WASCAL

West African Science Service Center on
Climate Change and Adapted Land Use

Report 2010-2014

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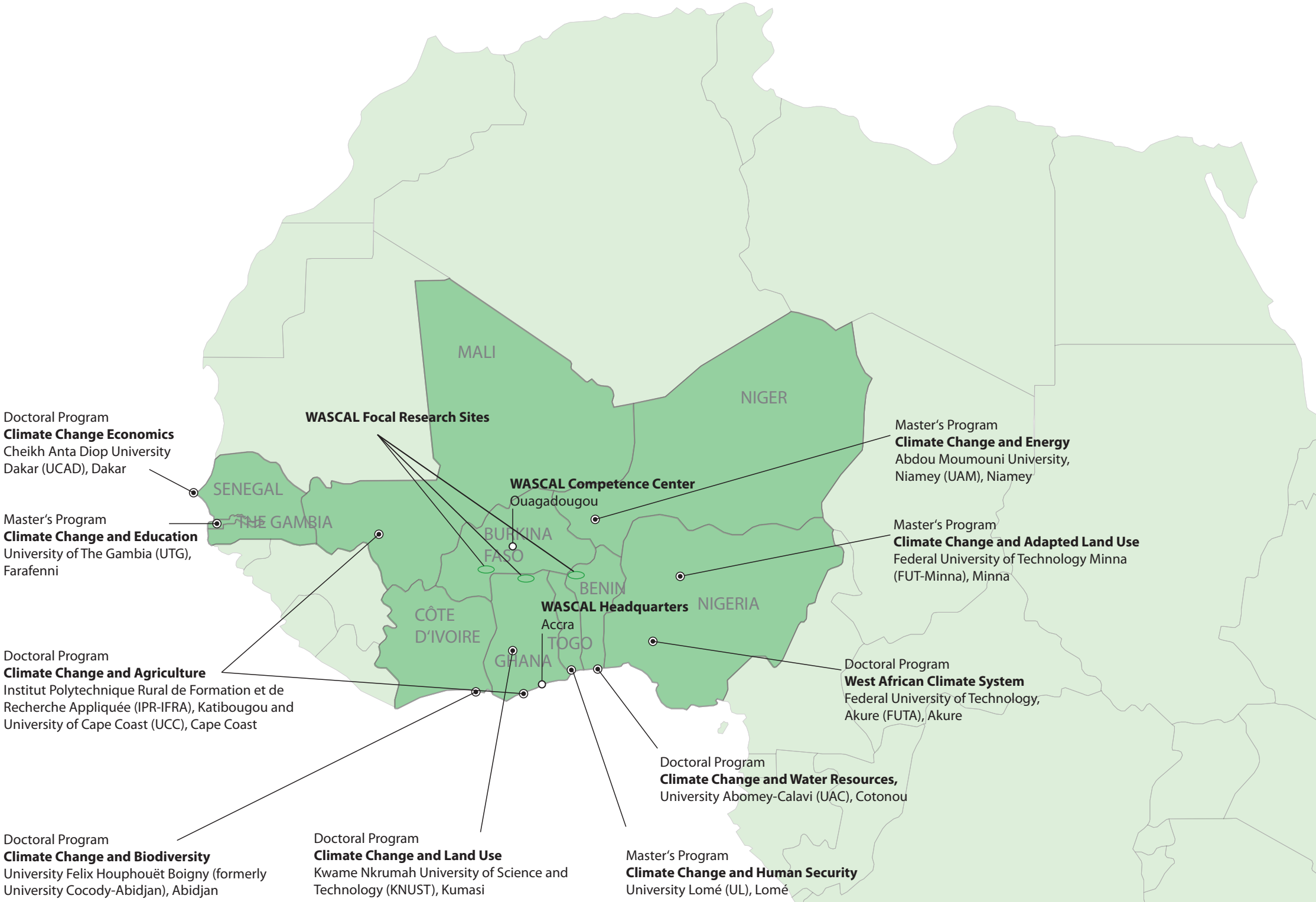

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June 2014

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Laurent Sédogo, Board Member *ex officio*, and Executive Director of WASCAL

Preface

It is a great pleasure and honor for me to address some words on behalf of the German Federal Government, and especially on behalf of Prof. Wanka, the German Minister of Education and Research.

WASCAL, our common institution, from humble beginnings with the first conference in September 2009, has grown in size and importance, gradually establishing itself as a regionally and internationally recognized quality assurance center for research and capacity building in the West African region. The German Federal Ministry of Education and Research is very proud as main funder of its contribution to this achievement. Today, WASCAL has become a living cooperation between Germany and ten West African partners firmly engaged to combat the impacts of climate change on the land use in order to improve the livelihood of the populations in the West African region. WASCAL, through its unique capacity building program with the ten Graduate Schools and its integrative Research Program has become a true platform of scientific exchange between German and African scientists who are working on common priorities in order to find adapted solutions to the challenges coming from the global warming effects.

The world is facing huge climate change challenges. Dealing with these challenges has often resulted in dramatic changes in land use patterns and land use intensities. These changes can frequently trigger serious conflicts in a country, in a region and finally also affect the world as a whole. We all know that climate change is not confined to national borders. But effects and consequences are local. Therefore, it seemed right to address climate change by developing regional scientific cooperation and collaboration, as we are doing now in the framework of WASCAL.

From the achievements, I am confident that our initial investments in WASCAL have created a solid regional setting to generate new research opportunities for West Africa. I am pleased that by the end of 2014, more than four hundred scientists and technical staff from all partner countries of WASCAL were already engaged in tasks directly linked to the implementation of WASCAL´s science plan, this number will steadily increase in near future to enhance the visibility of science from Africa, to strengthen long-lasting cooperation between African and German universities and research institutes, to support working and career options for scientists in Africa and then to strengthen the capabilities of scientists and organisations in Africa to manage and to implement knowledge for their own development objectives over time.

The ten Graduate Schools for master's and doctoral degrees newly established at our lead universities will contribute to enforce the existing scientific human resources and substantially support the existing networks in the region.

The different equipment my ministry generously financed for research activities and for the observation networks will work accordingly to enable data collection at the national level, which are based on standards, which will also allow their worldwide utilization.

I would like to express my sincere gratitude to the entire Governing Board of WASCAL, to the staff in Ghana, Burkina and in Germany, for their strong and tireless dedications have been the true engine in the process of successfully accrediting WASCAL.

I am confident that WASCAL is on the right way to become a regional reference research center which my ministry has contributed to set up. I wish the WASCAL community great success.

Thank you!

Wilfried Kraus
Federal Ministry of Education and Research, Germany

Introduction

Introduction by the Chair of the Governing Board

It is with great pleasure and pride that we present this first WASCAL report.

Indeed, the document which you have in your hands is illustrative of an exemplary level of cooperation between the ten states of West Africa and the Federal Republic of Germany and has resulted not only in successful research and training activities being established in record time, but also, and in particular, in the setting up of a very useful institution in this region of Africa, a region so often confronted by the hazards related to climate variability and climate change.

As you read this report, you can get a sense of the various twists and turns which led to the creation of WASCAL, this important institution which is dedicated to research, the provision of services, and the strengthening of capacity in relation to climate change in the West African region, as well as of the significant progress that has been made — but also of the difficulties and obstacles that have been encountered and overcome.

I would like to acknowledge here the dynamism and dedication of the various parties who have worked for the establishment of WASCAL, from the initial ministerial meetings to the meetings of the Task Force, the support of PT-DLR and of the Center for Development Research (ZEF), University of Bonn and the able and exceptionally efficient leadership of Professor Paul Vlek and his field teams. I would also like to mention the many partners in academic institutions, research institutions and departments from various countries and the consortium of German universities and institutions which have played their part so admirably in relation to the implementation of WASCAL and these key components.

West Africa now has an institution with all the attributes necessary to function as a normal international center: a Council of Ministers, a Governing Board, a management headed by an Executive Director, statuts and headquarters agreements. Infrastructures have been built or rented in order to host the Headquarters in Accra (Ghana) and the Competence Center in Ouagadougou (Burkina Faso), and three research stations, which now host as many African as German researchers and students, have been equipped with high-tech scientific instruments. Six training programs at the doctoral level and four programs at Masters level are up and running and will produce their first graduates in late 2014 or early 2015.

These achievements have been possible thanks to the political will of the West African States and the generosity and commitment of the German Federal Ministry of Education and Research (BMBF). Without a doubt WASCAL will be a powerful symbol of the cooperation between Germany and West Africa.

The appointment in early 2014 of a new, able and dynamic Executive Director, who is well aware of the issues relating to climate change in the West African region, will enable the activities of WASCAL and the relations and scientific collaborations between training and research institutions in Germany and West Africa to develop, intensify and continue to grow deeper.

Long live WASCAL, our powerful instrument for cooperation and integration for the development of our West African sub-region.

Modibo Haïdara
Chair of the Governing Board

Message from the Executive Director

2014 certainly marks a significant turning point in the life of WASCAL. In fact, three major developments have taken place in WASCAL which can be seen as decisive for our fledgling institution. Specifically, and in chronological order:

My selection as the new Executive Director by the Board, followed by the transfer of responsibilities from Professor Paul Vlek, the outgoing Executive Director, on February 12, 2014;
The signing of the headquarters agreement by the President of the Republic of Ghana on March 5, 2014;
The establishment of the KFW fund in July 2014.

These three facts are worth mentioning because they represent a very strong symbolism which demonstrates the determination of the initiators of WASCAL to build an institution with full West African ownership, enjoying full international recognition, and having control over the human and financial means to forge its own destiny.

By looking back to the year 2010, which can be regarded as the beginning of WASCAL's great story, we can easily see how far we have come. This success was certainly not a foregone conclusion.

Firstly it needed the German Federal Ministry of Education and Research (BMBF) to share its vision with policy-makers and scientists: namely the wish to see the creation on our African continent of the concept of the Regional Climate Service Center as one of the responses to the major challenge for the West African region represented by climate change — some manifestations of which are already so dramatic and are already affecting millions of men and women.

Then it needed a group of scientists from the Center for Development Research (ZEF), University of Bonn, led by Professor Paul Vlek, to take the concept on board and to have the know-how to share and refine it in partner- ship with West African colleagues in order to translate it into a skillfully arranged project which was sufficiently relevant to be implemented in the sub-region.

Workshops, scientific symposia and very lively debates have helped to patiently build the scaffolding of this wonderful structure for the genuine development of our region.

Finally, by signing the cooperation agreement on February 10, 2012, African and German Ministers launched the beginning of the process for the transformation of WASCAL into an institution with the status of an international organization, established through strong political actions in each of the states — such as the adoption of WASCAL's governing documentation by the governments, their ratification by the parliaments of the various countries, the signature of the headquarters agreement by Burkina Faso for the construction of the Competence Center, and finally the signature of the headquarters agreement by the Republic of Ghana.

This dynamic has been made possible by the commitment of the various stakeholders who have worked on setting up WASCAL. In this regard, in addition to thanking those initially responsible for WASCAL such as African and German Ministers, who demonstrated an unwavering commitment, I would also like to pay tribute to the important contribution of the diplomatic representations of all the parties. All these stakeholders have shown great commitment, which is reflected in their direct involvement in the various meetings, both bilateral and multilateral, enabling in-depth discussions to be held and clear guidelines for the implementation of this enormous project to be agreed.

On the German side, the provision of the necessary funds within the agreed timeframe, as well as the appropriate disbursement mechanisms have enabled the planned actions to be launched (sometimes ahead of schedule).

The formalization of the WASCAL governance bodies and their proper functioning is to be acknowledged and welcomed. Indeed the executive management has been fully set up and functional since 2012, and the Board has held regular meetings in the course of

which the principal activities and management procedures have been discussed and adopted.

Partnership, which is a guiding principle for WASCAL, has worked well and has helped WASCAL to function smoothly for two years. It is appropriate at this point to gratefully acknowledge the cooperation of ZEF (University of Bonn), the Alliance for the Green Revolution in Africa (AGRA) and the International Water Management Institute (IWMI) for their kind and supportive mediation.

It is admirable to note that in three years the Graduate Program has not only been able to get all the higher education institutions envisaged in WASCAL's university partners up and running, but also, and especially, to ensure that they are being run properly by the African and German stakeholders (academic activities, administrative and financial management), in an atmosphere of frank and close collaboration. The presentation of dissertations by the first batch of students at the end 2014 will represent a concrete manifestation of the enthusiasm, dynamism and commitment shown by all of these stakeholders, who deserve to have their qualities recognized and acknowledged here.

The WASCAL headquarters, whose construction is nearing completion, is another example both of the commitment of the people behind WASCAL and of the dynamism which characterized the executive management of this previous phase.

Finally let us also acknowledge the start-up and implementation of the research activities and observation networks through the Core Research Program and the operational implementation of the Competence Center.

In conclusion, I would like to pay tribute to Professor Paul Vlek for his foresight and for the courage and dynamism which he has shown along with his team — qualities which have helped WASCAL to attain a significant organizational and operational level within a short space of time. As I take over from him, I am very conscious of the scale of the task and the challenges which we will have to deal with so that we can help WASCAL achieve its full potential. Together with the management team, we take on the commitment, in Professor Vlek's wake, to ensure that WASCAL can contribute effectively to giving hope to the millions of men and women in West Africa, enabling them to be better prepared to face climate change and climate variability.

Laurent Sédogo
Executive Director

Building a Regional Climate Service Center – Looking back on four years of WASCAL

During a visit to German-African research projects in Southern Africa in 2007, the German Chancellor Angela Merkel announced the idea to allocate funds to in- crease the involvement of the German research com- munity on the continent. The aim would be to help strengthen the research capabilities of sub-Saharan Africa and foster research partnerships. Some years later, as the idea took shape, she addressed the German Parliament and made it clear that these funds would not be used for research in Africa, nor for research for Africa but for research with Africa in which partners would work together on a level playing field. It is in this spirit that the German Federal Ministry of Education and Research (BMBF) took up the responsibility to transform this idea into a solid concept. Early on the decision was made that this new program would address issues related to climate change and adapted land use with a focus on West and Southern Africa where considerable experience had been gained over the previous decade with such concerted German-African research efforts as GLOWA and BIOTA. The BMBF settled on the development of Regional Science Service Centers (RSSC) on climate change with an emphasis on the interaction between the atmosphere and the land surface.

The ministry contacted the embassies of the countries in the target regions to gauge their interest in joining this effort and called upon the German research community to develop concepts on what such a Climate Service Center might look like. The Center for Development Research (ZEF), University of Bonn headed a German research consortium and proposed the creation of a Center dedicated to the alleviation of three major bottlenecks in dealing with climate change: to generate continuous and high quality data, to produce talented experts and to provide science based policies for adaptation and mitigation. The concept foresaw the creation of a headquarters in Ghana from where the capacity building efforts would be coordinated and a climate service center in Burkina Faso. The latter would implement regional Observation Networks with national agencies in order to generate panel data on climate, hydrology, land use, biodiversity and socio-economics. It would also be a research center generating options for the creation of resilient and productive landscapes which sustain the key ecosystem functions that society relies on.

Ten countries in West Africa expressed interest in being affiliated with this new initiative: Benin, Burkina Faso, Côte d'Ivoire, The Gambia, Ghana, Mali, Niger, Nigeria, Senegal, and Togo. Following two workshops convened by the BMBF in Burkina Faso and Benin, respectively, the ZEF concept was selected for implementation from the four entries in this competitive bidding process. The BMBF attached the condition that Professor Vlek from ZEF would personally lead this endeavor from provisional headquarters to be established in Accra, Ghana. The contract between the University of Bonn and BMBF to this effect was signed in April 2010 and I moved to Ghana in May of that year

to establish WASCAL. The design phase of the project was accompanied by the guidance of a Task Force with representatives of the ten member countries and Germany. Following a series of intricate meetings, they agreed on the text of a Cooperation Agreement as well as a Constitution for WASCAL, which was eventually signed during a Ministerial meeting in Lomé, Togo in February 2012. These agreements would then enter into force following ratification by six of the ten member countries, which was accomplished in record time by June 1, 2013. WASCAL was born. The Task Force was disbanded and a Board of Governors was established as the highest authority of WASCAL.

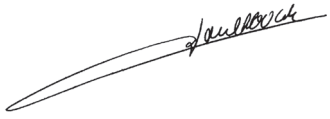
Two institutional agreements were key to the early establishment of WASCAL. First, the Alliance for the Green Revolution in Africa (AGRA) agreed to host WASCAL as a project at its regional headquarters in Accra, thus offering it administrative support as well as privileges and immunities. This facilitated the hiring of Dr. Mamadou Ouattara as the Director of the Graduate Studies Program. The International Water Management Institute (IWMI) offered additional support in particular in providing Professor Vlek with an honorary appointment and seconding Dr. Boubacar Barry to serve as the Director of the Climate Service Center in Ouagadougou, Burkina Faso. Having established this core team, WASCAL proceeded with the implementation of the program.

Of equal importance to WASCAL has been the excellent working relationship with the two host countries and their institutions. Both Ghana and Burkina Faso supported WASCAL with headquarter agreements that provide it with the necessary immunities and privileges and made land available for the construction of the headquarters building on the CSIR campus in Ghana and near the University of Ouagadougou for the construction of the Climate Service Center in Burkina Faso.

