Projektträger Jülich
Forschungszentrum Jülich

DLR Projektträger

SPACES II – SCIENCE PARTNERSHIPS FOR THE ADAPTATION TO COMPLEX EARTH SYSTEM PROCESSES IN SOUTHERN AFRICA

The interactions between geosphere, biosphere, atmosphere and ocean are in the focus of the research programme SPACES.

ERKENNEN. FÖRDERN. GESTALTEN.

INHALTSVERZEICHNIS

EINLEITUNG

One of the greatest challenges of the 21st century is climate change. The ongoing global warming, accumulation of extreme weather conditions with storms, heavy rainfall or lasting droughts, associated soil erosion as well as melting glaciers, changing ocean circulations and sea-level rise threaten not only vegetation and wildlife, but also our habitats, health and food security. Developing countries are largely the most affected by climate change. The people there are particularly dependent on an intact nature and hardly have access to the resources needed to cope with the climatic changes. Furthermore, anthropogenic influences such as the intensive land use, aquaculture and environmental pollution have severe consequences for the environment.

Climate change no longer concerns science alone; the topic has arrived in the middle of our society quite a while ago. Worldwide initiatives, for example the movement "Fridays for Future" funded in 2018, demand rethinking and specific measures for a more effective climate protection.

Climate change and global change are also central topics of the Agenda 2030 passed by the United Nations in 2015: All countries work on achieving the 17 Sustainable Development Goals (SDGs) since 2016. Two of these goals have a central meaning for the preservation of natural habitats: SDG 14 "Life below water: Conserve and sustainably use the oceans, seas and marine resources for sustainable development" and SDG 15 "Life on land: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reserve land degradation, halt biodiversity loss".

The continent Africa is facing the greatest dangers due to the inevitable climate change. Furthermore, the implications of global change such as competition for raw materials, difficult food supply and associated land-use conflicts are particularly huge. In their resolutions, the international communities of

states have demanded the support of developing and emerging countries in the adaptation to climate change; numerous African countries and the African Union have identified areas of activity, too.

Within the framework of the Scientific and Technical Cooperation with countries in southern Africa, the Federal Ministry of Education and Research (BMBF) has initiated and funded the programme "Science Partnerships for the Assessment of Complex Earth System Processes" (SPACES) from 2012 until 2018. Scientists from German universities and extramural research institutions together with South African and Namibian partners have investigated the interactions between oceans, atmosphere, geosphere and biosphere (see brochure on SPACES).

In the second phase of the research programme, the focus moves to the adaptation to the complex processes, to management options and specific recommendations for action for policy and society. The cooperation of scientists from Germany, South Africa, Namibia, Angola and Zambia has the following focal points:

- seasonal and interannual variability and trends of coastal current systems around southern Africa, their influence on land-ocean-atmosphere interactions and on biogeochemical cycles as well as the management of marine resources
- transport of water, carbon, nutrients and pollutants, considering their transformation mechanisms in rivers, estuaries and coastal areas as well as regarding their importance for the population, biodiversity and ecosystem services
- functioning of multiple-use landscapes regarding sustainable land use, land-use changes, carbon and water fluxes as well as their impacts on biodiversity, habitats and ecosystem services
- management options for multifunctional landscapes, for the formation of ecosystems and for the strengthening of societal resilience to environmental change
- development and implementation of measures for the restoration and sustainable use of degraded ecosystems with the goal of adaptation, resilience and mitigation

This brochure presents the nine collaborative projects which conduct research on the aforementioned topics within the framework of SPACES II from 2018 until 2021. They are accompanied by a project supporting junior scientists by means of scholarships and summer schools.

The German project partners are funded by BMBF and overseen by Project Management Jülich (PtJ) and the DLR Project Management Agency (PT-DLR). The South African and Namibian partners are supported by the South African Department of Science and Innovation (DSI) and the Namibian National Commission on Research, Science and Technology (NCRST).

SPACES II
Science Partnerships for the Adaptation to Complex Earth System Processes in Southern Africa

MEERES- UND KÜSTENFORSCHUNG

BANINO – BENGUELA NIÑOS: PHYSICAL PROCESSES AND LONG-TERM VARIABILITY

BACKGROUND

Coastal waters along the Southwest African countries that are part of the Eastern Boundary Upwelling Systems (EBUS), host a highly productive ecosystem supporting a coastal population living in tropical to subtropical climate zones. This marine ecosystem plays a key socio-economic role for societal development, fisheries, and tourism. EBUS face significant changes associated with climate variability and global warming. The impact of climate change on EBUS regions is not fully understood and assumed complex, due to the different and interacting effects of increasing temperatures, acidification and deoxygenation. Local and remote forcing of ocean variability plays a crucial role in shaping the conditions in the Southwest African EBUS, and they must be considered in attempts to predicting the climate in that region. This requires a continuous improvement of numerical model systems and their validation against observations. However, the coastal observing system of the Southwest African EBUS is not well developed; their improvement is a primary goal of the international research community. The collaboration between German and African institutions is thus crucial to understand the processes driving coastal upwelling and high biological productivity in the Southwest African EBUS, which is the focus of this project.

OBJECTIVES AND RESEARCH APPROACH

The goals of this research project are to enhance the database and improve the understanding of the Southwest African EBUS using ocean observations as well as forced ocean and coupled climate models. The research is aimed at improving the prediction of climate variability and impacts of climate change and investigating poorly understood processes relevant for upwelling variability and its consequences for biological productivity. We will study the wind-stress forcing

over the Southwest African EBUS, including large-scale and local alongshore wind stress and curl, tidally-generated internal waves, induced mixing on the shelf affected by riverine freshwater input and precipitation, frontal dynamics at the Angola Benguela frontal zone, and the role of stratification within the boundary current region on the development of Benguela Niño events. Observations and modelling are applied to study the Southwest African EBUS variability on time scales from sub-seasonal to decadal and the overlying atmosphere to enhance climate prediction for Southern Africa. Developing the cooperation between German and African partner institutions by enhancing the local capabilities in ocean observing, numerical modelling and data analysis is the aim of this project.

STUDY AREA AND METHODS

The Southeast Atlantic Ocean encompassing the areas off Angola, Namibia and South Africa is the study area of interest. Data collected from all areas of the tropical Atlantic Ocean, particularly the equatorial Atlantic, will help to better understanding local changes in climate and ecology, to perform and analyze regional and global ocean and climate model simulations. Field experiments are carried out including shipboard observations, the use of autonomous gliders and the maintenance of long-term moorings. In-situ data acquired within the project are analyzed in comparison to other datasets including remote-sensing satellite and Argo float data. Results from data analysis are synthesized with output from high-resolution ocean and climate models. Specific model simulations are analyzed with regard to process and climate variability in the Southeast Atlantic Ocean.

ACTIVITIES AND EXPECTED OUTCOMES

Ocean observations and modelling will particularly focus on Benguela Niños and Niñas, events that characterized by anomalously warm and cold coastal sea surface temperature (SST), respectively (Fig. 1). Our findings suggest that most of the extreme events are associated with the propagation of equatorial Kelvin waves along the equatorial waveguide, which trigger poleward-propagating coastally trapped waves

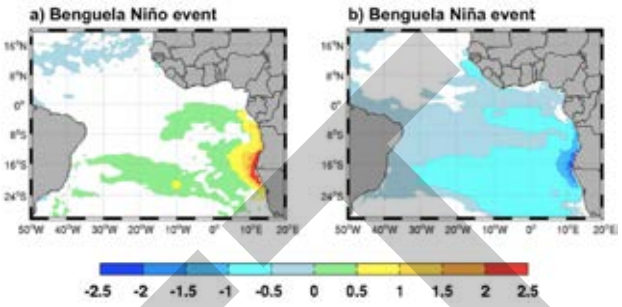

Fig. 1: Composite maps of temperature anomalies at 10 m depth from an Ocean General Circulation Model showing the signature of Benguela Niño (a) and Benguela Niña (b) in the Southeast Atlantic.

along the southwestern African coast. One to two months before the peak season (usually March–April) of the anomalous coastal events, a large-scale surface wind pattern is observed, encompassing both variations of alongshore coastal winds over the southeastern Atlantic and zonal winds along the equatorial Atlantic.

The SST exhibits a strong variability at interannual time scales in the Angola-Benguela Area (ABA, 8°E to the coast; 10°S-20°S), with maximum variability during March-May (MAM), the season when most of the Benguela Niños/Niñas occur. However, a strong multidecadal reduction of the interannual SST variability occurred in the ABA region in MAM in the post-2000 (2000-2017) period relative to the pre-2000 (1982-1999) period (Fig. 2). Area (blue box in a) as function of the calendar month: 1982-1999 (red) and 2000-2017 (blue) calculated for different SST datasets.

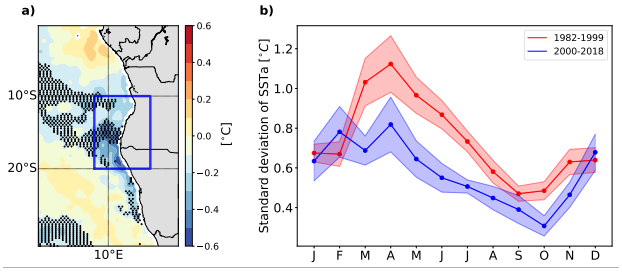

Fig. 2: a) Difference between 2000-2017 and 1982-1999 of March-May SST-standard deviation. b) Ensemble-mean standard deviation of SST averaged over the Angola-Benguela.

PROJECT STRUCTURE AND PARTNERS

The research questions of the project are studied within four subprojects (SPs). The focus of SP1 is on observations and data analysis regarding the tropical Angolan upwelling system. SP2 investigates the physics of upwelling and warm events in the Northern Benguela upwelling system off Namibia. Investigating the relevant physical processes responsible for the temporal and spatial variability of the Benguela upwelling system using in-situ data, remote-sensing and high-resolution ocean model is the focus of SP3. Finally, SP4 focuses on the relationship between the mean state of the Southeastern Tropical Atlantic Ocean and the characteristics of Benguela Niño events.

Group picture of the scientific crew of Meteor cruise M158 during September/October 2019.

BANINO – BENGUELA NIÑOS:
PHYSICAL PROCESSES AND LONG-TERM VARIABILITY

COORDINATION:

GEOMAR Helmholtz-Zentrum für
Ozeanforschung Kiel

PROJECT PARTNERS:

- Leibniz-Institut für Ostseeforschung
  Warnemünde, Rostock, Germany
- Universität Hamburg, Centrum für
  Erdsystemforschung und Nachhaltigkeit,
  Institut für Meereskunde, Hamburg, Germany

INTERNATIONAL PROJECT PARTNERS:

- Instituto Nacional de Investigaçaõ Pesqueira,
  Luanda and Namibe, Angola
- National Marine Information and Research Centre,
  Swakopmund, Erongo, Namibia
- Gobabeb Research and Training Centre, Namibia
- University of Cape Town,
  Department of Oceanography,
  Rondebosch, South Africa

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TRAFFIC – TROPHIC TRANSFER EFFICIENCY IN THE BENGUELA CURRENT

BACKGROUND

Along the west coasts of the continents, nutrient-rich water dwells up due to the wind systems prevailing there and causes a high phytoplankton production. This is followed by high zooplankton and fish productivity. These coastal upwelling areas produce about 20% of the annual fish landings and thus play a significant role in the food supply of the world population and in the carbon and nutrient turnover in the ocean. The Benguela upwelling area off the coasts of South Africa, Namibia and Angola is one of these highly productive coastal upwelling systems. However, the high phytoplankton productivity in this area is in surprising contrast to the low productivity of the higher trophic levels compared to other upwelling systems such as the Humboldt Current off Peru. Nutrients that reach the surface during upwelling are apparently exported again quickly, so that organisms of the higher trophic levels cannot effectively exploit the available primary production. The consequence of this inefficient recycling of nutrients is that, despite short trophic paths, the biomass of all zooplankton in the northern Benguela system is close to the global average of only 1.3-1.8 g C m-2, and fishing yields in 2006 were only about 0.42 million tonnes. In the upwelling area off Peru, the yield in the same year was more than ten times higher at 6.8 million tonnes, with fishing areas of similar size.

