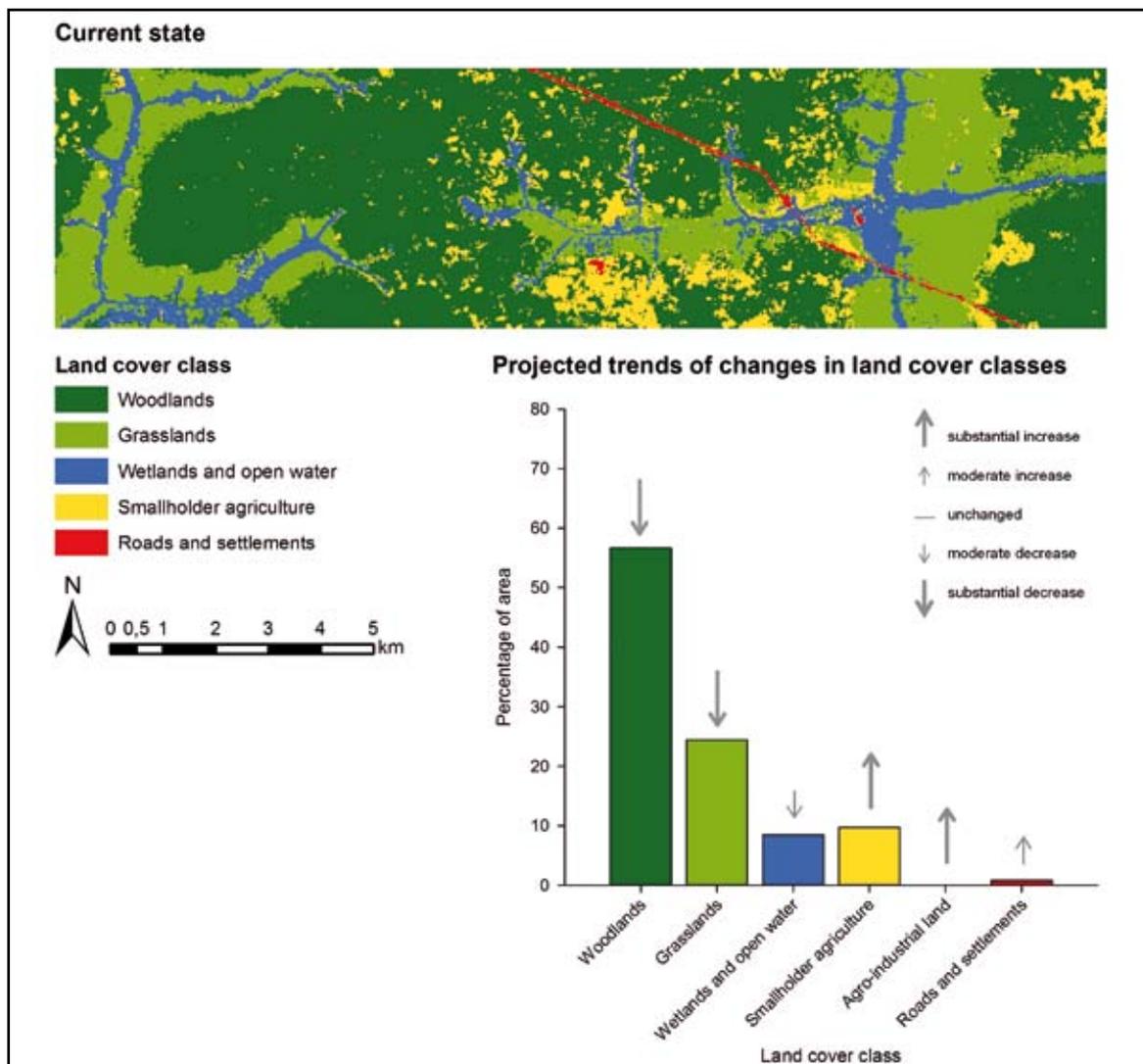


Fig. 141: The map depicts the simplified land cover classes of the core site of Cusseque at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Basin Quarry'. Note: The arrows indicate a relative change in their respective land cover class only.

to commercialize local products. Secondary earth roads and tracks expand into the hinterland of the core site, e.g. from Chingueia to the upper Cusseque valley and from Satchijamba to Soma Cuanza. Boreholes for domestic water use, rural electrification and cell phone coverage extend to all villages along the main road.

Investors acquire land for irrigation schemes on the sandy plains along the Cusseque River. Local farmers are encouraged to join contract-farming schemes or to work on commercial farms. Heterogeneous farming systems develop: increasingly, innovative and well-connected rural smallholders take part in training offered by extension services and use the chance offered by the government to modernize their agriculture with machinery, chemical field inputs and improved seeds. These farmers turn to conventional production systems with tractors, fertilizers and pesticides and hire neighbours as casual workers for their holdings. They acquire additional land from their neighbours, who provide it in exchange for payment and work opportunities. However, poverty persists in the core site. Only a few people find jobs in agricultural or silvicultural enterprises, while the majority of the farmers are not able to improve their household income and instead expand the slash-and-burn agriculture further in the hinterland. Due to increasing land scarcity many smallholders turn into semi-permanent farmers

with the related problem of ongoing soil degradation. The process of social stratification and growing inequity causes considerable strain within the rural communities. Some of the marginalized smallholders oppose the development, along with local authorities, who see a threat to the traditional land tenure system.

Migration towards the urban centres is very common. But some re-migration to the communities which function as a repository is also ongoing.

However, there are critical shortcomings in the sectorial integration of environmental policies. Environmental regulations are not given high priority. Only severe cases of pollution and degradation are taken to court. Trade of resources like charcoal, timber and bushmeat is de facto not controlled. As the total area of pristine land has shrunk greatly, the extraction of resources in the remaining natural areas has grown considerably. Charcoal production has exhausted its own resources and shifted eastwards into Moxico. Timber production from natural forests is scarcely enough to satisfy the local demand of the villages. Large parts of the grasslands along the Cusseque River are replaced by agro-industrial green schemes for rice production. Miombo forests are being converted to smallholder fields and forest plantations with fast-growing *Eucalyptus* and *Pine* species.



The core site of Cusseque – Slow Growth

Scenario settings:

- Integrated transboundary management.
- Focus on ecological, social, and economic sustainable development.

Main characteristics of the *Slow Growth* scenario storyline for Angola:

- The government implements rural development strategies and functional agricultural extension services; interventions focus specifically on small farmers.
- Investors acquire land for sustainable agricultural and forestry investment schemes; regional, political, and legislative bodies control investments, looking at social and ecological externalities.

Main characteristics of the *Slow Growth* scenario storyline at the core site of Cusseque:

- Educational and medical infrastructure has been improved considerably.
- Customary land rights are effectively enforced by state authorities. The administration has initiated participatory land-use planning processes taking into account ecological concerns.
- A medium-sized irrigation scheme for organic horticultural products has been established together with the community along the Cusseque River.
- Smallholders receive agro-credits and training to improve soil fertility and yield levels.
- Total inequity has increased. However, mechanisms are in place to assist farmers in avoiding poverty traps.
- The monitoring and enforcement of environmental regulations has been significantly improved. Charcoal production is restricted to selected areas, with strict post-harvest fire control.
- A conservation area has been established as a 'community forest' to preserve the Miombo ecosystems. The sustainable land-use and the conservation area maintain the potential for future touristic developments in some areas.
- The landscape integrity of the central part of the core site is considerably reduced. On the other hand, natural forests and grasslands in the conservation zone are maintained mostly intact.
- Water quality is only locally affected by pollution.

The fire regime stays more or less the same as at it was in 2015, with the exception of the agricultural enterprises at the Cusseque floodplain, which realize controlled burning at the beginning of the dry season.

The landscape integrity is greatly reduced; natural landscapes are fragmented and degraded by agriculture, charcoal production, and forest plantations. The formerly pristine grasslands in the valleys have been transformed into fields. Agro-industrial infrastructure and tracks further alter the landscape. Larger fauna have disappeared completely, due to habitat losses. Endemic and sensitive species have also largely disappeared.

Tourism remains nonexistent in the Cusseque area. No land was dedicated to conservation in the area, and the subsequent exploitative land-use has destroyed the potential for future touristic activities.

The extraction of river water from the Cusseque and Sovi River reaches up to 50 % of their current base flow in the dry season. The spread of the settlements along

the roadside causes sanitary problems, especially with regard to safe drinking water. Water quality is affected by reduced flow in combination with domestic waste water, nutrient, and pesticide input from the irrigation schemes. Most water courses lose their former drinking-water quality.

5.3.5 Scenario 4: *Slow Growth*

Major development trends

The underlying framework of the Slow Growth scenario envisions close cooperation between the basin countries, the catchment being managed as an economic and ecological entity.

Angola shares the vision that to combat poverty and promote economic growth, industrialization and marketization are essential. With the help of international research and development partners, better knowledge of the interactions between land-use and the provision

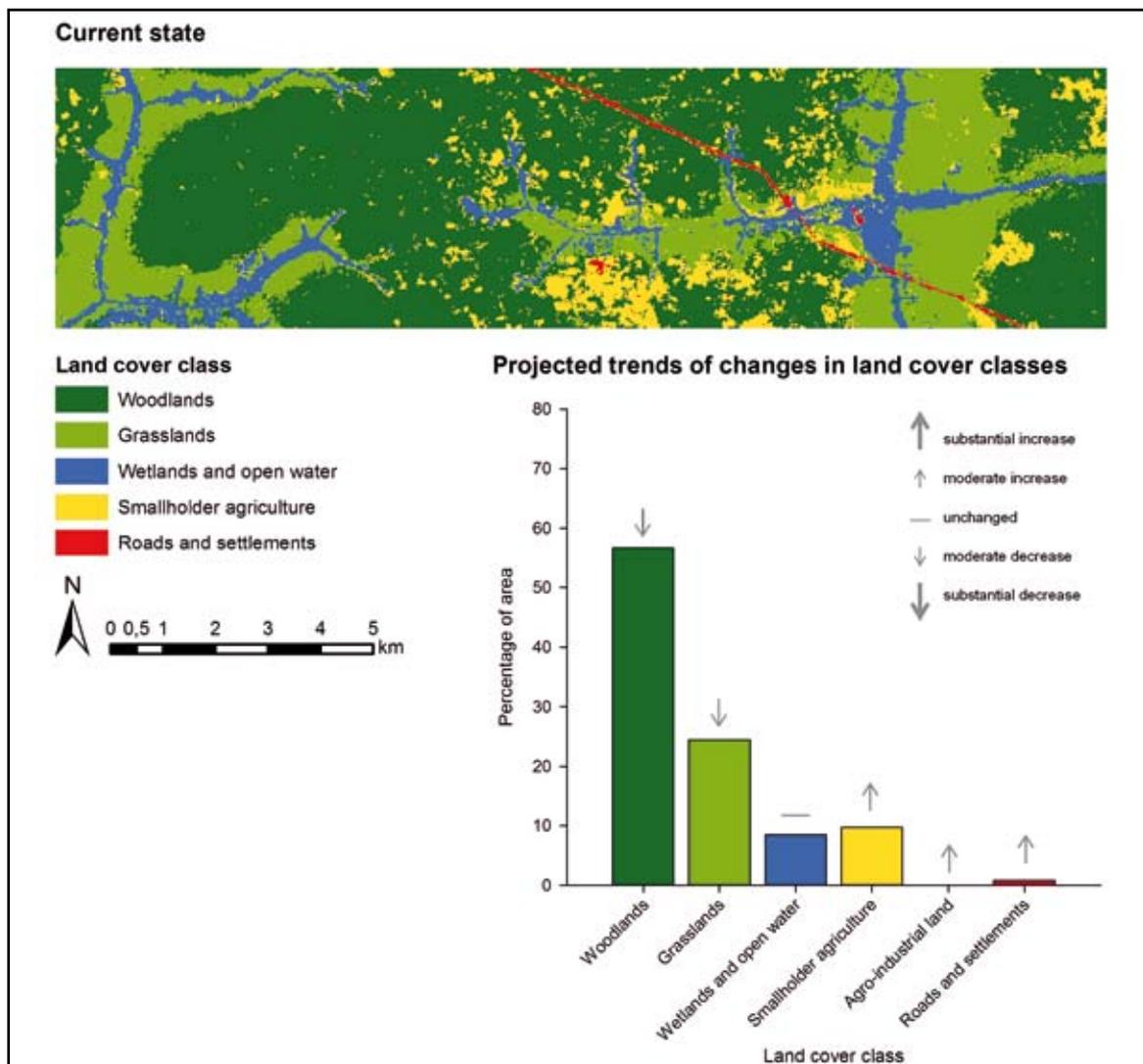


Fig. 142: The map depicts the simplified land cover classes of the core site of Cusseque at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Slow Growth'. Note: The arrows indicate a relative change in their respective land cover class only.



Fig. 143: The forest grassland-ecotone in the Cusseque Valley still untouched (photo: M. Finckh).

of ecosystem services becomes available. The national and provincial governments implement rural development strategies and functional agricultural extension services in cooperation with development agents (USAID, GIZ, UNDP, Worldbank, FAO). The interventions focus specifically on enhancing the yields of small farmers, providing donor-funded or subsidized low-cost farming technologies (i. e. rotations, crop diversification, soil fertility management, and enhanced water-use efficiency).

Investors acquire land for sustainable agricultural and forestry investment schemes. The upper part of the catchment sees the development of new agricultural products for transboundary markets (e. g. rice, soya, citrus fruits). Menongue and Chitembo experience a rapid development of the commercial sector, advertising and trading all sorts of modern consumer goods. However, regional political and legislative bodies control investments and the creation of such new markets. In particular the commodification of timber for charcoal is controlled and substituted by alternative technologies. There is an increasing awareness in Bié of the necessity to produce, trade, and export agricultural and silvicultural products in a sustainable manner.

The effects on the core site of Cusseque

Improved and aligned customs practices, enhanced transboundary commerce, and improved road infrastructure open new opportunities for land-use in the southern parts of Bié. The population is mainly concentrated in the villages along the main road. Secondary roads provide access to the lodges in the hinterland. Educational and medical infrastructure has been improved considerably. Rural electrification, cell phone coverage, and boreholes for domestic water provision extend to all villages along the main road in order to attract people to live there permanently all year round.

A medium-sized irrigation scheme for the organic production of horticultural products has been established together with the community of Calomba on the sandy plains along the Cusseque River. The province supports innovative members of the local communities, helping them to intensify the agricultural use of the current fields using conservation agriculture approaches with tractors and fertilizers. The expansion of fields in the western hinterland is impeded by a large conservation area including forests, wetlands, and grassland, which allows only sustainable extraction of selected resources for smallholders (honey, medicinal herbs, controlled timber extraction). Smallholders are therefore forced to stay on their current fields, but receive agro-credits and training to improve soil fertility and yield levels. Many smallholders have turned to innovative farming practices. The reasons for this are either soil degradation – with the resulting need to adapt production practices – or the will to earn more cash income to pursue a ‚modern‘ lifestyle. Other farmers, i. e. those that are able to invest a higher amount of labour in their holdings and those that are satisfied with their current production and livelihoods, continue to rely on resource-degrading cultivation practices. Total inequity has increased due to the fact that some farmers successfully apply the new practices while others survive on increasingly degraded land. However, mechanisms like village trusts, government training and subsidies are in place to assist farmers in avoiding poverty traps.

A conservation area has been established as a ‚community forest‘ south-east of Chitembo to preserve the Miombo ecosystems. The area also serves as a centre of research into Miombo ecology for the Southern African Region.

Migration towards the urban centres takes place. However, due to the increased national efforts to improve rural livelihoods and labour opportunities, many people still live in rural settlements, and re-migration to those communities is common.



Fig. 144: Morning light in the surroundings of Kalomba, Angola (photo: M. Finckh).

Customary land rights are effectively enforced by state authorities. Transfer of collective land from communities to individuals and commercial enterprises is based on the approval of traditional authorities and community members. Compensations are based on market prices, governmental regulations, and consensus. The poor are given access to equivalent land. The coherent interplay between customary and statutory land rights makes communities less prone to land grabbing by powerful players. This increases their incentives for sustainable land management on the remaining commons.

The administration has initiated local participatory land-use planning processes taking into account ecological concerns. The monitoring and enforcement of environmental regulations has been significantly improved; the close collaboration between statutory and traditional authorities is crucial in this regard. Subsidiary principles are applied, reducing the monitoring and enforcement costs for the government. As a result, customary and statutory laws restricting resource extraction, controlling fires, and regulating the clearing of forest are strictly enforced. Local leaders encourage community discussions on the use of natural resources and introduce new customary laws restricting resource overexploitation.

Forests in the hinterland are managed by the communities under sustainable forestry paradigms. Charcoal production is restricted to selected areas, with strict post-harvest fire control. Timber production from natural Miombo forests is increasing – partly for domestic uses, partly oriented towards urban markets. Limitations on the use of bark and systematic management together improve the quantity and quality of timber regrowth. As large tracts of the hinterland have been declared conservation areas, use of these tracts of land (and thus the intensity of extraction of non-timber products) is limited. Game resources recover under this *de facto* protection. Game resources are managed collectively and

selected game are being reintroduced. In the remaining tracts of collectively owned land, the area with natural vegetation has shrunk only slightly due to the support of permanent smallholder agriculture. The intensity of extraction of natural resources in the remaining natural areas has increased; however, the environmental externalities are limited due to better usage practices. The frequency and intensity of fires is declining, as the government has introduced, and enforces, strict regulations on fire application, limiting fire to the first two months of the dry season (May and June).

The landscape integrity of the central part of the core site is considerably reduced, and the formerly coherent grasslands in the Cusseque and Sovi valleys have been partially converted into fields. Agricultural infrastructure and tracks further alter the landscape. On the other hand, natural forests and grasslands in the conservation zone are maintained mostly intact. Some larger game species recover or are reintroduced. However, endemic and sensitive grassland species disappear in the surroundings of the villages.

The strategic location of the site along the main access road to central Angola has opened opportunities for tourism. There are small hostels along the roadside, and two lodges operate in the lateral valleys close to the conservation area. Hostels and camps create income and employment opportunities for members of the local communities. The sustainable land-use and the conservation area maintain the potential for future touristic activities in some areas.

The extraction of water from the Cusseque and Sovi River increases. Flow decreases by 10 % (rainy season) to 20 % (dry season). Wetlands largely continue to provide their regulating services. Water quality is only locally affected by domestic waste water, reduced flow, and nutrient input from the horticultural irrigation schemes. The river water of the main streams loses its former drinking-water quality.

5.4 Trends of possible future developments for Mashare

According to the scenario logic described above, four possible alternative future developments for the core site of Mashare have been developed.

5.4.1 Future developments for all scenarios

In the period from 2016 to 2045, the models project a warmer and drier climate. The annual precipitation is expected to decrease by up to 100 mm, with no obvious changes for the rainy season. The annual mean temperature is projected to increase by 1.5 to 2 °C, the minimum and maximum temperatures in the wet season are expected to increase by 1–2 °C and 1.5–2 °C, respectively.

In general, the whole area of the Kavangos has experienced a continuous population growth of about 3 % annually. At the core site of Mashare, due to the high natural fertility (Total Fertility Rate, TFR, for Kavango in 2011 was 4.5 children per woman) the overpopulation of the riversides and the strong competition for the remaining resources, triggering hinterland migration, has continued. Internal migration towards the urban centres has been high, especially by the younger generation seeking a better school education or looking for jobs. The urban population of the Kavangos of Rundu, Nkurenkuru, and also Katwitwi, as the border post, has increased by 3.5 %. Correspondingly, the education policy has strongly focused on supporting

higher education, especially in urban centres. There, a small but notable middle class has developed. By 2030 a great increase in the numbers of urban poor living in squatter settlements around the major urban centres has occurred. The growth and expansion of urban areas has caused ongoing localized depletion of natural resources, discharge of unprocessed wastes into the environment, and challenges to the provision of basic services such as housing, roads, piped water, sanitation and waste disposal, and security against criminal activities, as well as health and education services.

Urban hubs like Rundu and Calai, and increasingly also Nkurenkuru, Cuangar, and Katwitwi have developed their commercial sectors, with advertising and trading in all sorts of modern consumer goods – which then influences other variables (e. g. cash demands, domestic energy demands). Urban cash-based markets also trading diverse goods as part of global commodity chains have had an impact on the remotest rural peripheries as new incentives have emerged, and to some extent even natural resources have been commodified for cash. The influx of consumer goods has resulted in various new shops in the rural areas such as Mashare. The existing settlements within the core site have further grown together, joined by small shops serving agricultural demands, overland trade (timber, thatch, crafts), and the commercialization of local products and crafts. Cash demand has strongly increased among the (currently subsistence-based) rural population as subsistent land users have become consumers, increasing the pressure to exploit the remaining natural resources in communal and public areas.