The initial funding of WASCAL allowed for the establishment of the Graduate Program and the Research Program. Following a dozen consultative workshops with university representatives from member countries, a total of 10 Graduate Schools were founded, six at the doctoral level and four at the master level. Each school was established at a national university of high competence and would admit one qualified student per member country every year. Each student was supplied with a stipend as well as research funds and, following intensive English training, participated in a course curriculum of six to nine months. Further, doctoral students have the option of spending up to six months at a host university in Germany. Over the first three years all ten Graduate Schools were activated and provided with funds to upgrade infrastructure and computing facilities. The schools all focus on climate change but with different vantage points such as hydrology, land use, economy, human security and biodiversity (for more information about the Graduate Program, please see page 14).

At the same time, WASCAL recruited a core team of scientists for the Climate Service Center in Ouagadougou and set up three flagship research watersheds in the Savanna-Sahelian zone across Burkina Faso, Ghana, and Benin. In anticipation of the construction of the new Climate Service Center headquarters, WASCAL rented temporary facilities to house its staff and rented office as well as guesthouse facilities at each of the flagship sites. Around 30 PhD students availed themselves of these facilities to initiate the WASCAL research program around the design of landscapes to sustain ecosystem functions and provide livelihoods to the rural populations under different scenarios of climate change. With the arrival of a second tranche of funding, WASCAL is now in a position to move forward with the establishment of the Observation Networks.

The WASCAL Governing Board undertook to search for a new Executive Director to replace Professor Vlek, who was due to retire in February 2014 after a 4-year stint as inaugural ED. Following a wide search, agreement was reached with Dr. Laurent Sédogo, who joined WASCAL on January 1, 2014 and took over as Executive Director on February 12. Establishing WASCAL has been a huge challenge and would have been impossible without the continuous support of the member countries, in particular of the German Federal Ministry of Education and Research. For me, it has been a privilege to serve as its first Executive Director, and I wish to thank all, family, colleagues and friends, who have helped make this idea a reality. I am confident that WASCAL will be heard of in the decades to come and will play an important role in helping the region cope with the consequences of climate change.



Paul Vlek
Founding Executive Director

Highlights 2010-2014

June 2010

Planning Meeting for the Graduate Studies Program

In order to identify the main areas of demand for expertise and human capacity development in West Africa, WASCAL brought together government and scientific actors in the region involved in climate change negotiations, national planning and research. Priority areas for the WASCAL capacity building program were identified during a workshop held in Accra, Ghana, in June 2010. The second step in the development of the Graduate Studies Program brought together representatives of the region's best qualified universities and training institutions to choose a lead university and develop a curriculum for each of the training programs.

Aug. 2010

Regional Workshop on Climate Observation Networks

In August 2010, a regional workshop on climate observation networks in West Africa was held in Accra bringing together the directors of the National Meteorological Services of Mali, Burkina Faso, Côte d'Ivoire, Ghana, Togo and Benin as well as the African Center of Meteorological Applications for Development (ACMAD). The aim of the workshop was to assess the state of the existing climate observation facilities in West Africa and to identify needs for support to strengthen West African climate observation.

Oct. 2010

Planning Meeting for the Core Research Program

WASCAL organized a three-day workshop in Accra to discuss the scope and foci of the WASCAL research program. The workshop was attended by scientists from the ten states supporting WASCAL, representatives of intergovernmental, pan-African and international organizations as well as scientists from German universities.

Feb. 2012

Ministers sign Cooperation Agreement in Lomé, Togo

On February 10, 2012 the ministers of research and education of the ten West African states supporting WASCAL and Secretary Georg Schütte of the German Federal Ministry of Education and Research (BMBF) met in Togo's capital Lomé to sign an intergovernmental cooperation agreement. The signature of the agreement was a milestone for WASCAL, as it officially set the basis for the cooperation of all participating partner states in their effort to meet the challenges of climate change.

Feb. 2012

The Graduate Studies Program welcomed its first students

The WASCAL Graduate Studies Program started in February 2012 with the opening of four doctoral programs on the West African Climate System (Nigeria), Climate Change and Water Resources (Benin), Climate Change Economics (Senegal), and Climate Change and Land Use (Ghana). Two more doctoral programs Climate Change and Biodiversity (Côte d'Ivoire) and Climate Change and Agriculture (Mali), as well as the two Master's programs Climate Change and Human Se- curity (Togo) and Climate Change and Adapted Land Use (Nigeria) followed in October 2012.

Mar. 2013

Biodiversity Monitoring Workshop of the Observation Network

The Biodiversity group at the Competence Center in collaboration with the Volta Basin Authority (VBA) and partners from six WASCAL supporting states plus German partners in the WASCAL research program organized a two-day workshop in Ouagadougou in 2013. The goal was to develop modalities for setting up a Biodiversity Observation Network that could facilitate the monitoring and response of biodiversity to climate change and land use (transformation, intensification).

40 Doctoral and Master students started their programs in October 2012. The program directors and the team of the Graduate Studies Program welcomed the students in Cape Coast, Ghana for a joint introductory seminar on climate change and land use. In June 2014, many programs already welcomed their second batch of students, raising the number of students to 158. Photo: Vasco Silas Alordome 2012.

June 2013

WASCAL officially becomes an organization

WASCAL officially achieved the status of a regional international organization in June 2013. Following Benin, Burkina Faso, Ghana, Niger and Togo, The Gambia was the sixth country to approve the constitution of WASCAL, as confirmed by the Economic Community of West African States (ECOWAS). The establishment of WASCAL as a regional international organization was an important step towards installing WASCAL as a permanent research facility in West Africa.

Dec. 2013

All Doctoral and Master's Programs operational

With the opening of the Master's Programs Climate Change and Energy (Niger) and Climate Change and Education (The Gambia) in December 2013, the Graduate Studies Program is complete, raising the total number of programs to six doctoral programs and four master programs.

86 researchers from 16 countries and all branches of WASCAL discussed initial research results and directions for future research in Bonn. Photo: Jelana Vajen 2014.

Jan. 2014

WASCAL welcomes it's new Executive Director

The year 2014 started with major changes for the WASCAL team. From January on, Laurent Sédogo, former Minister of Agriculture, Water Resources and Fishery of Burkina Faso joined WASCAL to assume the office of executive director. On February 12, 2014 Paul Vlek officially handed over his mandate to Dr. Sédogo.

Jan. 2014

WASCAL's Research Agenda: Program Planning Meetings in Ouagadougou and Bonn

WASCAL held a Research Program Planning Workshop in Ouagadougou, Burkina Faso, to outline its future research program. Participating were researchers from the Competence Center as well as representatives of the Graduate Studies Program and the Core Research Program. The workshop was followed by a science meeting at ZEF in Bonn where initial results of the Core Research Program and future research activities were discussed.

June 2014

Meeting of the Graduate Studies Program

In June 2014, the directors of the Graduate Studies (GSP) Program, representatives of the host universities and the GSP team from Accra met in Abidjan, Côte d'Ivoire, to evaluate the progress of the program. Experiences were discussed to identify constraints and share best practices and lessons learned to further improve the program.

Graduate Studies Program

Developing Human Capacity: Training the Next Generation of African Climate Scientists

The Graduate Studies Program of WASCAL aims at strengthening West Africa's human scientific capacities to analyze the regional climate and climate change impacts and to design strategies to adapt to threats, opportunities and uncertainties of climate change.

Regional Consensus in Priority Setting

To ensure WASCAL addressed the main areas in which human capacity and expertise need to be developed, WASCAL initially brought together science policy makers, West African university officials and scientists involved in climate change negotiations, national planning and research. These included representatives of all WASCAL member states (Benin, Burkina Faso, Côte d'Ivoire, The Gambia, Ghana, Mali, Niger, Nigeria, Senegal, and Togo) as well as regional and international organizations (ECOWAS, the Volta Basin Authority, AGRA, ACMAD, AfricanNess, FARA, CORAF, INDEPTH, IWMI, ECOWAS/WRCC, UNU-EHS). During a workshop held in Accra in June 2010, they identified the following thematic priority areas to be addressed by the WASCAL Graduate Studies Program (GSP): climate change and the West African Monsoon; climate change and land; climate change and biodiversity; climate change and water; climate change and agriculture; climate change and people (security); climate change and resource economics. These areas were later translated into ten graduate programs.

Development of the Program

The second step in the development of the program brought together representatives of the best qualified universities and training institutions in the region to plan each graduate program according to the identified priority areas.

During planning workshops, faculty members of invited universities and representatives of German universities discussed and decided consensually on the lead university for each of the training programs. The selection of the lead universities in the region was based on competence and comparative advantage: existing programs, staff strength and regional partnerships. Arrangements such as the role of lead institutions, identification of potential universities to support the lead university by providing visiting lecturers, skill profile of graduates and curriculum development processes were discussed and agreed upon during the planning workshops. It was also during these workshops that the composition of advisory boards intended to support the development of each program was decided. The international advisory boards are composed of representatives of regional and German part- ner universities and chaired by the program directors. They assist each of the graduate research programs in ensuring the relevance and quality of the curriculum, setting criteria for faculty membership, allocation of courses and selection of students.

Implementation of the Graduate Studies Program

WASCAL assisted each of the lead universities in establishing a coordination office, headed by a program director. These units benefit from support staff such as secretary and accountant to help in management, as well as from infrastructure, classroom equipment, teaching aids, improved means of communication and access to scientific literature. Since 2012, six doctoral and four Master programs have been established, currently supporting a total number of 158 students.

Doctoral Programs

West African Climate System
Federal University of Technology, Akure, Nigeria
Change and Water Resources
University Abomey Calavi, Cotonou, Benin
Climate Change Economics
University Cheikh Anta Diop, Dakar, Senegal
Climate Change and Land Resources
Kwame Nkrumah University of Technology, Kumasi, Ghana
Climate Change and Agriculture
Agricultural Training and Research Institute, Katibougou, Mali
Climate Change and Biodiversity
University Felix Houphouët Boigny (formerly Cocody-Abidjan), Abidjan, Cote d'Ivoire

Master's Programs

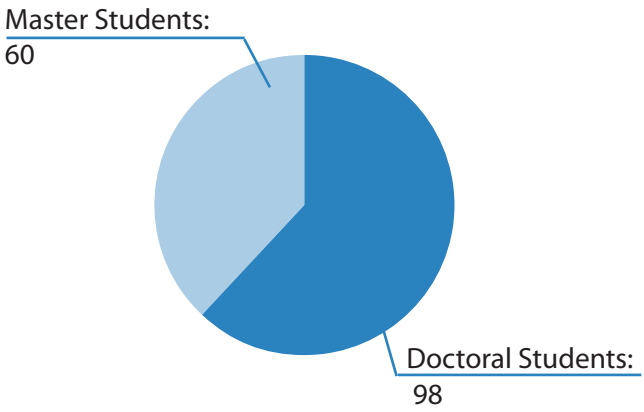
Climate Change and Human Security
University of Lomé, Togo
Climate Change and Adapted Land Use
Federal University of Technology, Minna, Nigeria
Climate Change and Energy
University Abdou Moumouni, Niamey, Niger
Climate Change and Education
University of the Gambia, (UTG), The Gambia

Strengthening Scientific Exchange in the ECOWAS Region

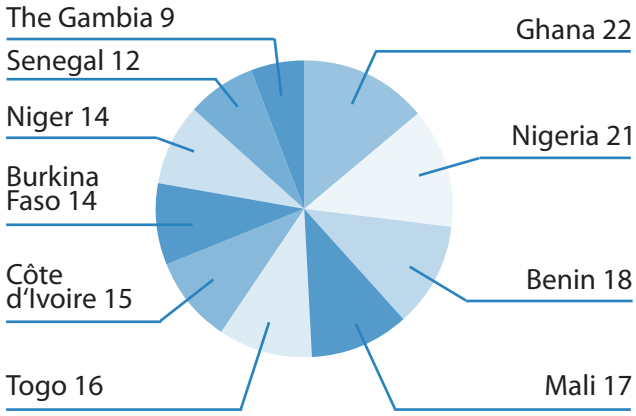
To strengthen academic exchange and to distribute scientific expertise evenly across the region each school is advised to admit one student from each WASCAL member country.
The cooperation in education and training activities further strengthens networks between French and English speaking universities of West Africa.

The Graduate Studies Program in numbers

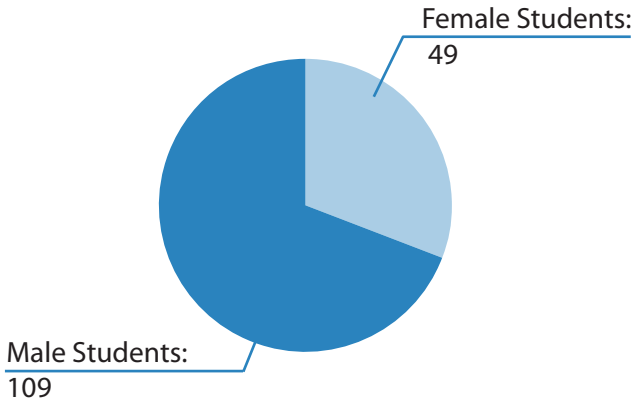
Total Number of Students: 158



Number of Students per Country



Number of Male and Female Students



June 2014

Graduate Studies Program
Mamadou I. Ouattara, Director

WASCAL Graduate Studies Department

West African Climate System

Federal University of Technology, Akure (FUTA), Nigeria

Current global and regional climate models are incapable of capturing the many local peculiarities that determine and shape the climate of West Africa because of their poor representation of surface heat, moisture fluxes and cloud systems. Furthermore, comprehensive solutions to climate change impacts are multi-dimensional and thus require a multi-disciplinary approach that should include meteorologists, climatologists, hydrologists, social scientists, economists, as well as environmentalists.

Developing Human Capacity in Meteorology and Climate Science

Meteorology and climate science education programs exist only in a few West African countries, and even fewer offer these courses at the Master and doctoral level. The Doctoral Program on the „West African Climate System", hosted by the Federal University of Technology in Akure, was founded to strengthen scientific capacity in the field of meteorology and climatology in West Africa.

Objectives

The Doctoral Program on the „West African Climate System" focuses on educating doctoral students in the fields of meteorology and climatology, providing the theoretical and practical training needed for the task of developing effective and sustainable adaptation and mitigation strategies to cope with the effects of climate change. The goal is to produce climate scientists with particular expertise regarding the West African climate system to address the challenges of climate change and variability as these will impact vital economic sectors such as agriculture, weather forecasting services, water resources, transport industry, energy, the environment and natural disaster management efforts.

Curriculum

The full-time program runs for 36 months, starting with a six-month period of course work during which students prepare their research proposals. Subsequently, students carry out their data collection and analyses during 25 months of research either within the region or in Germany. During the last five months, students complete the program by writing up and defending their thesis.

Director Jerome Omotosho with the first batch of students at their matriculation ceremony in 2012. Photo: GRP West African Climate System 2012.

Regional and International Cooperation

The program is fully international in its scope with lecturers, students, and research supervisors coming from WASCAL partners from across Africa. High academic standards, including curriculum development, are ensured by an Advisory Board with members from the University of Augsburg, Germany; University Cheikh Anta Diop, Dakar, Senegal; University Abdou Moumouni, Niamey, Niger; AGRHYMET, Niamey, Niger; University Abomey-Calavi, Benin; Kwame Nkrumah University of Science & Technology, Kumasi, Ghana; and University Cocody-Abidjan, Côte d'Ivoire.

West African Climate System
Jerome Omotosho, Director

Federal University of Technology, Akure, Nigeria
Start of the Program: 2012
Number of Batches: 2
Number of Students: 19

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Climate Change and Water Resources

University Abomey-Calavi (UAC), Benin

The need to understand climate change and climate variability as well as their impacts on water resources cannot be overemphasized in West Africa. The region has arid, semi-arid and tropical climates and the impacts of climate change and climate variability on water resources vary in time, space, and intensity. Providing adequate water for people, for food production, and for sanitation are some of the challenges governments are facing. Economic growth, efforts to reduce poverty and enhance social change drive demand for water and for the respective infrastructures to support food production, generate energy and provide goods and services. Such developments have a significant impact on water resources and managing these is increasingly complex.

Managing Water Resources for Sustainable Economic and Social Development

Climate extremes have led to various catastrophes, such as floods, droughts, and hydro-energy shortcuts, which impact negatively on human well-being, economic development and the achievement of the Millennium Development Goals (MDGs). Mismanagement of water resources leads to underuse of economic potential and to an inability to adequately deal with climate risks and hydrological variability. The region's weak capacity to buffer and manage the effects of varying water availability generates uncertainties and risks for economic activities.

Sustainable economic and social development at national and regional levels requires that hydrological forecasting systems are continuously developed for communities at risk, which in turn demands an optimal combination of data, forecasting tools and well trained specialists.

Curriculum

The curriculum of the program "Climate Change and Water Resources" combines basic courses including applied mathematics and statistics, applied physics, meteorology and climatology and specialized courses in hydrology. To enable students to convert knowledge of complex physical, chemical and biological processes into modeling concepts and apply this to real world situations, the curriculum is complemented by courses on climate and hydrological modeling, as well as on climate systems related to topics such as land-use, agriculture, integrated water resources management (IWRM), climate change impact, adaptation and mitigation as well as policy development.