OBJECTIVES AND RESEARCH APPROACH

Changes in the Southeast Atlantic over the last decades have also altered ecosystem services, with different consequences in the northern and southern Benguela Upwelling System (nBUS, sBUS). In addition to fisheries, e.g. CO2 uptake is also affected. In order to understand the mechanisms of these changes and impacts and to obtain a better prediction of the future behaviour of the ecosystem and thus the provision of its services, TRAFFIC is conducting fundamental research on the processes of the subsystems nBUS and sBUS and their responses to climate change.

Three potential scenarios in the trophic systems of the nBUS and sBUS are conceivable and shall be tested. 1) The classic upwelling ecosystem with small pelagic species (sardines) in central function (Fig. 1a), as still largely found in the sBUS.

Der wissenschaftliche Nachwuchs: Austausch eines Teils der Jungforscher während Meteorreise M153, um mehr Nachwuchswissenschaftlern eine Teilnahme zu ermöglichen

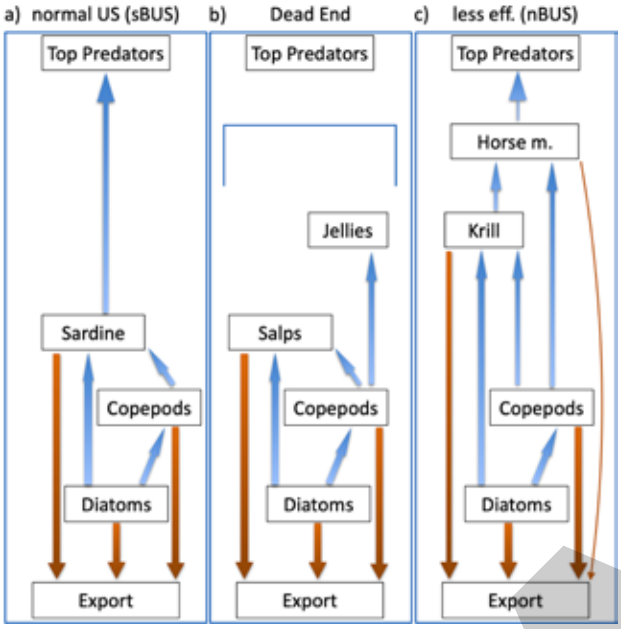

Fig. 1: The three potential scenarios to be tested in the structure of the trophic systems in the northern and southern Benguela Upwelling Areas.

2) A completely restructured ecosystem in which jellyfish and salps are dead ends in the food chain (Fig. 1b). 3) A system that is less productive, where sardines are replaced by krill and horse mackerel (Fig. 1c). One research cruise each in southern summer and winter in the nBUS and sBUS are carried out.

TRAFFIC thus addresses objectives 4 and 5 in the FONA-SPACES programme for proposals on „Adaptation of complex processes in the Earth System in the Southern African region". FONA3 has set itself the goal of protecting common goods such as climate, biodiversity, land and seas.

Capacity development is a major concern of TRAFFIC and is carried out in the form of master and PhD theses and on-board training during the research cruises.

STUDY AREA AND METHODS

DThe Benguela upwelling system off southwest Africa comprises a coastal upwelling zone of approximately 150 to 200 km width. Enclosed between two warm water currents, the Angola Current in the north and the Agulhas Current in the south, the Benguela upwelling system is divided into two very different subsystems by the very strong upwelling cell off Lüderitz (Fig. 2): the northern part is dominated by the South Atlantic Central Water (SACW), which is accompanied by a pronounced oxygen minimum zone, while the southern part is influenced by the Eastern South Atlantic Central Water (ESACW). While the SACW in the north is rich in nutrients and CO2, the ESACW in the south is comparatively poor in nutrients and CO2. This leads to different food web structures and productivity. Since primary production in both subsystems is very similar, these relationships indicate a more efficient use of nutrients in the sardine-dominated south.

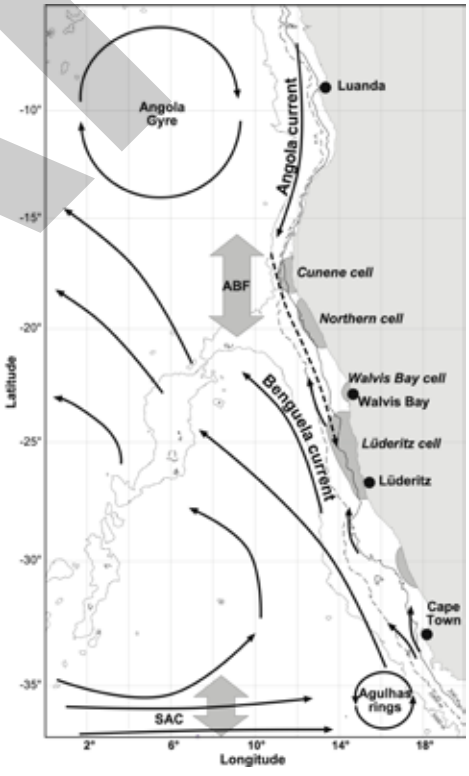

Fig. 2: The study area of TRAFFIC, The Benguela Current Upwelling System.

ACTIVITIES AND EXPECTED OUTCOMES

TRAFFIC benefits from the long lasting trilateral cooperation in all sub-projects. Decisive data bases used in TRAFFIC have

been developed in GENUS (Geochemistry and Ecology of the Namibian Upwelling System) and other predecessor projects (BENEFIT, WTZ, Namibgas) and will be supplemented within the framework of TRAFFIC. Especially in the southern Benguela system, studies on the physiology and condition of some key pelagic organisms are lacking.

TRAFFIC will use two international and interdisciplinary research cruises for this purpose, a cruise with FS Meteor already carried out in 2019 and a further cruise planned and approved for 2021. In addition, individual sampling with the South African FFS Africana and the Namibian research vessel FFS Mirabilis are planned, in order to also deploy mooring systems for continuous recording of carbon exports.

The results of the TRAFFIC investigations will be directly translated into recommendations for management by the project partners DEAFF (formerly DAFF and DEA) and NatMIRC in South Africa and Namibia, who are conducting their research as part of their fisheries and environmental management tasks. TRAFFIC's participation in regional research forums, such as the Science Forum of the Benguela Current Convention (BCC), are therefore important activities.

In order to strengthen the research partners, TRAFFIC will be involved in capacity development at the cross-network level. The integration of MSc and PhD candidates from Germany, Namibia and South Africa is firmly planned in all subprojects. Summer schools and contributions to MSc programmes will be organised.

The investigations in TRAFFIC will contribute to improve our knowledge of the ecological processes in the northern and southern Benguela upwelling systems to better understand the complex trophic systems and their interactions with fisheries and climate and to model them. Based on the results obtained in the project, fundamental knowledge can be gained for science, politics and society to develop management plans for sustainable ecosystem services.

PROJECT STRUCTURE AND PARTNERS

The project consists of three scientific work packages that map different levels of trophic activity: 1) production and sedimentation processes, 2) primary consumption level consisting mainly of zooplankton as the central converter of energy and biomass, and 3) the level of higher consumers with mainly fish and warm-blooded animals. Partners from Germany and Southern Africa are working together on the different research questions in the work packages.

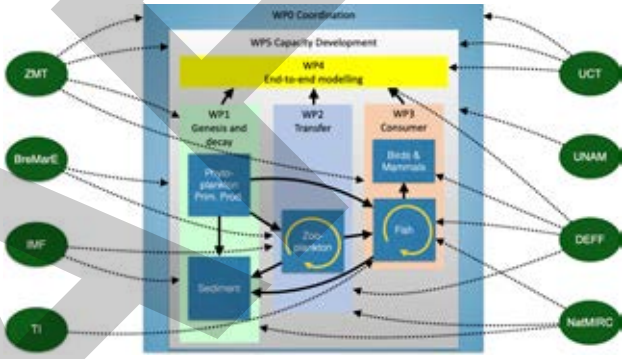

Fig. 2: Work packages and partners in TRAFFIC.

ZMT is responsible for the overall coordination of the project, which consists of five subprojects assigned to different institutes. In addition, four German and five institutes from southern Africa are involved:

COORDINATION:

Leibniz-Zentrum für Marine Tropenforschung

PROJECT PARTNERS:

- Bremen Marine Ecology, Zentrum für Forschung und Lehre (BreMarE), Universität Bremen
- Institut für Marine Ökosystem und Fischerei-Wissenschaften (IMF), Universtiät Hamburg
- Institut für Geologie (IFG), Universität Hamburg
- Leibnitz-Zentrum für Marine Tropenforschung
- Thünen Institut der Seefischerei, Bremerhaven

INTERNATIONAL PROJECT PARTNERS:

- University of Cape Town, Kapstadt, Südafrika
- Department of Environment, Forestry and Fisheries (DEFF), Kapstadt, Südafrika
- Ministry of Fisheries and Marine Resources (MFMR), Namibia
- University of Namibia (UNAM), Henties Bay, Namibia

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CASISAC – CHANGES IN THE AGULHAS SYSTEM AND ITS IMPACTS ON SOUTHERN AFRICAN COASTS

BACKGROUND

The waters around southern Africa play an important role in the world-wide system of ocean currents. They are shaped by the Agulhas Current, which transports, as one of the largest currents in the world ocean, warm and saline water from the tropical Indian Ocean along the African coast towards the southern tip of Africa. A part of this heat and salt reaches the South Atlantic, and eventually finds its way towards the North Atlantic. There it has the potential to influence the overturning circulation, and in consequence Europe's climate.

The Agulhas Current has not only a large-scale influence but also determines the climatic conditions around and in southern Africa. Ocean currents dynamically influence the regional sea level which is already subject to a general rise under climate change. Together with floods caused by wind waves, rising sea levels put southern Africa's coastlines under threat. In addition to this oceanic, there is also an atmospheric risk: The surrounding warm ocean influences rainfall in southern Africa, and may cause more extreme rainfalls and different drought frequency or intensity under a warming climate. Compound events of the oceanic and atmospheric events could cause the southern African coastlines being more vulnerable to coastal hazards in the future.