The core site of Mashare – Race for Money

Scenario settings:

- National interests first: economic development by encouraging large-scale agricultural investments and creating new markets.
- Natural resource exploitation as basis of the economic development.
- Weak monitoring and enforcement of environmental regulations.

Main characteristics of the *Race for Money* scenario storyline for Namibian Kavangos and the core site of Mashare:

- Large parts of the Namibian Kavango have been transformed into agro-industrial irrigation schemes (breadbasket of Namibia).
- Intensified cattle production.
- Smallholders are driven to the less productive hinterland.
- Rural and urban poverty has risen.
- Commodification of nature (esp. wood and fish extraction).

In sum:

In this scenario the economic development achieved has been to the detriment of larger parts of the regional population and the country's natural resources. In particular the amount of water abstraction has led to conflicts with the neighbouring countries.

5.4.2 Scenario 1: Race for Money

Major development trends

Within this scenario we assume that the **collaboration between the three countries** was abandoned in favour of fierce competition within the region to become a player in the global economy. That means that for the Kavango Regions of Namibia too, **natural resources have been mainly viewed as the economic basis for growth-oriented development** and that Namibia has tried to exploit its national resources to the maximum, not taking ideas of sustainability seriously into consideration. There is no regulation, transboundary water management, or agreement between Angola, Botswana, or Namibia regarding the maximum amount of water which can be extracted from the rivers in the headwater region of the Okavango Basin. As part of this isolated **development policy**, large-scale agricultural investments for food self-sufficiency have been actively encouraged, despite the fact that **climate change** projections for Mashare had suggested a reduction in annual precipitation and an increase in annual mean temperature.

Due to the policy-makers' focus on the formal sector, no policies have been put into place that aim to assist smallholders. Rural and, due to migration, also urban

poverty levels have risen, and with them associated problems such as social tensions and an increasing stratification and social inequality. Smallholders were seen as something of an obstacle to economic growth, and certainly not as a part of any growth strategy. Therefore, large parts of the rural population have been excluded from the formal sector and have remained in precarious subsistence, in a state that can be described as **'sustainable poverty'**. Due to the competition with agro-industrial agriculture the subsistence farmers were driven from the more productive land to the hinterland, where yields are lower. Under such conditions traditional agricultural livelihoods have remained under strong pressure, with related consequences such as low productivity, poverty, urbanization, and commodification of nature.

The connection to global **markets for cash-based consumer goods** has been strongly promoted and facilitated by regional political and legislative bodies. Demand for cash has greatly increased among the (currently subsistence-based) rural population as subsistent land users have become consumers, increasing the pressure to exploit the remaining natural resources in communal and public areas. However, the massive investments in green schemes have had little effect with regard to labour for the rural population. Shops and cash-based

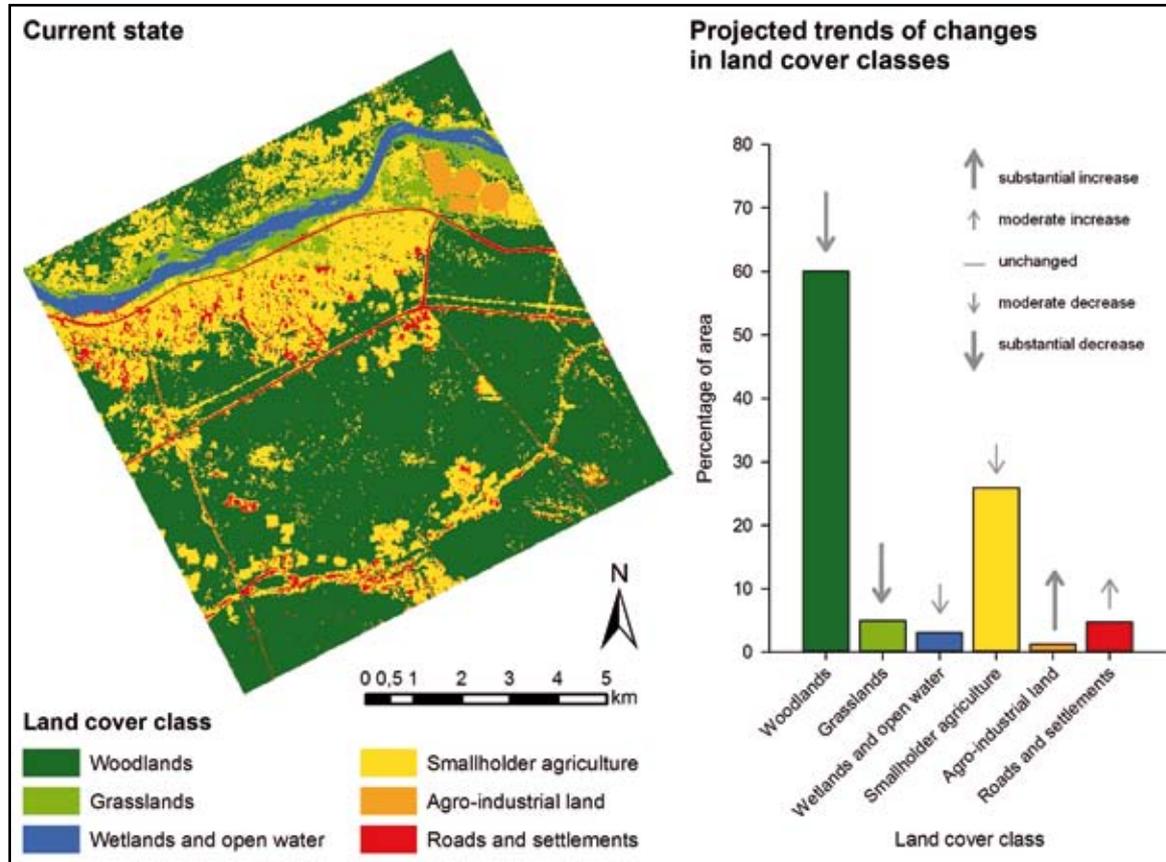


Fig. 145: The map depicts the simplified land cover classes of the core site of Mashare at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Race for Money'. Note: The arrows indicate a relative change in their respective land cover class only.



Fig. 146: Floodplains in the Mashare area, Namibia (photo: H. Göhmann).

transactions have played a major role in rural contexts. Farmers have perceived cash-based markets (labour/jobs, trade) and the commercialization of their land-use as the only one option.

In this scenario, by 2030 **existing environmental laws** related to forest, water, and land have barely been enforced, and traditional authorities have not been supported in the **monitoring and enforcement** of customary environmental laws. There have still been critical shortcomings in the sectorial integration of **environmental policies**. The legislative provisions for environmental impact assessments (EIAs) have remained unclear and unspecific. There has been little effort made to increase the general knowledge of the multidimensional consequences of resource-use decisions. As such many projects such as large-scale irrigated farms or commercial logging have been widely approved.

The monitoring of **environmental regulations** has not been given high priority. Only severe cases of pollution and degradation have been investigated and taken to court. As such there have been no significant changes to the state of affairs in 2015.

Most community land is being held under **customary rights**. Strong social control within the communities has prevented ordinary outsiders from gaining unauthorized access to the land. Nevertheless, powerful individuals or organizations have managed to corrupt traditional authorities, have ignored customary land rights, and have grabbed land. Furthermore, the land board system has effectively been enforced. Investors can directly address the land board, which supports the transfer of land from the community. Compensations are paid, but independently from the state of the land. Overall, the situation has reduced incentives for sustainable communal land management.

The effect on the core site of Mashare

By 2030 large parts of the river terraces and lands adjacent to the Namibian Kavango have been transformed into **agro-industrial irrigation schemes** as the government has focused on promoting technological innovations to strengthen the national economic development, and thus has followed its strategy to become the breadbasket of Namibia. National and regional governments have supported connectivity to international markets (infrastructure improvement, information technology, wholesale markets). Therefore, not only maize and wheat but also fruits and vegetables are being produced so as to help Namibia to become more independent of imports.

Furthermore, Namibia has been expanding **meat production** for both national food supply and export markets. The national and regional governments have actively attracted investors offering subsidies, credit, and tax reductions. The government has established an intensive cooperation in particular with multinational agro-chemical and agricultural companies. Despite a shortage of jobs local rural farmers have been encouraged to join contract-farming schemes or to work on commercial farms.

By 2030 the opposition between the few industrial permanent farmers on the one side and the degraded permanent farming of the majority of households has become aggravated. There are a few successful farmers that have either purchased or rented land from their neighbours; they are applying industrial field inputs and machinery and regularly employ a grown class of landless labourers. Many of the remaining farmers have been caught in a poverty trap, with low levels of productivity and health, and degraded household resources. They have been investing the scarce cash they earn by working on the fields of the wealthy farmers in food, as well as in hiring oxen for ploughing. They have been unable to invest in other commodities such as the edu-

cation of their children or cheap, unsustainable food and commodity products from the world markets. As a result, a class of landless labourers has emerged that have given up on self-sufficient farming.

Cattle densities have remained high, but are now concentrated on the land controlled by the very few successful households that can purchase additional fodder and medicine (degraded communal pastures). These cattle farms have also tried to intensify production. Control of movement across the Angolan border has been tightened to favour the farmers who lease parcels of communal land in Kavango East for cattle ranching. The few wild animals that venture into the area have been destroyed due to the fear that they will spread foot-and-mouth disease to cattle.

By the year 2030 the **water availability** has decreased in accordance with the climate models that projected less precipitation and higher temperatures causing increased evaporation from the FORA during the period 2016–2045. Taking into account the additional water extraction within the headwater catchments, the amount of downstream available water has decreased. The southern hinterlands of the Namibian Kavangos north of the veterinary fence – originally communal lands – have been completely leased out to financially potent elites, and are used for intensified cattle farming.

Due to the lower and even more unpredictable yield, the rural poor are dependent on natural resources: the general intensification of wood extraction in communal woodlands has caused a **significant degradation of the remaining woodland ecosystems**. Migrants to the hinterland are causing a large-scale transformation of natural woodlands and forests.

Game has mostly been exterminated outside of the protected areas. **Overfishing** and unsustainable fishing techniques have reduced fish stocks already affected by the decreasing quality of riverine habitats and disturbed river dynamics.

5.4.3 Scenario 2: Green Growth

Major development trends

In this scenario, the three basin countries are following **individual national interests** and rely on their respective shares of the basin as a source of resources. National and local/regional policies have targeted development with **sustainable resource-use**, taking into account the whole range of benefits from natural resources for present and future generations on both local and national scales. However, they have not given any special attention to particular externalities on the catchment scale (esp. water use). There is no regulation, transboundary water management or agreement between Angola, Botswana, or Namibia regarding the maximum amount

of water which can be extracted from the rivers in the headwater region of the Okavango Basin.

National and regional policy-makers have made considerable efforts to increase their knowledge of the multidimensional consequences of **resource-use decisions**. The states have given higher priority to the monitoring and enforcement of statutory and customary environmental laws. Fines and punishments have been increased and have a deterrent effect on resource-degrading activities such as illegal logging.

There is increasing awareness of the necessity to produce, trade and export national and local products in a sustainable manner. But the focus has been on strong economic growth options, as national and regional Kavango policy-makers share the paradigm that to combat poverty and promote **development economic growth, industrialization and marketization** are essential. They have therefore been investing in and supporting modern land-use practices **under consideration of ecological externalities**. Large-scale agricultural investments are being actively encouraged. Organic-label and fair trade certification have been promoted. The national and regional governments have been deliberately attracting investors by offering subsidies, credit, and tax reductions. The government has established an intensive cooperation in particular with development agents (USAID, GIZ, UNDP, Worldbank, FAO). With the help of international research and development partners (USAID, SASSCAL etc.) better knowledge of the interactions between land-use and the provision of ecosystem services has been available among various players. On the basis of improved knowledge, the local administration has initiated a participatory land-use planning process taking into account ecological concerns.

Differences from Scenario 1 (**Race for Money**) include some national investments in training, education, access to land, and other measures to secure sufficient yields. While the **general ideology is that of a rapid 'jump' into** a better economic future, there have been some national/regional investments in the improvement of these services, and also in the Green Scheme industry as well as other green productive sectors (small-scale hinterland farms) has offered **more labour for rural populations**.

Accordingly, the education policy has focused on supporting higher education to meet the qualified labour demands of the export sector. Some **new job opportunities** in the rural areas have been created by ecotourism and large-scale organic production schemes, as well as by certified commercial logging businesses. However, the number of new jobs in these sectors has not met the high demand for jobs requiring little formal qualification in the rural areas.

Effects on the core site of Mashare

Since the large-scale organic farms are predominantly situated within a band of ca. 1 km along the river, the remaining smallholders' access to river resources has been restricted. As a consequence smallholders have remained in rural poverty and are partially **migrating towards urban centres**. Together with a still high natural fertility, the urban population is growing quickly, and belts of poor squatter settlements form around the major cities. All countries and regions involved have acknowledged the need to mitigate urbanization, waste production, river pollution, and resource commodification, but have not been able to keep up with the growing population. The tertiary sector in the cities has been growing. In sum, the labour opportunities for qualified staff also in rural settings are better than those in Scenario 1. Local farmers are being encouraged to join cooperatives or to work on commercial farms.

Overall, inequality has increased less than in the previous scenario. The national governments have tried to maintain the social peace by providing baseline services in education and health care sectors, and with subsidies for staple foods.

Apart from these national efforts, global **markets for cash-based consumer goods** have expanded strongly. However, regional political and legislative bodies have attempted to promote and facilitate the import of more

environmentally-friendly and sustainable products. **Cash-based markets and new shops** have had an impact on rural peripheries like Mashare as new incentives have emerged and natural resources have been partly commodified for cash (though to a lesser degree than in Scenario 1). Due to the better income situation of parts of the population, shops and cash-based transactions have come to play a major role in rural contexts.

Customary land rights have more effectively been enforced by state authorities. Transfers of land from communities to individuals and organizations intending large-scale commercial land-use have been based on the approval of traditional authorities and the community members. Compensations have been based on market prices, governmental regulations, and consensus. The poor have been given increased access to equivalent land. The relatively coherent interplay between customary and statutory land rights has made communities less prone to land grabbing by powerful players. This has increased their incentive to pursue sustainable land management on the still-communally managed land.

Significant efforts have been made to improve the **monitoring and enforcement of environmental regulations**. Standardized procedures for conducting environmental impact assessments, resource extraction, and pollution control have been carried out by specialized staff, particularly on the large-scale farms. Environmental aspects



The core site of Mashare – Green Growth

Scenario settings:

- National policies target development on the basis of sustainable resource-use.
- Support of modern land-use practices like large-scale organic agriculture, certified commercial logging, and eco-tourism.
- Improvement of the monitoring and enforcement of environmental regulations.

Main characteristics of the *Green Growth* scenario storyline for Namibian Kavangos and the core site of Mashare:

- Large-scale organic farms within a band along the river and small-scale organic hinterland farms offer some job opportunities for the better-trained rural population.
- The villages in the Mashare core site have benefitted indirectly, because the successful farmers have specialized in production of organic foods.
- However, smallholders' access to river resources has been restricted; they remain in rural poverty with low levels of productivity and health, and degraded household resources and are partially migrating towards urban centres.
- As a result, there has emerged a class of landless labourers that have given up on self-sufficient farming.
- The national government provides baseline services in urban education and health care sectors, and with subsidies for staple foods.
- Natural resources are partly commodified for cash, but traditional land-use rights of local communities (e. g. hunting, timber use, pasture, etc.) have been cancelled, therefore, exploitation of natural resources is less severe than in Scenario 1.

In sum:

In this scenario parts of the rural population have benefitted from additional labour and the environment has benefitted from a generally sustainable ideology. However, as the general paradigm has been that of an isolated 'jump' towards growth, the lack of transboundary cooperation has been to the detriment of comparative economic advantages (as outlined in Scenario 3) and has thus slowed economic progress. Furthermore, the development of sustainable products and labels has been much slower than in the uncontrolled profitization context of Scenario 1.

have been critical in the renewal processes of organic-label certificates. On the remaining communal land, traditional authorities have been empowered to enforce natural-resource-related customary law.

On the local level, traditional leaders have encouraged community discussions about the use of natural resources, have introduced **new customary laws** restricting unsustainable resource management, and are strictly enforcing the traditional laws. Specific topics that have been discussed are the uncontrolled clearing of forest to make fields, the misuse of fire, and the pollution of the river.

Namibia has developed its **eco-tourism sector** individually and has applied aggressive marketing strategies, creating fierce competition for tourists. The tourism development has strongly been driven by the policy paradigm to create maximum income with as little ecological impact as possible. The diversity of tourism activities caters to trophy-hunting, photographic tourism, adventure tourism, angling, and cultural and educational tourism with an eco-friendly and community-based orientation. Border crossing for tourists remains complicated, especially into Angola. Even though conservation is considered important, no transboundary managed conservation area such as KAZA is in place (KAZA).

Infrastructure development has followed national business demands under consideration of environmen-

tal criteria. In Namibia, roads have been built in order for tourists to be able to reach the Khaudum Park.

Regarding the **dominant sector of agriculture**, by 2030 the opposition between eco-industrial permanent enterprises and the degraded permanent subsistence farming of the majority of households has developed to a lesser extent than in scenario 1. This has mainly been due to the better labour opportunities for the rural areas. Agricultural innovations and environmentally friendly technological solutions (e.g. drip irrigation) have been applied with an emphasis on high-price organic products for export markets and national high-end eco-tourism (e.g. large-scale organic production schemes, conservancies). Decisions regarding forest management (e.g. certified commercial logging) are made taking into account the whole range of environmental impacts at the national scale (e.g. sustainable forestry oriented towards high timber quality rather than exploitation licences).

The villages in the Mashare core site have benefitted indirectly, because the successful farmers have specialized in production of organic foods (which may increase labour demand and thus provide job opportunities for poorer households) and have applied for certified production. If these certificates include social criteria as well, they also benefit the poorer households. However, still some of the remaining farmers are caught in a po-

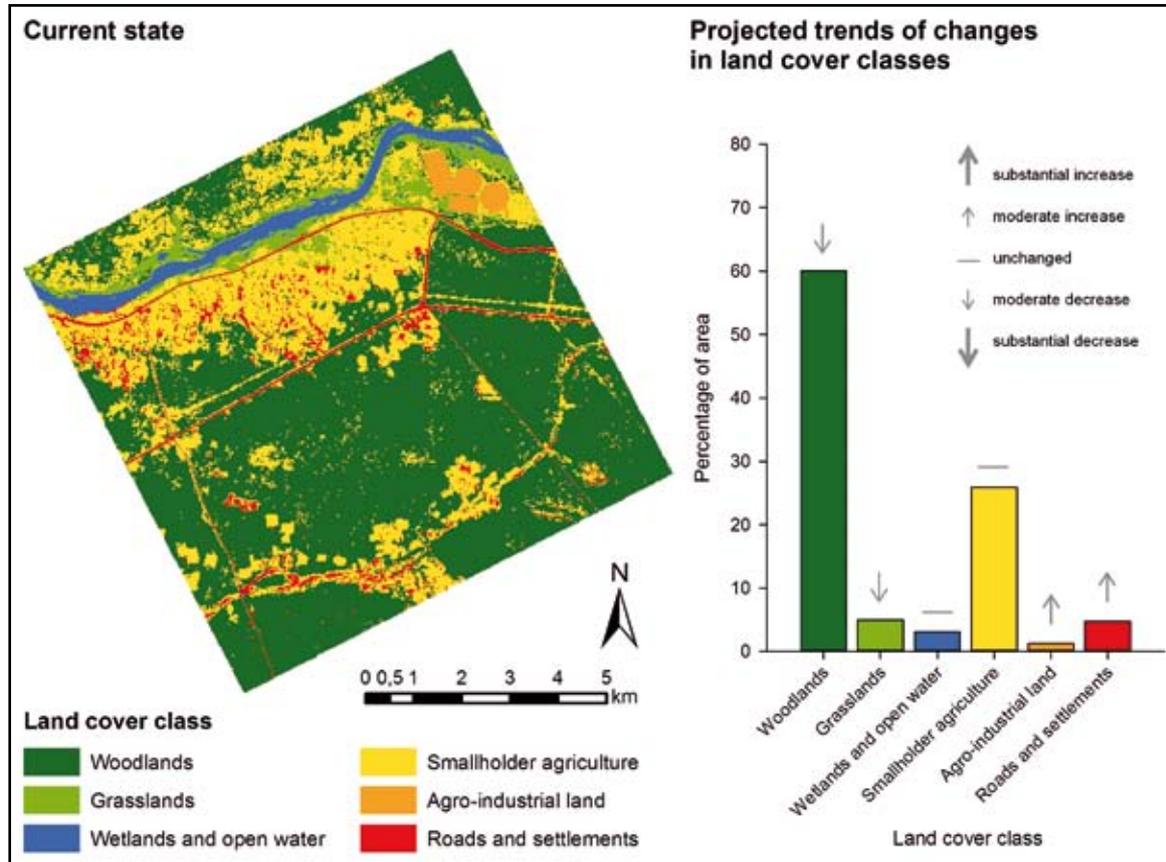


Fig. 147: The map depicts the simplified land cover classes of the core site of Mashare at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Green Growth'. Note: The arrows indicate a relative change in their respective land cover class only.

verty trap, with low levels of productivity and health, and degraded household resources. They have invested the scarce cash they earn by working on the fields of the wealthy farmers in food, and also for hiring of oxen for ploughing. They have been unable to invest in other commodities such as the education of their children or cheap food and commodity products of the world markets. As a result, there has emerged a class of landless labourers that have given up on self-sufficient farming.