Objectives

- To increase capacity building for water resource scientists;
- To strengthen e-science infrastructures for education and training and to contribute to filling the gaps between climate and water research findings and operational applications;
- To promote awareness about the value of climate and water information among decision makers.

Regional and International Partnerships

The program "Climate Change and Water Resources" is implemented by the Laboratory of Applied Hydrology of the University of Abomey-Calavi (UAC), Benin in collaboration with partners, including the University of Ouagadougou of Burkina Faso; International Institute for Water and Environmental Engineering (2iE), Ouagadougou, Burkina Faso; University Nangui Abrogoua d'Abobo-Adjamé, Côte d'Ivoire; Kwame Nkrumah University of Science & Technology, Kumasi, Ghana; University de Bamako, Mali; University Abdou Moumouni, Niamey, Niger; AGRHYMET; Ahmadu Bello University, Zaria, Nigeria; University Cheikh Anta Diop, Dakar, Senegal; University of Kara, Togo and the University of Bonn.

Climate Change and Water Resources
Abel Afouda, Director

University Abomey-Calavi, Benin
Start of the Program: 2012
Number of Batches: 2
Number of Students: 20

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Website: www.wascal-uac.org

Climate Change Economics

Cheik Anta Diop University, Dakar (UCAD), Senegal

West Africa faces an urgent need to develop effective adaptation and mitigation strategies related to climate change through the design of appropriate science based policies. The Doctoral Program „Climate Change Economics", led by the Cheikh Anta Diop University, Dakar (UCAD), focuses on applying economic rationality to analyze adaptation and mitigation strategies related to climate change.

An Economic Perspective on Climate Change

In climate change research advocacy and outreach programs, economics uses analytical tools to identify mitigation and adaptation scenarios, assess the costs of these scenarios, and propose solutions to finance them. Economic aspects related to climate change such as development strategies, energy pricing, and policies are analyzed as are the role of multilateral negotiations and international strategies to deal with public goods. Planning, monitoring and evaluation as well as costs benefits analysis are aspects of the many economic tools that are necessary to mainstream climate change in development policies in Africa.

Climate Change Economics – A New Discipline in Africa's Higher Education Landscape

The WASCAL Doctoral Program „Climate Change Economics" focuses on economic aspects of climate change — a unique approach in the African higher education landscape. The program develops strong synergies with other universities involved in the WASCAL Graduate Studies Program in order to ensure an interdisciplinary and comprehensive approach to climate-related analysis and policy.

Curriculum

The curriculum of the program encompasses both a core theoretical component as well as methodological and quantitative tools from the areas of mathematics, statistics, and econometrics to perform state of the art research in applied economics. The subjects covered deal with topics related to climate economics, development economics and resources, theories of sustainable development, climate change and finance, and integrated approaches to climate modeling and policy.

Bindayaoba Thomas Yameogo, doctoral student at the GRP Climate Change Economics, presented his research topic at the WASCAL Science Meeting during his research stay in Bonn in January 2014. Photo: Jelana Vajen 2014.

Partnerships

The program enjoys a unique set of national, regional and international partners. Several institutions and scholars within UCAD and other Senegalese universities are contributing to the program through teaching, student supervision and research. Likewise, the program draws from the rich and diversified expertise in the area of resource economics at regional level, from both Anglophone and Francophone universities. The Center for Development Research (ZEF) at the University of Bonn is teaming up with UCAD and the partner universities to implement the program's research, teaching and outreach agenda.

Climate Change Economics
Aly Mbaye, Director

Cheik Anta Diop University, Dakar, Senegal
Start of the Program: 2012
Number of Batches: 2
Number of Students: 20

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Climate Change and Land Use

Kwame Nkrumah University of Science and Technology (KNUST), Ghana

The populations in the West African sub-region are mainly agrarian; scientific knowledge of climate change and its impact on land use are thus essential for developing appropriate adaptation and mitigation measures. The variations in climate conditions compounded by poor land management practices are threats to the development of the region. The region is yet to develop approaches and applications based on the use of geographic information systems (GIS) and remote sensing technologies to provide data and information related to effective land use management and land administration.

Challenges to Effective Land Use Management in West Africa:

- Limited opportunities for land use and geo-scientists to improve their capacity at the graduate level;
- Lack of electronic science infrastructure for land use education and training;
- Gaps between climate and land use research findings and implementation;
- Lack of awareness about the value of climate and land use information among decision makers.

Understanding the Impact of Climate Change on Land Use

In view of the identified knowledge and capacity gaps, and the unsustainable management of land in the sub-region accompanied by recent climate change, the sub-region risks failing to achieve the Millennium Development Goals (MDGs). Therefore, there is a pressing need for a comprehensive understanding of the changing climate of the region and its impact on land use. This calls for adequately trained human resources in land use and related geo-sciences to ensure sustainable development and use of land for the present and future generations.

Knowledge and Capacity Building

The Doctoral Program „Climate Change and Land Use" is focusing on capacity building to help develop the knowledge necessary for sustainable land use and management in the face of climate change, The program will train participants in developing skills in data acquisition, analysis and interpretation of spatial data focusing on the use of remote sensing, geographic information systems (GIS) and empirical and mathematical modeling tools related to climate change and land use. This should contribute to strengthening human capacity in the sub-region for developing appropriate adaptation strategies to manage the impact of climate change on land and to develop resilient land use systems.

Students of the GRP Climate Change and Land Use with Dr. Christine Fürst and visiting students from the Center for Development Research (ZEF), Germany.

Land use Experts and Geoscientists for West Africa

The program aims at strengthening the research, educational and policy capacity and competency of West African countries to deal with issues of climate change through adapted land use on a scientific basis in partnership with German institutions.

Climate Change and Land Use
Samuel Odai, Director

Kwame Nkrumah University of Science and Technology, Ghana
Start of the Program: 2012
Number of Batches: 2
Number of Students: 20

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Climate Change and Agriculture

Institut Polytechnique Rural de Formation et de Recherche Appliquée de Katibougou (IPR/IFRA), Mali, in collaboration with the University of Cape Coast (UCC), Ghana

In Africa, the agricultural sector contributes about 30% of the continent's GDP and provides a source of livelihood for almost 70% of the population. The agricultural sector has its own problems such as rapid urbanization pushing more fertile arable land out of production, competition with subsidized farmers in Western countries, low productivity of lands, use of obsolete equipment and many more. Compounding the problems of the African farmer are the impacts of climate change; increased variability in rains, higher overall temperatures, and storm events that are more frequent and/or more intense.

African Agriculture Vulnerable to Climate Change Effects

Agriculture in Africa is climate-dependent, generally rain fed. This makes the continent highly vulnerable to climate change. The Intergovernmental Panel on Climate Change (IPCC) projects: 75-250 million people in Africa will face severe water stress by 2020 due to climate change and 350-600 million people by 2050; agricultural production in Africa will be severely compromised due to loss of land, shorter growing seasons, and increasing uncertainty about what and when to plant due to climate change; a possible 50% reduction in yields from rain-fed crops by 2020 in some North African countries, and crop net revenues likely to fall by as much as 90% by 2100 in South Africa.

Adaptation Strategies to Meet Changing Climate Conditions

Crops, livestock and fisheries are highly dependent on specific climate conditions. Trying to understand the overall effect of climate change on our food supply can be difficult. Increases in temperature and carbon dioxide (CO2) can be beneficial for some crops in some places. But to realize these benefits, nutrient levels, soil moisture, water availability, and other conditions must also be met. Changes in the frequency and severity of droughts and floods could pose challenges for farmers and ranchers. Training highly qualified human resources (with relevant infrastructures and equipment) constitutes one of the major adaptation strategies to climate change.

Objectives

- Train experts for West African countries to anticipate the effects of climate change;
- To define and implement strategies towards mitigation and adaptation to the negative effects of climate change in agriculture;
- Strengthen the synergetic relationship between the West African universities and the partnership with German universities.

GRP students visiting the WASCAL research site in Dano, Burkina Faso. Photo: GRP Climate Change and Agriculture 2013.

Curriculum

The program comprises a six-month teaching period with courses in research methodology, scientific writing, statistics and modeling tools and specific courses from the fields of agricultural production and management. During the second part of the program, students plan and carry out their research, analyze their data and finalize their thesis.

Climate Change and Agriculture
Amoro Coulibaly, Director

Institut Polytechnique Rural de Formation et de Recherche Appliquée de Katibougou (IPR/IFRA), Mali, in collaboration with University of Cape Coast (UCC), Ghana
Start of the Program: 2013
Number of Batches: 1
Number of Students: 10

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Climate Change and Biodiversity

University Felix Houphouët Boigny (formerly Université de Cocody-Abidjan), Côte d'Ivoire

The Graduate Research Program Climate Change and Biodiversity is training PhD students as experts to understand and protect species richness, genetic diversity, ecosystems and ecosystem services for the next generations. The understanding of strategies developed by living organisms and ecosystems in the face of climate change can make a substantial contribution towards the adaptation of humanity to these changes and towards the effective conservation of biodiversity under future conditions.

The doctoral students presented their research topics to the international Advisory Board at their annual meeting in 2013. Photo: GRP Climate Change and Biodiversity 2013.

Theory and Practice – Learning in the Classroom and on Field Trips

The program is hosted at the campus of Bingerville, Univer- sity Félix Houphouët-Boigny, located in Abidjan and equipped with offices, laboratories for plant diversity and animal diversity, a library and a classroom. Central to the students' practical training are field trips and excursions within Côte d'Ivoire and to the WASCAL study sites in Benin, Burkina Faso and Ghana, to study the variety of plants and animals in different ecosystems.

Curriculum

The curriculum of the program "Climate Change and Biodiversity" starts with six months of course work in the fields of ecology and climate change, statistics and modeling tools, biodiversity management, climate science and biodiversity, functional aspects of major organism units, and the human dimension in biodiversity. Course work is followed by a period of 24 months for field research, during which students will collect and analyze data for their doctoral thesis.

Group picture with visiting lecturer Jan-Henning Sommer from the Center for Development Research. Photo: GRP Climate Change and Biodiversity 2013.

Partnerships – the Doctoral Program is Constantly Growing

The program is constantly growing and new partnerships with national institutions working on biological diversity, such as the botanical garden of Bingerville, the Ivorian office of parks and reserves (OIPR) and the Ecological Field Research Station in Comoé National Park, will be established. To offer a comprehensive theoretical and practical education the program works with resource persons for field trips such as Professor AKE-ASSI (plantsystematics), and Dr. YEO Kolo, the Director of LAMPTO reserve.

Climate Change and Biodiversity
Daouda Kone, Director

University Felix Houphouët Boigny (formerly University Cocody-Abdjan), Côte d'Ivoire
Start of the Program: 2012
Number of Batches: 1
Number of Students: 9

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Climate Change and Human Security

University of Lomé (UL), Togo

Climate change affects human beings acting in socio-ecological settings in which biophysical, sociocultural, economic, institutional, political, and legal mechanisms operate. It is in this complex system that disasters emerge and by which people's responses to disasters are shaped.
Many phenomena associated with climate change are still poorly captured by research approaches so that future scenarios on the effects of climate change on land use and its related human dimensions are very unreliable and inconsistent. Human security within the context of climate change remains relatively underexplored, whereas natural scientists tend to address the biophysical dimensions of climate change, both on a worldwide and regional scale, more rapidly. Thus, there is an urgent need to deal with the human security aspect of climate change through both adaptation and mitigation.

Experts for Climate Disaster and Risk Management

Climate change and human security is a new concept of integrated and interdisciplinary education, combining domains such as meteorology, geosciences, social, health and economic factors as well as institutions in the fields of law and policies. The approach focuses on the integrated management of areas, resources, and societies affected by climate change. Students are trained in the development of strategies and concepts to reduce people's vulnerability and increase their coping capacity and to successfully manage climate disaster and risk.

Specific Objectives

The Master's Program "Climate Change and Human Security" will educate students to understand the threats and risks associated with climate change, to become familiar with the design of early warning systems and to know means to improve the resilience and coping capacity of affected social-ecological systems. Students will be exposed to interdisciplinary and transdisciplinary approaches to assessing threats and to work in multidisciplinary teams with affected groups in harnessing their inherent resilience to hazards.

The first batch of students started the Master program in 2012. Photo: MRP Climate Change and Human Security 2013.

Students will learn to:

- Understand the threats and risks to society or communities due to the impact of climate change;
- Synthesize knowledge regarding integrated management strategies to climate change effects, specifically to improve human security;
- Prepare background documents and policy notes that offer options to deal with climate change;
- Assist communities in dealing with climate change by adaptation and mitigation.

International and Regional Cooperation

Kwame Nkrumah University of Science and Technology (Ghana); United Nations University - Institute for Environment and Human Security; University of Würzburg and University of Bonn (Germany); Federal University of Technology, Minna (Nigeria); University of Abomey-Calavi (Benin); University Felix Houphou- et Boigny (Cote d'Ivoire); University of Cheikh Anta Diop (Senegal); University of Ouagadougou (Burkina Faso); University of Abdou Moumouni (Niger); Federal University of Technology, Yola (Nigeria).

MRP Climate Change and Human Security
Kouami Kokou, Director

Université de Lomé (UL), Togo
Start of the Program: 2012
Number of Batches: 2
Number of Students: 20

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Website: www.wascal-togo.org

Climate Change and Adapted Land Use

Federal University of Technology, Minna, Niger State, Nigeria

Changing climatic conditions as well as human activities such as agricultural intensification lead to changing land cover patterns like deforestation, desertification but also regeneration or reforestation. To better understand the impact of climate change on land cover and the social-ecological system, students are trained in the use of state-of-the-art modeling tools for the analysis of environmental and socio-economic datasets. During the course of the program students further will be enabled to produce quantitative results for scenario development and the assessment of the impacts of climate change on land cover and the environment with the aim of proffering the most suitable adaptation measures to minimize these impacts.

Curriculum and Impact Areas

Central to the program is a sound training in quantitative methods for climate change and land use analysis and assessment. During the two-year program, students complete practical and theoretical courses on remote sensing, geographic information system (GIS), geo-statistics, research methodology, land use dynamics as well as regional climate modeling. Students have the option of further specialization in five impact areas of climate change: agriculture, land management, economic resources, water resources and climate systems.

Vision and Mission

Our vision is to become the leading master's program for educating vibrant young scientists and conducting cross-disciplinary, multi-sectoral and innovative research on climate change that aims at bridging the gap in knowledge on land use changes, climate stress and possible feedbacks; while our mission is to produce graduates equipped with the highest quality education and training in the use of innovative research methodologies and application of state-of-the-art digital technologies and modeling tools for assessing climate change impacts with a view to deriving climate change scenarios that can guide policy formulation across the West African region.

WASCAL students visiting a dug well as part of a field course. The community based project was carried out in Busugi village, Niger state, Nigeria, 2013.

International and Regional Partners

Currently, the national and international partners form the regional advisory board. They are: Federal University of Technology, Akure (Nigeria), Kwame Nkrumah University of Science and Technology (Ghana), University of Abomey-Calavi (Benin), University of Cheikh Anta Diop (Senegal), University of Lomé (Togo), WASCAL Headquarters in Accra, and the Center for Development Research (ZEF), University of Bonn, Germany.

Climate Change and Adapted Land Use
Apollonia Okhimanhe, Director

Federal University of Technology, Minna, Niger State, Nigeria
Start of the Program: 2012
Number of Batches: 2
Number of Students: 20

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Climate Change and Energy

University Abdou Moumouni de Niamey (UAM), Niger

West Africa's high vulnerability to climate change is exacerbated by endemic poverty, economic and institutional weakness, and limited access to infrastructure, technology and energy. For its ongoing development, the region needs more energy despite its vulnerability to changing climate. More than 80% of energy consumed world-wide derives from fossil fuels, a finite resource unevenly distributed beneath the Earth's surface. Reserves of fossil fuels are progressively decreasing and their continued use produces harmful pollutants and greenhouse gases associated with global warming and climate change. But energy is a basic necessity for human activity, economic and social development. Thus, one challenge for West Africa is to develop strategies reconciling rising energy demand with sustainable resource management.

Satisfying Energy Demand without Exacerbating Social, Economic and Environmental Problems

The region continues to face several critical challenges related to its energy sector such as energy access, energy security and the unsustainable use of wood re- sources. The main challenge remains to satisfy the in- creasing energy demand without exacerbating social, economic and environmental problems caused by the changing climate. The Master's Program "Climate Change and Energy", led by Abdou Moumouni University of Niamey, Niger and implemented in collaboration with African, German and international universities and institutions, aims at offering students an integrated learning environment to qualify them as climate change and energy specialists.

Skilled Manpower and Institutional Capacity

Despite the fact that Africa is the most vulnerable continent to the impacts of climate change, constraints exist in the availability of skilled manpower, training and research facilities, effective climate change adaptation policies, as well as institutional capacity to coordinate climate change activities. The Master's Program "Climate Change and Energy" addresses the energy challenges of adaptation and resilience to climate change in West Africa in an integrated, interdisciplinary and multi-sectoral approach. The interdisciplinary approach allows a better understanding of present-day energy infrastructures in West Africa, their strengths and weaknesses, energy policies, practices in a changing climate context and the search for sustainable solutions.

Students visiting a research site of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Photo: GRP Climate Change and Energy 2014.