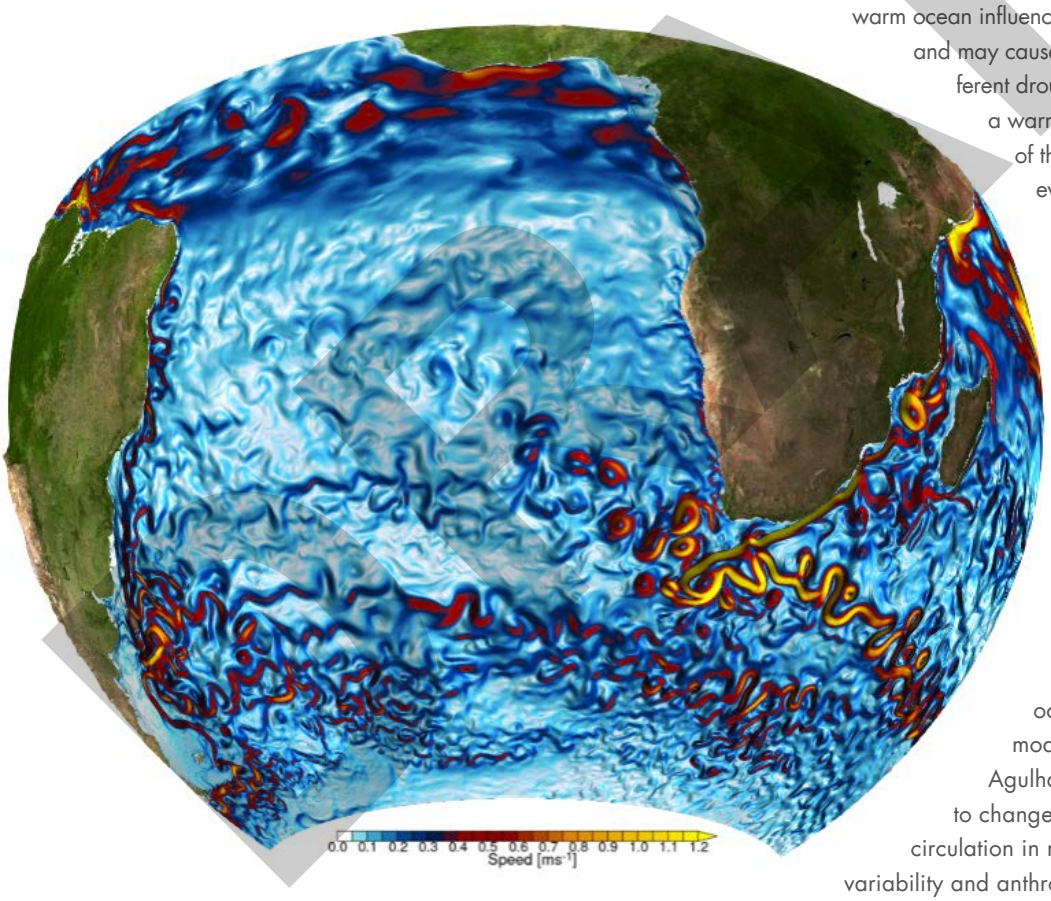

Fig. 1: Snapshot of surface speed (in m s−1) as simulated in 1/20° ocean model INALT20 (from Schwarzkopf et al., 2019)

OBJECTIVES AND RESEARCH APPROACH

In CASISAC, changes in the oceanic conditions and regional sea level around southern Africa are explored through global ocean and coupled climate modelling. The highly variable Agulhas Current System is subject to changes in the hydrography and circulation in response to atmospheric variability and anthropogenic trends. Owing to its embedding into the large-scale circulation, high-resolution ocean models of the Atlantic and Indian oceans with grid resolution of down to 1-5 km, nested into global models at

Fig. 2: Simulated compound flooding at the Breede estuary case study (from a compound event corresponding to the 1-in-100y river discharge, 1-in-100y waves and spring tide)

coarser resolution, are used. Global and regional climate models allow to research the climate response to increasing CO_2 concentrations and future recovering of the Antarctic ozone hole. A particular emphasis is on the climate extremes, such as rainfall, in southern Africa.

Sea level changes are studied using water levels hindcasts from an ocean model and tide gauges. By combining extreme water levels that occur during storm surges with significant wave heights and increased water levels from heavy precipitation the risks and joined probabilities of compound flooding events are explored. Coastal flood impacts are assessed for South Africa at regional and local spatial scales using high-resolution hydrodynamic models of different complexity in order to accurately analyse the impacts of today's and future flood events, but also the potential benefits of different adaptation options.

STUDY AREA AND METHODS

As a strong boundary current, the Agulhas Current flows southward close along the South African coastline. After overshooting the southern tip of Africa, it follows an extraordinary path: Instead of flowing directly into the Atlantic Ocean, it performs an abrupt turn back into the Indian Ocean with only a minor portion, about 1/4 to 1/3 of its original volume, finding its way into the Atlantic. This happens in form of ocean eddies with horizontal diameters of several hundred kilometres and depth extensions of more than one kilometre.

In consequence, the waters southwest of southern Africa are a very variable region, called the 'Cape Cauldron'. Here, the warm and saline Indian Ocean water mixes with the colder and fresher South Atlantic water, directly influencing rainfall in the western Cape around Cape Town. In contrast, rainfall in the eastern provinces are determined by the Indian Ocean. The large asymmetry in hydrographic conditions in the oceans east and west of South Africa therefore has very important consequences for regional climate and the different coastlines.

ACTIVITIES AND EXPECTED OUTCOMES

Ocean currents and hydrography are strongly shaped by eddies and fronts acting on the mesoscale (scales in the order of 100 km). CASISAC simulates the Agulhas Current

system at high resolution to quantify the amount of heat and salt transferred from the Indian to the Atlantic Ocean, called 'Agulhas leakage', and its influence on the global overturning circulation. Of particular importance for Agulhas leakage are the westerly winds blowing south of Africa. Using ocean-atmosphere coupled climate models CASISAC studies the impact on the westerlies by two compensating effects: the increase in anthropogenic greenhouse gases leading to an intensification of Agulhas leakage, and a recovery of the ozone hole over Antarctica with an opposite effect. The impact of the ocean conditions on precipitation and droughts in southern Africa is investigated.

In the past decades, severe, compound events led to critically high water levels at southern African coasts and as a consequence to property damage and loss of human life. The co-occurrence of storm surges, wind waves, and flooding through heavy precipitation and runoff increases the risk of flooding and exacerbates the impacts along the vulnerable Southern African coasts. To mitigate the associated high-impacts, CASISAC investigates the probability and causes of these compound events. CASISAC assesses the current and future flood impacts of the Southern African coasts and accounts for different plausible socio-economic developments.

Regional flood assessments performed in CASISAC allow to locate potential future hotspots where flood adaptation measurements will be required. At local or city-scales, CASISAC assess compound flooding using detailed hydrodynamic models, which allow the analysis of interactions between flood drivers and induced effects on the resulting inundation.

PROJECT STRUCTURE AND PARTNERS

The project is structured among four national partners, with the GEOMAR Helmholtz Centre for Ocean Research Kiel providing the large-scale ocean and climate modelling to research the variability of the Agulhas Current system in the past and future. Using boundary conditions from the global models, Helmholtz-Zentrum Geesthacht GmbH (HZG) performs a regional climate model for the climate evolution in southern Africa. The Research Institute for Water and Environment at the University of Siegen (fwu) provides the joint analysis of sea level, wind waves, rainfall and runoff. These are used by Kiel University to perform coastal flood impact assessments using hydrodynamic models for the entire South African coastline as well as for dedicated hotspots. South African partners include research bodies in Cape Town, Stellenbosch and Pretoria.

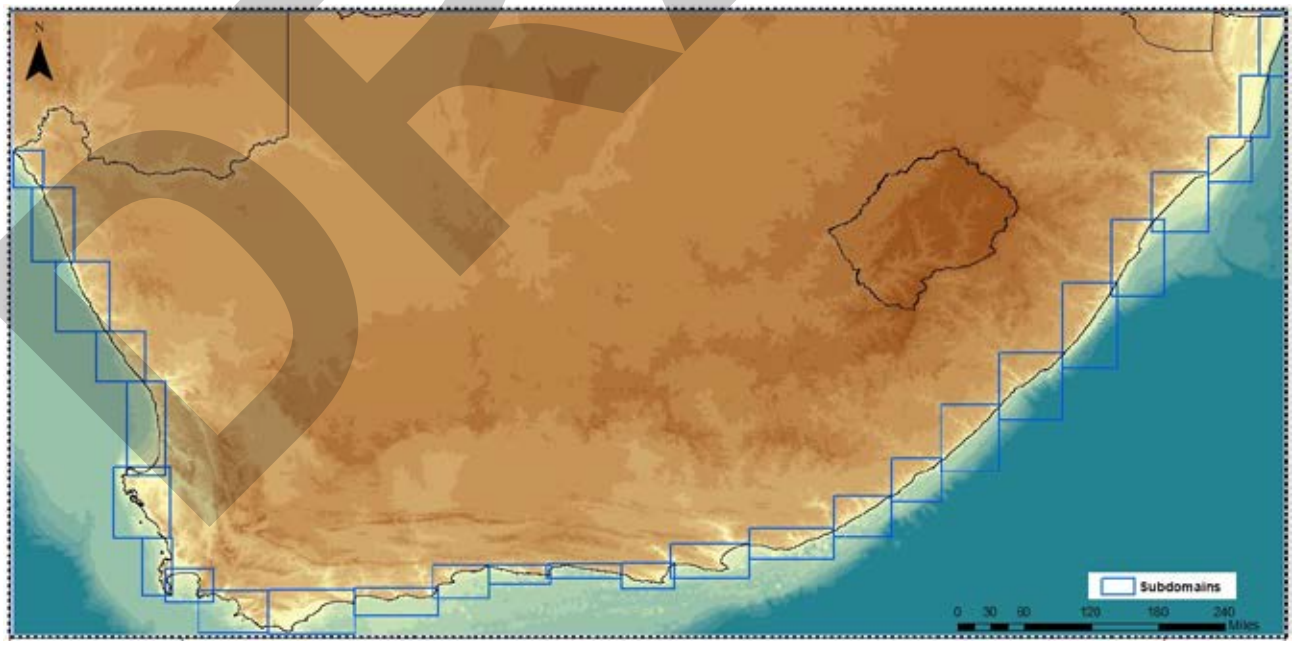

Fig. 3:Elevation-Bathymetry dataset created in CASISAC by merging global, regional and local datasets and subdomains (blue boxes) for the regional flood assessment.

CASISAC – CHANGES IN THE AGULHAS SYSTEM AND ITS IMPACTS ON SOUTHERN AFRICAN COASTS

COORDINATION:

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel

PROJECT PARTNERS:

- Helmholtz-Zentrum Geesthacht GmbH (HZG)
- Forschungsinstitut Wasser und Umwelt an der Universität Siegen (fwu)
- Christian-Albrechts-Universität zu Kiel (CAU)

INTERNATIONALE PROJECT PARTNERS:

- University of Cape Town, Kapstadt, Südafrika
- Council for Scientific and Industrial Research (CSIR), Stellenbosch
- University of Pretoria
- South African Environmental Observation Network (SAEON)

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INTERAKTION LAND UND MEER

TRACES – TRACING HUMAN AND CLIMATE IMPACTS IN SOUTH AFRICA

BACKGROUND

The fifth report of the Intergovernmental Panel on Climate Change (IPCC) describes southern Africa as one of the most climatically vulnerable regions in the world. The rapidly growing population and the developing industrial sector have led to a number of pressures on available ecosystem services. Contamination of air, water, soil and marine sediments has been studied at various locations in Southern Africa. All results show trends of increasing threats to ecosystems, food webs and water resources. In particular, changes in precipitation in terms of its type, quantity and regional distribution have an extreme influence. In addition to climatic phenomena, other factors directly caused by humans can also be of great importance for the development of ecosystems. For example, the form of land use or industrial and agricultural pollution often plays a decisive role. Soil erosion, the over-fertilization of water bodies, the input of pollutants from mining and industry generally have a negative impact not only on biological diversity. In particular, they threaten the quality and, to some extent, the quantity of one of our most important resources - fresh water. Answering the questions which factors have which potential consequences and how different natural and human-induced processes influence each other, can only be answered reliably on the basis of a detailed and data-based understanding of the system. Improving the latter also in terms of a sustainable use of resources is the overarching goal of the German-South African research network TRACES.