Regarding the challenge of cattle farming, alternative markets for Namibian beef have turned foot-and-mouth disease control into a non-issue, as well-managed indigenous cattle resist the disease. However, Namibia's non-cooperation with neighbouring countries has further restricted the transboundary movement of wild animals, so attempts at game farming in a confined environment have largely been unsuccessful.

Cattle densities have remained high, but cattle are concentrated on the land controlled by the very few successful households that can purchase additional fodder and medicine, since there has been a general degradation of communal pastures. Those cattle farms have also tried to intensify production. Control of movement across the Angolan border has been tightened to favour the farmers who have leased parcels of communal land in Kavango East for cattle ranching. The few wild animals that venture into the area have been destroyed due to fears that they might spread foot-and-mouth disease to cattle.

Water extraction from the Okavango does not take into account the interests of the downriver neighbours, but avoids excessive water extraction in order not to harm the 'green' image of the export products.

Sustainable forestry has been promoted through the cancellation of the traditional land-use rights of local communities (e. g. hunting, timber use, pasture, etc.). Natural resources outside of protected areas have been sustainably managed by long-term-oriented enterprises, and so deforestation decreases.

5.4.4 Scenario 3: *Basin Quarry*

Major development trends

The underlying logic of this scenario is the idea that the three basin countries have decided on increased **economic collaboration and distributed resource exploitation** to tap the area's economic growth potential and thus produce added value through **comparative economic advantages**. Stakeholders and policy-makers have made no significant efforts to increase their knowledge of the multidimensional consequences of land-use decisions for the environment. Like its neighbours, Namibia shares the paradigmatic view that to combat poverty and promote economic growth, industrialization, marketization and shared/distributed resource exploitation are necessary. The countries have thus exchanged and marketed produced resources.



The core site of Mashare – Basin Quarry

Scenario settings:

- Increased economic collaboration between the three basin countries.
- Economic development is based on industrialization and marketization.
- Natural resources are increasingly exploited.

Main characteristics of the *Basin Quarry* scenario storyline for the Namibian Kavangos and the core site of Mashare:

- Strong investment in transboundary infrastructure. No policies have been put into place with the aim of assisting smallholders. Large parts of the rural population remain in a state that could be described as 'sustainable poverty'.
- Shops and cash-based transactions have played a major role in rural contexts.
- Farmers perceive cash-based markets and the commercialization of their land as only options for the future.
- Agro-industrial schemes have expanded on favourable soils. Green schemes have caused little in the way of labour effects for the rural population.
- Smallholders have migrated to marginal lands in the hinterland of roads and rivers.
- High intensity of extraction of natural resources (esp. water and wood).
- Some additional labour opportunities offered by transboundary migration esp. of farmers into Angola.
- Increase in social inequality.

In sum:

Under this scenario the exploitative economic development achieved has been to the detriment of larger parts of the local immobile population, who have remained in continuing poverty. The regions and countries have benefitted from comparable short- and mid-term economic advantages but in the long run have suffered due to the increased extractive use of natural resources.

Comparative economic advantages in the basin have been achieved in productivity zones which have been targeted to generate more income per country. A regional forum of the three countries within SADC has emerged. Integrated transboundary economic management has included a land-use planning process that identifies spatially optimal areas for making best use of comparative advantages. The Namibian Kavangos have been developed for intensive forestry, and meat and crop production.

This paradigm has favoured **open internal borders and markets** (e. g. for goods, labour, tourists), improved and aligned customs practices are in place – with all expectable implementation problems. No special attention has been given to putting up trade barriers against market incentives that promote exploitative NRM. Large-scale **agricultural investments** have been actively encouraged, despite the fact that **climate** change projections for Mashare had suggested a tendency towards lower annual precipitation and higher annual mean temperature. The national and regional governments have attracted investors offering subsidies, credit, and tax reductions. The government has established intensive cooperation in particular with multinational agrochemical and agricultural companies. Local farmers have been encouraged to join contract-farming schemes or

to work on commercial farms, as transboundary labour migration is easier.

There have been strong investments in **transboundary infrastructure** such as tarred roads, bridges, tracks, and professionally operated border points and customs services. Water abstraction and use have been prioritized and realized by run-of-the-river (Namibia) and conventional (Cubango and Cuito tributaries) hydro-power schemes. The hydropower potential has been developed to the fullest possible extent.

The three countries have cooperated in **tourism** and have tried to maximize profits from the tourist sector. To avoid conflicts with other land uses, tourist activities have concentrated on selected zones (delta, selected parks and game reserves). Tourism products have been more diversified and have increasingly allowed for mass tourism. Transborder traffic of tourists has been simplified (visa & customs regulations). This approach has created new jobs, especially for a small number of local residents who are living in the designated zones. New tourism concepts have been developed within the basin to maximize tourist numbers. The concept of transboundary management of wildlife has been adhered to for profit maximization.

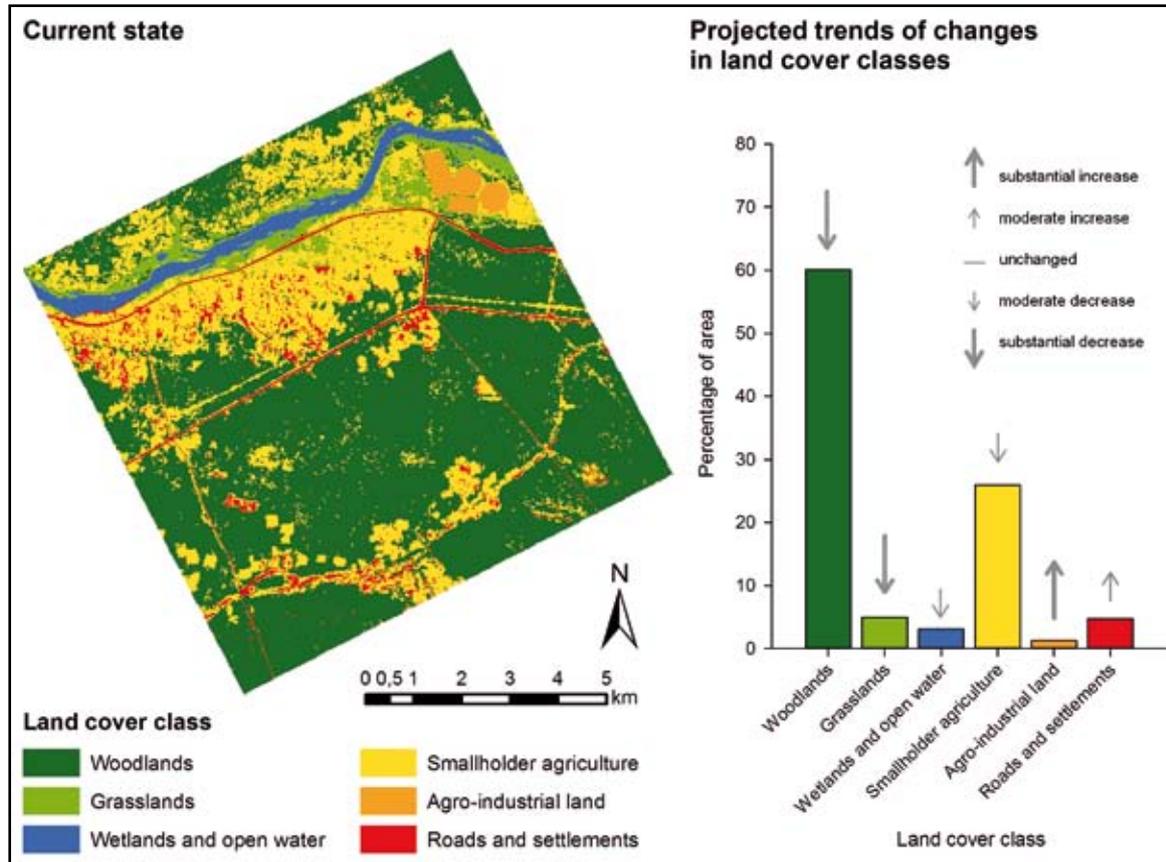


Fig. 148: The map depicts the simplified land cover classes of the core site of Mashare at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Basin Quarry'. Note: The arrows indicate a relative change in their respective land cover class only.



Fig. 149: Mokoros and wood carvings on sale for tourists (photos: M. Finckh).

Effects on the core site of Mashare

Due to the policy-makers' focus on the transboundary formal sector, no policies have been put into place with the aim of assisting smallholders. Rural and, due to migration, also urban **poverty levels** have risen, as have associated problems such as social tensions, and increasing stratification and social inequality. Smallholders have been seen as something of an obstacle to economic growth, and certainly not as a part of any growth strategy. Large parts of the rural population have therefore remained excluded from the formal sector and still subsist precariously in state that could be described as **'sustainable poverty'**.

The connection to global **markets for cash-based consumer goods** has been strongly promoted and facilitated by regional political and legislative bodies, and has been additionally boosted by the open borders and trade options. However, the massive investments in green schemes have caused little in the way of labour effects for the rural population. Shops and cash-based transactions have played a major role in rural contexts. Farmers have perceived cash-based markets (labour/jobs, trade) and the commercialization of their land-use as their only option for the future. In contrast to Scenario 1 there is an additional potential for transboundary labour migration that has been tapped by some farmers, who are venturing particularly into Angola.

Existing environmental laws related to forest, water, and land have still barely been enforced, with the exception of cases of severe pollution and degradation. In this sense, the situation is not significantly different from the state of affairs in 2015. Kavango traditional authorities have not been supported in the **monitoring and enforcement** of customary environmental laws. There have still been critical shortcomings in the sectorial integration of **environmental policies**. The legislative provisions for environmental impact assessments (EIAs) have remained unclear and unspecific. There has been little effort made to increase the general knowledge of the multidimensional consequences of resource-use decisions. As such,

many projects such as large-scale irrigated farms or commercial logging have widely been approved.

Most community land has been held under **customary rights**. Strong social control within the communities has prevented ordinary outsiders from gaining unauthorized access to the land. Nevertheless, powerful individuals or organizations have managed to corrupt traditional authorities, have ignored customary land rights, and grabbed land. Furthermore, the land board system has been effectively enforced. Now, investors can directly address the land board, which supports the transfer of land from the community. Compensations have been paid, but independently of the state of the land. Overall, the situation has reduced incentives for sustainable communal land management.

As **agro-industrial schemes have expanded on favourable soils (river terraces etc.)**, **smallholders have migrated to marginal lands** in the hinterland of roads and rivers where yields are lower. Traditional agricultural livelihoods have been further marginalized and have remained under severe pressure, with related consequences such as low productivity, poverty, urbanization, and commodification of nature.

Due to lower and more unpredictable yields, the rural poor are dependent on natural resources: the intensified wood extraction in communal woodlands has caused a significant degradation of the remaining forest ecosystems. Migrants to the hinterland are causing a large-scale transformation of natural woodlands and forests.

By the year 2030 the **water availability** has decreased in accordance with the climate models that projected less precipitation and higher temperatures causing increased evaporation from the FORA during the period 2016–2045. Taking into account the additional water extraction within the headwater catchments and by the expansion of irrigation schemes, the amount of downstream available water has decreased.

The modalities of this scenario have increased and accelerated the **social stratification process** within the



Fig. 150: Fish and sorghum as daily supply for smallholder farmers (photos: M. Pröpper).

rural areas as the Mashare core site and have led to a very heterogeneous society. Increasingly, the innovative smallholders have taken part in training offered by extension services and have used the chance offered by the government to modernize their agriculture with machinery, chemical field inputs and improved seeds. Investments in public infrastructure (transport, electricity) have facilitated their market integration. They have extended their holdings by acquiring land from their neighbours, and increasingly employ these neighbours as casual labourers on their farms. Those farmers that were threatened by poverty in 2014 have not managed to fully benefit from the modernization programs offered by extension services and other government bodies. Since they lack information about alternative production practices, they have increasingly fallen into a poverty trap. Many have seen no choice except to become landless labourers or to move to urban centres, where they have formed a growing class of rural poor.

Cattle: Ranchers in Kavango East have occasionally got good prices for beef they can export, but they have often faced quarantine restrictions that have forced them to overstock. They have sometimes even had to face their entire herds being slaughtered to comply with disease control regulations when a disease has broken out somewhere nearby in their veterinary zone.

5.4.5 Scenario 4: *Slow Growth*

Major development trends

The underlying logic of this scenario is that there is strong **cooperation between the basin countries, and the basin is managed as an economic and ecological entity** (prioritized before national interests). **Climate change** projections which suggested a tendency towards lower annual precipitation and an annual mean temperature increase have been taken seriously. A transboundary trust, e.g. OKACOM, has been given a strong

mandate. It has been carrying out monitoring and assessment activities and has been issuing recommendations which have strongly been taken into account in the national and local policy-making and have guided the close cooperation between these bodies.

In contrast to the other scenarios, a **different development paradigm** has been considered here. To mitigate the dependence of rural populations on intensified land-use and resource extractions mainly for cash purposes, the national and regional governments have developed **rural development strategies** in cooperation with development agents (USAID, GIZ, UNDP, Worldbank, FAO) which have seriously invested in conservation agriculture training, education, access to land, and other measures to secure sufficient yields.

While the general ideology has been that of a **stepwise economic development**, regarding rural poverty as a serious challenge, there have been some national/regional investments in the Green Scheme industry as well as other productive sectors (small-scale hinterland farms) as these sectors have been regarded as offering more labour for rural populations.

Another important assumption has been that **notions of sustainability are able to fundamentally change the values and lifestyles of society**. With the help of international research and development partners, better knowledge about interactions between land-use and the provision of ecosystem services has been made available among the various players. On the basis of existing participatory land-use planning processes, and taking into account ecological concerns, the local administration has initiated a **zoning process to develop key regions for sustainable forestry, and meat and crop production**. This process has weighed up comparative economic and ecological advantages and has encouraged trade between the countries.

Although markets have been the main economic mechanism of development, social, cultural and environmental values have been equally important. Stakeholders'

economic activities – especially agricultural innovations, forest management and hydropower developments – have been decided upon taking into account the whole range of benefits from natural resources for present & future generations on the local, national, catchment and global scales.

Effects on the core site of Mashare

To further facilitate trade both between the three countries and with neighbouring countries, and also to support improved connectedness, **the infrastructure has been considerably improved**. This has included the building of a bridge near Rundu, and additional border posts to enhance more frequent transitions between the countries. More storage capacities for agricultural products have been built near the towns and bigger villages as well as open markets for the sale of small-scale agricultural products. The use of renewable energy has been strongly supported.

In the crucial field of **rural agricultural development strategies**, interventions have specifically focused on improving the yields of small-scale farmers providing donor-funded or subsidized low-cost farming technologies (i. e. rotations, crop diversification, soil fertility, enhanced water use efficiency, organic and inorganic

nutrient use). The education policy has focused on basic education. Smallholder farmers have received training in adapted and sustainable resource-use practices such as drip irrigation, conservation agriculture, community forest management, community-based rangeland and livestock management, and community-based tourism. This kind of training has been offered to a large number of people. The interventions have led to an increase in productivity without diminishing the natural resource base. The use of biodiversity has been a major asset in the development model.

By 2030, the majority of rural households in Mashare and the wider Kavangos are employing central aspects of the **Conservation Agriculture** approach on parts of their plots to secure minimum food production. Composting and communal pasture management are ensuring increased supplies with animal manure. However, there has been insufficient manure and mulch, so farmers have not been able to rely solely on Conservation Agriculture but have complemented their production with traditional fields; here, advanced crop rotations and improved seeds have helped to stabilize production. The government has subsidized the availability of improved seeds and has offered intensive training via Extension Services. It has helped more successful farmers to specialize their production via financing, e. g.



The core site of Mashare – Slow Growth

Scenario settings:

- Strong collaboration between the three basin countries with the Okavango Catchment managed as an ecological and economic entity.
- Sustainable management of natural resources.
- Focus on rural development strategies.

Main characteristics of the *Slow Growth* scenario storyline for the Namibian Kavangos and the core site of Mashare:

- The infrastructure has been considerably improved.
- Agricultural interventions have specifically focused on improving the yields of small-scale farmers providing donor-funded or subsidized low-cost farming technologies.
- The Conservation Agriculture approach to secure minimum food production has been widely adopted.
- The influx of consumer goods has been limited by the enforcement of quality and health controls. With improved yields, cash demand has increased less markedly among the subsistence-based rural population than in other scenarios, reducing the pressure to exploit the remaining natural resources.
- A close collaboration between statutory and traditional authorities has helped facilitating a coordinated land-use planning process.
- Traditional leaders have encouraged community discussions on the use of natural resources, have introduced new customary laws restricting unsustainable resource management, and have strictly enforced the traditional laws.

In sum:

Under this scenario major parts of the rural population have benefitted from a different development paradigm, and the environment has benefitted from a generally sustainable ideology. However, as the general paradigm has been that of a stepwise development towards growth and transboundary cooperation using comparative economic advantages, the whole process takes a long time, is slow, and requires a lot of negotiations. The development of sustainable products and labels has been much slower than was the case with the uncontrolled profitization of Scenarios 1 and 3.

for the purchase of irrigation equipment. Improvements in public infrastructure (transport, electricity) have aimed at increasing smallholders' market integration, with the goal of supplying the entire Namibian market with food. Specialization and modernization have taken place among the better-off households, but adapted farming strategies have also enabled poorer smallholders to break out of the ongoing impoverishment process, to stabilize their livelihoods and ultimately to invest in their holdings or in the education of their children.

According to this focus on rural development, **urbanization** has been rather moderate for large parts of the **population**. Nevertheless, the populations of Rundu and Nkurenkuru/Katwitwi have increased. More villages have grown as they have bundled new small and medium enterprises thanks to new economic opportunities. Some of them have become towns. Nevertheless, local policies have avoided and mitigated localized depletion of natural resources, increased demand for energy, water, and transport, and discharge of unprocessed waste.

However, market-based growth and efforts to promote investments in cash markets have continued, but the **influx of consumer goods** has been limited by the enforcement of quality and health controls. With im-

proved yields, cash demand has increased less markedly among the subsistence-based rural population than in other scenarios, reducing the pressure to exploit the remaining natural resources in communal and public areas. Urban hubs like Rundu and increasingly Nkurenkuru and Katwitwi have also greatly developed their commercial sectors, with advertising and trading in all sorts of modern consumer goods. Shops and cash-based transactions have played a role in rural contexts. Farmers have perceived cash-based markets (labour/jobs, trade) and the commercialization of their land-use as one option; however, a large proportion of farmers have also invested in a sustainable future for farming.