Curriculum and Objectives

The curriculum focuses on topics such as climate change and global warming, knowledge of the impacts of climate change, vulnerability of natural systems and the built environment, and methods for adaptation as well as energy production, delivery, and consumption for both, traditional systems and sustainable energy alternatives with special emphasis on energy efficiency, energy management and locally available renewable energy. The main objective of this Master's Program is to train a new generation of interdisciplinary professionals capable of proposing adapted solutions to face the climate change and energy crisis.

Climate Change and Energy
Alassane Abdoulaye, Director

Lead University: University Abdou Moumouni de Niamey (UAM), Niger
Start of the Program: 2013
Number of Batches: 1
Number of Students: 10

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Climate Change and Education

University of The Gambia (UTG), The Gambia

Climate change is scientifically complex, and is accompanied by economic, social and political ramifications. Article 6 of the 1992 United Nations Framework Convention on Climate Change (UNFCCC) urges the development and implementation of educational and public awareness programs on climate change and its effects; it further urges parties to the convention to develop and implement education and training programs. UNFCCC advocates for capacity building on climate change to be a priority in all regions of the world, especially in West Africa, through the facilitati- on of more national and regional activities to combat climate change adversities.

From Scientific Evidence to Social Policy

The capacity to translate scientific evidence on climate change to viable social policies comes not only with the understanding of science by experts, but also the capacity to effectively disseminate and translate scientific findings for the understanding of all stakeholders. Consequently, education is an essential element of the global response to climate change. It helps young people understand and address the impact of global warming, encourages changes in their attitudes and behavior and helps them adapt to climate change-related trends.

Increasing Climate Literacy

The Master's Program "Climate Change and Education" at the University of The Gambia aims to strengthen climate change education as part of the in- ternational response to climate change, to contribute to the understanding of the impact of global warming today, and to increase climate literacy. It is imperative, therefore, that students and the public are prepared to understand current scientific policies, take part in ethical discourses on climate change so as to partici- pate as informed citizens in public decision making processes for managing and reducing climate risks.

Professionals to Tackle Climate Change Consequences

Climate change is the product of the interaction between humans and socio-ecological settings in which

From left to right: Hannes, Pascal, Corine, GRP Director Musa Sowe, Abdul Rasmane, Cynthia, Mamoudou, Stefan, Constantine, Dauda, Afi, Bore and Irit Eguavoen (Center for Development Research). Photo: Hannes Lauer 2014.

natural and artificial phenomena operate together, thus forming complex systems that can generate calamities that society is forced to cope with. In this regard, the WASCAL Master's Program on "Climate Change and Education" at the University of The Gambia with its partner institutions, and alongside other WASCAL pro- grams, is poised to provide a critical mass of qualified professionals in various disciplines of climate change in West Africa. These professionals will be well equip- ped to contribute immensely to the prevention and amelioration of the adverse consequences of climate change.

Climate Change and Education
Musa Sowe, Director

Lead University: University of The Gambia (UTG), The Gambia
Start of the Program: 2013
Number of Batches: 1
Number of Students: 10

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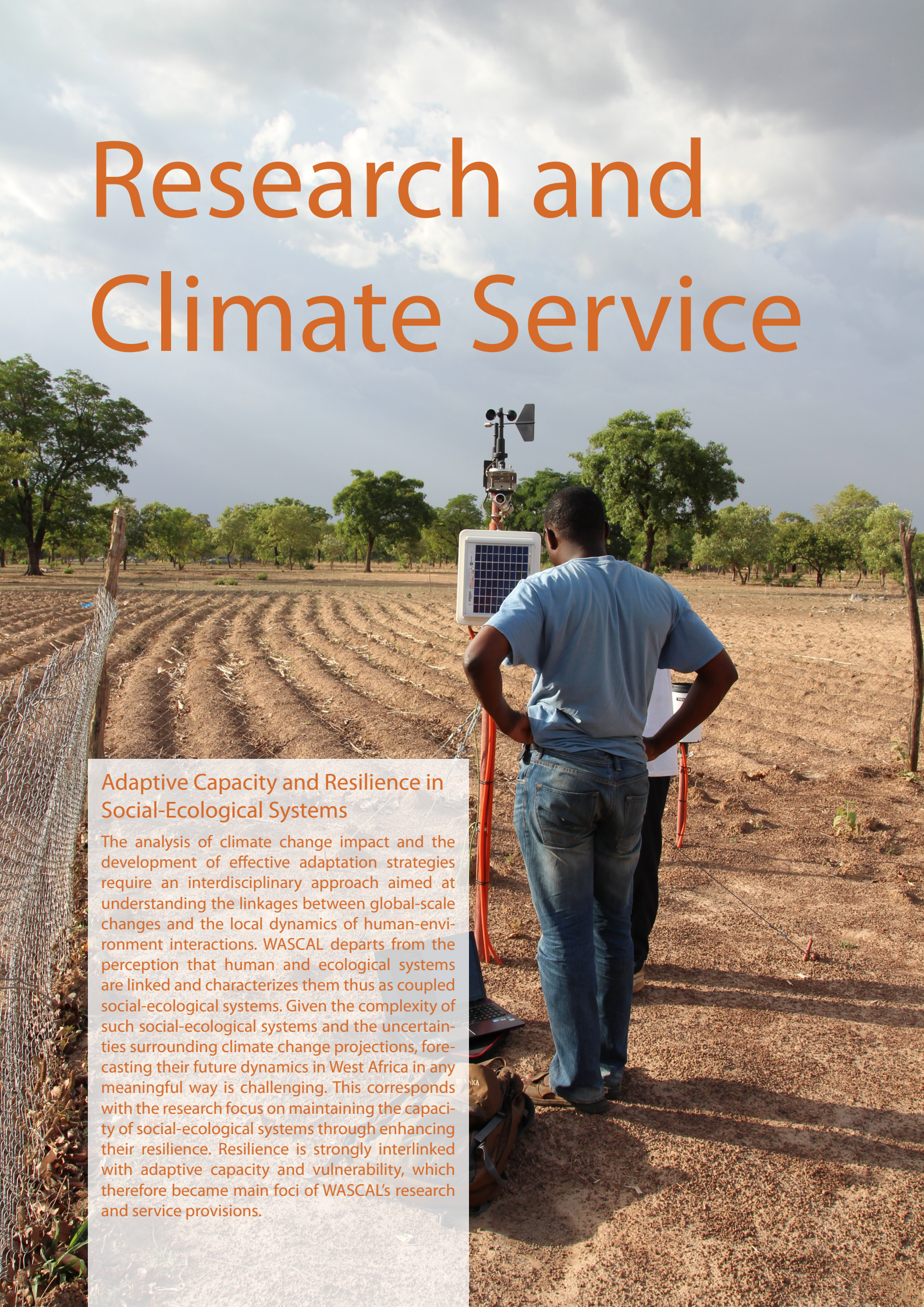
Research and Climate Service



Adaptive Capacity and Resilience in Social-Ecological Systems

The analysis of climate change impact and the development of effective adaptation strategies require an interdisciplinary approach aimed at understanding the linkages between global-scale changes and the local dynamics of human-environment interactions. WASCAL departs from the perception that human and ecological systems are linked and characterizes them thus as coupled social-ecological systems. Given the complexity of such social-ecological systems and the uncertainties surrounding climate change projections, forecasting their future dynamics in West Africa in any meaningful way is challenging. This corresponds with the research focus on maintaining the capacity of social-ecological systems through enhancing their resilience. Resilience is strongly interlinked with adaptive capacity and vulnerability, which therefore became main foci of WASCAL's research and service provisions.

Research and Climate Service

One challenge in climate change and land use research in West Africa is the lack of continuous and high quality data. WASCAL aims to tackle this through the establishment of a research infrastructure, which allows to conduct state-of-the-art and long-term research. Based on the research findings, WASCAL will provide information and evidence-based advice on climate change impacts, adaptation and mitigation measures in West Africa to the public and private sectors and translate their demand into research questions.

The Competence Center

WASCAL's research activities and climate service provision are coordinated from our Competence Center located in Ouagadougou, Burkina Faso. This center serves as a hub connecting partners and networks for data collection and analysis. It houses scientific staff from the fields of climate science, hydrology, biodiversity, land use, economics, and social sciences as well as administrative support personnel and visiting scientists to analyze the consequences of climate change on land and water use and reflect on adaptation strategies. It further accommodates the infrastructure for receiving, maintaining and analyzing data, as well as for conducting training and outreach activities aimed at regional stakeholders.

The German Aerospace Center (DLR) is currently installing a geographical information system (GIS) laboratory whilst the Research Centre Juelich in cooperation with the University of Bonn is establishing a data management infrastructure system (WADI) for the collection of observational data and simulation outcomes. A high performance computing environment will be established by the German Climate Computing Center (DKRZ) to support regional climate change simulations and many further modeling studies in WASCAL. These capabilities are at the basis of science-based policy advice on climate change impacts, adaptation, and mitigation measures in West Africa.

Connecting Regional Partners in Data Gathering and Sharing: The Observation Networks

WASCAL strives to build Observation Networks in West Africa to connect WASCAL and its partners in data-gathering and sharing in order to address the impacts of climate and land use changes. These networks play a pivotal role in linking WASCAL to national institutions in the WASCAL mandate region for the long-term collection of data in the fields of meteorology, hydrology, agriculture, land management, biodiversity, and socio-economics. The Observation Networks will initially be installed in six target countries: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, and Togo. These represent the natural climate gradient and various types of ecosystems of the WASCAL-mandate region.

Data Collection and Data Exchange

The aim of the Observation Networks is to collect and centralize data for long-term analyses and evaluation of models, to integrate information from the various disciplines in scenario analyses, and exchange competence and information with the partners of the networks. WASCAL aims to intensify collaboration with and among regional policy-makers by linking national and regional monitoring services and scientific institutions through the Observation Networks to strengthen and capacitate the participating institutions and other stakeholders to take part in the climate change and variability dialogue and enable them to provide informed policy advice.

Starting with stakeholder workshops in 2010 to establish partnerships and assess the state and needs of the existing national and regional monitoring networks, the Competence Center is initiating, coordinating and implementing the regional Observation Networks and connecting new partners to the data collection and data exchange process. Further, it conducts outreach, communication and networking activities concerning the implementation of the Observation Networks.

3 Research and Climate Service
Observation Networks and Core Research Program

Climate Observation Network

WASCAL cooperates with the international and national meteorological services in West Africa in renewing and extending the existing national observation networks, as well as in the training of technical and scientific personnel. The work is intended to be in close collaboration with the German partner institutions in WASCAL and the World Meteorological Organization (WMO) to meet the standards of the Global Climate Observing System (GCOS). The long-term goal is the establishment of a trans-national climate observation network and the establishment of novel climate databases based on long-term historical measurements at a fine temporal and spatial resolution for an improved regional climate analysis.

Biodiversity Observation Network

In collaboration with the Volta Basin Authority (VBA), partners from the six target states and German research partners, the WASCAL Biodiversity group organized a two-day workshop in Ouagadougou in 2013. The goal was to develop modalities for setting-up a biodiversity Observation Network that could facilitate monitoring the response of biodiversity to climate change and land use. Fifteen observatories were selected based on existing observatories and historical datasets from previous research initiatives, the representativeness of phyto-geographical and agro-ecological zones, as well as the existing climatic and land use gradients.

Hydrological Observation Network

The WASCAL Hydrological Observation Network aims at strengthening the national hydrological observation networks in terms of infrastructural support and capacity building efforts. The Competence Center serves as a platform for an information network that ensures transparency in data collection, processing, storage, and sharing in order to improve the homogeneity, quality and applicability of hydrological data. WASCAL organized a first workshop in Accra in August 2010 to assess the current status of the national hydrological services and their needs. The concrete planning phase will start at the end of 2014, with another workshop bringing all national hydrological services as well as relevant research institutions together.

Partnerships in the Observation Networks

The Competence Center has entered into initial agreements with national, regional and international institutions such as the national hydrological services, the national Meteorological Services, the National Institutes of Demography and Statistics of Burkina Faso, Benin, Ghana, Niger, Mali and Senegal. Further initial agreements were made with the Institut National de l'Environnement et des Recherches Agricoles (INERA) Burkina Faso; the African Centre for Meteorological Application for Development (ACMAD); Centre Regional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle (AGRHYMET); the International Livestock Research Institute (ILRI); the International Institute for Water and Environmental Engineering (2iE), Burkina Faso; the International Wa- ter Management Institute (IWMI); Centre de Coopéra- tion Internationale en Recherche Agronomique pour le Développement (CIRAD) and the Volta Basin Authority (VBA). The signing of official Memoranda of Understanding between the Competence Center and these institutions is foreseen for the future.

Core Research Program

The Competence Center collaborates with a German research consortium led by the Center for Development Research (ZEF), University of Bonn in its Core Research Program (CRP) on adapted land use and management under changing climatic conditions. Regional stakeholders were involved early on in the planning process to ensure the CRP meets regional demands. In 2010, West African and German scientists as well as members and representatives of intergovernmental, international and pan-African organizations discussed the research gaps, needs and priorities. Based on these intensive exchanges, research themes of the CRP were grouped in six thematic research clusters. The nine German partners in the Core Research Program have the lead in the six research clusters. 44 doctoral students, of whom 27 originate from WASCAL member countries, conduct

Research Cluster

- Climate and Weather
- Landscape Dynamics
- Agricultural Systems
- Markets and Livelihoods
- Risk Management
- Integrated Assessment

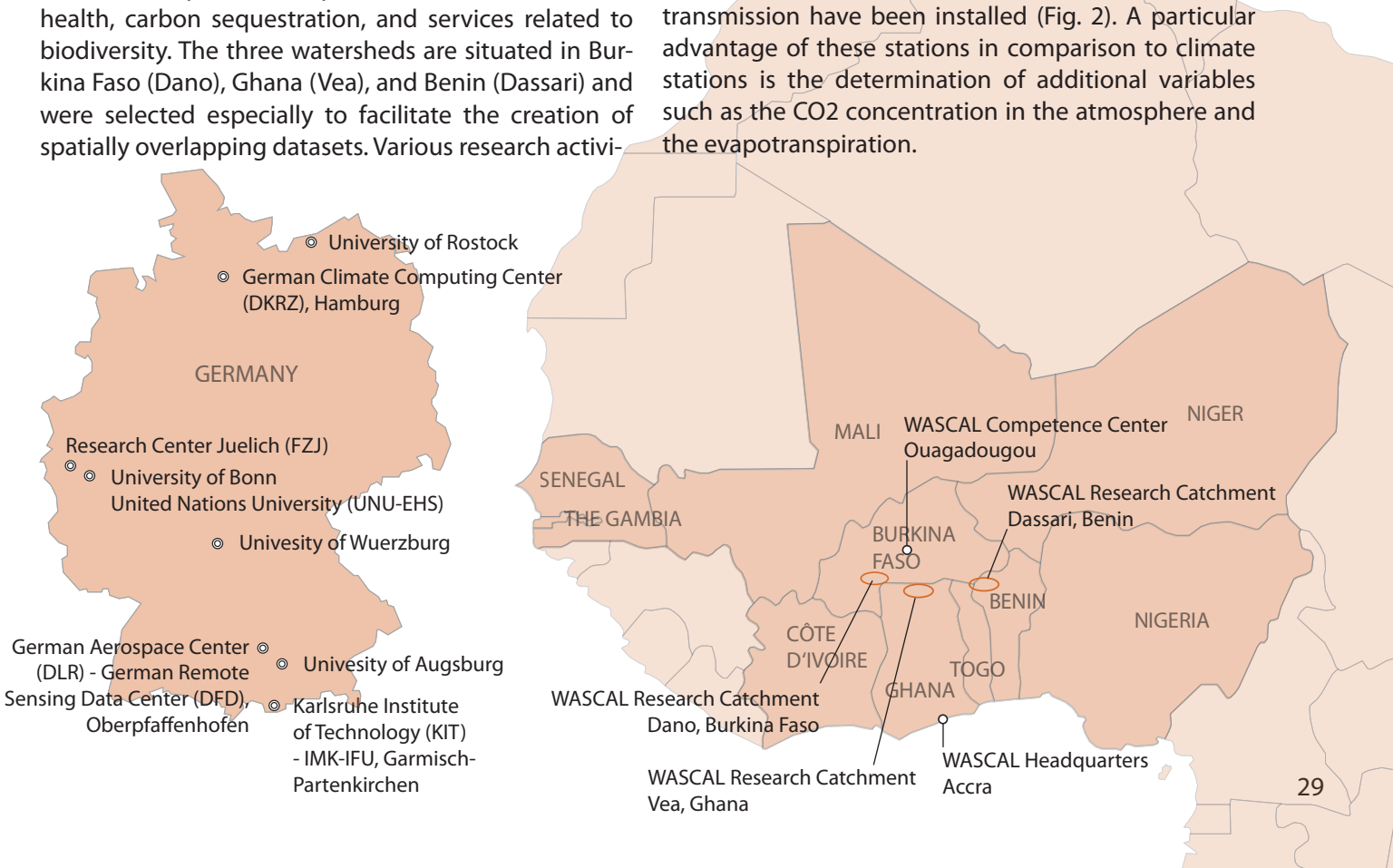
Figure 2: Installation of micro-meteorological stations for investigating the impact of land surface changes on water, energy and CO^2 fluxes in the West African Sudanian Savanna.

their studies in the CRP. Researchers from the CRP are also closely involved in teaching and supervising master and doctoral students from the Graduate Studies Pro- gram.