OBJECTIVES AND RESEARCH APPROACH

The aim of the investigations in TRACES is, in addition to taking stock of current conditions, to reconstruct the respective local development histories of selected ecosystems. For this purpose, a multi-parameter approach is used to analyze primarily the inorganic and organic components of sedimentary deposits. In addition, investigations on the distribution of special indicators, such as persistent organic pollutants, so-called POPs, and individual groups of organisms, which have already proven themselves in other studies as indicators for the quality status and functionality of ecosystems, are carried out. Sediment deposits of the last 250 years serve as archives with a high temporal resolution. With their help, the definition of the pre-industrial and ecological reference states will be carried out. Due to the different economic developments in the three selected study areas, we expect to be able to prove different forms, intensities and effects of anthropogenic and climatic influences. These will be made available to the local authorities and political decision makers in order to derive concrete recommendations for improved sustainable use.

Abb. 1: E. Schefuss (rechts) und M. Zabel (links) beim Filtern von Proben aus dem Mkhuze Fluss während einer Beprobungskampagne im November 2018.

In addition to the pursuit of pure research objectives, the training of students and young scientists within a framework of capacity development activities plays an important role within TRACES.

STUDY AREA AND METHODS

In order to answer our research questions, three research areas along the eastern part of South Africa were selected. These areas differ in recent environmental conditions, their environmental history and the extent of anthropogenic influences. As research areas were selected:1) Richards Bay with the catchments of the rivers Mhlatuze and Mfule and the Goedertrouw reservoir, 2) Mkhuze swamps with the river catchments of Mkhuze and Polongo and the Pongolapoort dam reservoir, 3) Olifants River catchment with the Loskop dam reservoir and two smaller reservoirs in the upstream.

On-site investigations are always performed jointly by scientists from both partner countries. Material from the listed areas, especially soil samples, sediment cores and suspension load samples will be analyzed in the laboratories of the participating project partners. In particular, determinations of element contents, biomarkers (plant waxes), organic pollutants, stable isotopes, various parameters for age determination (e.g. 14C, 137Cs), pollen and microorganisms (diatoms, ostracoda, foraminifera) are applied.

ACTIVITIES AND EXPECTED OUTCOMES

Joint fieldwork forms the basis of the activities in TRACES. This is where the samples are taken, which are later examined in detail in the various national institutions, and where the first, still preliminary findings are discussed. Furthermore, the field work serves to establish direct contact or exchange with the local population and to train young colleagues. A total of at least four phases are planned in which the working areas are visited together. A very important component for knowledge transfer, training and general cooperation are also mutual research stays in the respective partner country.

The investigations in TRACES do not pursue any immediate economic objectives. However, it is expected that the results obtained in the project on recent climate history and anthropogenic changes in the three areas under investigation will provide important new bases for environmental and economic policy decisions. In particular, this concerns the release and behavior of potential pollutants, as well as the associated preservation of ecosystem functions. An important economic factor of South Africa is the „marketing" of its unique animal world. Recently increasing mass mortality, even in supposedly protected areas such as the Kruger National Park (along the Olifant River - Working Area 3), demonstrates the urgency of a more sustainable use of these important natural resources. In this respect, TRACES aims to make an important contribution to a better understanding of material cycles and the factors that determine these cycles - climate and mankind.

PROJECT STRUCTURE AND PARTNERS

TRACES is divided into five German-South African tandem sub-projects that reflect the individually different scientific and

analytical expertise of the partners involved. Since the fieldwork is carried out by participants from several subprojects, a very close linkage of the subprojects and data exchange is guaranteed. South African partners in the network are the Council for Geosciences (Dr. H. Cawthra), the University of KwaZulu Natal (Prof. A. Green, Prof. T. Hill, Dr. J Finch), the University of the Free State (Prof. L. Scott) and the University of the Witwatersrand Johannesburg (Prof. M. Humphries, Dr. F. Neumann). German partners in the network are the universities in Greifswald (Prof. T. Haberzettl, PD Dr. Viehberg), Jena (Prof. P. Frenzel) and Bremen (Dr. E. Schefuss, PD Dr. M. Zabel).

Abb. 2: T. Haberzettl (Mitte) und T. Viehberg (rechts) in Diskussion mit Studenten beim TRACES Trainingskurs TRAIN-Me zur geowissenschaftlichen Probenahme, der im September 2019 an der Nordostküste Südafrikas stattfand.

TRACES – TRACING HUMAN AND CLIMATE IMPACTS IN SOUTH AFRICA

COORDINATION:

MARUM – Zentrum für Marine Umweltwissenschaften,
Universität Bremen

PROJECT PARTNERS:

- Physische Geographie, Universität Greifswald
- Allgemeine und Historische Geologie,
  Friedrich-Schiller-Universität Jena

INTERNATIONALE PROJECT PARTNERS:

- Council for Geosciences,
  Pretoria, Südafrika
- Geography Department,
  University of KwaZulu Natal,
  Pietermaritzburg, Südafrika
- Geology Department,
  University of KwaZulu Natal,
  Durban, Südafrika
- Natural and Agricultural Sciences Faculty,
  University of the Free State,
  Bloemfontein, Südafrika
- Evolutionary Studies Institute,
  University of the Witwatersrand,
  Johannesburg, Südafrika
- Chemistry Department,
  University of the Witwatersrand,
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www.marum.de/en/about-us/Sediment-Geochemistry/Traces/Project.html

LANDSCHAFTEN IM WANDEL

Fig. 1: ORYCS researchers from NUST and a veterinary team from UNAM have put e-Obs GPS collars with 3D accelerometer on female Springbok antelopes (in the picture) but also on Kudu and Eland antelopes. These will record data on the movement and behavior of the animals for about 1 year.

ORYCS – OPTIONS FOR SUSTAINABLE LAND USE ADAPTATIONS IN SAVANNA SYSTEMS

BACKGROUND

Changing climatic conditions and increasing land use pressure threaten ecosystem functioning and services in savannas by altering drivers and key geo-biosphere feedbacks at the interface between soils, vegetation, wildlife and climate. In Namibia, similar to many other savannas worldwide, traditional land use based on domestic livestock has in many cases reached its limits.

One fast-growing alternative management option is a shift towards the use of native wildlife. Such wildlife-based strategies are predicated on the assumption that indigenous herbivores have higher adaptive capacities to unfavorable conditions as compared to livestock. These strategies include options based on both, game meat production and wildlife management for trophy hunting and tourism. In Namibia, already about 40% (not including National Parks) of the land surface is currently dedicated to wildlife-based management, including communal and freehold conservancies and private game farms.

However, despite the strong support by national policies and the rapidly increasing number of wildlife-based businesses, many examples of degraded wildlife farms already exist. To date, it remains unclear if, and under what conditions, wildlife-based land use options are indeed more sustainable than traditional forms of land use under the ongoing pressures of global change.

OBJECTIVES AND RESEARCH APPROACH

Building on the successful Namibian-German collaboration in the SPACES project OPTIMASS, ORYCS aims to evaluate the benefits but also risks of alternative wildlife-based land use options to conserve ecosystem functions and services in Namibian savannas under current and future climatic conditions. The complex geo-biosphere feedbacks acting at the landscape scale hamper our understanding of ecosystem processes. There are major knowledge gaps on the full feedbacks between vegetation composition, condition and dynamics, animal behavior, soil processes, eco-hydrological dynamics, and biodiversity. To tackle this, the interdisciplinary and integrative research approach of ORYCS combines field observations, experimental manipulations, GPS-telemetry, remote sensing, social ecological assessments, and modelling to analyze

interactions and feedbacks between climate, water, vegetation and wildlife for different types of wildlife-based land use options. Centered around an understanding of spatial and temporal patterns of habitat and resource use by key endemic antelope species, ORYCS is assessing the impact of wildlife management on key ecosystem services like water provision, forage and food production, biodiversity and tourism but also looking into human wildlife conflicts arising around those types of land use. ORYCS will provide a first scientific basis for optimizing innovative strategies that are critically needed for sustainable wildlife-based land use management options in diversely used savanna landscapes.

STUDY AREA AND METHODS

Research will focus on a semi-arid Mopane savanna southwest of and including the western part of Etosha National Park, Namibia. Land use types present in the area are representative for the Namibian wildlife sector and comprise national park, communal conservancy, and commercial farmland all featuring various compositions of livestock and wildlife. In this area we find an excellent framework to integrate existing hydrological, ecological and socio-ecological data with the planned research. Importantly, the Ehi-Rovipuka communal conservancy within the study area, is amongst the earliest conservancies established in Namibia, meaning geo-biosphere conditions have had time to change. Our permanent field station is located at the 47.000 ha sized private game reserve "Etosha Heights".

In close dialogue with stakeholders, ORYCS will apply a combination of animal movement studies, vegetation surveys, eco-physiological and hydrological measurements and experiments, remote-sensing, socio-ecological assessments, and different process-based computer models to close the abovementioned knowledge gaps. Our intense science-stakeholder dialogue (fig. 1) and particularly the partnership with the Ministry of Environment and Tourism allows ORYCS research to be relevant for policy and management.

Fig. 1: ORYCS team with stakeholders from farms, conservancies and other institutions during stakeholder workshop in Outjo, Namibia – April 2019

ACTIVITIES AND EXPECTED OUTCOMES

ORYCS research is based upon a profound understanding of large herbivores movement in the savanna landscape. Therefore, ORYCS deploys GPS collars with 3D-accelerometers (fig. 2) on different key wildlife species. Combined with data from MET (e.g. on movement and densities of Elephant, Giraffe, Kudu, Eland, Springbok) this information is used to understand resource and space use of wildlife over time. Additionally, the effects of wildlife on the ecosystem will be assessed by fusing field measurements on biodiversity across taxa, soil characteristics, vegetation structure and groundwater with highly resolved data from airborne and satellite sensors, with experimental and observational eco-physiological data (e.g. fig. 3) and with social-ecological information from interviews and surveys on management frame conditions, strategies and human wildlife conflicts. Different process-based simulation models will integrate the information, to predict vegetation dynamics and composition, animal spaces use and functional composition of wildlife communities for various scenarios of climate and land use.

The interdisciplinary approach will result in comprehensive information leading to fundamental insights into the mopane

savanna ecosystem and the ecology of large herbivores, the water fluxes in this ecosystem but also into applied questions like i.e. ecological and economic sustainable strategies for wildlife-based land use and biodiversity conservation. In a continuous effort, ORYCS assures transdisciplinary cooperation with the Namibian Ministry of Environment and Tourism, the Etosha National Park, with local farmers and conservancy representatives. In this way, results can be generated that are easily applicable to land users and decision makers.