Significant efforts have been made to improve the **monitoring and enforcement of environmental regulations**. A close collaboration between statutory and traditional authorities, as well as with OKACOM, facilitating a coordinated land-use planning process, has been critical. Subsidiary principles have been applied, reducing the monitoring and enforcement costs for the government. Standardized procedures on environmental impact assessments, resource extraction, controlling fires, and pollution control have been carried. Existing or newly established fields of large-scale agricultural production schemes have to comply with

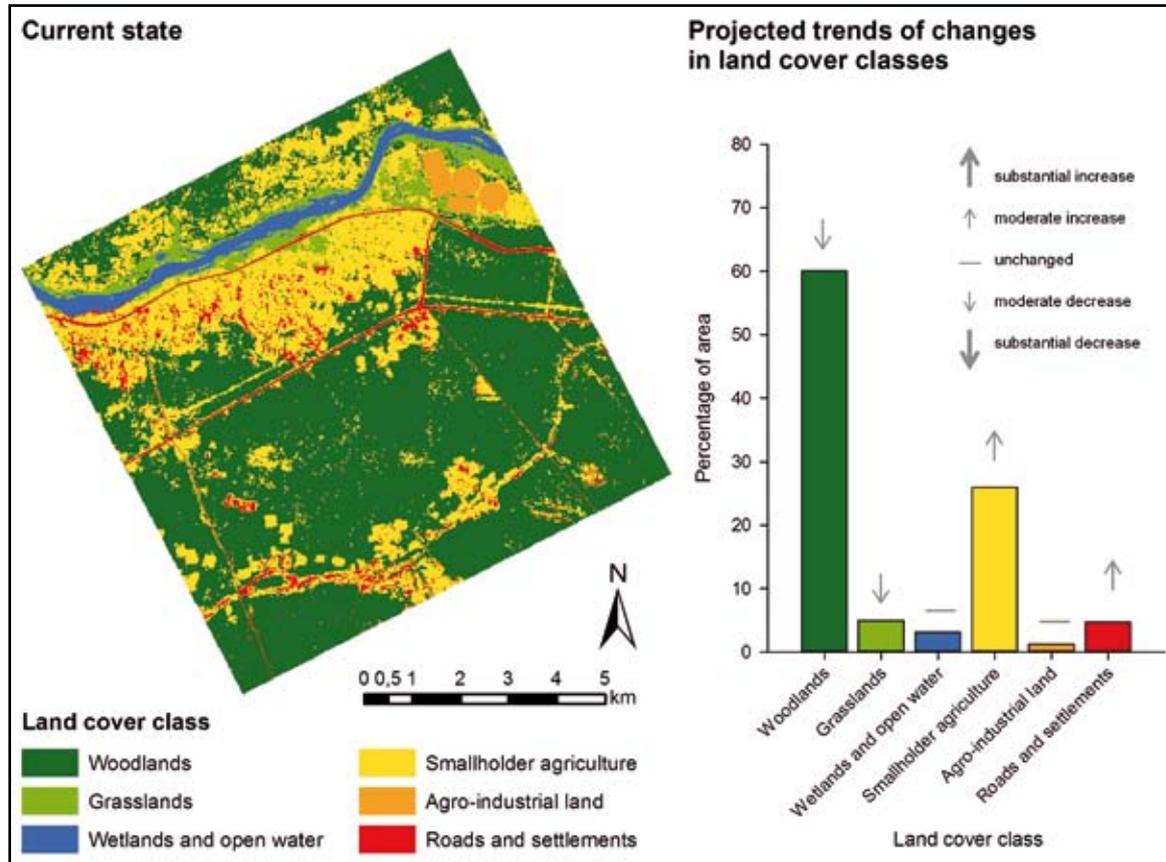


Fig. 151: The map depicts the simplified land cover classes of the core site of Mashare at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Slow Growth'. Note: The arrows indicate a relative change in their respective land cover class only.

these strict environmental requirements. This refers in particular to water abstraction, but also to soil and water quality and other natural resource-uses. **Customary land rights** have also been effectively enforced by state authorities. Transfers of land from communities to individuals and organizations intending large-scale commercial land-use have been based on the approval of traditional authorities and the community members. Compensations have been based on market prices, governmental regulations, and consensus. The poor have been given access to equivalent land. The relatively coherent interplay between customary and statutory land rights has made communities less prone to land grabbing by powerful players. This has increased their incentives for sustainable land management on the still-communally managed land.

On the local level, **traditional leaders have encouraged community discussions** on the use of natural resources, have introduced new customary laws restricting unsustainable resource management, and have strictly enforced the traditional laws. Specific topics discussed have been the uncontrolled clearing of forest to make fields, the misuse of fire, and the pollution of the river.

The Namibian Kavangos have offered some high-end **eco-tourism**, but this has been concentrated in jointly selected zones, especially around national parks. Tourism products have been diversified (photographic tourism, trophy-hunting, adventure tourism, angling, cultural and educational tourism) in order to generate maximum income from natural habitats, and therefore increasing incentives to preserve them. The local population has been strongly integrated into tourism concepts.

In Namibia, the planned **Manketti Park**, about 100 km south of Rundu, has been opened. By 2030, another small game park – similar to Mahangu – has also been established close to Rundu (< 50 km) and to the river to allow locals and visitors to make easy day trips. A local community is running the park with guidance of the government. Profits are shared between the local community, government and OKACOM. The park has a lodge next to the river that is run by a local community group that contributes part of the profits.

Thus, the majority of rural households do not need to **harvest natural resources** to generate more cash because of the increased opportunities to generate income from agriculture and tourism, and the actively stimulated entrepreneurship and processing of goods.

Foot-and-mouth disease has become a non-issue, since well-managed cattle and game animals resist the disease.

5.5 Trends of possible future developments for Seronga

The future developments at the catchment scale, as specified in chapter 5.2, will have repercussions for future local developments all over the basin, thus also affecting the core site of Seronga. However, due to the remoteness and lack of direct connection between the World Heritage Site of the Okavango Delta as an area of overarching interest, and the Kalahari Sandveld hinterland as an area of very low development potential, the development options for the Seronga site are restricted, and so some specific processes and indicators do not vary between the four scenarios. Before outlining how the four scenarios will affect the core site of Seronga, we will therefore indicate some future developments which are foreseen within all scenarios.

5.5.1 Future developments for all scenarios

Between 2016 and 2045 the climate models project a warmer and drier climate. The annual precipitation is expected to decrease by up to 100 mm, with no obvious change for the rainy season. The annual mean temperature is projected to increase by 1.5–2.5 °C, and the minimum and maximum temperatures in the wet season are expected to increase by 1–1.5 °C and 1–2 °C, respectively.

A bridge spans the Okavango at the northern end of the Panhandle. Seronga is connected with Shakawe by tarred road. Urban hubs like Maun and Shakawe experience a rapid development of the commercial sector. Growing cash income promotes businesses to advertise and trade all sorts of modern consumer goods. At the same time this intensifies people's desire for these goods and the wish to gain cash income.

At the core site of Seronga human natural fertility remains high and is a dominant driver of population growth. However, due to its remote position internal migration towards the urban centres is still a strong incentive, especially for the young.

5.5.2 Scenario 1: *Race for Money*

Major development trends

Within this scenario we assume that the three countries see no benefits in coordinating basin-wide development. A major expansion of the commercial sector is encouraged by infrastructure development and supportive policies. Regional and national policies, laws and regulations clearly encourage large-scale investments and the creation of new markets. The Botswana govern-



Fig. 152: The Okavango Delta, a UNESCO World Heritage Site (photo: Kralisch).

ment actively offers subsidies, credit, and tax reductions. The government establishes an intensive cooperation in particular with multinational mining, tourism and agrobusiness companies, according to their zoning concepts.

As part of this paradigm, environmental standards are reduced in so far as they are not part of the business model (e. g. tourism). This has a growing impact on the rural peripheries. Especially the overutilization of water (hydropower, irrigation) in Angola and Namibia negatively affects the downstream areas of the Panhandle and delta. This leads to regional conflicts as it jeopardizes major economic sectors such as tourism in Botswana.

At the same time Botswana itself expands commercial ranching and mining. New mines (mostly base metals) are established in the hinterland of the Panhandle. This increases water demands, and facilitates power and road infrastructure development and labour migration. At the same time, the development of the district is based on a clear zoning policy. While the region west of the Panhandle is more intensively used for commercial livestock production, the east rim is zoned as a Wildlife Management Area for tourism. High-end tourism activities continue in the delta area. Due to increasing drought risk and ecosystem degradation³ in the southern part of the delta, locations of tourism concessions shift northwards and include the east side of the Panhandle and its hinterland.

Sectoral integration of environmental policies is given no priority outside of the designated Game Management

Areas (GMAs). The monitoring of environmental regulations is not given high priority. Only severe cases of pollution and degradation are investigated and taken to court. Input subsidies support in particular large-scale cattle ranching and high-end tourism. Little effort is made to increase the general knowledge of the multidimensional consequences of resource-use decisions. Thus, many projects such as large-scale farms, new mines, and resettlement projects for tourism are widely approved without taking ecosystem services or social costs into account.

Botswana formalized land administration in the 1960s. The power of traditional authorities was largely given to state-controlled land boards. Local farmers hold formal land rights which prevent ordinary outsiders from gaining unauthorized access to the land. Nevertheless, powerful investors directly address the land board, which supports the transfer of land from the community in order to promote the implementation of new zoning plans. The zoning policies promote large-scale commercial investments and resettle smallholders from the east rim in a small number of selected towns. In order to implement this policy expropriation mechanisms are also used. In such cases compensations are paid, but they are set by the state without negotiations with local communities. Overall, the situation reduces incentives for sustainable communal land management. The poor interplay between customary and statutory land rights makes communities more vulnerable to land grabbing by powerful players. This reduces their incentives for sustainable land management.

³ These effects may in fact favour larger wildlife (large herbivores and their associated predators), as the increased frequency of extreme events will maintain large areas in the category of 'occasionally flooded grassland', which is a good wildlife habitat.

The effects on the core site of Seronga

The resettlement of people into larger rural towns (among them Seronga), the mining operations along the Panhandle, and the expanding tourism sector create new jobs and cash income, which promote the development of an increasingly prospering local commercial sector. The development is further supported by the upgrading of the road infrastructure. A new bridge and tarred road connect the mines and people on the eastern side of the Panhandle with Shakawe. The connectivity to regional hubs like Shakawe and Maun has strongly increased. As a result Seronga becomes increasingly involved in cash markets. Households purchase and dispose of an increasing variety of modern consumer goods.

Thanks to new job opportunities migration towards the urban centres becomes increasingly attractive, especially for the young. Small farmers are encouraged to work on commercial farms or to look for jobs in the mining or tourism sectors. Temporary and permanent migration are also promoted by the expansion of the nearest urban centers, Shakawe, Maun, and Sepupa, and the improved travel connectivity between Seronga and these centres. As Seronga gains increasing economic power there is increasing migration to Seronga from surrounding more rural areas.

The average cash income per capita is rising as the result of the new economic opportunities and increasing number of job opportunities. At the same time the income inequality has increased, which is for instance reflected in livestock ownership, leading also to new social conflicts. The growing economic sectors require well-trained professionals and the education policies promote the establishment of an academic elite. However, for the majority of the people of Seronga education opportunities are still limited. As the result of restrictions on

self-provisioning from areas under commercial concessions, local communities have decreasing access to ecosystem services. This particularly affects the poor, who rely more heavily on ecosystem services as the basis for their livelihoods and to mitigate risks. No modern insurance mechanisms are introduced to compensate for this effect.

Agricultural land-use is restricted to small fenced perimeters of ca. 3 km radius around the rural towns and 1 km within the floodplain. Semi-permanent cultivation agriculture in combination with small-scale livestock production remains an important livelihood component, even though it contributes only a rather small share to the community's overall income. Smallholder farmers only marginally improve their productivity. The general intensity of agricultural use increases in the fenced agricultural perimeters.

The increasingly intensive land-use increases the demand for land, and land markets develop. Some small-scale farmers rent their plots to better-off households and external investors, who can realize economies of scale. The new 'landlords' work as labourers or manage to enter other economic sectors. This dynamic brings new opportunities for investments but also increases food insecurity as no buffering or insurance mechanisms for the poor are in place.

Nevertheless, national agricultural development policies focus rather on large-scale commercial production in more fertile regions of Botswana and new technologies targeting small- to medium-scale farmers are not actively promoted or subsidized. Therefore, adoption rates for new farming techniques are low. The majority still continue to rely on ox- or donkey-drawn ploughs, or else abandon agriculture altogether.



The core site of Seronga – Race for Money

Scenario settings:

- National interests: encourage large scale investments and create new markets.
- Weak monitoring and enforcement of environmental regulations.

Main characteristics of the *Race for Money* scenario storyline for Botswana:

- Development is based on a clear zoning policy: large scale commercial livestock production on the west side of the Panhandle; high-end tourism activities on the east side.
- On the west side: veterinary services are improved.
- On the east side: new Game Management Area; the Northern Buffalo Fence has been removed to restore wildlife migration; protection of large game for the tourism industry.

Main characteristics of the *Race for Money* scenario storyline for the core site of Seronga:

- Agricultural land-use is restricted to a small fenced-off area around the town; intensity of agricultural uses increases; number of cattle on the east side drops sharply.
- Average cash income per capita is rising; at the same time social inequality is also increasing.
- Presence of new goods creates new desires; exploitation of natural resources by the less well-off.

As large-scale commercial livestock production is zoned for and encouraged on the west side of the Panhandle, veterinary services there are improved to meet export requirements for meat and livestock products from the newly established commercial farms there. Thus, the Northern Buffalo Fence has been removed and the Okavango River Bridge at Mohembo constitutes the new veterinary border.

Accordingly, veterinary regulations impede the commercialization of livestock products from the Seronga area in national and international markets. Cattle posts in the hinterland of Seronga are dissolved, and numbers of cattle drop strongly. Livestock farming is limited to the fenced perimeters around the rural towns. Wildlife migration is encouraged in the open corridors between the fenced perimeters.

The core Wildlife Management Area of the Okavango Delta keeps its status as a protected area. As the southern part of the delta is increasingly affected by droughts, high-end tourism shifts northwards to the eastern side of the Panhandle. Protection of large game for the tourism industry is given priority over agricultural or pastoral land-uses, and people from the villages are resettled to a few larger rural towns with fenced agricultural perimeters, creating large corridors without agricultural activities between the perimeters. Several new lodges are placed in those corridors

within the newly expanded Wildlife Management Area on the east side of the Panhandle. New employment opportunities arise in the lodge business. Increasingly medium-price facilities are also established by hostels and lodges in the rural towns, offering day trips into the WMA. Wildlife in the hinterland is more strongly managed, using boreholes in order to satisfy the photograph- and trophy-hunting tourists. Consumptive use of wildlife will mainly take place on privately owned game ranches. Overall wildlife numbers increase and wildlife migration between the delta, Ngamiland and Chobe is facilitated by removal of the Northern Buffalo Fence. The fencing of the agricultural perimeters around the rural towns reduces the number of human-wildlife conflicts.

The area under nature conservation has been increased by the establishment of the new Game Management Area east of the Panhandle. The removal of the Northern Buffalo Fence allows game migrations from the delta and the Chobe Region into the Kalahari Sandveld area between the Kwando and the Panhandle in the newly expanded WMA. The intensity of tourism activities in this area and on the eastern rim of the Panhandle increases strongly.

The core site of Seronga continues to present intact natural wetlands in its south-western part, and fairly intact Kalahari Sandveld in the north-eastern half of the

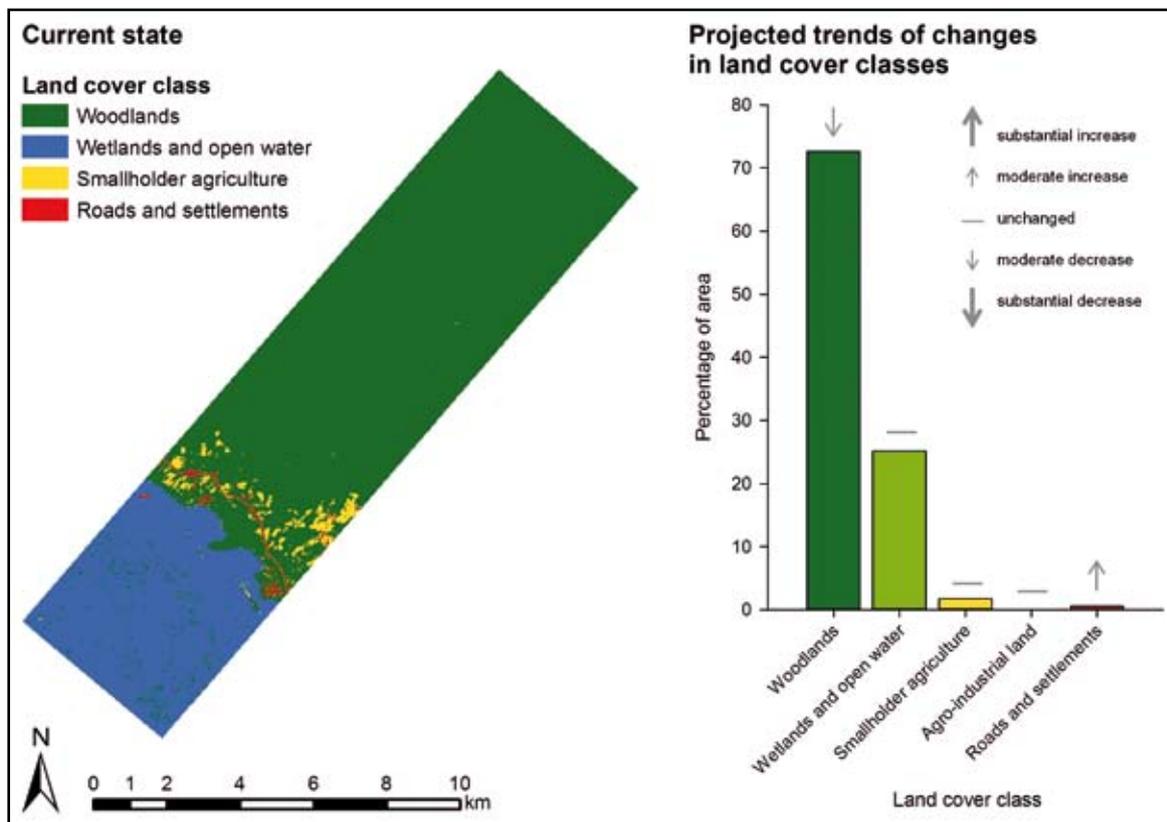


Fig. 153: The map depicts the simplified land cover classes of the core site of Seronga at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Race for Money'. Note: The arrows indicate a relative change in their respective land cover class only.

site. Human impacts on landscape features focus on the fenced-off perimeters for agricultural production around Seronga. They are all located within a 3 km radius of the town. Landscape integrity of the hinterland remains very high; however, increasing numbers of herbivores transform especially the Mopane woodlands into more open habitats. The landscape within the agricultural perimeters has changed strongly towards a mosaic of intensively used medium-sized fields, the relative share of fallows and woodlands in these perimeters has decreased greatly. An additional alteration compared to the current situation is the tarred road from Shakawe to Seronga, with its correspondingly considerably increased traffic. Within an area of 100 km² around Seronga 7 % of the land area is now used as arable land, while ca. 85 % is still in a relatively natural state. The fire regime remains more or less the same as it was in 2015, with the exception of the larger agricultural perimeter around Seronga.

The wetlands south-west of Seronga have been partly transformed into fields in the 1 km strip along the dryland edge, for agricultural use, and are increasingly affected by reduced flood pulses, shorter inundation periods, and increasingly polluted water due to the more intensive water use upstream. Untreated river water is hardly suitable for livestock or other direct uses anymore due to chemical and microbial pollution. Nevertheless, water supply for domestic consumption and the tourism industry is secured on the basis of pumped groundwater of good quality. This becomes even more critical in the face of climate change and more frequent drought. However, the changes are not so notable as in the southern part of the delta.

The strong presence of goods creates new desires to participate in the modern lifestyle. This creates strong incen-

tives for those who do not manage to find jobs to exploit marketable natural resources. In particular the harvesting of grass, thatch grass, and fish will increase. As the result of lower water quality and quantity in the river, this resource-use increasingly disturbs the ecological functions and dynamics of the river. Overfishing and unsustainable fishing techniques reduce fish stocks.

Several mines are established in the hinterland of the Kalahari Sandveld. Workers' settlements and access roads locally fragment the sandveld landscape and facilitate access for poachers and their clients. Poaching levels, however, still do not really endanger the elephant population.

5.5.3 Scenario 2: *Green Growth*

Major development trends

In this scenario, the three basin countries are following their individual national interests, and rely on their respective shares of the basin as a source of resources. National policies of the three countries target development with sustainable resource-use, taking into account the whole range of benefits from natural resources for present and future generations on the local and national scales. However, they do not give any special attention to particular externalities on the catchment scale (esp. water use). In general Botswana more strongly favours and supports commercial organic agriculture, and horticulture and ecotourism. The east rim between the newly built bridge at Shakawe and the tarred road to Seronga is zoned as a corridor for wildlife-based tourism, including high-end lodges with airstrip connections. High-end tourism activities also continue in the delta area. There will be neither cattle ranches nor mining activities on the eastern side.



The core site of Seronga – Green Growth

Scenario settings:

- National policies target development on the basis of sustainable resource-use.
- Improvement of the monitoring and enforcement of environmental regulations.

Main characteristics of the *Green Growth* scenario storyline for Botswana:

- National policies target development on the basis of sustainable resource-use.
- Improvement of the monitoring and enforcement of environmental regulations.
- Investments in eco-tourism, commercial organic agriculture and horticulture.