WASCAL Focal Research Areas

Three areas, all located in the Sudanian Savanna belt, coined as the potential breadbasket of Africa, were selected as focal investigation areas where meteorological, hydrological, agricultural, biological and socio-economic research is concentrated. Inside these areas, the CRP has adopted the watershed as the unit of analysis for focusing on the resilience of ecological and socio-economic systems in the face of climate change and land use change to ensure the flows of key ecosystem services. For WASCAL, ecosystem services are functions of the ecosystem which benefit human livelihoods such as food production, provision of clean water, soil health, carbon sequestration, and services related to biodiversity. The three watersheds are situated in Burkina Faso (Dano), Ghana (Vea), and Benin (Dassari) and were selected especially to facilitate the creation of spatially overlapping datasets. Various research activities obviously go beyond the watersheds and are using administrative scales for economic or political research. By developing qualitative and quantitative tools and models which are able to link the bio-physical and socio-economic processes and feedbacks, the CRP aims at strengthening the future analytical capability of the Competence Center. WASCAL, the German research partners, and local stakeholders together will ultimately employ these tools for analyzing scenarios of the impacts of climate change.

A dense local hydro-meteorological observation network is operated by WASCAL and its partners at the three watersheds to get a robust database for process analysis and model evaluation. This network consists of 18 climate stations and more than 35 sites for measuring the groundwater level, river discharge, soil moisture and many further parameters. In addition, three micro-meteorological stations with an automatic data transmission have been installed (Fig. 2). A particular advantage of these stations in comparison to climate stations is the determination of additional variables such as the CO2 concentration in the atmosphere and the evapotranspiration.



Climate and Weather

Harald Kunstmann, Jan Bliefernicht, Ursula Gessner, Joël Arnault, Dominikus Heinzeller, Seyni Salack, Moussa Waongo, Luitpold Hingerl, Kim Knauer, Cornelia Klein, Jonatan Siegmund, Igor Klein and Patrick Laux

The aim of this research cluster is the advancement of tools and databases for a better understanding, simulation and prediction of atmospheric processes and land-atmosphere interactions that drive climate variability and climate change in West Africa. Special attention is paid to weather extremes such as droughts and heavy rainfall.

Over the past ten years significant progress has been made in modeling the regional climate of West Africa. Despite these achievements, current regional climate models are still subject to a number of shortcomings when applied to the West African region. These shortcomings were defined by West African climate scientists and German partners at a research workshop in the preparatory phase of WASCAL. A key interest is the establishment of a regional climate modeling system for the West Africa region which is capable of simulating characteristic features of the West African monsoon. To this end, novel land surface datasets based on earth observations and advanced modeling schemes are incorporated into the modeling system to improve the simulation of land surface processes and their interactions with the atmosphere. A further common interest is the advancement of techniques in short-term climate prediction for an enhanced prediction of weather extremes and agriculturally relevant variables such as the onset of the rainy season. The modeling activities are accompanied by micro-meteorological field experiments for a better understanding of land atmosphere exchange processes.

The work of this research cluster is closely linked to the climate related activities of the Competence Center, such as the WASCAL climate change simulation experiments. The climate and weather information provided by these activities is required for numerous studies across all research clusters of the Core Research Program and for the Graduate Studies Program. Close cooperation with the national and international meteorological services is maintained to improve the existing forecasting systems and climate observation networks in West Africa.

Establishing a Regional Climate Modeling System for West Africa

An integral part of the regional climate modeling system is the Weather and Research Forecasting (WRF) model which incorporates a large number of model configurations. A comprehensive WRF sensitivity experiment is performed to figure out an adequate configuration for West Africa. An example of this experiment is illustrated in Fig. 1 showing the strong impact on the simulation of precipitation if a slightly different WRF configuration is selected.

A frequent shortcoming of regional climate models is that they neglect components of the land surface such as rivers and the corresponding hydrological processes for describing the lateral flow of surface water. To improve the description of these processes in the models, the regional climate model WRF is coupled with a hydrological model, and the performance of this coupled model WRF-Hydro is evaluated for specific rainy seasons and regions.

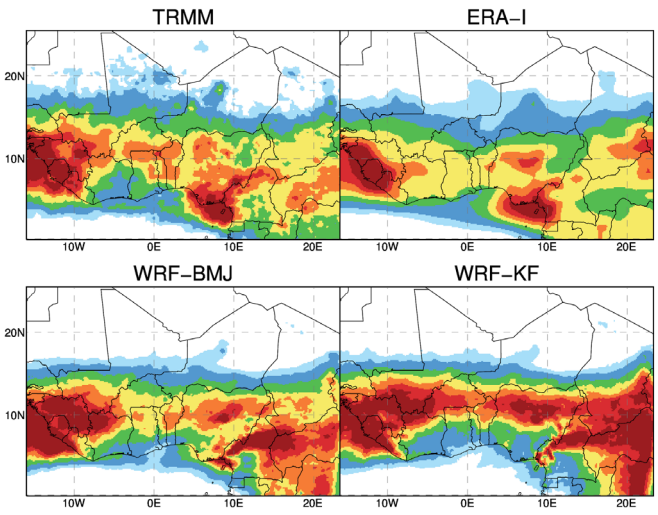


Figure 1: Mean daily precipitation amount using two configurations of the Weather and Research Forecasting model (WRF-BMJ and WRF-KF) with different choices for a simulation of convective rainfall with respect to observations from the Tropical Rainfall Measuring Mission (TRMM) and a global reanalysis model (ERA-I), June-July-August 1999.

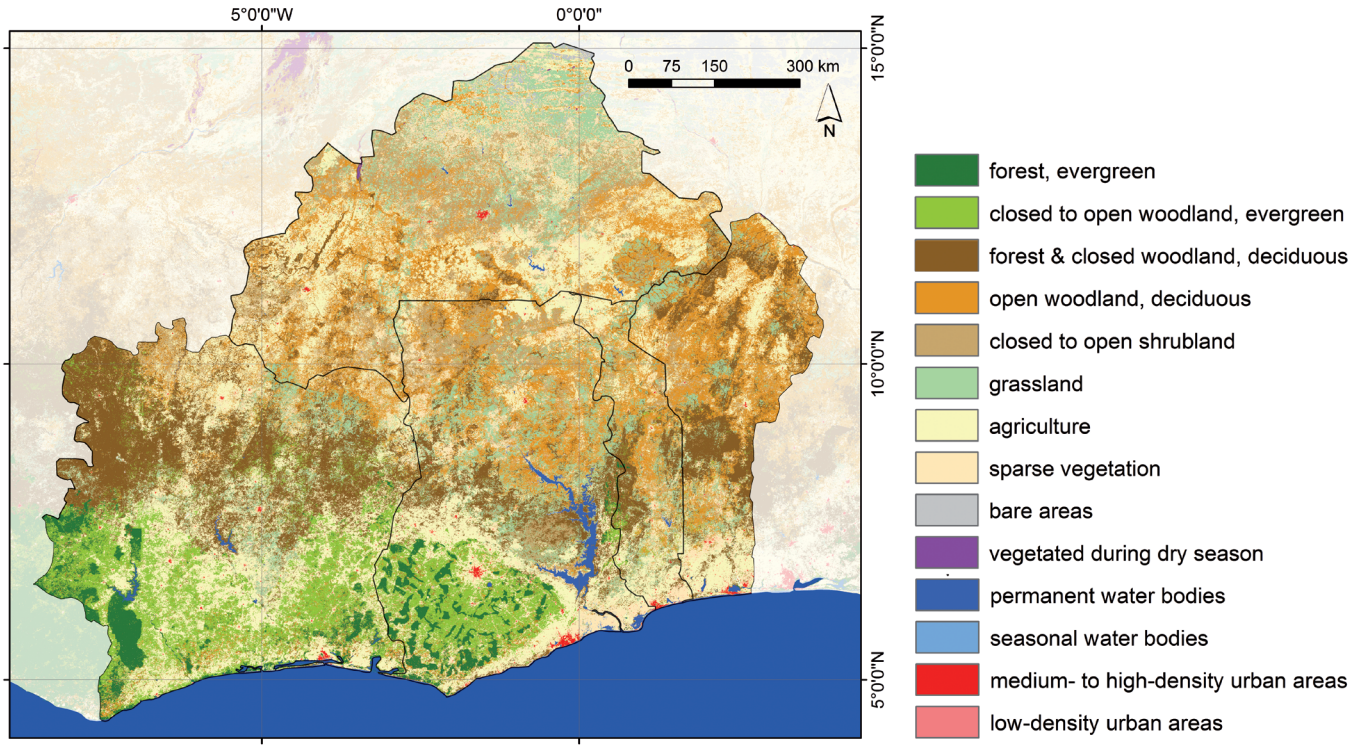


Figure 2: Preliminary version of an improved land cover map for several countries in West Africa.

In addition, a local climate observation network has been established within the core research sites for an in-depth evaluation of the novel modeling system and for an improved understanding of land-atmosphere interactions. The network consists of three micro-meteorological stations which have been installed along a transect of changing land cover characteristics to investigate how differences in land surface alter water, energy and CO^2 fluxes between the surface and the atmosphere.

Novel Land Surface Data Sets for Regional Climate Studies

A weak point in current regional climate models is the inadequate representation of vegetation dynamics and related properties of the land surface, such as the reflective power (albedo). This information is often based on global land cover maps, which are usually not sufficiently accurate for regional climate simulations. To tackle this problem, novel land cover information and a number of further land surface variables are generated using advanced remote sensing techniques. Remote sensing offers the possibility to create consistent data sets and capture the inter-annual and seasonal changes of the West African land surface. These data sets are validated by using more than 300 in-situ plots that were recorded during several WASCAL field campaigns in 2012 and 2013, and during previous research projects. The novel land surface data sets are used to replace less reliable information within the current regional climate models used in WASCAL. The remote-sensing based products are also required for subsequent studies in hydrology, ecology, agriculture and other disciplines. Furthermore, we use remote sensing time series data to analyze the land surface phenology and its relation to climate change and variability in West Africa.

Forecasting the Onset of the Rainy Season

Inarguably, the most important variable in short-term climate forecasting for West Africa is the date of the onset of the rainy season. A late onset can put the lives of many people at risk because a considerable fraction of the population in West Africa depends on the income produced from rain-fed agriculture. To improve the operational practice in West Africa, a novel, regional short-term climate prediction system is being tes-

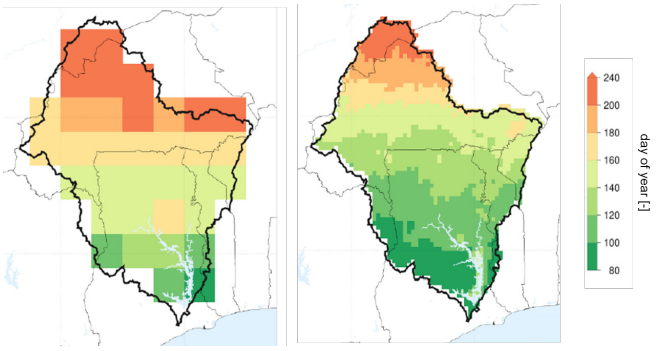


Figure 3: Forecasting the date of the onset of the rainy season for 2013 using a novel regional ensemble prediction system (right) in comparison to a global model, the Climate Forecast System (left).

ted for the Volta river basin. The example in Fig. 3 illustrates that this approach can add valuable information to the standard approach taken today.

A Tool for Defining the Optimal Date for Planting

Another key item of information for farmers in West Africa is the optimal time for planting to decrease the risk of crop failure due to water stress situations occurring after planting. This information is crop specific and is highly variable on spatial and temporal scales. The climate research group developed a tool for defining an optimal time window for planting by combining climate model output with a crop model and by adding expert knowledge to the system described by mathematical equations. A current research activity also deals with the crucial question of how optimal planting dates may change in the future and how this will impact future crop production.

Lead Institutions and Core Partners

- University of Augsburg, Chair for Regional Climate and Hydrology, Germany
- German Aerospace Center, German Remote Sensing Data Center, Germany
- Karlsruhe Institute of Technology, Inst. of Meteorology and Climate Research, Germany
- WASCAL Competence Center, Ouagadougou, Burkina Faso
- National Center for Atmospheric Research, United States
- Federal University of Technology Akure, Nigeria University of Bonn, Germany
- German Climate Computing Centre, Germany

Doctoral Research in this Area

Moussa Waongo: Development of Techniques for Optimizing Agricultural Management Strategies for Decision-Making Support.

Luitpold Hingerl: Development and Validation of Physically-Based Land Surface Models for West Africa using Energy and Water Flux Measurements from Eddy Covariance Stations.

Cornelia Klein: Analyzing Regional Land-Atmosphere Interactions of the West African Climate System Using an Advanced Version of the WRF model.

Kim Knauer: Remote Sensing of Vegetation Dynamics in West Africa.

Selected Publications

Bliefernicht, J. et al., 2013. Field and simulation experiments for investigating regional land-atmosphere interactions in West Africa: Experimental set-up and first results. IAHS-AISH publication, 226-232.

Gessner, U. et al., 2012. Land cover maps for regional climate modeling in West Africa – a comparison of datasets. 32nd EARSeL Symposium Proceedings, May 21-24 2012, Mykonos, Greece, 388-397.

Gessner, U. et al., 2013. Inter-comparison of Leaf Area Index products for a gradient of sub-humid to arid environments in West Africa. *Remote Sensing* 5, 1235-1257.

Jung, G., Wagner S., and H. Kunstmann, 2012. Joint climate-hydrology modeling: An impact study for the data-sparse environment of the Volta Basin in West Africa. *Hydrology Research* 43:3, 231-248.

Knauer, K. et al. 2014. Remote sensing of vegetation dynamics in West Africa. International Journal of Remote Sensing. 35:7, 6357-6396.

Waongo, M. et al. 2014. A crop model and fuzzy rule based approach for optimizing maize planting dates in Burkina Faso, West Africa. J. *Appl. Meteor. Climatol.* 53, 598–613.

Climate and Weather

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Landscape Dynamics

Michael Thiel, Bernd Diekkrüger, Gero Steup, Jan Henning Sommer, Dethardt Goetze, Katharina Stein

The aim of this research cluster is to analyze linkages between climate change, land use and land cover changes to better understand the dynamics and processes of the social-ecological system in West Africa.

The effects of climate change and variability in West Africa have been evident in the past decade. Extreme events like floods and droughts, changes in the onset of the rainy season, and a gradual shift of climate zones, such as the desertification of the Sahelian zone, have resulted in economic and ecological losses. Concurrently, the growth of the population in the region has led to changes in land use and land cover, due to an intensification of agricultural activities, deforestation and expanding human settlements. The combined effects of climate change, as well as land use and land cover changes have the tendency to adversely affect landscape dynamics and the provision of ecosystem services. Already, there is evidence that land use and land cover changes have led to changes in water fluxes, soil erosion as well as habitat and biodiversity loss. Thus, a better understanding of the linkages between climate and land use and land cover changes is essential to the maintenance and functioning of the so-called social-ecological system. So far, these linkages are poorly understood in West Africa.

Understanding the Influence of Climate Change on the Social-Ecological System

To assess the specific influences of climate change or land use change on the social-ecological system (SES) and to evaluate the potential effects of varying adapted land management practices, the aim of this research cluster is to understand the dynamics and processes of the social-ecological system at the local scale (i.e. watershed level). A variety of landscape indicators will be estimated to assess the state of the social-ecological system. These indicators include land use and land cover such as fragmentation and deforestation, ecosystem integrity, water fluxes (e.g. recharge and discharge), biodiversity (species numbers and richness), and soil characteristics such as soil carbon. The derivation of the abovementioned indicators will aid a better understanding of the ecological system as well as provide a basis for assessing the ecosystem services it provides. Based on the data collected and its analysis, we will assess the impacts of existing coping and adaptation strategies with a view to expected climate change.

Mapping of Cropland, Tree Cover and Grazing Areas

The basis for most analysis is information about the spatial distribution of land surface elements, actual and past, that is provided in maps. Remote sensing imagery from satellites or airborne and other ancillary data is used to map land use and land cover change in West Africa. The focus is on mapping the spatial distribution of crops and crop groups as well as the historical dynamics of cropland expansion at varying scales such as the focal watershed level and Sudanian Savanna. Additionally, changes in tree cover density, which serve as an indicator for deforestation and settlement expansion, are mapped to determine driving forces for changes. In addition, we focus on the spatio-temporal analysis and assessment of grazing areas and the factors that lead to their degradation. In view of the expected changes in climate conditions, the major goal is to find sustainable grazing strategies which can maintain livestock production and increase food security in the region.

The Water Cycle

In many regions water availability is a limiting factor for development, particularly in the agricultural sector. Water availability depends on meteorological conditions, terrestrial processes, and water abstraction. Climate change, land use and land cover change as well as economic and demographic development are affecting water availability and water demand. While hydrological processes are driven by small scale climate and landscape properties as well as human activities, large scale assessments are required for the management of water and land resources especially under global change.

Fig. 1: Soil water sensors of a soil water station (left) and advanced climate station (right) in Dassari. Photograph: Gero Steup 2013.