Fig. 3: Different sensor systems are installed in the field. Continuous sap flow measurements (A) are used to understand how water fluxes through woody plants are affected by different simulated browsing scenarios. Browsing is experimentally simulated by clipping leaves of single branches or whole trees at different ratios. Logger systems (B) store the continuous information alongside with additional data on climate, soil moisture, solar radiation and other environmental parameters are measured.

To also achieve academic sustainability, ORYCS includes a profound education and exchange component and fair data sharing and publication protocols. Embedded in the SPACES II training and the SPACES II DAAD programmes, ORYCS will facilitate the exchange of students between southern Africa and Germany and their education by means of training courses and jointly supervised thesis projects. Exchange is further supported by the ORYCS Tandem program where a student from Namibia teams up with a student from Germany to jointly conduct their thesis on complementary subjects.

PROJECT STRUCTURE AND PARTNERS

ORYCS is a German-Namibian cooperation of three Namibian and three German institutions (fig. 4). The project is coordinated by the University of Potsdam together with the NUST Biodiversity Research Centre in Windhoek, Namibia. Further partners are the Freie Universität Berlin, the Institute for Social-Ecological Research (ISOE), the University of Namibia and the Namibian Ministry of Environment and Tourism (MET).

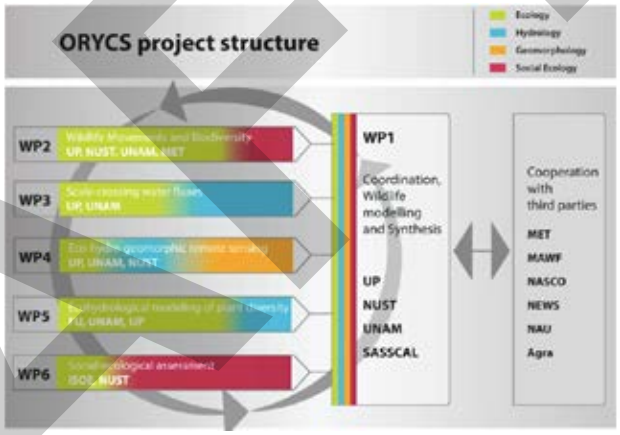

Fig. 4: Project structure and cooperation partners; UP: University of Potsdam, NUST: Namibia University of Science and Technology, UNAM: University of Namibia; FU: Freie Universität Berlin; ISOE: Institute for Social Ecological Research; MET: Namibian Ministry of Environment and Tourism, MAWF Namibian Ministry of Agriculture, Water & Forestry, NEWS: Namibian Environment and Wildlife Society, NACSO: Namibian Association of Community Based natural Resources Management support organizations , NAU Namibia Agricultural Union, NAPHA: Namibia professional hunting association

ORYCS – OPTIONS FOR SUSTAINABLE LAND USE ADAPTATIONS IN SAVANNA SYSTEMS

COORDIANTION:

Universität Potsdam,
AG Vegetationsökologie und Naturschutz

PROJECT PARTNER:

- Freie Universität Berlin
- Institut für sozial-ökologische Forschung (ISOE)

INTERNATIONALE PROJECT PARTNERS:

- NUST Biodiversity Research Center in Windhoek, Namibia
- University of Namibia
- Namibian Ministry of Environment, Forestry and Tourism (MEFT)

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Fig. 1: Rangelands: Cattle on rangeland with high grazing pressure at the end of the rainy season in October 2019

SALLNET – SOUTH AFRICAN LIMPOPO LANDSCAPES NETWORK

BACKGROUND

Rangelands, arable lands and tree orchards are very common land-use types in southern Africa. In their specific spatial arrangements, they constitute multifunctional landscapes that provide essential ecosystem services, for example: food production, biodiversity, pollination, and carbon sequestration. Many of the ecosystem services provided by these landscapes are crucial for supporting local livelihoods and protect biodiversity, and a wide range of other Sustainable Development Goals (SDGs) of the UN, in particular: no poverty, zero hunger, good health, clean water, climate protection and sustainable land-use respectively. Yet, through continued strong population increases and accelerated climate change with more frequent and severe adverse climate extremes such as drought in southern Africa, the already fragile savannah ecosystems and the multiple services they provide are increasingly threatened.

Therefore, SALLnet focuses on how to enhance the resilience of multi-functional landscapes in southern Africa under the conditions of climate change, a growing population and increased resource limitations

OBJECTIVES & RESEARCH APPROACH

The main objective of SALLnet is to answer the overarching question: "How can the resilience of the multi-functional landscapes in South Africa's Limpopo region be enhanced under future climate conditions?"

SALLnet considers climate variability and change as the main source of risk, but approaches them as a multiplier of existing socio-economic risks and is therefore paying due attention to other drivers of land-use change such as urbanisation processes.

Aiming to enhance the resilience of land-use, ecosystem services and landscapes, to anticipate changes in climate and socio-economic drivers, SALLnet designs an inter- and transdisciplinary framework to develop and evaluate alternative land-use management scenarios at multiple scales. To do so, SALLnet identifies, selects and investigates a set of different possible land-use management scenario options paying special attention to link these scenarios to the Sustainable Development Goals (SDGs) and local policy objectives. Assessing the effectiveness of management options is key

to enhance the resilience of different land-use systems and reduce risks to ecosystem services..

STUDY AREA & METHODS

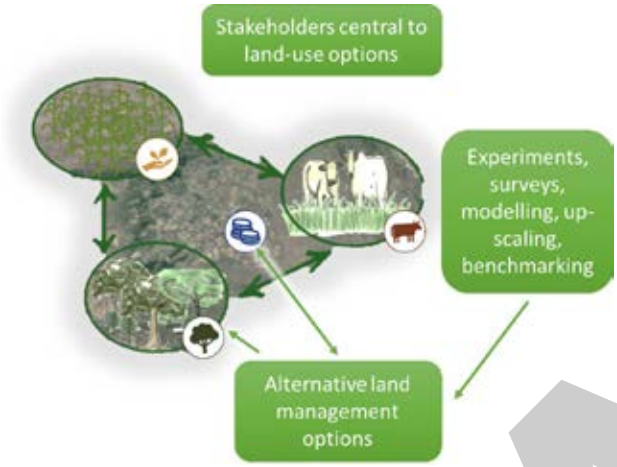

Fig. 2: SALLnet research components

SALLnet focuses on the province of Limpopo as its case study area because of the diverse land-use, biodiversity and high spatiotemporal climatic variability of this region. Due to these characteristics, the region is particularly appealing to generalise the findings and make recommendations for similar managed ecosystems in southern Africa. SALLnet is developing and testing new approaches and methods for more sustainable land-use, with a focus on the interactions between the connected land-use types: arable lands, rangelands and tree orchards.

ACTIVITIES & EXPECTED OUTCOMES

SALLnet focuses on the management of the three major land-use types within Limpopo's multifunctional landscapes in the given socio-economic context –arable lands, rangelands, and tree orchards– and connects these land-use types in an integrated analysis. To analyse sustainable land-use options, SALLnet carries out experimentations and surveys. Generated data will be used to develop integrative tools and modelling platforms for an overall risk evaluation and to develop alternative land-use scenarios and management options to enhance the ecosystems' resilience. The modelling results will be scaled up to various decision levels (farm, province).

The scenarios will be developed in close interaction with local stakeholders, who are involved in the entire research process, and they will be evaluated and compared with respect to a set of pre-defined sustainability indicators (ecological, economic and social). They will build on issues that have emerged in previous or ongoing science-policy dialogues in/about the Limpopo region.

This eventually will result in a synthesis for the land-use types, their interactions and policy implications to generate alternative land-use strategies, to protect the functionality and resilience of multifunctional landscapes in southern Africa and to enhance food security.

Fig . 3: Arable land: Smallholder maize field & cob example, May 2019

PROJECT STRUCTURE & PARTNERS

In SALLnet, research is carried in four subprojects focusing on the specific land-use types and the modelling and scenario development. Within these subprojects, six German institutions at the University of Goettingen, the Senckenberg Nature Research Society and the University of Bonn cooperate with five South African partner institutions at the Universities of Limpopo, of the Witwatersrand and of Venda. To meet the goals of the project, researchers from different disciplines such as agroecology, agronomy, soil science, agricultural economics, and agricultural systems modelling are contributing.

Fig.4: Tree orchards: Taking soil samples in macadamia orchards at Neuhof farm, fall 2019

Fig. 5: In discussion with farmers: Small-scale farmer survey, spring 2019

SALLNET – SOUTH AFRICAN LIMPOPO LANDSCAPES NETWORK

COORDINATION:

Georg-August-Universität Göttingen:
Tropischer Pflanzenbau und
Agrosystem Modellierung (TROPAGS)

PROJECT PARTNERS:

- Georg-August-Universität Göttingen:
  Agrarökonomie und Rurale Entwicklung,
  Agrarökologie und Graslandwissenschaften
- Senckenberg Gesellschaft für Naturforschung,
  Frankfurt am Main: Biodiversität und
  Klima Forschungszentrum
- Rheinische Friedrich-Wilhelms-Universität Bonn:
  Institut für Nutzpflanzenwissenschaften und
  Ressourcenschutz (INRES)

INTERNATIONALE PROJEC TPARTNERS:

- University of Limpopo, Sovenga:
  Risk and Vulnerability Assessment Centre
- University of Venda, Thohoyandou:
  School of Mathematical and Natural Sciences,
  Department of Soil Sciences
- University of Witwatersrand, Johannesburg:
  School of Animal, Plant and Environmental Science,
  The Global Change Institute

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EMSAFRICA – ECOSYSTEM MANAGEMENT SUPPORT FOR CLIMATE CHANGE IN SOUTHERN AFRICA

BACKGROUND

Along with increasing temperatures, the projected impacts of climate change in southern African terrestrial ecosystems include altered patterns of rainfall and fire, as well as increased frequency of extreme weather events. Higher levels of carbon dioxide in the atmosphere affect the interactions between plant groups. At the same time, terrestrial ecosystems are affected by human activities, such as livestock grazing, cultivation, fuelwood extraction, and the spreading of invasive alien species.

Climate change and human management affect the distribution of plants, leading to shifts and alterations of entire biomes. The dynamics and functioning of ecosystems are also projected to change, altering their ability to sequester carbon from the atmosphere.

The complexity and interdependence of climate-management interactions make the ecosystem responses difficult to predict. The current understanding of the feedbacks between key savanna ecosystem responses to, for example, fire dynamics and grazing is insufficient. Due to lack of long-term experiments especially in managed ecosystems, the role of Africa in the global carbon dynamics remains poorly known.

OBJECTIVES AND APPROACH

EMSAfrica introduces a multidisciplinary approach, where various experiments, surveys and measurements, conducted under a carefully designed field setup, feed into a variety of models at multiple scales.

The project has four broad aims:

Eddy Kovarianz Messturm am Feldstandort Middelburg, Ostkap.

- Establish infrastructure and modelling tools to estimate the carbon balance of main South African terrestrial ecosystems;
- Assess the potential impacts of climate change on biodiversity and ecosystems in South Africa;
- Provide information to support sustainable land-use and climate-relevant decision making via multiple levels of stakeholder interaction;
- Develop capacities via researcher exchange and degree grants, and implement summer schools and workshops, in particular to enable future sustainable use of the project research infrastructures.