Main characteristics of the *Green Growth* scenario storyline for the core site of Seronga:

- Agricultural land-use is intensified and restricted to a small fenced-off area around the towns in a small strip along the edges of the wetlands.
- Eco-tourist activities are extended to the new Wildlife Management Area along the east rim of the Panhandle.
- Seronga becomes increasingly involved in cash markets and consumerism.
- New job opportunities created by eco-tourism and large scale organic farms; therefore, commodification of natural resources is less strongly developed.

Policy-makers make considerable efforts to increase their knowledge of the multidimensional consequences of resource-use decisions. On the basis of improved knowledge, the governments initiate a top-down land-use planning process, taking into account ecological concerns. Transfers of land from communities to individuals and organizations intending large-scale commercial land-use is based on the approval of the Land Boards. Compensations are based on market prices and governmental regulations. Botswana gives higher priority to the monitoring and enforcement of statutory and customary environmental laws. Fines and punishments are increased and have a deterrent effect on resource-degrading activities such as poaching, overfishing and commercial logging.

The overutilization of the water resources in Angola and Namibia has had an impact on the downstream wetlands in the Panhandle and delta. The economic interests of the Botswana Tourism sector are strongly affected, and relations with the neighbouring countries are tense.

The effects on Seronga

The nearer urban centres of Shakawe, Sepupa, and Maun have grown significantly, and the greater connectivity to them through the improved road infrastructure

rapidly increases people's access to modern goods, and so also influences the behaviour of the population. Internal migration towards the urban centres remains a strong incentive, especially for the young. However, due to the increased national efforts to support agricultural livelihoods and create labour opportunities in tourism, considerable numbers of people remain in the rural communities, re-migration by relatives is rather common. Rural residents find new job opportunities created by eco-tourism, modern organic farms, or related tertiary sectors. In sum, agriculture and tourism are the main sources of income for the local population.

Seronga becomes increasingly involved in cash markets and consumerism. Households acquire and dispose of a wide variety of modern consumer goods and the connectivity to regional retail businesses in Shakawe and Maun has greatly increased. Consequently the pressure to exploit the remaining natural resources in communal and public areas around the villages has increased. However, due to the job opportunities offered by tourist enterprises and administrative infrastructure, such commodification pressure has developed less strongly than in the other sites. Poor households without salary-earners nevertheless still depend strongly on the extraction and commodification of natural resources.

Agricultural land-use is restricted to small fenced perimeters of ca. 3 km radius around the rural towns and a

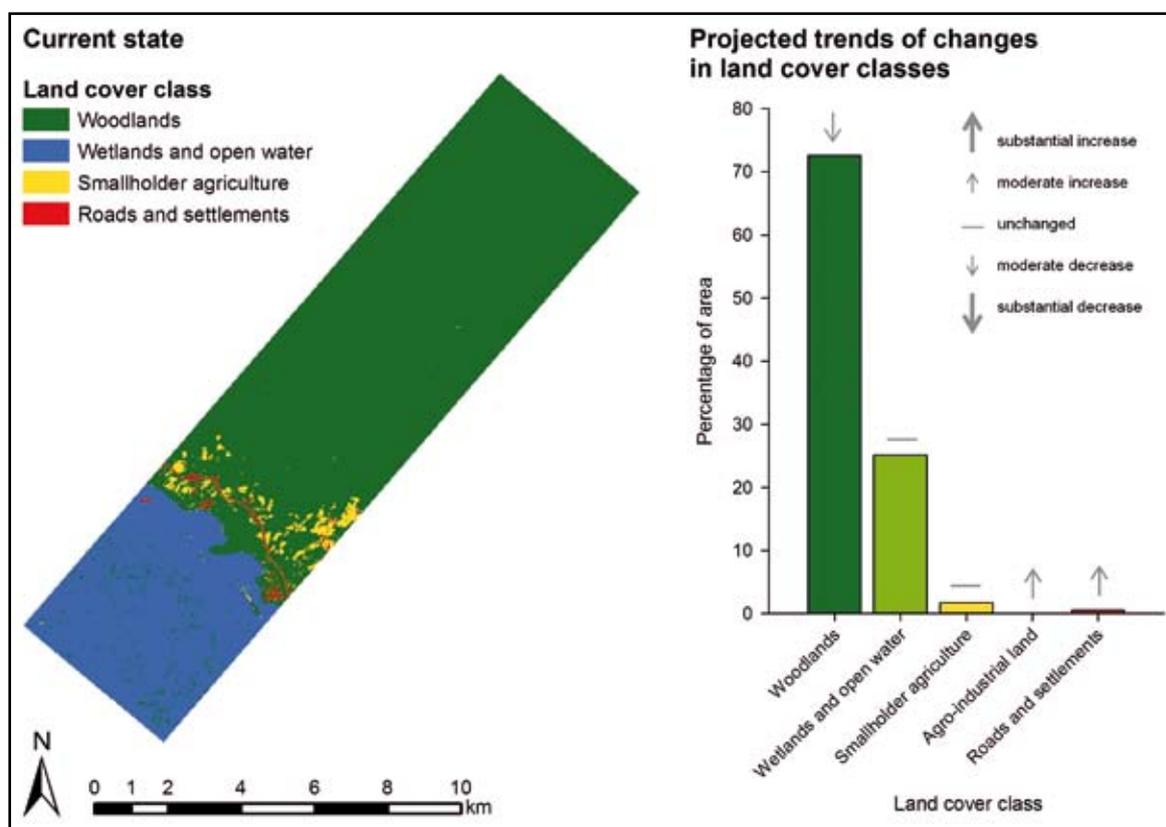


Fig. 154: The map depicts the simplified land cover classes of the core site of Seronga at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Green Growth'. Note: The arrows indicate a relative change in their respective land cover class only.



Fig. 155: Community-based tourism in Seronga, Botswana (photo: S. Domptail).

strip of 1 km within the floodplain. For the most part, permanent agriculture in combination with small-scale livestock production is an important livelihood component, even though it contributes only a rather small share to the community's overall income. Commercial organic agricultural investments are actively encouraged. Organic-label and fair trade certification is promoted. Local farmers are encouraged to join cooperatives or to work on commercial farms. Investments are made in professional training and education for a few specialists. Due to the promotion of intensive organic and conservation farming practices, farming land will become permanent in Botswana. Some farmers practise small-scale irrigation for horticultural products using small volumes of irrigation water. Increasing risks of extreme event will eventually cause a loss of the possibility of flood recession agriculture and marginalize farmers. Up to that point horticulture and medium-sized conservation farming extend into the floodplain and products are commercialized in the urban centres, the mining towns, and central Botswana.

Significant efforts are made to improve the monitoring and enforcement of environmental regulations. Standardized procedures for environmental impact assessments, resource extraction and pollution control are carried out by specialized staff, particularly on the large-scale farms. Environmental concerns are critical in the renewal processes for organic-label certificates.

The urbanized core of Seronga society, especially the availability of electricity and cash, has created a small but reliable market for selling local agricultural surplus. Thanks to the growing economic power of Seronga a few well-off farmers have easier access to agricultural knowhow, training, capital and markets. The growing local markets for both agricultural and consumer goods also create incentives to sell larger shares of their harvests. The remaining smallholder farmers only marginally improve their productivity.

National agricultural development policies focus on modern 'green' production and new technologies targeting medium-scale farmers, and agricultural en-



Fig. 156: Is tourism endangered due to resource overutilization upstream? (photo: A. Gröngroft).

trepreneurs are actively promoted and subsidized. Investments in machinery are subsidized and improved road access has made servicing of machinery easier and cheaper, so most of the better-off farmers and new agricultural entrepreneurs use tractors. Therefore adoption rates for new farming techniques are increasing among the better-off members of the community. The poorer farmers still continue to rely on a poverty-ridden low-input agriculture, with high importance of natural resources and small livestock. Other complementary livelihood sources (formal wage labour, small business, and natural-resource retail) and mixed livelihood strategies are used by the households and have gained increasing importance.

Cattle production is facilitated in the newly enclosed ranches in the south-west of Ngamiland. In order to protect this enclave, the veterinary cordon, i. e. the former Northern Buffalo Fence, is moved to the western side of the main Okavango channel in the Panhandle area. Seronga is excluded from the veterinary control zone, and animal husbandry is reduced and limited to the fenced agricultural perimeters. Thus, incentives for increased beef production are limited and the number of cattle drops considerably.

Cattle ownership is concentrated among a minority of households, but total cattle density is about 50 % of that in 2014.

In Botswana protected areas and national parks are maintained as they were in 2015 to maintain eco-tourism, which is fostered by the nomination of the delta as a UNESCO World Heritage Site. The assigned World Heritage status helps to promote the delta worldwide as an international eco-tourism destination and is successfully managed by an integrated resource-management committee to sustain the title in the long run. The northern part of Ngamiland east of the Okavango is included in a new Wildlife Management Area which connects the delta with the Chobe National Park and the National Parks in Namibia.

The airstrip in Seronga is modernized and slightly expanded to serve as an arrival point for tourists who visit



Fig. 157: Future tarred roads allow improved connectivity (photo: L. Schmidt).

the mid-price lodges along the Panhandle. Overall wildlife numbers increase, and wildlife migration between the delta, Ngamiland and Chobe is facilitated by removal of the Northern Buffalo Fence. The corresponding expansion of tourist activities enhances the number of visitors significantly, and partly compensates for the increasing drought risk and ecosystem degradation in the southern part of the delta.

The spatial separation between the fenced agricultural perimeters and the Game Management Areas reduces the number of human-wildlife conflicts.

The core site of Seronga continues to present intact natural wetlands in the south-western part of the site, and fairly intact Kalahari Sandveld in the north-eastern half. Human impacts on landscape features focus only on the locally assigned (and fenced-off) zones for agricultural production. They are all located within the current 3 km distance from the road. The main change compared to the situation in 2015 is the expansion of agricultural activities (i. e. ‚green‘ horticultural production) in a small strip along the edge of the wetlands, and the overall increase in land-use intensities of the agricultural perimeters. Landscape integrity of the hinterland and the wetlands remains very high. The tarred road from Shakawe to Seronga carries considerable traffic. Resource extractions (e. g. thatching grass, timber, fish, and use of forests) are restricted in the delta as well as in other protected areas.

Water extraction is mostly restricted to that necessary to fulfil the needs of urban and domestic consumption at Seronga, the adjacent villages, and the lodges. Water quality has decreased due to agriculture in Namibia and Angola. The urban water supply for Seronga is secured by boreholes and a water treatment facility. Agricultural water use is limited to small-scale irrigation, which is supported in the assigned horticultural lots at the edge of the wetlands. Total volumes of extracted water are low. In Botswana, irrigated industrial agriculture is not supported due to scarcity of water resources and the focus on water-related eco-tourism.

Overfishing and unsustainable fishing techniques reduce fish stocks already affected by decreasing quality of ri-



Fig. 158: Improved public services by better road infrastructure? (photo: L. Schmidt).

verine habitats and disturbed river dynamics. Changing annual flooding patterns have severe impacts on plant communities and on animal migration.

There are no mining projects on the eastern side of the Panhandle.

Fires continue to occur in large parts of the Kalahari Sandveld, mostly in August and September. However, in comparison to the other core sites the fire frequency continues to be much lower, with fire return periods above 5 years.

5.5.4 Scenario 3: Basin Quarry

Major development trends

The underlying logic of this scenario is the idea that the three basin countries could come to the conclusion that under an increased economic collaboration and distributed resource exploitation the economic growth potential and thus added value for all three partners might be highest. A strongly determining factor would thus be the paradigmatic view, shared by all states, that to combat poverty and promote development economic growth, industrialization and marketization and shared/distributed resource exploitation are necessary.

While the three countries remain autonomous, the basin serves as a source of resources for transboundary needs and interests. The basin is thus perceived and developed with the goal of an increasing economic and market integration (prioritized before national interests). As part of this paradigm environmental standards are reduced in so far as they are not part of the business model (e. g. tourism). This has a growing impact on the rural peripheries. The trend toward overutilization of water resources in Angola and Namibia negatively affects the downstream areas of the Panhandle and delta.

A regional forum of the three countries within SADC has emerged. Integrated transboundary economic management includes land-use planning processes that identified spatially optimal areas for making the best use of comparative advantages. Consequently Botswana

has continued to invest strongly in meat production, mining, and tourism; not, however, with an emphasis on long-term sustainability, but rather on short-term economic success. That includes areas with intensified livestock production, higher stocking rates, and fodder cultivation. New mines (mostly base metals) are established in the hinterland of the Panhandle. OKACOM has been relegated to the role of an environmental monitoring agency with little enforcement potential.

To strengthen the regional integration, the road from Divundu to Sehitwa and Ghanzi has been strongly expanded and improved, in order to connect the Caprivi and the Transkalahari Highways. The new mining sites east of the Panhandle are connected to the tarred road system. A good gravel road has been constructed between Maun and Seronga along the eastern edge of the delta, in order to allow the flow of tourists into the new tourist areas of north-east Ngamiland.

The eastern side of the Panhandle has become a zone for high-end wildlife-based tourism. On the west side of the Panhandle, there is intensive cattle ranching for meat production. Localized mining activities will take place on the eastern side of the Panhandle - outside of the World Heritage Site Buffer Zone. Larger perimeters of 5 km radius around the villages are fenced off and used for intensive agriculture, including livestock grazing for the local population.

Sectorial integration of environmental policies is given no priority outside of the designated wildlife and tourism zones. The monitoring of environmental regulations is not given high priority in ranching and mining areas. Only severe cases of pollution and degradation are investigated and taken to court. There is little effort

made to increase the general population's knowledge of the multidimensional consequences of resource-use decisions. Thus, many projects such as large-scale farms, new mines, and resettlement projects for tourism are widely approved without taking ecosystem services or social costs into account. However, large upstream-downstream trade-offs are taken into account to prevent major regional conflicts.

Local farmers hold formal land rights which prevent ordinary outsiders from gaining unauthorized access to the land. Nevertheless, powerful investors directly address the land board, which supports the transfer of land from the community in order to promote the implementation of new zoning plans. The zoning policies promote large-scale commercial investments and resettle smallholders of the east rim in a small number of selected towns. In order to implement this policy expropriation mechanisms are also used. In such cases compensations are paid but set by the state without negotiations with local communities. Overall, the situation reduces incentives for sustainable communal land management. The poor interplay between customary and statutory land rights makes communities more vulnerable to land grabbing by powerful players. This reduces their incentives for sustainable land management.

The effects on the core site of Seronga

In Botswana we find a strict zoning, between cattle zones on the west bank of the Panhandle and wildlife/tourism industry on the east bank of the Panhandle area. Livestock production zones are particularly used as a major control strategy for livestock disease. The former Northern Buffalo Fence is moved westwards to the



The core site of Seronga – Basin Quarry

Scenario settings:

- Increased economic collaboration between the three basin countries.
- The basin serves as a source of distributed resource exploitation.
- Integrated transboundary management.

Main characteristics of the *Basin Quarry* scenario storyline for Botswana:

- Land-use plans identify spatially optimal areas for making the best use of comparative advantages.
- Investments in meat production, tourism, and mining.
- Environmental standards are reduced outside of the designated wildlife and tourist zones.

Main characteristics of the *Basin Quarry* scenario storyline for the core site of Seronga:

- The east side of the Panhandle has become a zone for wildlife-based tourism.
- Increase in tourism activities on the eastern side of the Panhandle; the newly expanded Wildlife Management Area connects the delta with the Chobe National Park in the north-east and national parks in Namibia.
- Therefore, smallholders are resettled from the east rim to a small number of rural towns, among them Seronga.
- Intensive agriculture and livestock farming is restricted to a larger fenced-off area around Seronga.
- New mines (mostly base metals) are established in the hinterland.

main channel of the Panhandle. Zoning includes some forced resettlements and had strong effects on the exercise of land rights.

The resettlement of people into larger rural towns (among them Seronga), the mining operations along the Panhandle, and the expanding tourism sector create new jobs and cash income, which promotes the development of an increasingly prospering local commercial sector. The development is further supported by the upgrading of the road infrastructure. A new bridge and tarred road connect the mines and people on the eastern side of the Panhandle with Shakawe. The connectivity to regional hubs like Shakawe and Maun has greatly increased. As a result Seronga becomes increasingly involved in cash markets and consumerism. Households acquire and dispose of an increasing variety of modern consumer goods, and there is improved connectivity to regional retail businesses.

Due to new job opportunities migration towards the urban centres becomes increasingly attractive, especially for the young. The urban populations of the nearer urban and town centres Shakawe, Maun and Sepupa are growing strongly, attracting young people from the villages. The connectivity between these centres and the smaller villages like Seronga has greatly increased the need for global products. Small farmers are encouraged to work on commercial farms or to look for jobs in the

mining or tourism sectors. Temporary and permanent migration are also promoted by the expansion of the nearest urban centres of Shakawe, Maun, and Sepupa and the improved travel connectivity between Seronga and these centres. As Seronga gains increasing economic power there is more migration to Seronga from surrounding more rural areas.

The average cash income per capita is rising as the result of the new economic opportunities and growing job prospects. At the same time the income inequality increases, which is for instance reflected in livestock ownership, leading also to new social conflicts. The growing economic sectors require well-trained professionals, and the education policies promote the establishment of an academic elite. However, for the majority of the people of Seronga education opportunities are still limited. As a result of restrictions for self-provisioning from areas under commercial concessions, local communities have decreasing levels of access to provisioning, regulating and cultural ecosystem services. This particularly affects the poor, who rely more heavily on ecosystem services as the basis for their livelihoods and to mitigate risks. No modern insurance mechanisms are introduced to compensate for this effect.

Agricultural land-use is restricted to fenced perimeters of ca. 5 km radius around the rural towns, including a 1 km strip of the floodplains. Semi-permanent cultivati-

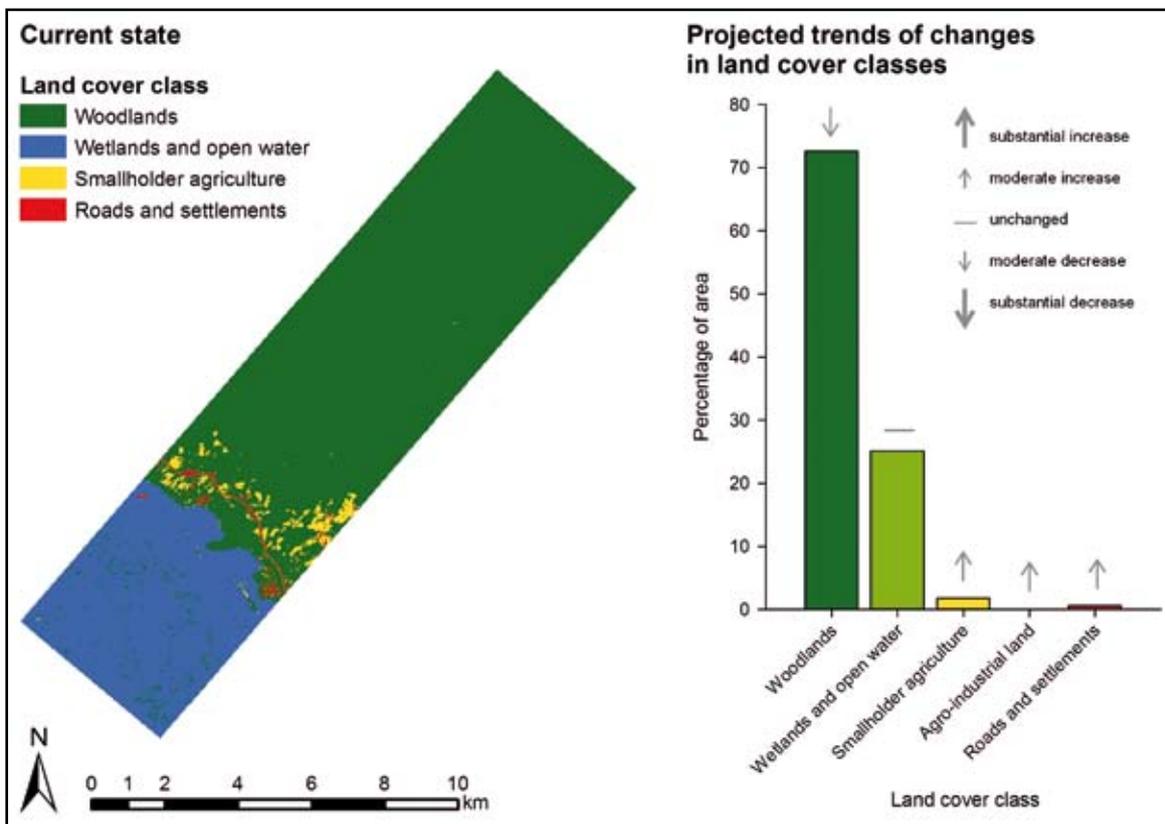


Fig. 159: The map depicts the simplified land cover classes of the core site of Seronga at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Basin Quarry'. Note: The arrows indicate a relative change in their respective land cover class only.