Often, studies are limited to a single scale such as studies on small scale processes or regional scale analysis of water availability. To develop strategies directed at a global phenomenon such as climate change, we need to incorporate small scale and large scale processes in our research design. Hence, we develop and apply dynamic hydrological models which are able to consider small and large scale processes. Classical hydrological studies mostly concentrate on discharge simulations, whereas patterns within the catchments and the link to runoff generating processes are often simulated in a simplified way. Thus our studies focus on water related ecosystem services (ESS), linking the results of hydrological analysis and assessment to social, agricultural, as well as biological science.
To be able to simulate regional scale hydrology based on an understanding of the processes at the local and the meso scale, we install long term field studies at the catchments. This is required in order to be able to differentiate between variability and trend, as agricultural activities and climate variability affect hydrological processes from year to year and long term trends may be hidden.

Hydrological and Meteorological Stations

Hydrological and meteorological equipment has been installed in the three focal watersheds in Burkina Faso, Ghana and Benin in order to obtain a robust data base for process analysis and for calibrating and validating simulation models. Each watershed is equipped with up to six basic weather stations measuring air temperature, relative humidity, rainfall, wind speed, wind direction and solar radiation.
Up to three soil-water stations have been installed in Dano, Burkina Faso and Dassari, Benin (fig. 1). They measure soil water content and water tension. Furthermore, two of these stations are combined with an advanced climate station which, in addition to the instruments of the basic weather stations, is equipped with different types of rain gauges and radiation sensors. Furthermore, we installed river gauging stations, turbidity probes, and piezometers to measure groundwater levels, whereas soil erosion is quantified by erosion plots. In addition to these installations, we investigated soil hydrological properties (infiltration, saturated hydraulic conductivity, texture, bulk density, etc.) in the focal watersheds in order to study the impact of land use and land cover on soil physical properties and hydrological processes.

What is the Status of Biodiversity in West Africa?

To assess ecosystem resilience in West Africa we evaluate the status of biodiversity at landscape level using spatially explicit approaches. The spatial distribution of plant species richness is used as a proxy for biodiversity and is statistically modeled applying different modeling approaches based on species distribution data. Moreover, we analyze the current status of habitats and their potential threat with the help of land cover and vegetation type classifications derived from remote sensing datasets. In this context, criteria for habitat degradation and vulnerability are analyzed such as habitat geometry like patchiness and fragmentation, as well as the degree of conversion and pressure from alternative land use options. Moreover, the relationship between species richness, habitat status and potential for biodiversity-related ecosystem service provision is incorporated based on empirical findings. The results achieved can be used as indicators for integrated assessment and land use impact modeling in order to facilitate the identification of scale-crossing linkages between the ecological and the social system and to test its resilience under different development scenarios and under climate change projections.

Biodiversity and Ecosystem Services

We examine the preservation of essential ecosystem services such as the pollination of important plant species by insects and their successful regeneration in the land use mosaic of various Savanna habitats under changing ecological conditions. Taking into account

the socio-economic relevance of ecosystem services we investigate which pollinators are most effective in important food crops. Furthermore, we analyze to what extent cash crops depend on pollinators as well as the effects of landscape mixes of habitat patterns of natural sites and agricultural land for high yield. Traps for catching insects were installed in 504 locations throughout the savanna and cotton fields. The first samples of insects are currently being sorted in orders at the University of Wuerzburg. A determination of the bee genera and possibly species is planned for the beginning of 2015. To assess the ecology and living conditions of important pollinators we further more collect data on floristic structure and phenology. All spatial parameters of habitat quality and structure are examined in terms of their ecosystem functionality in the landscape matrix (especially pollination and the establishment of seedlings) in areas of varying land use intensity and the results are integrated in an interdisciplinary approach into the modeling of the overall network. The purpose is to develop recommendations for the sustainable use and capacity of regeneration of the Sudanian Savanna's natural resources under changing climate and usage conditions.

Lead Institutions and Core Partners

- Botanical Institute, University of Cologne
- Center for Development Research (ZEF), University of Bonn
- Competence Center, WASCAL
- Dreyer Foundation, Munich/Dano
- German Aerospace Center (DLR) - German Remote Sensing Data Center (DFD), Oberpfaffenhofen
- Faculty of Agriculture, University of Bonn
- Faculty of Biology, University of Wuerzburg
- Faculty of Geography, University of Bonn
- Faculty of Life and Earth Sciences, University of Ouagadougou
- Faculty of Mathematics and Natural Sciences, University of Rostock
- Faculty of Natural Sciences, Nangui Abrogoua University, Abidjan

Doctoral Research in this Area

Kristijan Canak: Rangeland quality indicators: individual traits and population ecology of the tufted savanna grass Stipagrostis uniplumis (LICHT. ex ROEM. & SCHULT.) DE WINTER var. uniplumis. A test of Holistic Rangeland Management in Namibia.

Drissa Coulibaly: Investigation of the diversity and ecology of bee pollinator species and their importance for the resilience of farming systems (model system: cotton) along a land use gradient in Burkina Faso.

Jessica Ferner: Remote sensing based study of forage characteristics of West African rangelands in the context of climate change.

Reginald Tang Guuroh: The Impact of Climate and Land Use on Grazing Lands: A Study in the Sudanian Savannas of West Africa.

Mouhamed Idrissou: Modeling the availability of surface and groundwater resources in inland valleys: case study of Dano catchment, Burkina Faso.

Louis Yamego: Management of seasonal soil N dynamics at different scales in the savannah zone of West-Africa.

Nicholas Moret: Status of biodiversity as indicator of ecosystem resilience in West Africa.

John-Baptist Naah: Towards an understanding and harnessing of Local Ecological Knowledge (LEK) of Forage Resources for sustainable rangeland management in the Sudanian Zone of West Africa.

Felix Op de Hipt: Soil erosion in Burkina Faso under climate change and land use change.

Ephraim Sekyi-Annan: Performance evaluation of reservoir-based irrigation schemes in in the Upper East Region of Ghana.

Wenceslas Somda: Adaptability of small irrigation systems to climate and land use changes in inland valleys in Dano.

Soma Soungalo: Diversity, functional characteristics and ecosystem services in Sudanian savannas of south-western Burkina Faso and northern Ghana in the context of climate change.

Yacouba Yira: Water resources in West Africa under climate and land use change.

Kangbéni Dimobé: Habitat patterns and variation of plant biodiversity models in savannas of Burkina Faso and Ghana in the climate change context.

Selected Publications

Bossa, A.A., Diekkrüger, B., Igué, A.M. and T. Gaiser 2012. Analyzing the effects of different soil databases on modeling of hydrological processes and sediment yield in Benin (West Africa). *Geoderma* 173–174, 61–74.

Ferner, J., Guuroh, R., Linstädter, A. and S. Schmidtlein 2013. Studying forage quality and quantity of West African rangelands in the context of climate change, in: Vegetation Science. Vegetation Patterns and their Underlying Processes, 54.

Linstädter, A., Canak, K., Bliefernicht, J., and S. Schmidtlein 2013. Impact of grazing management on phenological events of rangeland vegetation in West Africa, in: Vegetation Science. Vegetation Patterns and their Underlying Processes, 137.

Landscape Dynamics

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Agricultural Systems

Thomas Gaiser, Jesse Naab, Marc Müller, Irit Eguavoen, Heidi Webber, Tobias Wünscher, Justice Tambo

Agricultural production is a complex interplay of various components, such as farming systems, climatic conditions, agricultural policies and extension, and of course, the farmers who face production challenges, observe environmental changes and take agricultural decisions. They experience and experiment with their environment and, at times, generate agricultural innovations.

Farming Systems and Crop Production

Agriculture plays an essential role in West Africa. It is the main economic activity of the largest part of the population and contributes strongly to the regional economy. Agriculture, however, is also the cause of some of the environmental problems. Small-scale farming in West Africa takes place under a wide range of soil, climatic and social-economic conditions. Studies describe a multitude of farming systems in Sub-Saharan Africa in general, as well as in the WASCAL countries.

WASCAL's three study sites are located within the Département Atakora in Benin, the Région Sud-Ouest in Burkina Faso, and the Upper East Region (UER) in Ghana (p. 29). Cereals accounted for around 50% of the total harvested area between 1990 and 2009 in the three study sites (fig. 1), with millet and sorghum as major crop categories. Differences in the composition of the overall cereal area are notable. The maize harvested area in UER, Ghana increased 10-fold between 1990 and 2010 from 4,000 to almost 40,000 ha, but remained at an average share of 5% during the last decade. Maize is a typical product of the Northern and Brong Ahafo Regions in Ghana; farmers in UER, Ghana expanded maize areas due to the comparatively short growing cycle of new maize varieties and the shorter rainy season. In contrast, rice production is more common with an average area share of 8% in the last decade in UER, Ghana. In Sud-Ouest, Burkina Faso, the rice share remained at a 2% level during the same period. The availability of irrigation (ca. 2,500 ha in UER, Ghana) can only partly explain this.

The production of groundnut is relevant in UER, Ghana but not substantial in the other two study regions. In Sud-Ouest, Burkina Faso and Atakora, Benin, cotton is a very important cash crop and its production is supported by marketing and processing organizations. Cotton production in UER, Ghana is marginal though the cultivated area has been expanded since 2010. Root and tuber crops are produced in all three study sites. They, however, contribute only little to the gross production value of rainy-season crops in UER, Ghana and Sud-Ouest, Burkina Faso. Yam is a major crop in Atakora, with a production value that exceeds the combined cereal production value in some years. The described cultivation of crops takes place in farming units averaging 2-6 ha farmed by 6-12 family members. Not all farmers work full time on their fields; many pursue additional income generation activities. Major differences in farming systems such as smallholder and cereal-root crop farming systems are determined by the access to market opportunities and the availability of irrigation, also for dry-season farming.

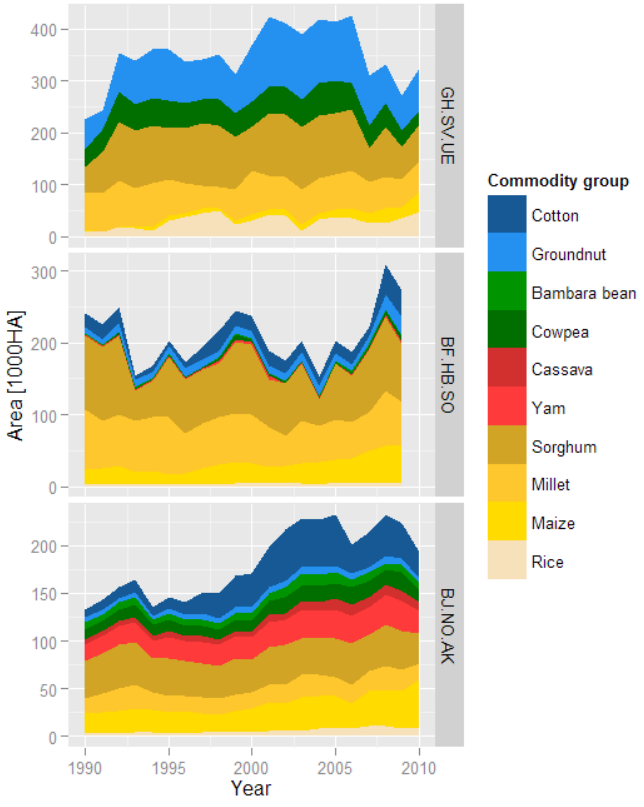

Figure 1: Harvested areas of rainy-season crops in the WASCAL study regions Upper East Region (Ghana, above), Sud-Ouest Region (Burkina Faso, middle) and Atakora Region (Benin, below). Source: Marc Müller 2013.

Climate Change Impacts on Crop Production

After a review which resulted in a list of major constraints to crop production, long-term central field experiments (CeFEx) were established in cooperation with national partners (INERA in Burkina Faso, INRAB in Benin, SARI in Ghana). The CeFEx experiments on hill slopes at Dano, Vea and Dassari investigate the site-specific impact of selected management practices such as residue retention, tillage, crop rotation, and nitrogen fertilizer levels. Research is conducted on interaction with landscape position and climate variability on crop yields and ecosystem services.

The results of the first year (2012) indicate huge differences between the three study sites in the average maize yield (fig. 2). In addition, immediate effects of nitrogen fertilizer levels and of landscape position on crop yields were observed. The interaction with climate variability as well as with the long-term effects of residue retention and crop rotation on yields requires a continuous monitoring over several years. A further focus is laid on the impact evaluation of extreme temperatures during sensitive development stages of key crops on yield. These empirical findings will be integrated into dynamic field and regional scale crop models. Literature reviews for different crops highlight the importance of the coincidence of extremely high temperatures for a certain time interval with sensitive development stages of the crop for the final yield. The effect on final yield is minor if extremely high temperatures (40°C over 10 days) occur in the vegetative phase or during grain filling of sorghum. However, the effect on final yield can be detrimental if the same temperatures occur over 10 days just before or at flowering (fig. 3).

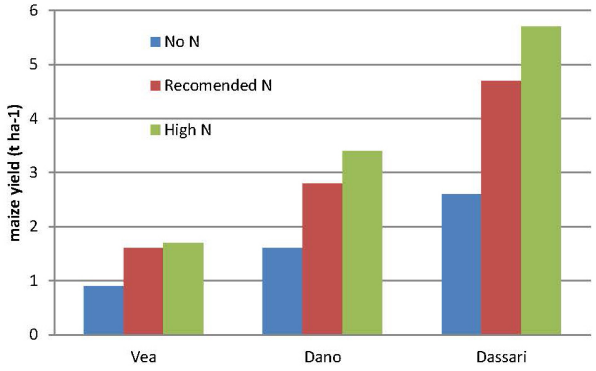

Figure 2: Maize yield in 2012 as related to the position of plots along the slope and nitrogen (N) fertilizer rate (kg per ha) in the three Central Field Experiments at Vea (Ghana), Dano (Burkina Faso) and Dassari (Benin) (Source: Danso 2012, unpublished).

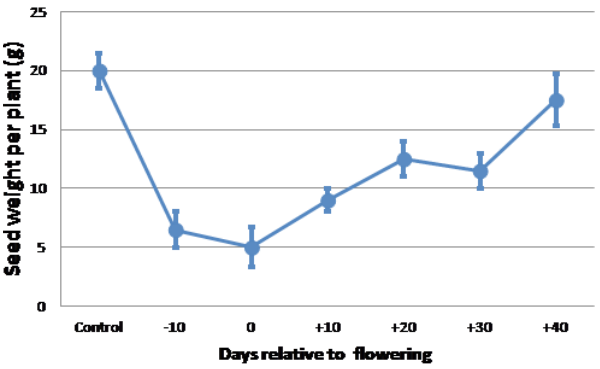

Figure 3: Influence of high-temperature stress (transferring plants from 32/22°C [optimum temperature, OT] to 40/30°C [HT]) at different times relative to flowering on sorghum seed weight per plant and respective control (Error bars show standard error of measurements) (adapted from Prasad et al. 2008, Crop Sciences 48:1911-1917.).

Impact of Cropping System and Climate Variability on Water and Nutrient Dynamics

There is still a knowledge gap on how climate change will impact water and nutrient cycles in cropping systems. Increasing temperature and altered patterns of rainfall could modify the soil-water and nutrient balances, which in turn could negatively affect crop productivity. Key processes in the soil, such as respiration and net nitrogen mineralization, could be affected by higher temperatures and changes in precipitation. As a result, ecosystem functions such as carbon storage and nutrient turnover and availability may also change. A long term experiment was established at Vea and Oriyori watersheds in Ghana and Benin to determine the effects of cropping system and tillage practices on soil moisture and nutrient dynamics. In this initial year, seven legume cover crops and native bush fallow plots were established as part of the cropping sequence. Soil properties in different depths, crop development, as well as biomass production are monitored.

Perceptions of Climate Change in Ghana, Burkina Faso and Benin

Agrarian studies on climate change adaptation in Africa increasingly contain paragraphs on farmers´ perceptions. WASCAL applied improved qualitative and historical methods combined with consensus analysis whose data can undergo both statistical and content analyses. The method semi-structures the interviews but allows respondents to prioritize the content of their conversation with the researcher. Farmers get a voice to be heard and analyzed. There is no word for ´climate change´ in most West African languages. Lo-

cal concepts of environmental change, pronounced as, for example, change in the weather or in the surroundings, are holistic in character. These concepts tend to emphasize the inseparable connectedness of the natural environment such as landscape, flora, fauna and weather to infrastructural development, human behavior, human and livestock health, agricultural production and the spiritual world. Farmers report observation of changes in precipitation, the shift in the agricultural season, a stronger wind and increased temperatures. Many older farmers, however, relate them directly to their practices and moral transgression in their community. Younger people who work on their family farms but are not decision-makers over agricultural production tend to adopt ´climate speech´ from the media. Differences in the research sites are remarkable. Many Burkinabe farmers perceive climate change as one challenge among many others and did not pay much attention, whereas many farmers and NGOs in Ghana are fully aware of support under climate change programs and talk accordingly. Thus, they are adjusting to adaptation opportunities. Local trajectories of blame, however, are very prominent. Climate change is not perceived as a phenomenon with global causes and manifestations. The information gap and/or public misinformation about climate change (mainly phrased as a result of cutting trees, burning the bush and environmental pollution) and the derived local adaptation measures are similar in all the countries. Policies tend to shift the blame and need for action to the population. Thanks to the political National Adaptation Programs of Action (NAPAs), politicians, local authorities and NGOs are much better informed about climate change than, for example, farmers and journalists.