STUDY AREAS AND METHODS

The EMSAfrica field setup is designed to distinguish between land-use and climate-induced impacts on ecosystem structure and function. Three focal research areas are located along a precipitation gradient, from low to high precipitation. In each area, paired observation sites represent different intensities of land use - for example, a protected ecosystem compared with livestock grazing or a peri-urban landscape.

On each site, an eddy-covariance flux tower measures the land-atmosphere exchange of carbon dioxide and water vapour. Plant ecophysiological traits are investigated with field measurements, and the responses of different plant growth forms to climate change are studied with phytometer experiments. Earth observation approaches are used to characterise the spatial dynamics of vegetation structure. On some sites, socio-economic surveys are conducted to study human use of ecosystems.

The various data, supplemented with pre-existing national datasets, are used to create, calibrate, and test vegetation and ecosystem models, and scale up to make predictions on the impacts of climate change at the biome level

PROJECT ACTIVITIES AND EXPECTED OUTCOMES

Continuous land-atmosphere measurements of the fluxes of carbon dioxide and water help us assess which factors affect primary production under different management regimes. Photosynthesis and soil respiration measurements support the analysis of carbon fluxes. In combination with other data and models, these measurements help improve the estimations of the overall carbon balance of southern African ecosystems.

To assess the changes in species ranges and biome shifts, EMSAfrica conducts field monitoring and species distribution modelling. Biome shift monitoring phytometers (BISMOPs) are small garden experiments where different plant growth forms, each characteristic of a specific biome, are planted in different climatic regions, and their physiological activity is monitored.

Projections of vegetation changes under different scenarios of climate change and land use are produced using Dynamic Vegetation Models (DVMs). DVMs are computer-based models used to simulate the growth and distribution of plants in response to drivers such as fire, climate, or grazing and the interactions between them.

Fig 1: Use of unmanned Aerial Vehicles (UAV) (Middelburg site in Eastern Cape, left), and UAV products for the Agincourt, Bushbuckridge site (right).

To support all analyses and models, we collect multi-temporal remote sensing and ancillary geospatial data from various platforms and sensing schemes on each project site. In addition, novel earth observation and analysis methods are developed to monitor and map South African ecosystems.

Socio-ecological survey data is collected to support analyses on e.g. the role of humans as fuelwood collectors. This data parametrized an agent-based model (ABM) to mimic firewood collectors' adaptive behaviour responding to population growth and climate change.

fig 2: Biome shift monitoring phytometer (BISMOP) construction.

To create climate-relevant support for ecosystem management, EMSAfrica researchers work with two local land user groups to provide solutions to locally defined challenges. In addition, a large-scale multi-agent modelling and simulation framework is used to develop management solutions for national parks authorities (SANParks).

EMSAfrica runs training workshops in South Africa, and is involved in activities to engage policy stakeholders into project steering and the use of project outcomes. Special emphasis is placed on collaboratively building technical capacity to transfer project infrastructures as part of South African environmental observation networks at the end of the project..

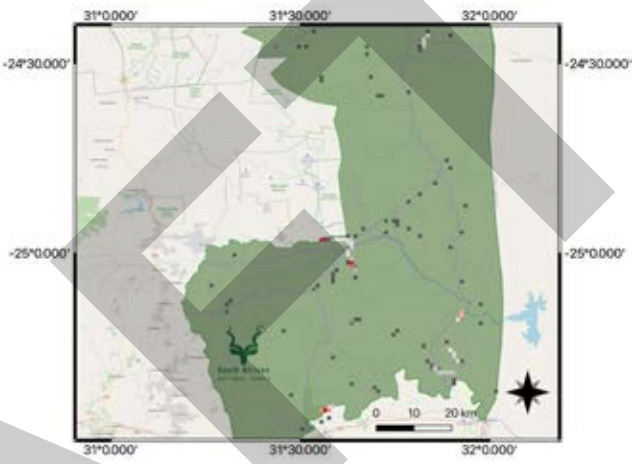

Fig 3: Tourist car density (red = high) in the southern part of the Kruger National Park (simulated).

PROJECT STRUCTURE AND PARTNERS

EMSAfrica is a collaborative project between South African universities (University of Stellenbosch, University of the Witwatersrand, University of Venda, Rhodes University) and research institutes (Council for Scientific and Industrial Research CSIR, South African Environmental Observation Network SAEON, Grootfontein Agricultural Development Institute GADI, Southern African National Parks SANParks), the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) as well as German Universities (University of Bayreuth, Goethe University Frankfurt, Friedrich-Schiller University Jena, Hamburg University of Applied Sciences) and research institutes (Thünen Institute, Senckenberg Institute).

EMSAFRICA – ECOSYSTEM MANAGEMENT SUPPORT FOR CLIMATE CHANGE IN SOUTHERN AFRICA

COORDINATION:

Universität Bayreuth
Thünen Institut für Agrarklimaschutz

PROJECT PARTNER:

- Universität Bayreuth
- Goethe-Universität Frankfurt
- Friedrich-Schiller Universität Jena
- Hochschule für Angewandte Wissenschaften Hamburg
- Thünen Institut
- Senckenberg Institut

INTERNATIONALE PROJECT PARTNERS:

- University of Stellenbosch
- University of the Witwatersrand
- University of Venda
- Rhodes University
- Council for Scientific and Industrial Research CSIR
- South African Environmental Observation Network SAEON
- Grootfontein Agricultural Development Institute GADI
- Southern African National Parks SANParks
- südafrikanisches Wissenschaftszentrum für Klimawandel und adaptives Landmanagement (SASSCAL)

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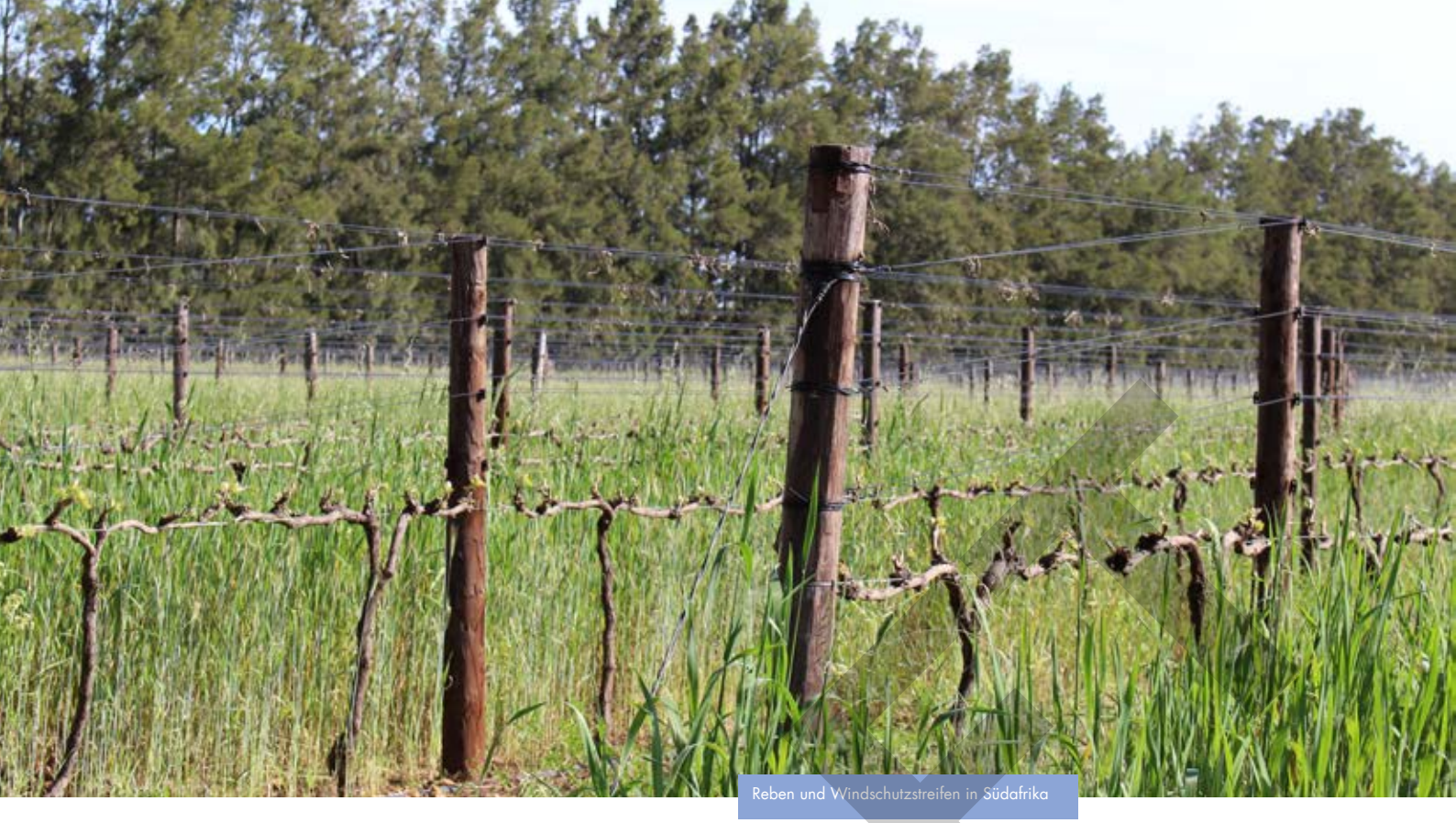

Reben und Windschutzstreifen in Südafrika

ASAP – AGROFORESTRY IN SOUTHERN AFRICA: NEW PATHWAYS OF INNOVATIVE LAND-USE SYSTEMS UNDER A CHANGING CLIMATE

BACKGROUND

New and innovative land use solutions are needed to adapt to a rapidly changing climate and to mitigate the predicted impacts on rural livelihoods. Projected changes caused by climate change are suggested to severely impact southern Africa. This may occur as an increase in drought and flooding events and shifts in rainfall patterns resulting in a reduction of production potential and a loss of productive cropland, thus negatively affecting economic, ecological and social aspects of sustainable development.

Agroforestry systems (AFS) present the potential to preserve natural resources and biodiversity against climate change influences, to improve the bio-economy in rural areas and to provide an adaptation strategy for human needs. The research project 'Agroforestry in Southern Africa - new pathways of innovative land use systems under a changing climate (ASAP)' targets the application of agroforestry systems as a suitable response to the impacts of climate change and to supplement awareness of the requirements of stakeholders, land managers and subsistence farmers in respect to the agricultural land they utilise and the potential pressures they will face due to a changing climate.

OBJECTIVES AND RESEARCH APPROACH

› In a transdisciplinary approach the ASAP project aims to both develop and cement knowledge concerning agroforestry systems in southern Africa utilising simple and replicable methodology as well as applying innovative technological solutions across the entire study region at the farm, landscape, and national scales. The three main goals of the ASAP project are:

› The investigation of ecosystem services and environmental benefits of agroforestry systems as an innovative, multi-purpose land-use management practice in southern Africa. The project will study the effects of the utilisation of trees within a farmed landscape in terms of soil mechanical processes, hydrological fluxes and flows, nutrient cycles, light regime as well as an assessment of the carbon sequestration potential.