Fig. 160: The Okavango Delta attracts high-end tourism (photo: L. Schmidt).

on agriculture in combination with small-scale livestock production remains an important livelihood component, even though it contributes only a rather small share to the community's overall income. Smallholder farmers only marginally improve their productivity. Thanks to the growing economic power of Seronga a few well-off farmers have easier access to agricultural inputs such as fertilizers or pesticides. Adoption rates of enhanced farming intensities are high among the well-off households, but the majority of the poor farmers are getting poorer. A few medium-sized agricultural schemes have been developed in those perimeters to support domestic food security plans. The growing local markets both for agricultural and consumer goods also create incentives for farmers to sell larger shares of their harvests. The general intensity of agricultural use increases in the fenced agricultural perimeters.

The increasingly intensive land-use increases the demand for land, and land markets develop. Some small farmers rent their plots to better-off households and external investors who can realize economies of scale. The new 'landlords' work as labourers or manage to enter other economic sectors. This dynamic brings new opportunities for investments but also increases food insecurity as no buffering or insurance mechanisms for the poor are in place.

As large-scale commercial livestock production is zoned for and encouraged on the western side of the Panhandle, veterinary services there are improved to meet export requirements for meat and livestock products from the newly established commercial farms there. Water required by the cattle ranches is mostly produced from deep boreholes, not directly affecting the flow of the Okavan-

go. Thus, the Northern Buffalo Fence is removed and the Okavango River Bridge at Mohembo constitutes the new veterinary border.

Accordingly, veterinary regulations impede the commercialization of livestock products from the Seronga area to national and international markets. Cattle posts in the hinterland of Seronga are dissolved, and numbers of cattle drop strongly. Livestock are owned by an even smaller share of the households, and many people only maintain small livestock for subsistence and lingering cultural reasons. Livestock farming is limited to the fenced perimeters around the rural towns. Wildlife migration is encouraged in the open corridors between the fenced perimeters.

The Okavango Delta, a UNESCO World Heritage Site, is affected by increasing levels of water extraction and contamination with pesticides and nutrients upstream. Especially the southern parts of the delta are affected by reduced water pulses. However, the area of the World Heritage Site remains unaltered, and the delta remains an asset for the Botswana tourism industry. As the southern part of the delta is increasingly affected by droughts, high-end tourism shifts northwards to the eastern side of the Panhandle. The KAZA initiative continues. Protection of large game for the tourism industry is given priority over agricultural or pastoral land-uses, and people from the villages are resettled to a few larger rural towns with fenced agricultural perimeters, creating corridors without agricultural activities between the perimeters. The newly expanded Wildlife Management Area on the eastern side of the Panhandle connects the delta with the Bwabwata NP, Nkasa Ru-

para NP, and Mudumu NP in Namibia, and the Chobe NP in the north-east. Several new lodges are placed in the WMA. New employment opportunities arise in the lodge business. Within the WMA, high-end tourism activities are extended. In order to maximize revenues, increasingly also mid-price facilities are established by hostels and lodges in the rural towns, offering day trips in the WMA. Wildlife in the hinterland is more carefully managed using boreholes in order to satisfy the photograph- and trophy-hunting tourists. Overall wildlife numbers increase, and wildlife migration between the delta, Ngamiland and Chobe is facilitated by removal of the Northern Buffalo Fence. The fencing of the agricultural perimeters around the rural towns reduces the number of human-wildlife conflicts.

The core site of Seronga continues to present intact natural wetlands in the south-western part of the site, and fairly intact Kalahari Sandveld in the north-eastern half. Human impacts on landscape features focus on the fenced-off perimeters for agricultural production around Seronga. They are all located within a 5 km radius of the town. Landscape integrity of the hinterland remains very high; however, increasing numbers of herbivores transform especially the Mopane woodlands into more open habitats. The landscape within the agricultural perimeters has changed strongly towards a mosaic of intensively used medium-sized fields, while the relative share of fallows and woodlands in these perimeters has decreased strongly. An additional alteration compared to the current situation is the expanded road infrastructure to mining sites and from Seronga to Maun, with the correspondingly considerably increased traffic. Within an area of 100 km² around Seronga 15 % of the total land area is used as arable lands and ca 70 % is still in a relatively natural state. The fire regime remains more or less the same as in 2015, with the exception of the larger agricultural perimeter around Seronga.

The wetlands south-west of Seronga are increasingly affected by reduced flood pulses, shorter inundation periods, and increasingly polluted water due to the more intensive water use upstream. Untreated river water is hardly suitable for livestock or other direct uses anymore due to chemical and microbial pollution. Nevertheless, water supply for domestic consumption and the tourism industry is secured on the basis of pumped groundwater of good quality. This becomes even more critical in the face of climate change and more frequent drought. However, the changes are not so notable as in the southern part of the delta.

The increased presence of goods creates new desires to participate in the modern lifestyle. This creates strong incentives for those who do not manage to find jobs to exploit marketable natural resources in communal and public areas around the villages. In particular the harvesting of grass, thatch grass, and fish increases. As

the result of lower water quality and quantity in the river, this resource-use increasingly disturbs the ecological functions and dynamics of the river. Overfishing and unsustainable fishing techniques reduce fish stocks.

Several mines are established in the hinterland of the Kalahari Sandveld. Workers' settlements, access roads, and power supply lines locally fragment the Sandveld landscape. The regional integration of access roads, the removal of fences, and the increasing transboundary traffic facilitate access and smuggling opportunities for poachers. The poaching levels increase significantly in eastern Ngamiland and in the delta region.

5.5.5 Scenario 4: *Slow Growth*

Major development trends

In this scenario different actors across the Basin and in Botswana commit to an ecological, social and economic sustainable development. This has implications for the social, cultural and environmental values and for the societies involved, which are taken into account in government policies and regulations as well as in markets. Stakeholders make considerable efforts to increase their knowledge of the multidimensional consequences of resource-use decisions. Any economic activities – especially agricultural innovations, forest management, and mining – are decided upon taking into account the whole range of benefits from natural resources for present & future generations on the local, national, catchment and global scales. This consideration is supported by a close coordination between the basin countries, in which OKACOM has been given a strong mandate. It carries out monitoring and assessment activities. The recommendations of OKACOM are taken into account in the national policy-making.

The national and regional governments formulate rural development strategies that specifically target small-scale farmers' productivity. This development paradigm is implemented in cooperation with development and research agents (USAID, GIZ, UNDP, World Bank, FAO, CGIAR, SASSCAL). There is a strong focus on low-cost farming technologies such as conservation agriculture, crop rotation and diversification, soil fertility, enhanced water use efficiency, and organic and inorganic nutrient use.

As part of the implementation of the sustainable small-holder-oriented development policy, authorities formulate and implement in cooperation with international research and development partners' land-use plans. Basin-wide zoning takes into account comparative economic and ecological advantages, and encourages trade between the countries. Botswana continues to invest strongly into eco-tourism, education and the sustainable development of the agricultural sector including livestock.

Tourism development is planned on a cooperative basis between the basin countries. Namibia and Botswana

support Angola in its efforts to become a well-established tourism destination. The Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) is very instrumental in this policy. The basin develops a trademark and manages to gain a greater share of the global market for eco-tourism products. In this way all basin countries benefit from the extension of the tourism sector.

On the local level, traditional leaders encourage community discussions about the use of natural resources, introduce new customary laws restricting unsustainable resource management, and more strictly enforce the traditional laws. Specific topics addressed are illegal fishing, the clearing of forest to make fields, the misuse of fire, and the pollution of the river.

Significant efforts are made to improve the monitoring and enforcement of environmental regulations. The close collaboration between statutory and traditional authorities is critical in this regard. Subsidiary principles are applied to reduce the monitoring and enforcement costs for the government. As a result, customary and statutory laws restricting resource extraction, controlling fires, and regulating the clearing of forest are effectively and efficiently enforced.

Local land rights are effectively enforced by state authorities. Transfers of land from communities to individuals and organizations intending large-scale commercial land-use is based on the approval of the land board. Compensations are based on market prices, governmental regulations, and community consensus. The poor are given access to equivalent land. Traditional authorities are again more strongly involved in land administration issues. Overall, the constructive and subsidiary interplay between customary and statutory law, and the balanced and careful approach of the government makes commu-

nities less vulnerable to land grabbing by powerful players. This increases their incentives to practise sustainable land management on the still-communally managed land.

The effects on the core site of Seronga

The energy supply for the community as well as the tourism sector is strongly based on renewable energies such as decentralized small- to medium-scale solar plants, and biogas plants.

Thanks to the growing population and higher income in Seronga, as well as the tourism sector's increasing demand for fresh food, a relatively powerful market for agricultural products develops in the town. Inputs and supplements for the improved cultivation and rangeland also become locally available. This reduces the production and transaction costs of farmers and increases their incomes.

Thanks to new education and job opportunities migration towards the urban centres is still attractive, especially for the young. Nevertheless, the promotion of more productive and sustainable agriculture and tourism results in improved local job opportunities and agriculture-based livelihoods. As a consequence there are also strong economic incentives to stay in Seronga. This again means that urbanization is rather moderate. The development paradigm focuses on rural-based livelihoods for a larger population. However, the nearer urban centres of Shakawe, Maun and Sepupa also grow due to their improved connectivity. An increasing number of small villages develop as they bundle new small- and medium-scale enterprises thanks to new economic opportunities. Some of them have become towns.

The average cash income per capita is rising as the result of new economic opportunities. The income inequality



The core site of Seronga – Slow Growth

Scenario settings:

- Integrated transboundary management.
- Focus on ecological, social, and economic sustainable development.

Main characteristics of the *Slow Growth* scenario storyline for Botswana:

- Customary and statutory laws restricting resource extraction are effectively enforced.
- Cooperation with international development and research agents (CGIAR, FAO, USAID, UNDP, World Bank).
- Sustainable rural development strategies are supported, i. e. conservation agriculture, water use efficiency, and livestock management.

Main characteristics of the *Slow Growth* scenario storyline for the core site of Seronga:

- Small-scale extensive irrigation of cereals, vegetables and fruits has become common all along the Panhandle; community-based rangeland management is actively promoted.
- The second economic pillar is built on eco- and ethno-tourism; community-based and foreign-run private tourism operations.
- In the context of the Transfrontier Conservation Areas wildlife corridors are established enabling wildlife migration, thus reducing human-wildlife conflicts.

remains at the high level it was in 2015, but at least it has not increased. Education policies target the broad population relatively equally. As the result of the ecosystem states provisioning, regulating, and cultural ecosystem services are continuously provided. This maintains and stabilizes the livelihoods of the poor in particular, who more heavily rely on ecosystem services.

Under this scenario agriculture and tourism are the main land-use practices and critical sources of income for the local population. Agricultural research and development projects will develop, test, pilot, and scale up adapted sustainable smallholder-oriented resource-use practices such as conservation agriculture, composting, agroforestry, and drip-irrigation. Vegetables and fruits are widely cultivated as cash crops. Small-scale extensive irrigation has become common all along the Panhandle. Knowledge exchange between communities within the basin is encouraged. All this has positive effects on the smallholders' productivity.

In contrast, irrigated industrial agriculture is not given priority by policy-makers and is only permitted if a thorough assessment provides evidence that there are no significant negative social and environmental impacts. The same holds true for other intensive extractive, non-sustainable resource uses such as mining. As a consequence, around Seronga, neither commercial irrigation nor mining projects have been implemented.

Livestock management is actively promoted. It is seen as a more tourism- and wildlife-management-compatible land-use alternative compared to cultivation agriculture. Livestock production requires less severe transformations of natural habitats. Community-based rangeland management is actively promoted by the government and other development agents. Thanks for instance to pooled herding practices, short-term intensive grazing and trampling, and long resting periods, the productivity substantially increases without major ecological deterioration.

The Northern Buffalo Fence and the existing FMD control system is dismantled to improve wildlife migration within the KAZA area, taking into account the potential impacts on the livestock sector.

Tourism development follows a diversified strategy. Communities are strongly supported in the development of community-based tourism operations. Seronga's community campsite is fully renovated. It offers eco- and ethno-tourism products which can be provided by community members largely with locally available resources. The tourists enjoy a relatively authentic experience of modern Botswana rural life, sleeping in traditional huts and participating in everyday resource-use and household activities such as fishing with Mokoro boats, making crafts or preparation of food or. In addition, nature viewing is offered by well-trained community

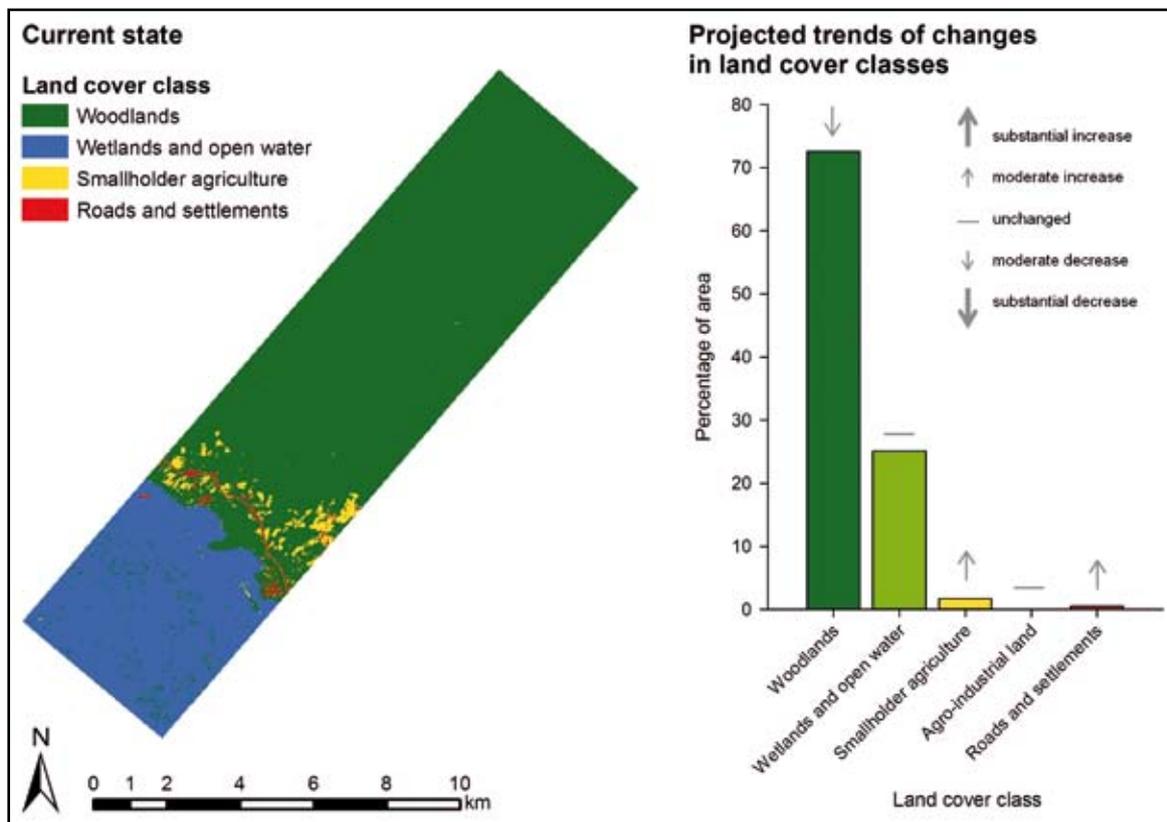


Fig. 161: The map depicts the simplified land cover classes of the core site of Seronga at its current state. The bar chart illustrates the percentage of area of each land cover class; the arrows above each class indicate the assumed changes within the scenario 'Slow Growth'. Note: The arrows indicate a relative change in their respective land cover class only.

guides. A differentiated picture of the life of the community is provided. These products target the mid-price tourism market.

The Seronga community is further affected by an up-grading and consolidation of the high-end tourism sector. It becomes part of the tourism development policy to concentrate foreign-run private tourism business on the high-end segment in order to avoid too strong and direct competition with community-based tourism products. High-end lodges are planned on the basis of sound ecological and social impact assessments. On the one hand, the Seronga community benefits from the extension of high-end tourism in that it increases concession fees paid to the Okavango Community Trust. On the other hand, new jobs are created and community members have the opportunity to receive professional training which allows them to work in better-qualified positions.

Protected areas are maintained as they were in the year 2015, but community-based natural resource management spreads. Overall tourism activities also expand further north as the result of increasing climate-driven drought risk in the southern part of the delta. This is done in a very sensitive way, however, avoiding further disturbance to the ecosystem as much as possible.

The assigned UNESCO World Heritage status helps to promote the delta as an eco-tourism destination and the site is successfully managed by an integrated resource management committee to sustain the title in the long run. In the context of basin-wide cooperation within the KAZA TFCA, wildlife corridors are established throughout the region. As result wildlife is enabled to migrate northwards, which reduces the convergence effect in north-eastern Botswana. As a consequence, total wildlife numbers and in particular elephant numbers decrease in the Seronga area, also reducing human-wildlife conflicts.

The ecosystem around Seronga continues to present intact natural wetlands. Water quantity and quality remain high, also thanks to the basin-wide coordinated natural resource management and low upstream-downstream conflicts.

The Kalahari Sandveld also remains in a good state. Landscape transformation has considerably slowed down since 2015 and is restricted to a four-kilometre-wide belt along the Seronga-Shakawe road. Landscape integrity of the hinterland has even improved due to newly established wildlife corridors to the north. Newly drilled water pumps in the hinterland in combination with improved rangeland management reduce localized degradation patterns.

Within an area of 100 km² around Seronga, 7 % of the total land area is used for arable lands, and 85 % is in a relatively natural state.

5.6 Comparison of major development pathways and their impacts

Within this chapter we have offered various pathways for future developments. It must be kept in mind that they are based on plausible and often simplified assumptions, and are not intended to be taken as predictions or forecasts of how things 'will' happen. Rather they investigate possible futures, and at best cover a broad array of possible futures in order to inform decision-making. In contrast to the **current state** description, or the **key findings** they project certain specific development pathways into the future, and they are intended to do so in an internally coherent way. That means they are based on alternative binary choices between e.g. strong or weak transboundary cooperation, or strong or weak resource governance and management – but in reality, these binary choices represent the extreme poles of specific continuous variables, and therefore situations which lie somewhere between these binary options are much more likely. Nevertheless, by boiling things down here at the end of the scenario chapter we would like to try to emphasize and discuss the range of options by focusing on the extreme opposing scenarios 1 and 4.

For this purpose we have summarized the tendencies for each variable within their different development pathways in tables, one for the Okavango Basin, and three others, one for each of the core sites. Within these tables we depict the assumed trends for certain variables as arrows, and thus offer an at-a-glance comparability of the trends across the scenarios. The directions of the respective trends are symbolised with arrows, the key to which is given in tab. 15.

Note that such arrows are an approximation of a more complex spatially explicit quantification of scenarios. However, as the scenarios are just one product among many others that the TFO project had to accomplish within 5 years, this is the interim output which we offer here. Further analyses, especially of the relationship between the indicator and the social situation, will have to follow in the future. However, the arrows are the results of an intensive interdisciplinary discussion within the TFO team.

Tab. 15: Direction and impact of trends of scenario variables.

↑	increase, improvement
↓	decrease, deterioration
↗	moderate increase, slight improvement
↘	moderate decrease, slight deterioration
→	no change



Fig. 162: Aerial view of animal pathways in the Okavango Delta (photo: H. Seidel).

Some broader development drivers, such as climate change, global market integration, urbanisation and poverty, play a significant role in the general transformation of the whole system, and have been described within the scenarios. Here, however, for the purposes of a condensed comparison, we will concentrate on aspects and variables where clear basin- and site-related differences between the scenarios become visible.