Agricultural Innovations Developed by Farmers

Innovations are important for the successful adaptation to climate change. If developed under local conditions, innovations may have the advantage of being able to better consider the needs and constraints of smallholders than expert-based innovations. Farmers may therefore adopt innovations developed by other farmers more readily than innovations developed by research organizations. Thus, WASCAL aims to identify local innovations and evaluate their agricultural and economic effectiveness. The research started with a Farmer Innovation Contest and surveys to identify locally evolved innovations and innovation potentials in Ghana. The local agricultural extension system of the Ministry of Food and Agriculture supported the contest. The contest was completed in with 30 applications 2012 and with 42 applications in 2013. Three winners were chosen by a committee each year (p. 41).

Lead Institutions and Core Partners

- Center for Development Research (ZEF), University of Bonn
- Competence Center, WASCAL
- Faculty of Agriculture, University of Bonn

Doctoral Research in this Area

Kokou Adambounou Amouzou: The dynamics of macronutrient cycles under the impact of climate change and land use in West Africa´s Sudan savanna.

David Boansi: Agricultural Impacts of extreme climate and weather events: case of selected countries in Sudan-Sahel Region of West Africa: Micro-Macro Linkages and Agricultural Policy Implications.

Isaac Danso: Evaluation of climate adaptation strategies for West Africa's Sudan Savannah cropping systems.

Justice Tambo: Farmer innovation in rural West Africa: determinants and implications for climate change and food security.

Selected Publications

Eguavoen, I. 2013. Climate change and trajectories of blame in Northern Ghana. *Anthropological Notebooks* 19(1): 5-24.

Naab, J. et al. 2012. African perspectives on climate change and agriculture: Impacts, adaptation, and mitigation potential, In: Hillel, D. and C. Rosenzweig (eds.) Handbook of climate change and agroecosystems. Global and regional aspects and implications. Imperial College Press, London: 85-106.

Worou O. N. et al. 2012. Simulation of soil water dynamics and rice crop growth as affected by bunding and fertilizer application in inland valley systems of West Africa. *Agriculture, Ecosystems & Environment* 162:24-35.

Agricultural Systems

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Farmer Innovation Contest: Local Innovations for Better Farming Results

John A. Akugre and Bukari Hassan from northern Ghana tackle their everyday challenges in farming with an experimental spirit and creativity. They were the winners of the first two WASCAL farmer innovation contests in 2012 and 2013.

Barakuk - A Local Herb helps to Store Onion Seeds and Treat Animal Wounds

Onion production is a major farming activity in John A. Akugre's community in Tilli, Bawku West District, Ghana. Farmers face a major production challenge in storing the onion seeds for longer periods as they often lose viability before the next planting season. John experimented using Barakuk, a local plant herb, to store the seeds. The 56 year old farmer collects the plants from the wild, dries, and burns them into char, and grinds them to powder. He mixes a quantity of the herb with the onion seeds and fills them into a bottle for storage in a cool, dry place. With this method, the seeds remain viable even after a year, and he obtains a high germination percentage. A large share of onion farmers in his community has subsequently adopted this innovation.

John Akugre Anyagre, winner of Farmer Innovation Contest 2012 explored multiple uses for the local herb Barakuk. Photo: Tobias Wünscher 2012.

For his innovative solution to protect his tree seedlings from termite attacks, Bukari Hassan won the first prize at the farmer innovation contest 2013. Photo Tobias Wünscher 2013.

John also uses the Barakuk herb to treat animal wounds with an ointment of mixed Barakuk powder and melted shea oil. The ointment is applied daily on a cleaned animal wound. John argues that the wound will be completely healed within a week, and the ointment is 90% effective in treating animal wounds. Thus, the use of Barakuk herb improves onion seed viability and saves the cost of drugs for treating animal wounds. A limitation on the innovation is the seasonality and limited distribution of the Barakuk plant. However, powdered Barakuk can be bottled, stored, and still be effective even after two years.

Carnivore Ants Fight Off Termites and Protect Bukari Hassan's Tree Seedlings

Bukari Hassan, 2013 regional winner of the Farmer Innovation Contest in Upper East Ghana tackled a termite problem by luring carnivore ants as a natural deterrent for termites. Termites used to kill Bukari Hassan's young tree seedlings until he started to lure what he refers to as 'Tiger Ants' using bones – left-overs from the butcher or his own family's meals. The ants feast on the bones and scare the termites away allowing his trees to grow until they are strong enough to defend themselves. This way, Mr. Hassan managed to solve his number one problem of growing trees. Meanwhile he has established a small forest with trees that provide him with fruit, nuts, medicine, firewood and timber. This is good news for Upper East Ghana, where tree cover is generally decreasing.

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Markets and Livelihoods

Marc Müller, William Fonta, Irit Eguavoen, Papa Sow, Jan-Niklas Bamler, Stephen A. Adaawen, Tobias Wünscher, Ursula Gessner

This research cluster provides data on the preferences of stakeholders and on basic mechanisms of decision-making with regard to land use, demography, markets and livelihood strategies. We work on thirteen empirical and analytical scales to get hold of the intertwined social, economic and political dynamics.

Statistical socio-economic database

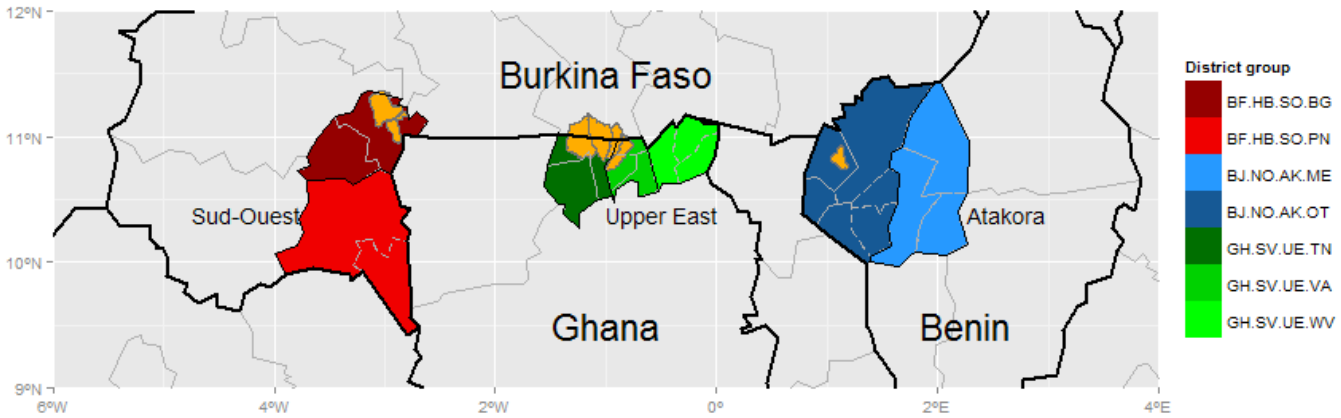
In this cluster, we aim to identify major driving forces of population dynamics, economic activities, land use changes, and the demand for agricultural land. As a prerequisite for the assessment of markets and livelihoods, we have set up a statistical socio-economic database for the administrative districts in which the WASCAL watersheds (orange shaded areas in map 1) are located. The statistical database was developed for administrative units within the Département Atakora in Benin, the Région Sud-Ouest in Burkina Faso, and the Upper East Region in Ghana (colored areas in Map 1). Because the targeted administrative units in the three countries differ substantially in agricultural area and population, we split them into comparable units of between 150,000 and 450,000 inhabitants and 100,000-150,000 ha of agricultural area, based on subcatchments of the Volta River basin and existing administrative borders at lower hierarchical scales (map 1).

Demography

We combined national population data with regional surveys to create complete time series between 1985 and 2010 (figure 1) to assess historical impacts of population growth on land use dynamics. Despite huge differences in land area (Atakora is by far the largest administrative unit with more than 2 million hectares total land area, compared to Upper East Ghana with less than 900,000 hectares), the population size is comparable with e.g. 700,000 inhabitants in Atakora and 1 million inhabitants in Upper East. Between the years 2000 and 2010, populations grew between 1.2% p.a. in Upper East Ghana and slightly above 3% p.a. in Atakora Benin.

Migration and other Population Dynamics

In both Ghana and Benin, gender and age configurations of mobility, work, and other activities seem to intersect in subtle ways with environmental variability. Conflicts arise particularly at moments when land and water usage shift to other users during the absence of emigrants. We have investigated the corresponding shifts in population dynamics and analyzed how economic responsibility is assigned in local communities under conditions where land and water resources are



Map 1: The orange shaded areas mark the WASCAL research watersheds.

abundant, as well as when people expect an environ- mental crisis to occur. Our data includes narrated experiences of those "left behind" trying to manage endangered resources in villages characterized by out-migration. We also compare out-migrations and in-migrations in the WASCAL watersheds and population dynamics related to land use, marriage practices, family changes as well as remittances to see how exactly environmental, demographic, cultural and economic variables intertwine.

Population and Employment

The economically active population (i.e. the age groups between 15 and 64 years) accounts for approximately 40% of the overall population in all three sites. The majority is informally self-employed in the agricultural sector (~80% in Sud-Ouest Burkina Faso, ~66% in Upper East Ghana). The second largest employers in Upper East Ghana are mining and manufacturing (15%), followed by trade, repair, and transport services (~10%). The latter is the second largest employer (6.7%) in Sud-Ouest Burkina Faso. It has not yet been possible to obtain employment figures for Atakora Benin. National employment statistics for Benin, however, show a comparable picture with informal self-employment in agriculture as the dominant occupation of the economically active population.

Demand for Agricultural Land

With agriculture the dominant sector for employment, we investigated the impact of population growth on demand for agricultural land. Population data were plotted against total harvested areas between the years 1985 and 2010. A clear correlation between population and agricultural land can be observed for Upper East Ghana prior to the floods of 2007 and for Atakora Benin, but less so in Sud-Ouest Burkina Faso. This is partly due to administrative reforms in 1997 and 2001, which cause some structural breaks in the agricultural production data. A regression model that accounts for such breaks indicates that across all sites, the total harvested area increases by 0.9% for each 1% increase in the population. Assuming that this relationship and population growth remain stable over the coming decade, an increase in the total agricultural area of up to 30% might be expected. However, such projections do not consider the effects of migration, possible increases in off-farm employment, and physical limits to the expansion of agricultural land. The investigation of such determinants of agricultural land demand is part of our ongoing research activities under the heading ´migration and population dynamics´.

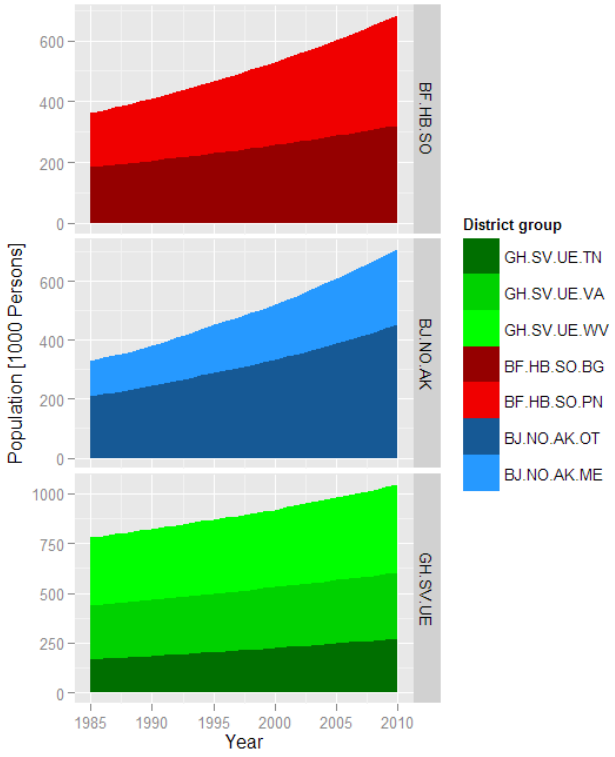


Fig. 1: Population in the research watersheds in Burkina Faso, Ghana and Benin from 1985 to 2010.

Gendered Commodity Chains, Agricultural Policies and Rush for Lands in Ghana

With a fast growing national economy and vibrant markets, Ghana is a prime example of successful debt reduction and economic liberalization and could offer growing opportunities even to smallholder farmers, if they are able to produce sufficient surpluses.

Yet, chronic poverty in rural areas in northern Ghana still prevails. After decades of restricted government expenditure, new "pro-poor" policies have been put in place. These policies employ familiar policy measures, such as the substitution of rice imports through local production and the promotion of exports in the agricultural sector. We have found that these import-substituting subsidies favor local male elites and are less accessible for poor and vulnerable farmers with little land holdings. Female farmers are still deprived of equal livelihood opportunities and positive policy outcomes. Development assistance and government subsidies seem not to consider gender differences and the potential of gendered crop markets.

Import substitution has led to a rush for irrigated land among Ghanaian farmers. As a result, marginal lands are left for the poor. Often, these lands are more af-

fected by flooding. Economically strong farmers are further attracted by export promotion funds which make them extend their land holdings at the expense of small scale farmers and women who rely on the collection of shea nuts.

Carbon Markets

The implementation of carbon markets addressing forestry may also offer potential income opportunities for rural farmers and other landholders. The influence of carbon markets on land use choices can also affect non-carbon ecosystem services like water provision. The objectives of our study are to assess likely impacts of a forest related carbon market on land cover, rural income and carbon sequestration, and to value related changes in the provision of ecosystem services. We are implementing a reverse auction for tree planting contracts in our study area in Upper East Ghana to reveal the true reforestation costs, including transaction and opportunity costs of land and labor. Spatial econometrics are then used to extrapolate the findings to a larger area and to determine likely land cover changes for alternative carbon prices. Water flows and the risk of flooding are the focus of our valuation efforts. We are addressing these by modeling the income effects of floods in a case study area in Benin. Data on the valuation component has already been collected and is currently undergoing analysis.

The spatial extrapolation analysis and the estimation of likely land cover changes are supported by remote sensing based analyses. Tree cover and tree cover changes are currently mapped for the Sudan savanna for the year 2000 at a spatial resolution of 30 m (figure 2). The map will be further improved and adapted using recently acquired high resolution remote sensing data. In addition, carbon sequestration related to tree cover and tree cover changes will be estimated based on remote sensing data and in collaboration with other working groups.

The Politics of Adaptation

While the major part of field research on politics was already finalized in the Core Research Program (see other research below) in early 2013, work on the politics of climate change adaptation in West Africa will commence shortly at the WASCAL Competence Center in Ouagadougou. Like many other African climate change research centers we argue that the particular governance contsxt, as well as politics need to be taken serious when planning adaptation policies, financial mechanisms and implementation strategies.

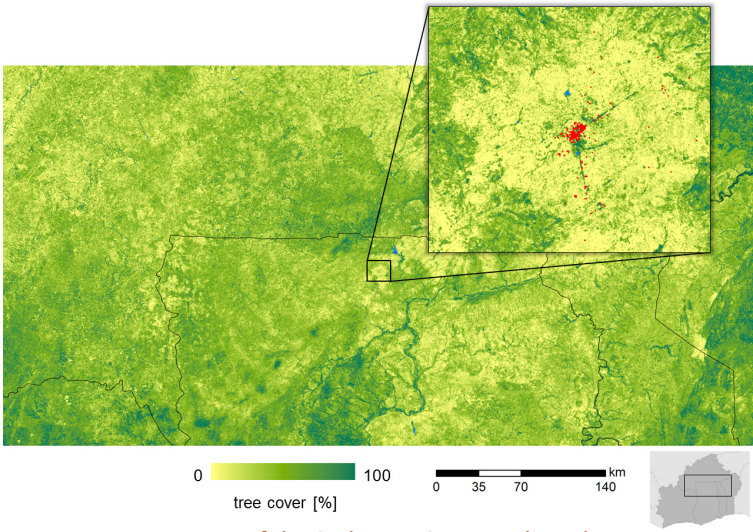


Fig. 2: Tree cover map of the Sudanian Savanna based on remote sensing data of the Landsat satellite. The map delineates percentage tree crown cover at a pixel size of 30 m x 30 m. Source: Ursula Gessner.

Introducing a greater understanding of the African political landscape into the adaptation discussion, would help in many different ways to avoid unrealistic planning. Thus, our research agenda on the politics of adaptation includes:

- identifying institutional constraints that impede the effective mainstreaming of climate change programs into sector development plans and strategies;
- research on how networks and the power relationship between actors play out in the flow of information and allocation of resources towards climate change adaptation and mitigation programs in West Africa;
- research on domestic resource mobilization and access to the existing climate finance lands- cape;
- identifying factors and conditions that work to under-represent and exclude the voices of small-scale farmers and producers in national and intermediate- level planning for adaptation;
- and research on the economy-wide implications of down streaming the energy sector for domestic resource mobilization for adaptation.