- An exploration of human-environment interactions within AFS and their benefits for rural livelihoods and local stakeholders. The project will also assess the social, political, and economic contexts guiding the establishment of agroforestry policies at national level and the effects or implications of utilising trees within agricultural land in order to guide regional policy makers.

- A development of German - southern African research cooperation and capacity building with the bi-directional transfer of knowledge and educational transmission, providing multiple opportunities for exchange and collaboration at all levels.

STUDY AREA AND METHODS

The ASAP project aims to study complementary and contrasting areas in southern Africa with a focus on existing agroforestry systems employed within them. Comparisons and disparities as well as synergies between differing agroforestry systems are analysed especially in terms of interactions between trees and crops influencing the surrounding bio-physical environment. Project partners in South Africa, Mozambique, Namibia, Zambia and Malawi are ideally located to collaborate with teams in Germany in research and dissemination tasks, with outreach and the sharing of knowledge for a mutual benefit and for stakeholders in the study regions.

ACTIVITIES AND EXPECTED OUTCOMES

The trees and crops, soils, water regime and microclimates are studied within selected agroforestry systems, and the interactions that occur between the different elements are analysed by experts in their field translating to a truly multi-disciplinary research approach. The project will identify and study some of the most appropriate tree species for defined agroforestry applications within southern Africa and will facilitate the dissemination of guidelines for the management of such systems. This will require the compilation and advancement of understanding of individual tree species within the southern African research area utilising traditional knowledge, established scientific methodology and combining it with innovative technical solutions (such as terrestrial laser scanning, airborne UAV-based NDVI and photographical analysis). Experimental design and applied scientific methodology across all disciplines is intended to be straightforward to establish and undertake in order to facilitate replicability across the study range by multiple partners, thus ensuring high resolution data capture and achieving a maximum collaboration potential across the study region.

The project undertakes an examination of the positive and negative effects of the utilisation of trees within a farmed landscape. Detailed measurements, analyses and modelling activities will be undertaken within multi-disciplinary fields including soil mechanical processes, hydrological fluxes and flows, nutrient cycles, shading, an assessment of the carbon sequestration potential as well as ecophysiological measurements. Such work will allow researchers and land managers to target future research where it is needed. Likewise, ASAP targets an understanding of the social demands and impacts that agroforestry systems can offer. The project will foster an understanding of the social demands and impacts that AFS can bring to the study region. This will aid regional policy makers in evaluating future support for such innovative land-use systems.

PROJECT STRUCTURE AND PARTNERS

Combining multiple partners, the project presents a multi-national, multi- and transdisciplinary collaboration. The project is lead and coordinated by the Chair of Forest Growth and Dendroecology, University of Freiburg, Germany and complemented in by the Chairs of Soil Ecology and Forest and Environmental Policy at the same institution. Teams from The Institute of River Basin Management from the Karlsruhe Institute of Technology (KIT), Centre for Energy Technology Brandenburg (CEBra), and from the Working group Landscape Pedology located within the Leibniz Centre for Agricultural Landscape Research (ZALF) are central within the project's implementation. These research groups collaborate with the Department of Forest and Wood Science, Stellenbosch University, South Africa; the Faculty of Natural and Agricultural Sciences, University of Pretoria, South Africa; Department of Forestry, Eduardo Mondlane University, Mozambique; Depart-

Fig. 2: Installeriung von Wassersensoren unter Agroforst-Bäumen

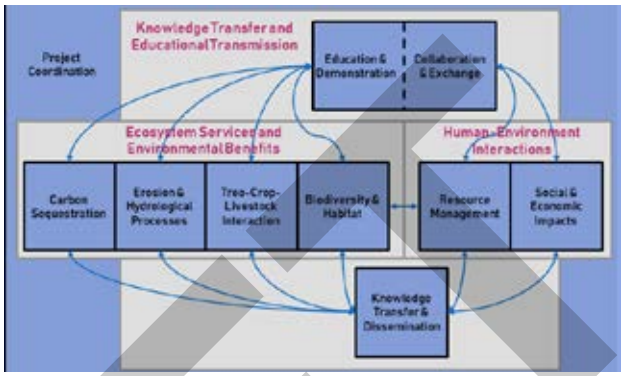

Fig. 3: ASAP Project Working Package structure showing interlinkages between research activities and dissemination

ment of Plant and Enviromental Sciences, The Copperbelt University, Zambia; Economic Botany Programme, National Botanical Research Institute, Namibia; World Agroforestry Centre (ICRAF, Southern African Node), Malawi) and SASSCAL, the Southern African Science Service Centre for Climate Change and Adaptive Land Management located in Namibia

ASAP – AGROFORESTRY IN SOUTHERN AFRICA:
NEW PATHWAYS OF INNOVATIVE LAND-USE SYSTEMS UNDER A CHANGING CLIMATE

COORDINATION:

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Fakultät für Umwelt und Natürliche Ressourcen,
Albert-Ludwigs-Universität Freiburg

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› Karlsruher Institut für Technologie
› Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V.
› Centrum für Energietechnologie Brandenburg e.V.

INTERNATIONALE PROJECT PARTNERS:

› University of Stellenbosch, Südafrika
› University of Pretoria, Südafrika
› National Botanical Research Institute, Namibia
› Eduardo Mondlane University, Mosambik
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› World Agroforestry
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SALDI – SOUTH AFRICA LAND DEGRADATION MONITOR

BACKGROUND

Land degradation deteriorates ecosystem functioning and services including soil fertility as well as biological productivity and is accompanied by a loss of biodiversity. In semi-arid and arid regions, this process is reinforced by climatic fluctuations on the decadal scale, resulting e.g. in prolonged draught and crop losses. Predicted future climate change and socio-economic challenges worsen the situation and call for a precise identification of areas affected by land degradation in order to allocate means to combat land degradation more effectively.

Recent developments in the fields of remote sensing and modelling of land surface processes as well as land surface–atmosphere interactions provide the opportunity to identify the underlying subtle processes of land degradation with unprecedented spatial resolution and precision. It is now possible to instantaneously monitor land surface change bi-weekly and in a spatial resolution that provides meaningful insight, i.e. on the "back-yard scale" of 10 m.

OBJECTIVES AND RESEARCH APPROACH

Taking advantage of recent technical and methodological developments, it is the aim of SALDi

- to develop an automated system for high temporal frequency (bi-weekly) and high spatial resolution (10 to 30 m) change detection monitoring of ecosystem service dynamics,
- to adapt and apply a Regional Earth System Model (RESM) to South Africa and investigate feedbacks between land surface properties and regional climate,
- to advance current soil degradation process assessment tools for soil erosion.

Protected areas within our study regions represent benchmark sites, providing a foundation for baseline trend scenarios, against which climate-driven ecosystem service dynamics of multi-used landscapes (cropland, rangeland, forests) will be evaluated. To make sure that the developed tools will be applicable across different stakeholder levels, the socio-economic dimension of land degradation and a validation of the usefulness of the monitoring products to local farmers is an important objective of the investigations.

Abb. 1: Regensimulationen im südlichen Kruger Nationalpark, Mpumalanga, zur Bestimmung von hydraulischen Bodeneigenschaften und der Erodibilität der Böden.

STUDY AREA AND METHODS

SALDi focusses on six study sites representing a major climate gradient from the (humid) winter rainfall region in the SW across the (semi-arid) all year around to the (very humid) summer rainfall region in the NE. The sites cover also different geological conditions and different agricultural practices. These include commercial, rain-fed and irrigated cropland, free range cattle and sheep farming, as well as communal and subsistence farming. Thus, the sites basically represent the climatological, ecological, socio-economic and cultural diversity of/in South Africa. Furthermore, sites were selected to consider the incisive biome changes expected under the predicted global climate change.

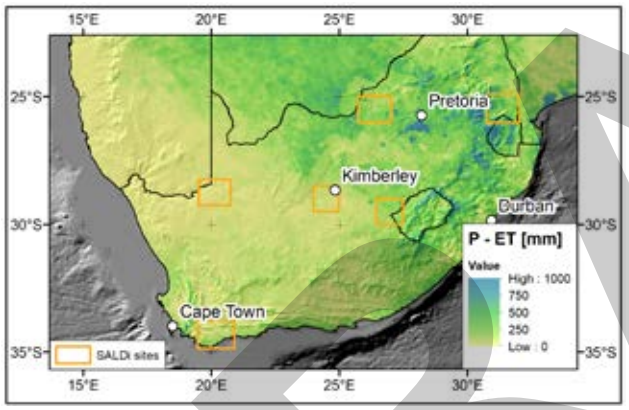

Fig. 2: SALDi study sites in South Africa and modelled water balance (precipitation (P) – evaporation (ET)) for the year 2010 highlight the strong underlying climatic gradient across the country providing the framework for land degradation processes

ACTIVITIES AND EXPECTED OUTCOMES

The SALDi activities during the first half of the project life time included field survey campaigns to assess soil properties and erosion (Fig. 2) and land surface dynamics (Fig. 3), the development of algorithms for the synergistic exploitation of the generated Sentinel-1 and Sentinel-2 remote sensing data cube, as well as the setup of the Regional Earth System Model (RESM) (WRF-Hydro®, Weather Research and Forecasting Model Hydrological modeling system) for the weather and climate modelling. First results of the later providing the water balance for the year 2010 were used to highlight the climatic gradient in the SALDi study site map (Fig. 1). According to this, the water balance in the year 2010 for our study sites varied from about 10 mm at Augrabies Falls in the Northwest to 400 mm in Mpumalanga in the Northeast.

Another example for first results is provided by the two remote sensing groups working on synergetic land surface change detection based on the optical and radar Sentinel satellites of the European Space Agency (ESA) . By combining different acquisitions, the Sentinel-1 radar backscatter (Fig. 3, left) can be used to draw conclusions about cultivation dynamics (e.g. ripening processes) in agricultural areas (pivot irrigation) as well as the surrounding grasslands. The figure shows this as an RGB composite, where each color represents the backscatter intensity of one acquisition. In detail, magenta areas represent high backscatter (due to volume scattering from the crops) in August 2017 and January 2018, whereas blue regions on the left have higher backscatter in January 2018, only,

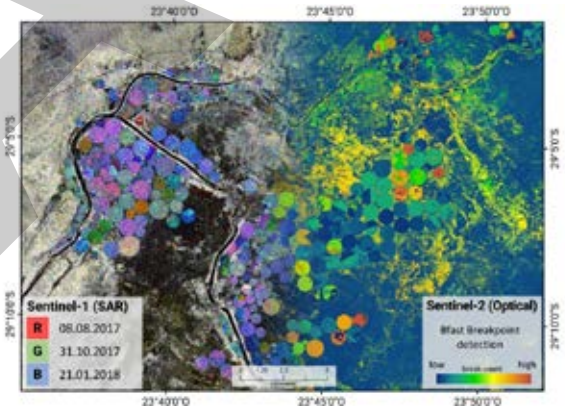

Fig. 3: Synergistic combination of Sentinel-1 radar (left) and Sentinel-2 optical (right) time series to monitor land surface dynamics (e.g. pivot irrigation and grasslands) near Douglas, Northern Cape Province, west of Kimberley. The figure contains modified Copernicus Sentinel data [2015 – 2020].

which allows interpretation of the growing cycles of the pivot irrigation areas. On the right, Figure 3, presents first results of the interpretation of the optical imagery for the neighbouring area. In this case a Normalized Difference Vegetation Index (NDVI) time series (2016-2019) derived from Sentinel-2 data and processed with the BFAST (Breaks For Additive Season and Trend) algorithm highlights different land use patterns in agricultural and natural environments. Here, blue indicates a

low number of changes whereas red stands for a high number of changes. Blue areas are interpreted as having a constant vegetation cycle over the entire time span, a few red areas apparently exhibit numerous changes in vegetation development, pointing to numerous crop changes. Colors in the natural vegetation are less pronounced and range from blue to yellow. Interpretation of the latter areas hints at changes in the natural vegetation cylcle. These areas need to be investigated in greater detail in order to find out, if land degradation plays a role.