5.6.1 Comparison of the major development trends

Imagine a future as described in scenario 1, in which the three neighbouring countries in the basin concentrate on their own fast-track economic success. The river will be viewed as a partial property to be used for damming, irrigation, and tourism, among other uses. Smallholder agriculture will be viewed as something that is outdated, which means that it will not be considered worth investing in an agrarian reform that might otherwise include training, awareness, new technologies and ecological agriculture. The future for farmers will rather be viewed in the context of a cash-based labour market, as they become e. g. workers on large-scale agro-industrial enterprises offering few jobs – or else migrate to the cities to work in the emerging businesses of e. g. international and national investors. Land, water, and natural resources will be viewed as commodities by international investors in search of fields on which to plant rice and other food items, dams to produce hydropower, timber for all sorts of purposes, or zoned landscapes to

be marketed to tourists. Those land users who remain in agricultural subsistence will most probably continue trends that are already visible today – including the commodification of e. g. timber, thatch, charcoal, or honey, so as to also enter the growing cash markets. But these smallholders will be pushed toward even less productive soils in the hinterland, reducing not only their yields and thus their food security, but also their food sovereignty. Cash will mediate access to necessary and highly valued goods and services such as electricity, clean water, and infrastructure, as well as to modern systems of education and health. A system to monitor and enforce the protection of natural resources will not be strictly established, but rather treated laxly. Economically this process will contribute to short- and mid-term economic growth within the three countries, and a reduction of poverty – measured by average income, reduced unemployment, health insurance statistics etc. However, conflicts over resources – most certainly over water – will be one of the downsides. Looking at some of the indicators that we have used for the scenarios, we show some of the ecological long-term negative consequences of this process (tab. 16). The spatial expansion and the intensities of several processes will increase – e. g. for the proportion of converted land, ranching land, irrigated plots, as will the intensities of resource extractions and landscape fragmentation. Water abstraction will also increase, and water shortages will first be recognizable in Botswana, with a reduced water flow reaching the delta. But in Namibia too the available water will decrease due to the increased water abstraction in the upper catchment and the increased

Tab. 16: Comparison of the evaluation of two extremely different development trends for the Okavango Basin.

	Race for money	Green Growth	Basin Quarry	Slow Growth
Scenario settings				
Integrated transboundary management	↓	↓	↑	↑
Policies of management of natural resources	↓	↑	↓	↑
Development policy paradigms	Jump	Jump	Jump	Stepwise
Drivers / Variables				
Monitoring and enforcement of natural resource governance	↘	↑	↘	↑
Ability of local actors to defend their land rights	↘	↗	↘	↗
Physical infrastructure development	↑	↑	↑	↑
Tourism activity	↑	↗	↑	↗
Area of effectively conserved land	→	→	→	↗
Area of natural land converted	↗	→	↗	↘
Area of commercial ranching	↑	↗	↑	→
Area under irrigated industrial agriculture	↑	↑	↑	→
Intensity of extraction of natural resources in non-cultivated areas	↑	↘	↗	↘
Area of smallholder production systems	→	→	→	↗
Amount of extracted river water	↑	↗	↑	→
Water quantity	↘	↘	↘	↗
Area affected by regular fires	↗	↑	↗	↑
Landscape fragmentation	↑	↘	↑	↘

domestic water abstraction by the spreading agricultural schemes and settlements along the river. In addition, an increase in irrigated farms on the river banks will cause a larger flow of nutrients into the Okavango River, diminishing the still rather high water quality.

In contrast to this pathway, on the other end of a spectrum in scenario 4, one could imagine a world where the three countries come to the conclusion that cooperation and benefit-sharing plus a long-term ecological and smallholder-oriented strategy might be the best option. This might sound a bit like the portrayal of a beauti-

ful green eco-future, but a national investment in the strengthening of the communal society might also be intended to support a sustainable and long-term driven process of integration of the local communities into the growing cash economy. The importance of smallholder productivity as a backbone of rural livelihoods within the Okavango Basin would be recognized. A major focus of an agricultural reform and campaign would be to increase yields on existing dryland plots with alternative technologies (e.g. conservation agriculture including (organic) fertilization, evaporation control, farmer-to-



Fig. 163: Charcoal production and water-use by the local communities in Angola (photos: F. Maiato, H. Göhmann).

farmer training). This would reduce food insecurity, but would only slightly raise cash income. It is a stepwise and long-term process that would include improved land rights and a better monitoring of environmental policies and rules. The effects might also show in different rates of land conversion, water- and resource extractions, or landscape fragmentation, to name just a few (tab. 16). Additionally the flow regime of the river would remain more stable than in scenario 1, ensuring the continued functionality of the delta and reducing the potential for conflicts. However, as we have shown in the scenario storylines themselves, these are values and benefits that are often non-monetary from a short-term perspective. They require political mitigation and rule-making with regard to investments, agro-industrial intensification, and the expansion of cash-based markets. Even more so they would require a renunciation of short-term economic growth and of a 'jump' into a fast-track economically profitable future. This is the major downside of this other extreme scenario.

In sum, it is apparent from a simple juxtaposition and comparison of the driving forces of the chosen scenario logics and the two extreme poles of potential development that **1)** the assignment of different development paradigms and their related policy decisions is likely to have a major impact on several variables over the next 15 years, and **2)** the orientation of **policies of management** of natural resources (i. e. exploitative or sustainable) is likely to have **significant impacts on the development** and on the state of the natural resources over the same period, as might be expected.

In addition, when comparing columns 1 & 2 (national interests first) with columns 3 & 4 (transboundary management) we find that a decision in favour of or against an integrated **transboundary management** does not lead to clear differences between the respective storylines. Especially when related to the short-term exploitative management of natural resources there is hardly any difference between the developments in scenarios 1 and 3. Only with regard to the tourism

activities and the intensity of extraction of natural resources does the approach of comparative economic advantages in scenario 3, **Basin Quarry**, lead to some slightly positive developments. Nevertheless, an integrated transboundary management approach between the three basin countries is of special importance when it is associated with long-term sustainable development and management policies, as can be seen in the case of scenario 4, **Slow Growth**. This is the only one of our scenarios with a positive trend shown for the protection of pristine forests, the use of natural resources, and the livelihoods of the smallholders.

Special attention has to be paid to the availability of water. Already our models predict a significant decline of water reaching the Panhandle in Botswana because of the cumulative effects of climate change together with increased water abstraction due to the expansion of hydropower and agricultural irrigation schemes. This imminent risk can only be reduced through a cooperative endeavour of the three basin countries and an ongoing monitoring and enforcement of the OKAKOM agreements.

5.6.2 A closer look at the development at the core site level

For the core site of **Cusseque** the major development trends in all scenarios follow the development depicted for the whole Okavango Basin, with the associated downsides described above. A short-term exploitative strategy will steer a growing and expanding population's perceptions and actions with regard to land viewed as an infinite resource. This leads to greater pressures on natural resources and negative impacts on landscape integrity, such as the fragmentation and degradation of Miombo woodlands, and the destruction of the buffering capacity of wetlands. However, implementing long-term sustainable policies of natural resource management will offer the chance to counter this development, and even offer the opportunity to establish tou-

Tab. 17: Comparison of the four different development trends for the core site of Cusseque.

	Race for money	Green Growth	Basin Quarry	Slow Growth
Scenario settings				
Integrated transboundary management	↓	↓	↑	↑
Policies of management of natural resources	↓	↑	↓	↑
Development policy paradigms	Jump	Jump	Jump	Stepwise
Drivers / Variables				
Global expansion of cash economy	↑	↗	↑	↘
Poverty	→	→	→	↘
Monitoring and enforcement of natural resource governance	↘	↑	↘	↑
Ability of local actors to defend their land rights	↘	↘	↘	↑
Tourism activity	→	↗	→	↗
Area of effectively conserved land	→	↗	→	↑
Area of natural land converted	↑	↗	↑	↗
Area of commercial ranching	→	→	→	→
Area under irrigated industrial agriculture	↑	↑	↑	↗
Intensity of extraction of natural resources in non-cultivated areas	↑	↗	↑	↗
Area of smallholder production systems	↗	↘	↗	→
Amount of extracted river water	↑	↗	↑	↗
Water quantity	↓	↘	↓	↘
Area affected by regular fires	→	↘	→	↘
Landscape fragmentation	↑	↗	↑	↗

rism, conservation agriculture, and community forests as alternative economic pillars. Tourism would further profit from joint efforts of the three countries to implement the already-signed agreements on trans-frontier national parks, allowing for the migration of large wildlife and their reintroduction into Angola.

A comparison of our four scenarios for the core site of **Mashare** shows that land, soils, and resources become even more imperilled under short-term exploitative ma-

agement policies, as many current processes of commodification will continue. Furthermore, Rundu, and Mashare will be strongly affected by the increased water abstraction in the upper catchment, because it is located before the Cuito confluence. The situation will be aggravated by increased domestic water abstraction by the spreading settlements along the river, leading to a reduced flow pattern. Providing support for sustainable agricultural practices is thus of special importance. An

Tab. 18: Comparison of the four different development trends for the core site of Mashare.

	Race for money	Green Growth	Basin Quarry	Slow Growth
Scenario settings				
Integrated transboundary management	↓	↓	↑	↑
Policies of management of natural resources	↓	↑	↓	↑
Development policy paradigms	Jump	Jump	Jump	Stepwise
Drivers / Variables				
Global expansion of cash economy	↑	↑	↑	↗
Poverty	↑	→	↑	↘
Urbanisation	↑	↗	↑	↗
Monitoring and enforcement of natural resource governance	↘	↗	↘	↑
Ability of local actors to defend their land rights	↘	↑	↘	↑
Foot and mouth disease management	↑	→	↓	→
Physical infrastructure development	↗	↗	↗	↑
Tourism activity	→	↗	↑	↗
Area of effectively conserved land	→	→	→	↗
Area of natural land converted	↑	↗	↑	↗
Area under irrigated industrial agriculture	↑	↗	↑	→
Intensity of extraction of natural resources in non-cultivated areas	↑	↗	↑	↓
Area of smallholder production systems	→	→	↘	↗
Amount of extracted river water	↑	↗	↑	→
Water quantity	↓	↘	↓	→
Area affected by regular fires	→	↘	→	↘
Landscape fragmentation	↑	↗	↑	↗

array of measures and institutional changes is necessary to promote more an agricultural paradigm-shift towards sustainable farming methods, including conservation agriculture, water-saving irrigation techniques, and horticulture, as well as agroforestry systems. Such

a stepwise, costly, and certainly cumbersome development of the agricultural sector would come at the price of politically controlled and limited expansion of modern cash markets in favour of a stabilization of the eroding subsistence-based cultural systems.

Tab. 19: Comparison of the four different development trends for the core site of Seronga.

	Race for money	Green Growth	Basin Quarry	Slow Growth
Scenario settings				
Integrated transboundary management	↓	↓	↑	↑
Policies of management of natural resources	↓	↑	↓	↑
Development policy paradigms	Jump	Jump	Jump	Stepwise
Drivers / Variables				
Poverty	↗	→	↗	↘
Urbanisation	↑	↗	↑	↗
Monitoring and enforcement of natural resource governance	↘	↑	↘	↑
Ability of local actors to defend their land rights	↘	↑	↘	↑
Foot and mouth disease management	↘	→	↗	↘
Tourism activity	↑	↑	↑	↗
Area of natural land converted	↗	→	↗	↘
Area of commercial ranching	↑	↓	↑	↗
Area under irrigated industrial agriculture	→	→	↗	→
Intensity of extraction of natural resources in non-cultivated areas	↑	↗	↑	↗
Area of smallholder production systems	→	→	↗	↗
Amount of extracted river water	↗	→	↗	→
Water quantity	↓	↘	↓	→
Area affected by regular fires	→	↘	→	→

For the core site of **Seronga** we have offered different pathways with regard to zoning and organizing different activities within the landscape. Due to the sandy soils, only a few places within the core site area are suitable for agriculture. Therefore, in an exploitative scenario a strict zoning approach is followed to allow for livestock production on the western side of the river and wildlife and tourism enterprises on the east side, these being the most important economic pillars. Agricultural production is restricted to fenced-off areas around the settlements on the east side. Under the Slow Growth scen-

ario, Seronga's zoning would not mainly serve to further the optimization of profits from effectively used units, but would mainly concentrate on mitigating conflicts between wildlife/tourism and agriculture, e.g. by establishing wildlife migration corridors. This rather long-term process of transformation would also emphasize sustainable rural development strategies, i.e. conservation agriculture, water-use efficiency, and livestock management, plus the support of eco- and ethno- and community-based tourism.

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Chapter 6

Synthesis

The vast Okavango Basin, which is connected by its tributaries, is a mosaic of partly overlapping socio-ecological systems of great ecological and cultural diversity that faces significant challenges in the future. Many inhabitants are keen to improve their livelihoods, to connect to global markets, and to improve the infrastructure, education and health systems of the area. To find better options for their futures, people move and migrate to urban hubs, they strive for new products and seek new labour opportunities, and they are often willing to sell their natural capital. Like many other places on the planet, the basin has become a place of global transformation. Lifestyles and ambitions change, new economic actors and markets for land, water, and natural resources emerge, as do markets for everyday commodities, and formerly remote areas are being opened up to these changes with the improvement of traffic and communication infrastructure. However, these developments bring along many risks – especially for the environment. Political actors and decision-makers are part of this complex setup. A key challenge they face is the question of how to balance such processes of development and modernization with ecological sustainability – especially since some of the processes

we are facing are not endogenously produced within the basin but enhanced or enforced by regional or global drivers of change.

Political decision-making should be informed by good scientific data. In this book TFO has first of all provided a **status analysis** and **key findings**.

We were able to take up existing worries about effects of climate change for Southern Africa, and model the likely future climate changes for the basin. The basin is expected to become warmer, especially in Southern Angola, Namibia, and the delta, where mean air temperatures at a height of 2 m from ground level is projected to increase by 1.5 to 2.5 °C in the period 2016–2045. Simultaneously, the amount of rainfall is projected to decrease over the whole region, and the duration of the rainy season to shorten by up to 20 days in the Angolan Highlands (over the period 2016–2045). That means that there is likely to be additional pressure on the cultivation of certain crops if precipitation falls below their tolerance limits. Not only farmers, but whole agricultural systems will have to adapt to these changes. Next to this global threat, we also showed that the ongoing endogenous process of land- and forest transformation has had and will continue to have a significant impact on



Fig. 164: Tar road passing Cusseque, Angola (photo: B. Kowalski).



Fig. 165: Thunderstorm in the Cusseque valley, Angola (photo: M. Finckh).

the carbon stores in the soils. In total the conversion of woodlands to long-term agricultural cropland leads to a carbon release of 50–63 t ha⁻¹ in the Miombo woodlands, 25–33 t ha⁻¹ in Angolan *Baikiaea* woodlands, and 10–24 t ha⁻¹ in the dry woodlands of Northern Namibia and Botswana.

The delicate flow regime of the river is another aspect to be examined, as it will be impacted by human intervention. It can be described as a **flood pulse system**, which means that during the rainy season, flood peaks deliver an essential amount of water to the delta. Most of the water runoff, which is necessary to keep the flow of the Cubango and Cuito Rivers stable, is generated in the Angolan highlands during the rainy season. Rainfall patterns in the northern part of the Okavango Catchment can reach up to 1,300 mm a⁻¹ and therefore generate essential amounts of river runoff delivered towards the delta in Botswana. The flow regime depends on several important factors – including the peak-flow buffering effects of peatlands in Angola, and the stabilizing function of the wetlands along the Cuito. Ultimately this pulsing system supports the pristine Okavango Delta in the lower part.

However, it is the transformations in human land- and water-use that will impact on the river most strongly – to a greater degree even than climate change. Damming and/or the implementation of reservoirs in the riverbed lead to buffered runoff generation. As such, flood pulses are buffered in their intensity and extended in duration. The implementation of expanded agro-industrial schemes, using large amounts of river water for irrigation, will pri-

marily affect regional flow patterns, and indirectly also the flow pattern of the entire downstream river system. Planned schemes in the Namibian Kavango region will abstract a maximum of 27 m³/s (7 % of the mean minimum flow) before entering Botswana. Several large schemes are proposed in the Angolan part of the head-water catchments, leading the subsequent abstraction rates to strongly affect the flow of small tributaries. For example, in the Cuelel Catchment a scheme is proposed to abstract 120 m³/s, which exceeds water flow even in the high flood period. In the neighbouring catchment of the Cuelebe, a planned scheme could abstract as much as 12 m³/s, which equals 75 % of the mean minimal flow in the river. Keeping in mind that both of these catchments contribute to the Cubango system, which is characterized by a high variability in flow pattern, this might affect low-flow conditions tremendously, especially in the border zone of Angola and Namibia before the confluence with the Cuito River.

Changes in land-use (woodland conversion, establishment of large-scale irrigation schemes, expansion of urban areas) and climate are likely to increase peak flows in the future. The locations of current settlements are adapted to the current flow situation, thus keeping damage during peak-flow situations low. With water levels exceeding the current peaks, damage to housing, cropping activities, infrastructure, and tourism facilities is very likely to occur. The actual level of damage that may be caused cannot be foreseen; however, as the livelihoods of people are strongly adapted to the current flow situation, it has to be regarded as potentially very severe.

While the whole system and its diverse landscapes are currently still largely intact, the rapid increase of human activities like slash-and-burn agriculture, road construction, and agro-industrial intensification clearly drive the fragmentation of ecosystems. We see three main processes of transformation and degradation, each of which has its own socioeconomic driver and causes its own pattern of ecosystem destruction. Firstly, poverty-driven smallholder subsistence agriculture penetrates into the hinterlands of the rivers and patchily transforms and degrades the savannahs, woodlands, and forests. In more densely populated areas smallholder agriculture rapidly converts natural forests and woodlands into agricultural fields. Secondly, the intensification of the production of firewood, timber, charcoal, thatch, bushmeat and honey has significant impacts. The marked transformation towards trade and marketization (commodification) of woodland products occurs along the main road and access routes, and causes large strips of transformation (of forests), degradation (e. g. of timber resources) and depletion (e. g. of larger wildlife). With the exception of the conserved areas in Botswana and Namibia, the fauna, and especially larger wildlife, are already severely degraded. Roads with their associated belts of land-use, as well as the system of veterinary fences, create significant barriers which interrupt wildlife migration patterns. Along these axes urban demands and lifestyles reach out, creating new demands and encouraging exploitation and commodification of natural ecosystems and resources.

Commodification for cash thus means increased pressure, due to mutual incompatibilities, on the mainte-

nance of some services (e. g. charcoal vs. honey production). Deforestation problems, e. g. through interrupted species regeneration cycles and decreasing distribution ranges, will be the longer-term effects. These problems are being aggravated by clear-cutting, rapid fire-return periods, and crosscutting road axes.

The third main driver of transformation is the investment-driven implementation of agro-industrial schemes. This agro-industrialization is currently targeting the best soils and the available water resources of the region along the main rivers. Agro-industrial irrigation schemes lead to spatially limited, yet locally profound landscape transformations. As they are rapidly increasing in both size and number, and are located in areas of high value for smallholder agriculture, tourism, and conservation, conflicts are inevitable.

At the same time forests – which have a lot of non-human-use-related ecological functions such as improving water quality, reducing surface runoff and soil erosion, and regulating water flows – are being converted into agricultural fields all over the place. While expansive slash-and-burn smallholder subsistence forms of agriculture are the dominant farming systems in the Okavango Basin, we were able to show that these forms are not efficient. Under the current cropping systems, limited land availability results in soil degradation and reduced yields. This may cause households to fall into a poverty trap, a vicious cycle of resource degradation and impoverishment from which they are unable to escape on their own, as they cannot make the investments needed for the adoption of improved farming



Fig. 166: Crushing of cassava in Angola (photo: H. Seidel).



Fig. 167: Cubango River south of Caiundo, Angola (photo: M. Finckh).

practices. Sandy, nutrient-poor soils, high evaporative water losses, and inefficient agricultural practices (e. g. inadequate management of organic matter and nutrient stocks in the soils, lack of fertilizer also due to a lack of investment capital) are additional causes of extremely low yields. Currently potential yields of dominant parts of the landscape are restricted to $< 600 \text{ kg ha}^{-1}$; yield assessments carried out in 2012 and 2013 showed even smaller grain yields. Consequently systems are on a pathway towards impoverishment and natural resource degradation. However, since these livelihoods feed several hundred thousand people in the basin, considerable productivity improvements in the agricultural systems are a must for the future.

Societies in the basin are in a state of transition. On the one hand land users still largely depend on natural resources for livelihood purposes such as building, energy, food, water, and medicine, and value traditional harvesting practices, and services like clean water. On the other hand, being entirely dependent on inefficient agriculture, and having no alternative labour options, they face massive constraints on their ability to integrate into a rapidly evolving modern cash economy. Processes of social stratification and commodification are among the consequences of this situation. Things and services from nature, e. g. planks of timber, wild medicine, and thatch grass, are often used and sold without their vendors even knowing their exact value. The absence of knowledge about the market values of sold resources also aggravates the rapid degradation of natural resources. This exposes a clear need for knowledge exchange and education. Additionally, households often have low in-

centives to invest in education due to poor labour-market integration and the high costs of education.