PROJECT STRUCTURE AND PARTNERS

Structured into four subprojects (SP) we investigate in close cooperation with South African partners the following major land degradation issues: current soil erosion (SP1) and long-term geological erosion (SP3), remote sensing-based land surface change and degradation (SP1, SP4) and land surface–atmosphere interactions (SP2). The joint project is coordinated by the Friedrich Schiller University Jena and includes in Germany scientists from the universities in Jena (SP1), Augsburg (SP2) and Tübingen (SP3) as well as from the German Aerospace Agency (DLR)(SP4). A number of academic and institutional partners in South Africa support the research and provide intellectual input, logistic support and critical assessment of project outcomes (Fig. 4).

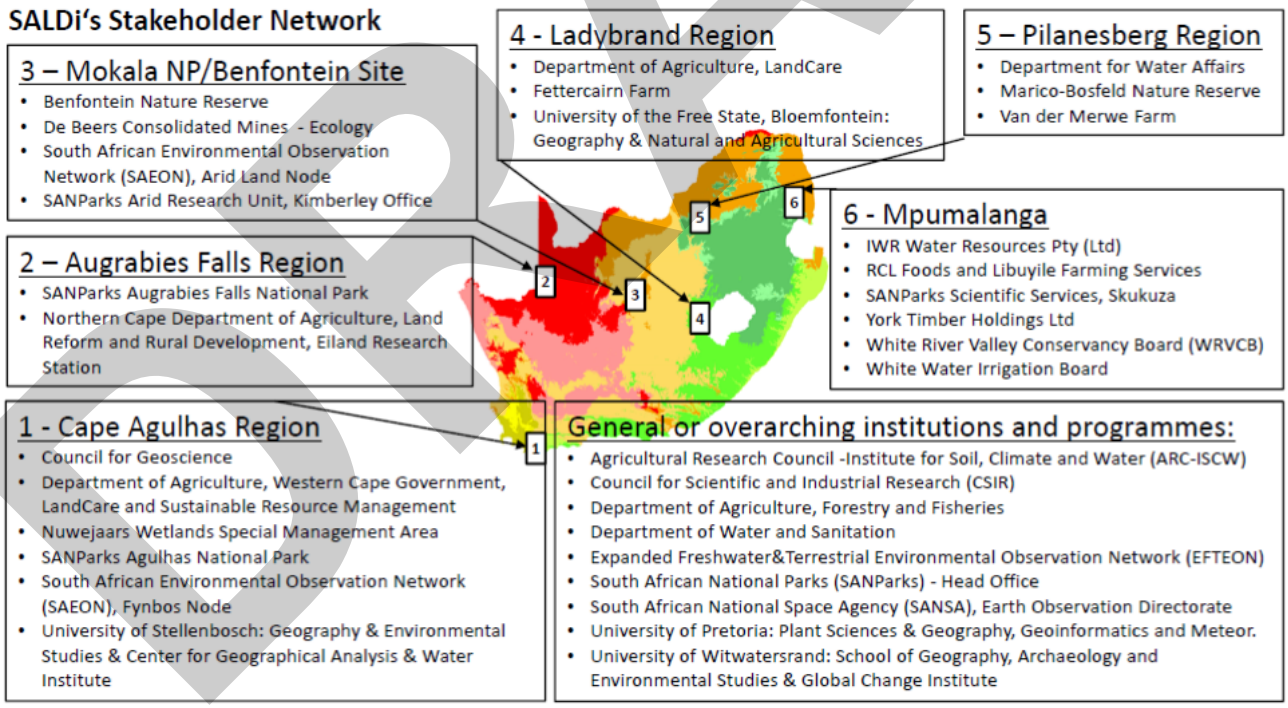

Fig. 4: SALDi stakeholder network in South Africa. Data sources: Köppen climate types calculated from WorldClim.org-data (https://commons.wikimedia.org/w/index.php?curid=52931993).

SALDI - SOUTH AFRICA LAND DEGRADATION MONITOR

COORDINATION:

Institut für Geographie,
Friedrich-Schiller-Universität Jena

PROJECT PARTNERS:

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- Universität Tübingen, Geowissenschaften
- Deutsches Zentrum für Luft- und Raumfahrt (DLR)

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- SANParks, Headquarters and regional Scientific Services, Südafrika
- Council for Scientific and Industrial Research CSIR, Südafrika
- SANSA Earth Observation Directorate
- Universities of Bloemfontein, Cape Town, Pretoria, Stellenbosch, Witwatersrand
- Department of Agriculture, Forestry and Fisheries, Südafrika
- Department of Water and Sanitation, Südafrika
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SPACES II CAPACITY BUILDING

Capacity building is a central aim of SPACES II. BMBF, together with DAAD (German Academic Exchange Service), initiated a Capacity Building/Development (CaBuDe) Programme, to enable Southern African scholarship holders' research visits, networking and further education in Germany as well as equivalent activities of German scholarship holders in Southern Africa. In addition, a programme of workshops and summer/winter schools was established by the SPACES II projects under a joint umbrella.

DAAD grants are awarded to African and German researchers associated with SPACES projects and working on the fields of environmental sciences, coastal and marine sciences, or geology. The different types of grants in the CaBuDe Programme comprise:

- PhD fellowships in Germany (max 52 months)
- Bi-nationally supervised doctorates: integrated research phase of PhD fellowship in Germany (6 to 24 months)
- Short-term research fellowships for bachelor students, master students, PhD students, postdoctoral researchers and senior experts (2 weeks to 3 months)

A total of six doctoral researchers from South Africa, Namibia and Zimbabwe were awarded the four-year PhD fellowship, starting their research in early 2020 associated with SPACES II projects. Additional short-term research grants are awarded to allow travel to Germany for exchange and networking with project partners.

The SPACES II Integrated Training Programme comprises nearly 30 summer/winter schools and workshops on key project skills and competencies. The programme aims to link the capacities of the southern African and German research communities, and offers hands-on training in key topics such as modelling, greenhouse gas measurements, earth observations, ecosystem assessments, and field surveying methods. Most courses take place on the SPACES II project field sites in South Africa and Namibia. All courses are planned and organized collaboratively between the South African and/or Namibian and German partners. Funded scholarships are always available for southern African participants, while many of the courses are also open for German participants.

The terrestrial projects training programme is coordinated by the Thünen Institute of Climate-Smart Agriculture under the SPACES II Board and Steering Committee. The training programme is aligned with and runs in collaboration with other southern African regional initiatives, in particular SASSCAL and ACCESS. The DAAD coordinates the marine projects' training courses and summer schools via its CaBuDe programme. As a result of Covid-19 travel restrictions, many courses of 2020 are run as webinars or postponed to the following year.

SPACES II aims to create incentives for effective networking also by inviting and participating early-career researchers to its meetings and events. Special initiatives are designed by the early-career researchers themselves, and workshops on key themes are organized by SPACES II senior researchers to strengthen the transferable as well as technical skills. SPACES II publishes a regular Newsletter, which particularly welcomes inputs from early-career researchers.

Participants of the SPACES II Eddy Covariance Flux Measurements Course's R Session with course assistant Tamryn Hamilton (SAEON). Photo: Mari Bieri

Participants of the SPACES II Eddy Covariance Flux Measurements Winter School at one of the hands-on sessions with course teachers Christian Brümmer (Thünen Institute, middle) and Amukelani Maluleke (SAEON/University of Stellenbosch, third from left) of EMSAfrica. Photo: Mari Bieri

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Bundesministerium
für Bildung
und Forschung

Abc ABKÜRZUNGSVERZEICHNIS

ABM	Agentenbasiertes Modell (Agent-based model)
AFS	Agroforstsystem
BCC	Benguela Current Convention
BISMOP	Biome Shift Monitoring Phytometer
BMBF	Bundesministerium für Bildung und Forschung
CaBuDe	Capacity Building/Development
CEBra	Zentrum für Energietechnologie Brandenburg
CSIR	Council for Scientific and Industrial Research
DAAD	Deutscher Akademischer Austauschdienst
DAFF	Department of Agriculture, Forestry and Fisheries, South Africa
DEA	Department of Environmental Affairs, South Africa
DEFF	Department of Environment, Forestry and Fisheries, South Africa
DLR Pt	Deutsches Zentrum für Luft- und Raumfahrt Projektträger
DVM	Dynamic Vegetation Model
EBUS	Eastern Boundary Upwelling System (Auftriebsgebiete an den Osträndern der Ozeane
ESA	Europäische Weltraumorganisation (European Space Agency
ESACW	Östliche Südatlantische Zentralwasser (East South Atlantic Central Water)
FONA	Forschung für Nachhaltige Entwicklung (Research for Sustainable Development)
GADI	Grootfontein Agricultural Development Institute
GENUS	Geochemistry and Ecology of the Namibian Upwelling System
GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel
GPS	Globales Positionsbestimmungssystem (Global Positioning System
HZG	Helmholtz-Zentrum Geesthacht GmbH
IPCC	Weltklimarat (Intergovernmental Panel on Climate Change)
ISOE	Institut für sozial-ökologische Forschung, Frankfurt
KIT	Karlsruhe Institut für Technologie
MET	Ministry of Environment and Tourism, Namibia
NatMIRC	National Marine Information and Research Centre, Namibia
nBUS	nördlich Benguela-Auftriebssystem (northern Benguela Upwelling System)
NDVI	Normalized Difference Vegetation Index
NUST	Namibia University of Science and Technology
PtJ	Projektträger Jülich
RESM	Regionales Erdsystem Model (Regional Earth System Model)
RGB	Red Blue Green (color model)
SACW	Südatlantische Zentralwasser (South Atlantic Central Water)
SAEON	South Africa Environmental Observation Network
SANParks	South Africa National Parks
SASSCAL	Das Wissenschafts-Zentrum für Klimawandel und alternative Landnutzung im südlichen Afrika (Southern African Science Service Centre for Climate Change and Adaptive Land Management)
sBUS	südlich Benguela-Auftriebssystem (southern Benguela Upwelling System)
SDG	Ziele für nachhaltige Entwicklung (United Nations Sustainable Development Goals)
SPACES	Forschungspartnerschaften für die Bewertung komplexer Prozesse im System Erde in der Region Südliches Afrika (Science Partnerships for the Adaptation to Complex Earth System Processes in Southern Africa)
TP	Teilprojekt
TROPAGS	Georg-August-Universität Göttingen Tropischer Pflanzenbau und Agrosystem Modellierung
UAV	Unmanned Aerial Vehicle
ZALF	Leibniz-Zentrum für Agrarlandschaftsforschung
ZMT	Leibnitz-Zentrum für Marine Tropenforschung

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