Furthermore we found significant potential for improving the governance of the system. There is a need to develop more equitable, effective, and inclusive water- and land-related policies and strategies for the sustainable use of water and natural resources of the basin. The fair inclusion of local stakeholders in this process would strengthen the role and function of transnational institutions. Furthermore, environmental rules and laws are insufficiently enforced, and transnational institutions are weakly empowered and insufficiently equipped to guide a process of transnational collaboration.

In the present volume, TFO has further connected these findings with **recommendations for future action**.

A relevant contribution that could be made by the involved countries to mitigate climate change lies in the issue of woodland conservation and sustainable forest management. By avoiding woodland conversion and subsequent rainfed agriculture, a carbon release of 10–63 tons can be prevented for each hectare, depending on the area within the catchment. To generate financial incentives for the avoidance of woodland conversion, the mechanisms of the multi-lateral UNFCCC agreement on climate change as defined in REDD+ should be applied.

Since the Cubango and Cuito River sub-basins are fundamentally different in their dominant hydrological processes and their intra-annual contribution to the Okavango Delta inflow, these differences should be taken into account in the planning of catchment management. The

hydro-meteorological measurement network within the Okavango River Basin should be extended to represent regional processes at a higher level of detail.

As our climate models up to the year 2030 showed that land-use change has a higher potential to impact runoff regeneration than climate change, great attention should be paid to large-scale land-use changes.

In order to safeguard the currently still-high quality of the Okavango River, transboundary water management and fine-grained water-quality monitoring should be built up to control intensive agricultural activities and other potential sources of water pollution.

Data repositories and information systems like the Okavango Basin Information System (OBIS) for data storage, management, analysis, and visualization should be used and expanded to support basin-wide water management and planning and to provide a platform for data- and knowledge exchange across different scientific disciplines and stakeholders.

An integrated and systematic conservation and land-use planning concept is urgently needed across the whole basin. As a robust foundation for any science-based response to the impacts of climate and other forms of environmental change on forests, savannahs, woodlands, and grasslands and their organismic diversity, the establishment of long-term monitoring plots is recommended. Additionally, the adaptive capacity and the sustainability of species of high ecological or economic value should be analyzed in detail. TFO has presented respective suggestions regarding nature reserves and parks, the securing of ecosystem- and migration-route connectivity, the multi-

ple and buffering functions of wetlands, and the important role of woodlands for livelihoods and the water flow regime (see chapter 4.3).

We have outlined the trade-off between the values generated by woodland compared to the values generated by crop production, and emphasize a general need to change people's perception of the forests and woodlands from the idea that they are an infinite and less valuable area to a view that regards them as a limited resource that offers high income opportunities. Such a change in perception should form the basis for conservation and land-use planning concepts, which should also aim to strongly restrict destructive uses, and issue exploitation permits only with the associated obligation that the permit-holders enable forest regrowth within a short time span.

Again we have suggested specific management concepts emphasizing aspects like restricted charcoal production zones in the Miombo forests, Burkea woodland forest management interventions focusing on Kiaat and Zambesian teak, and further studies of the conditions and processes allowing and controlling regeneration of riparian woodland in the delta.

In general we advocate that protective measures on the local scale should have a strong emphasis on outreach to engage communities and prioritize advocacy, rather than regulation.

With regard to fires, TFO mapped the high frequency of bush fires in large parts of the basin with their detrimental effects on animals, losses of nutrients (especially nitrogen), and the regeneration potential of woodlands.



Fig. 168: Burnt woodlands in Namibia (photo: M. Finckh).



Fig. 169: Traditional farming and conservation agriculture in comparison (photo: I. Zimmermann).

Reducing the frequency of human-induced fires, especially on fallows and clearcuts in the first 5 years after abandonment, should therefore be of high priority. Grasslands should only be burnt early in the dry season when the risk of fires spreading into woodlands is still low. Burning should never be allowed in hot and windy weather conditions. A training and awareness campaign about the short-term and long-term effects of fires should be initiated.

For parts of South-East Angola, wildlife-based tourism presents a new and challenging income opportunity, not only for areas within KAZA. As was shown for Botswana and Namibia, preserving the number and diversity of large wildlife species is a prerequisite for tourism, together with landscape beauty. Enforced hunting regulations and the establishment of corridors for wildlife migrations are therefore necessary to establish the frame conditions for the expansion of larger wildlife, and thus income generation from high-end tourism.

Crop production by smallholders, though largely inefficient in terms of yields, is and will likely remain the backbone of rural livelihoods within the Okavango Basin. We have already outlined the problems associated with a spatially expansive form of agriculture encroaching on pristine habitats. An agricultural reform and awareness campaign should therefore focus on increasing yields on existing dryland plots by encouraging the use of alternative technologies (e.g. conservation agriculture in-

cluding (organic/alternative) fertilization, evaporation control, farmer-to-farmer training). Such a shift in development paradigms is needed due to improve livelihoods for the growing rural population facing the low fertility of the majority of soils, the harsh climatic situation, the restricted possibilities for extracting surface water or groundwater for irrigation, and in consideration of the high value of woodlands. We have made specific recommendations for the identification of agricultural priority areas; the optimization of rural farmer support, training, extension, awareness, ownership and access; and further research on locally adapted farming techniques (small-scale and water-saving irrigation techniques, home gardening, pest management, manure and organic residues, bacterial inoculant technology etc.) (see chapter 4.4). Based on the successes of the CA farming technique in the Kavango regions we advocate that future research should include the CA farming system as a key option for sustainable land-use in land restricted areas. However, the participating farmers need further support in order to facilitate full establishment of this approach.

With increasing rural populations concentrating on arable lands and using woodlands for timber and other products, sustainable land-use strategies require a reduction of livestock densities. Frequent livestock censuses should be used to control the increase of livestock numbers in the villages of the basin. Institutions that guarantee fair and equitable access to cattle are needed.



Fig. 170: Slash-and-burn agriculture in Angola (photo: A. Gröngröft).

These institutions should allow for improved communal grazing management, and regularly reassess optimal communal cattle densities.

Furthermore, we have emphasized the complex linkages between ecology and society. People certainly do have economic relationships with the wider biotic world (extracting food, fodder or fibres) but also perceptive, bodily, emotional and spiritual connections with the landscapes (senses of home, beauty, belonging, sociality etc.). All these factors shape their values and may influence their decisions and actions upon ecosystem services. Furthermore these interactions have to be seen as embedded into a globalizing world that rapidly transforms and demands rapid adaptations to changes.

Responsible policy-makers are faced with the challenge of identifying value-based decisions and frame conditions by which ecosystems may be safeguarded, and at the same time also that of accounting for socially sustainable processes of valuation and environmental action. A policy solution to the dangerous and detrimental effects of globalization and consumerism, taking into account not only cash-based but also immaterial values, and mitigating and controlling processes of land- and resource sale and commodification is one urgent requirement. Development should not be considered as being driven only by economic and cash-market-based values and incentives; the continuous functioning of social-cultural systems and the ecosys-

tem should also be considered. However, local land users are also challenged to think and act about their natural resources and accept their responsibility to apply sustainable farming and extraction methods, to ask for appropriate prices for their products, and to demand decent services from their political and traditional leaders. In addition, policy should acknowledge the importance of tackling the emerging diversification and stratification of communities and livelihoods, for instance by regulating and securing livelihood- and income options for a broader land user population. We further advocate a harmonization of traditional and modern rules and laws governing access to and regulation of natural resources so as to ensure sustainable resource use and to protect the resource rights of all community members without removing useful incentives and motivations. The harmonizing of customary and statutory law can be an effective means by which to monitor and enforce natural resource laws. In particular in the context of community-based natural resource management programs such as community forests or conservancies, by-laws should be developed in an open and participatory way. By-laws which are more strongly based on deep-rooted norms can be enforced at very low cost by the community itself. A consequent subsidiary enforcement system is recommended.

Education, training, awareness creation, grants, and the improvement of governmental extension services are other aspects that require policy attention and funding to



Fig. 171: Gap in understanding between stakeholders and researchers (photo: A. Gröngröft).

incentivize and facilitate innovations and reduce dependency on relatively unproductive subsistence agriculture.

Equally important is a focus on establishing inter-scale, international and inter-sectorial communication processes to avoid potential conflicts. In particular, it is necessary to recognize in each conflict what values are at stake (e. g. ‚smallholder agriculture is a motor of rural development‘ vs. ‚urban employment is the motor of rural development‘ and what scales are involved. On a macro-scale this involves especially the Permanent Okavango River Basin Water Commission (OKACOM) which currently performs less effectively than it could. Committed state-based funding, independent of donor support, and a stronger mandate are needed to promote coordinated and environmentally sustainable regional water-resources development, while addressing the legitimate social and economic needs of each of the riparian states and including various stakeholder levels into the process.

Beyond these fact-based recommendations TFO has striven to develop scenarios that illustrate possible pathways into an uncertain future. These scenarios have been developed to give stakeholders attached to the basin the opportunity to critically think through the consequences of potential developments, to learn and to compare them with their own perceptions, and to improve decision-making. Comparing pathways defined by such variables as **1)** more or less transnational cooperation; **2)** more or less exploitative strategies of land and water-use-inclusive guiding policies; and **3)** different development-paradigmatic views on a global ideology of growth, we outlined four different pathways for the basin and for our three core research sites. It turns out that depending

on the viewpoint adopted all scenarios have their advantages and downsides. However, the TFO scenarios do not constitute rigid development pathways which depend on a single decision taken at a critical ‚crossroads‘ point in time; on the contrary, the scenarios should be read by stakeholders and decision-makers at all levels as an invitation to think about future developments which optimize economic and environmental benefits and reduce environmental and social detriments.

Five years is really only sufficient time to allow a team of researchers from several disciplines to get started – if one considers the sheer width of the basin, the size and diversity of the population, and the multiplicity and complexity of the many processes going on in the basin. Consequently the output of the project and the **experiences** of those involved have to be **self-critically reflected upon** as limited, with regard to several factors.

TFO benefitted from the work of researchers from a wide array of disciplines; however, regarding the multitude of problems and questions, the addition of insights and research from those working in other disciplines, e. g. fish biodiversity, or water quality, would have improved the outcomes.

Especially regarding the many different needs and demands of stakeholders, and the different scales at which they operate, the rather academic aim to better understand the interactions between ecosystem services and land-uses proved to have a rather low assessment- and practical implementation capacity. TFO researchers repeated many times when interacting with stakeholders that ‚We are providing knowledge for better decision-making, but we do not provide tractors, electricity or roads‘. But for many people who live in an immedi-



Fig. 172: Ecologists explaining a weather station to the traditional authorities around Cussequ, Angola (photo: M. Finckh).

ate context of poverty, the fact that an improved understanding of the value of an ecosystem service might contribute to improved planning for land-use was not very visible or tangible. It was this gap in the mandate/expertise of researchers to address development interests that may have caused some frustration on both sides. There remains a challenge to be met, however: before any urgently needed and requested solutions and implementation plans are suggested or put in place, there is an ongoing need for research to understand the socio-ecological system and its dynamics. This must be investigated prior to the attempt to develop any practical implementation strategies. It is hardly feasible to complete both of these steps within a period of only five years.

In addition to this, stakeholders are not a homogeneous group; rather we speak of the stakeholder 'landscape'. This landscape is formed by different scales and interests, by differences in wealth and power, in culture and language, and also, differences associated with locations separated by the vast spatial distances within the basin. An international investor is a stakeholder, as is the international labour migrant, the regional politician, or the local farmer. In sum, it is very challenging and at times costly for a research project to meet, inform, and involve representatives from all sides of this landscape. Furthermore TFO is by no means the only project operating in the area; there is a growing number of parallel and newly established research- and NGO-sector development projects. It is challenging even to ensure that the project remains informed about all these activities, let alone to follow up on all the networking and meeting activities required without specially hired staff on the ground.

In the face of this landscape, local stakeholders often also experience a sort of 'research fatigue'. They are confronted with the demands of many parallel (participatory) processes in the region, and, as we have outlined, local stakeholders often demand concrete progress rather than abstract results. This holds also true for the exchange forums for integrated land management (FIRM) that TFO initiated: The ongoing support and facilitation that is needed in order to involve not only scientific knowledge but also all sorts of other service providers (from water offices, to electricity providers, to agricultural extension officers and government officials) to improve land-use systems could feasibly be achieved by a research project. However, such experimental processes of integrating various levels of expertise to the benefit of local farmers can only be initiated by research; they then need to be subsequently stabilized and facilitated by professional agencies.

Lastly, there are all sorts of issues in terms of timing and logistics that pose additional challenges and impact on the performance of a project within a given time frame. Problems associated with different timings and schedules (academic conferences, cropping period for research, political meetings to attend) make it difficult for the project members to always keep each other updated. There are also bureaucratic/political challenges to be negotiated with regard to e. g. contracts and visas. Especially in Angola, where there is a great need for research, but at the same time a rather long, complex and expensive visa process, serious difficulties had to be surmounted in order to pursue research activities.



Fig. 173: Helmeted Guineafowl, *Numida meleagris* at core site Caiundo (photo: M. Finckh).

Prospect / Future directions

Like many other developing regions of the globe, also the Okavango Basin is facing serious challenges caused by climate change, other environmental change and societal change. With the report presented here TFO offers a wide spectrum of novel knowledge, based on cutting edge scientific methods and in close interaction with stakeholders in the basin. We are confident that this report will be of help for informed decision-making towards protecting ecosystems and resources while also improving the well-being of the populations of the whole Okavango Basin. Yet many open questions and necessities for future research activities remain – of which we would like to mention a few here.

- There is a large potential to improve agriculture within the basin based on the improved understanding of nutrient cycles and taking the local settings into account. In this regard practical experimental approaches to adaptive land use are recommended.
- Similarly, a more efficient and sustainable use of the vast woodland areas requires further studies on how the values of the forests could be developed, protected and turned into a higher and more predictable income. The now available improved knowledge regarding spatial patterns of plants and animals should be turned into an applied project that uses systematic conservation planning methods to identify priority areas and corridors for new conservation areas and national parks.
- TFO made available data, models and scenarios that improve the understanding of the factors that control the water flows in the catchment. Additional more applied research should turn this knowledge into more applicable tools that in future will allow to integrate all decisions that impact on the remaining flow of water, at local, national and regional scale, also consi-

dering transboundary governance instruments within the OKACOM framework.

- It is very obvious that the Okavango Basin is experiencing an unprecedented rate and diversity of changes, related to many environmental and societal variables. Therefore we recommend to monitor not only these changes but also the effectiveness of processes and measures that aim of adaptation, conservation and sustainable resource management.

At the end of this five-year research program we are fully aware of the complexity of all the interacting processes and activities within the different stakeholder areas.

Due to this complexity we are also fully aware that it is not possible to deliver the scientific results to decision-makers as a one-off event, even though a series of dissemination events in July 2015 includes a wide range of stakeholders and events in all three involved countries within a time span of three weeks.

Therefore we regard it as most important to keep the communication process between stakeholders and scientists alive, even after the end of the funded project. Research staff that were responsible and active in the coordination of TFO will be accessible via the TFO Website:

<http://www.future-okavango.org/>

The home page of the website will be maintained so as to provide contact and communication details on a variety of topics. In addition, all contact details and links to further resources can be found in the following chapter. There you will find a list giving the details of the whole TFO consortium. The Appendix of this report also offers subproject-specific reports, including contact details. Furthermore, the data and products will also be available via the regional Science Service Center SASSCAL (www.sasscal.org) and its Open Access Data Center (OADC).

Chapter 7

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Chapter 8

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Chapter 9

Content and utilization of the electronic appendix

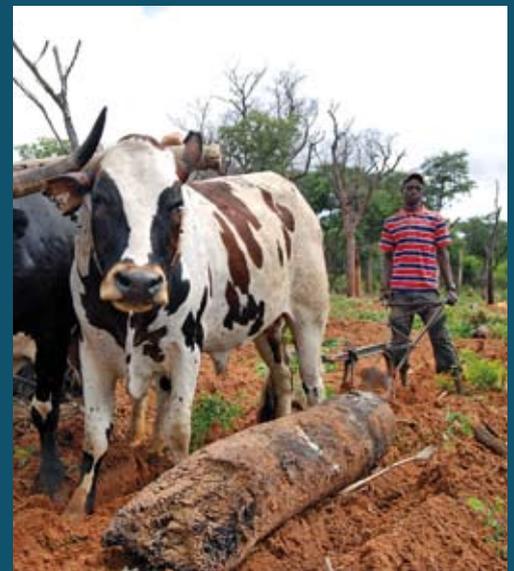
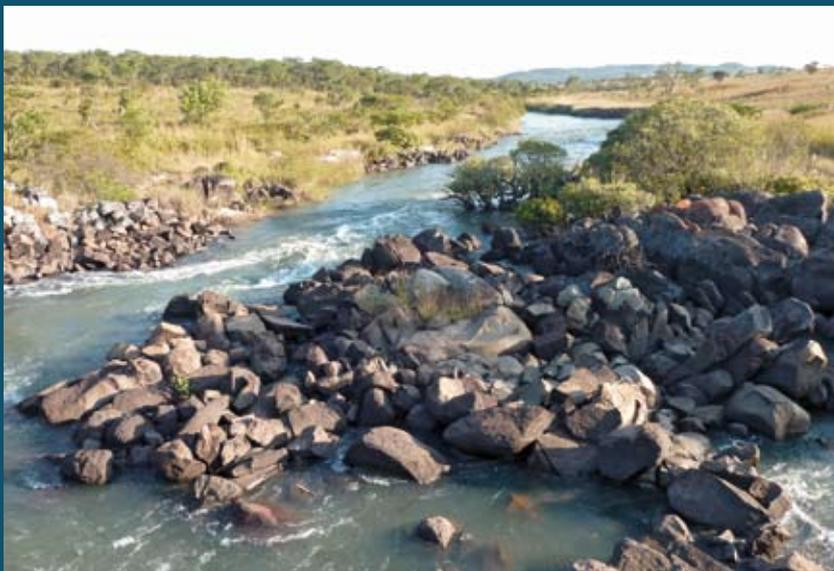
In addition to this printed book TFO provides an electronic appendix which contains further material that might be of interest for in depth reading, watching or working with a map-based decision support system. The Electronic Appendix consists of 2 DVDs:

DVD A contains further TFO materials. There you will find:

- Background information on the scenario development process, such as definitions of the variables, and detailed descriptions of the variables that were described and analyzed for the production of the chapter 'Current state' of the Okavango basin and the three TFO core sites, respectively.
- The freely accessible TFO special issue, *Biodiversity & Ecology 5* (2013), in which the interim results of TFO have been compiled in a subproject-overarching and multi-disciplinary manner.
- Additional sub-project specific reports on disciplinary results which complement the results given in the key findings.
- The document 'OBIS: Where to find..?' outlines how the post-TFO data storage portal OBIS was organized, and where interested readers can find data, maps, publications, and other materials that were produced by TFO.
- The digital version of a wall calendar that has been produced for the local stakeholders in the core sites of Cusseque, Caiundo, Mashare and Seronga. It contains twelve messages derived from TFO research findings that aim to provide assistance for the local land users with regard to a sustainable use of their resources. The calendar has been translated into the respective local languages and has been distributed in the local communities during the Final Dissemination Tour of TFO in July 2015.
- Several participatory films were produced in collaboration with rural dwellers from the project's core sites in order to communicate their knowledge and share their perspectives with the project's stakeholders as well as the broader audiences. These participatory films are available on the TFO-website (<http://www.future-okavango.org>) and the video portal Vimeo (<https://vimeo.com/biodivafrica>). Further information on these participatory films produced within TFO is contained in a special document on the DVD.

DVD B

DVD B represents a Decision Support System (DSS) that contributes towards sustainable land management in the Okavango basin. It was designed with low requirements regarding internet access, software licenses and computing power in mind. The system contains the 'TFO Browser', which links all its features in one interface. Furthermore, a special distribution of the Geographic Information System SAGA (System for Automated Geoscientific Analyses) is part of the DSS. It was developed by participants of SP09.2 and tailored to the needs of TFO. With SAGA, it is possible not only to view but also interact with a variety of spatial datasets. These digital maps can be used by stakeholders and policy-makers as base on which to make reasonable decisions. They can be analyzed with multiple tools and also be enhanced or combined with own datasets depending on the particular needs. For quick and easy use, a number of static maps with the main TFO results in png and pdf format are also included on the DVD.



Over a period of five years (September 2010 – August 2015), 140 researchers from eight countries, 23 universities, and additional research institutions – mainly from Angola, Botswana, Namibia, and Germany – carried out the transdisciplinary research project ‘The Future Okavango’ (TFO) across the whole basin of the Okavango-Cubango. This book is one of the outcomes of this endeavour, containing key findings, scenarios describing potential future developments, and recommendations for a sustainable management of the Okavango Basin.