Lead Institutions and Core Partners

- Center for Development Research (ZEF), University of Bonn
- Climate Service Center, WASCAL
- German Aerospace Center (DLR) - German Remote Sensing Data Center (DFD), Oberpfaffenhofen

Doctoral Research in this Area

Stephen Ataamvari Adaawen: Migration from and to the North of Ghana. Historic Paths and Confrontation with Environmental Risks.

Jan-Niklas Bamler: Sustainable Smallholder Development and Agricultural Market Interventions in Northern Ghana.

Gebrelibanos Gebremariam: Clean Cooking Stoves and their impacts on health, forest cover, carbon emissions and livelihood.

Aminata Germer: Climate Change, Vulnerability, Livelihoods, Food and Nutrition Security.

Karsten Schulz: Climate Change Adaptation in Ghana: Institutions, Discourses, Vulnerabilities.

Selected Publications

Sow, P., S. A. Adaawen, and J. Scheffran 2014. Migration, Social Demands and Environmental Change amongst the Frafra of Northern Ghana and the Biali in Northern Benin. *Sustainability* 6, 375-398.

Eguavoen, I. and B. Schraven 2013. The ambiguous representation of the savannah landscape and its new political relevance in Ghana, IN: Yaro, J.A. (ed.) Rural development in Northern Ghana. Nova Science Publishers: 207-223.

Eguavoen, I., K. Schulz, S. de Wit, F. Weisser, D. Müller-Mahn 2013. Political dimensions of climate change adaptation. Conceptual reflections and African examples. *ZEF Working Paper* 120. Bonn.

Sow, P. 2012. Uncertainties and conflicting environmental adaptation strategies in the region of the Pink Lake, Senegal. *ZEF Working Paper* 101, Bonn.

Markets and Livelihoods

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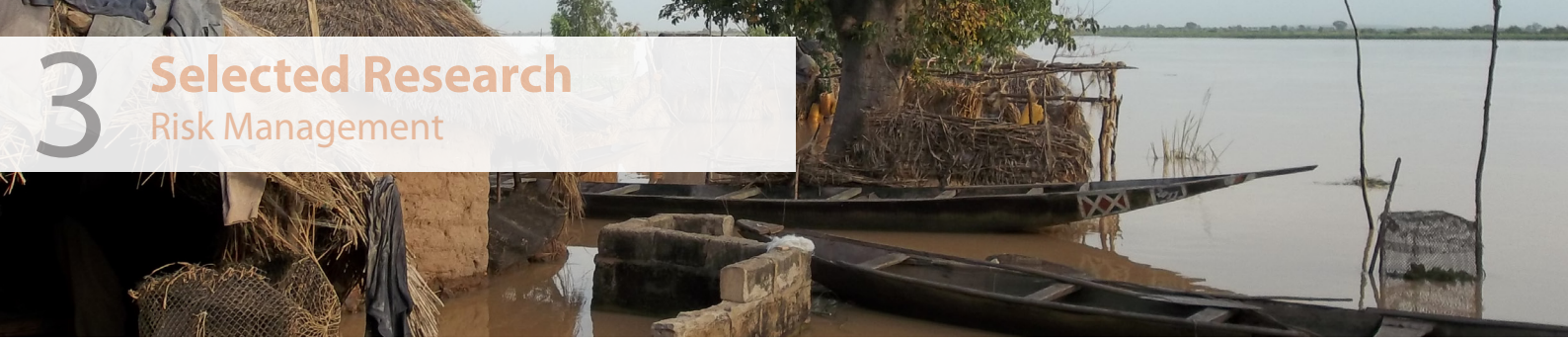


Climate Change Impact and Risk Management

Fabrice Renaud, Julia Kloos, Stella Hubert, Marc Müller

In this cluster we investigate the linkages between climate change related natural hazards such as floods and droughts, and the state and the security of rural livelihoods. The research aims to help reduce the likelihood of future disasters through the analysis and assessment of risks, as well as through the evaluation of risk management strategies.

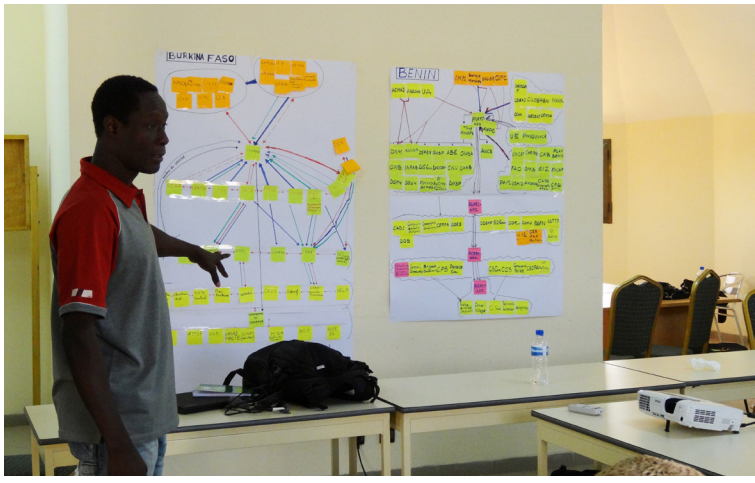
The present and future impacts of climate change and related natural hazards on the livelihoods of exposed communities are manifold and diverse. In many cases, these impacts are very likely to increase the risks faced by households which are already vulnerable to environmental hazards and poor or poverty endangered. As such, feasible concepts for innovative and adapted risk management strategies are becoming vital to secure these livelihoods and maintain or improve human security in the long run.
In this context we investigate the linkages between climate change related natural hazards such as floods and droughts and the state and security of rural livelihoods in the Western Sudan Savanna eco-region of Burkina Faso, Benin and Ghana. This research aims to contribute to more targeted risk management to reduce the likelihood of future disasters in the context of climate change related hazards. Our focus therefore lies on two main issues: (1) the analysis and assessment of risks, on the one hand and (2) the evaluation of risk management strategies, on the other.

Risk Assessment

The assessment and analysis of risks for different social groups includes identifying the relevant hazards that threaten different types of households or communities and analyzing the mechanisms through which these households can be differently affected and/or respond differently, taking into account multiple spatial scales such as watersheds, sub-national boundaries and, eventually, the eco-region. The researchers measure the exposure of households to these hazards, their susceptibility and the existing coping and adaptive capacities to identify various levels of vulnerability. Risk can be determined by bringing findings on vulnerability and hazards together. This approach provides a sound basis for targeted interventions by policy-makers to reduce risks, as they are informed about the risks that different social groups face in different locations taking into account their respective coping and adaptation capacities and the institutional support they receive. There will be empirical evidence to determine which socio-economic aspects and social groups demand immediate attention and thus facilitate a more efficient allocation of scare resources.

Institutional Landscape of Disaster Management

The research conducted so far has started by understanding the institutional landscape of disaster risk reduction and climate change adaptation in the three considered countries, Burkina Faso, Ghana and Benin, and connecting the researchers with the main actors in these fields. An international two-day stakeholder workshop in Ouagadougou organized in November 2012 brought together a number of stakeholders from national disaster risk agencies, ministries, NGOs and international organizations. This workshop helped set the basis for targeted research that can build on and contribute to ongoing processes.



Discussing the actors and their linkages in the field of disaster risk management during an expert workshop in Ouagadougou, Burkina Faso, November 2012. Photo: Ursula Gessner.

Compiling a Database on Floods and Droughts

As there is a lack of sufficient information on past disasters, we are currently compiling a historic database of floods and droughts, their impacts and their spatial extent. Existing information from different data sources is often relatively vague and even contradictory. In a first step, this information was collected and will now be supplemented by more detailed information from partners in the region. The aim is to get a clearer indication of past events and their impact on affected communities as well as to build a database which can be continuously updated and thus be used for further analysis (e.g. changes in frequency or impact of events over time).

Mapping Drought Hazards and Potentially Exposed Population

To get a better understanding of the potentially exposed population we use remotely sensed data in combination with other socio-economic information to disaggregate population data. Moreover, we use remote sensing to test to what extent vegetation indices and phenological metrics like start of season and end of season can be used to adequately characterize agricultural droughts and shifts in rainy seasons. Based on these analyses, we will develop drought hazard maps.

Understanding Vulnerability and Risk

Two PhD students were recruited in 2012 and have started to work on two closely linked research topics; the first on an in-depth assessment of vulnerability to multiple natural hazards and the second on an indicator based multiple hazard risk assessment on a broader scale. While the first PhD researcher is concentrating on the three focal watersheds of WASCAL and aims to characterize vulnerabilities and their root causes for different household types through a qualitative approach, the second researcher's approach addresses vulnerability, response capacities and finally risk more quantitatively by constructing indicators relevant within the context of the watersheds, sub-national levels and the eco-region respectively. A participatory indicator validation process was undertaken by experts from various fields in the three watersheds and the results showed that 58% of the indicators deemed to be relevant by the local experts are rarely used in traditional risk assessments in the region. Some indicators were unique to each country, reflecting the differences in economic development, population density and resource degradation between the countries.

Ten students from the Master Program Climate Change and Human Security in Lomé, Togo learned about humanitarian coordination, emergency preparedness and response procedures in a training module on Disaster Risk Reduction organized by UNU-EHS. Photo: UNU-EHS 2013.

Besides the indicators that are unique to each country, differences in risk perceptions, socio-economic conditions and other factors became obvious, meaning that even the same indicator will invariably be ranked differently by different societies. A fundamental mistake is often made by assigning the same weights to indicators for different countries or when countries are treated with the same set of indicators, ignoring obvious heterogeneity on many fronts. The effect of this is that risk and vulnerability comparisons among countries could lead to policy interventions that do not reflect reality and to the ill-informed allocation of scarce resources.

Assessing Risks at Multiple Levels

First results from the qualitative work suggest that despite the variations in economic and political contexts, there are considerable similarities between the three focal watersheds in terms of frequency, impacts, coping and adaptation strategies in relation to floods and droughts. The apparent comparability of the case studies seems to validate the possibility of upscaling the local data across the Sudanian Savanna Region. Coping strategies related to floods and droughts revolve around alternative occupations and livestock re- sources, but the time required for a complete recovery following a hazard stroke is not always available before another hazard strikes. A preliminary overview of the data thus suggests that limited livestock

resources, a lack of alternative livelihood sources and alternative livelihood sources that are also impacted by floods and droughts are important factors contributing to vulnerability.

Risk Management Strategies

The economic analysis of risk management strategies for farm-households in the research areas requires as a first step the assessment of the risks to which they are exposed. The research activities so far focused on the risks associated with the impact of historical and anticipated seasonal rainfall events on production of rainy-season crops, as this is the major source of income for the regional population. To quantify the probabilities of seasonal rainfall events and their impact on farm outputs, we compiled a database on crop production and monthly precipitation for the last 25 years. Our findings show that a 75% reduction in monthly precipitation in June, July, and August, would each lead to a 50% reduction in gross output values. This finding is particularly interesting as the situation is the same in all three case-study regions, which can in all cases be characterized as cereal-root crop mixed farming, but with different shares of root and cash crops. Building on these findings, the upcoming research activities will involve analyses of impact on alternative farming systems, in particular with regard to projected changes in the regional climate and the probabilities of certain rainfall events (e.g. a 75% reduction in July rainfall is currently not highly probable, but may be more likely in the future). Knowledge regarding the impact of rainfall events on farm outcomes is a prerequisite for the further assessment of risk management strategies, like the introduction of index-based insurance concepts. An example of ongoing efforts to introduce such insurance schemes for smallholder farmers is the Ghana Agricultural Insurance Program (GAIP), which aims at insuring against dry spells during the main vegetation period. Comparable programs are also being discussed for Benin and Burkina Faso. In addition to such novel insurance concepts, we will also evaluate the introduction of new crops (e.g. maize or soybean production is comparatively new to Upper East Ghana).

Lead Institutions and Core Partners

- Center for Development Research (ZEF), University of Bonn
- German Aerospace Center (DLR) - German Remote Sensing Data Center (DFD), Oberpfaffenhofen
- United Nations University - Institute for Environment and Human Security (UNU-EHS), Bonn, Germany
- WASCAL Competence Center

Doctoral Research in this Area

Daniel Asare-Kyei: Spatially explicit methodologies for indicator-based vulnerability assessment, multi-risk mapping and upscaling in West African socio-ecological systems under climate change.

Joanna Pardoe: Assessing vulnerability to multiple hazards in the West African Sudanian Savannah.

Selected Publications

Asare-Kyei, D., Kloos, J., and F. Renaud 2013. Participatory approaches to develop indicators for multiple risk assessment linking different scales in West African Social-Ecological Systems under climate change. in: Srinath Perera et al. (Eds.), Proceedings of the First ANDROID Residential Doctoral School: 7–16.

Kloos, J. and F. Renaud 2014. Organic cotton production as an adaptation option in North West Benin. *Outlook on Agriculture* 43(2): 91-100.

Climate Change Impact and Risk Management

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Integrated Assessment

Mahamadou Belem, Christine Fürst, Grace Villamor

The management of socio-ecological systems requires a high level of integration of natural and social sciences knowledge. Integrated Assessment attempts to shed light on the complexity of coupled human-natural systems, supports the understanding of cause-effect relationships and thereby decisions on how to develop the systems. By linking research findings from social sciences and natural sciences, and taking into account the interlinkages between human and natural systems, Integrated Assessment is a scientific approach to supporting long-term policy planning processes.

With our research on ecosystems change and ecosystem services in WASCAL, we are dedicated to the integrated assessment of socio-cultural, economic and environmental effects of land use and land use changes under climate change. A main aim of integration in WASCAL is to (a) consult policies for climate change adaptation including also a sensitivity analysis of competing environmental and land use policies and (b) to put the knowledge gathered by different disciplines into action consistently. Therefore, WASCAL seeks to employ integrated assessment modeling (IAM) to link disciplinary research findings with a focus on vulnerability, resilience, and climate risk assessment.

Our main aim is to assess the concurrent impacts of different land use and land management practices on major ecosystem services and disservices, such as carbon and nitrogen storage, water quality and availability, soil degradation, biodiversity losses, and greenhouse gas emission. We also consider social aspects such as poverty reduction and food security, and economic benefits such as income generation (see table).

Our research will ensure the integration of expert knowledge from different sources such as researchers, policy consultants, local stakeholders, and research results by using a methodology that supports (1) the co-production and integration of knowledge at different scales of description, (2) the elaboration of an integrated framework, (3) consistent data generation, storage and distribution, and (4) informing land system development on potential responses to global change.

Dimensions of analysis in WASCAL integration

Social dimension

demography, poverty reduction, gender roles, collective management, food security, land tenure, social organization, land use (forestry, agriculture, pasture, water use, etc.), innovation diffusion, adaptation, etc.

Environmental dimension

soil, biodiversity, hydrology, biomass, energy, biochemical cycle (carbon, nitrogen, etc.), climate (precipitation, temperature), etc.

Economy dimension

input cost, commodity prices, access to market, access to labor, income, etc.

Policy dimension

infrastructure development, price support, access to credits, access to fertilizers, intensives for environmental conservation, intensives for food production, intensives for energy access, land tenure, technology, etc.

To ensure integrated research in WASCAL, we will first tackle the land use policy at the local scale by developing a generic multi-agents system model. The objective is to handle land use at plot, farm and local level. The model will be developed to pro- vide a multi-point of view representation of the target system (from different disciplines, decision makers and farmers), while accounting for the socio-economic, biophysical and policy dimensions.
Secondly, our focus will be on modeling land (use) systems at a larger scale. The objective is to develop a modeling approach for the integrated assessment of agricultural policy impacts on sustainable development at the national scale in West Africa. Top-down and bot- tom-up approaches will be coupled for a multi-scale analysis (from pixel to administrative or country level)., An integrated data warehouse will be developed and associated to our framework in order to provide a relevant framework for knowledge sharing and management. The data warehouse will be published as semantic web data following semantic web standards.

Agent-based Modeling for Integrated Assessment

Our research is focused on identifying resilient and adaptive land use systems. We use agent-based models such as the Land Use DynAmic Simulator (LUDAS) platform, which have the ability to simulate emergent phenomena, e.g. resilience.
One of the strengths of this modeling approach is to integrate the decision-making processes of human agents such as farmers. This includes their perception of climate change and adaptation to cope with climate change impacts. We developed and calibrated an agent-based model called "Vea-LUDAS" for the Vea catchment in Ghana.
In our research, we coupled this modeling approach with participatory gaming simulations to validate and explore social learning processes which are pertinent to understanding the adaptive management of the land use systems. We call our gaming simulations "the Grazing Game". It was implemented and replicated 29 times in the Vea catchment, Ghana and in Tanguieta, Benin as a social learning tool as well as a validation of the Vea-LUDAS model.

The Grazing Game: Fun and Educational

The research team working on agent-based modeling has conducted a role-playing game called the "Grazing Game". More than 240 local farmers participated and played the game around the Vea catchment, in Bolgatanga, Northern Ghana between August and October 2013. During the game our participants discussed decisions regarding the use and distribution of cattle and grazing areas and the prospective effects on the area. The aim of the game is to explore dynamically the behavior and perception of the local farmers under climate variability while simulating the processes leading to over-grazing and desertification.
From this game, the stylized behavior of households will be used to develop a decision tree for an agent-based model (ABM) as well as to validate the simulation results. Moreover, the game explores the local ecological knowledge in the study area crucial for understanding the socio-ecological landscape of the catchment. In addition, the local farmers enjoyed playing the game together with their neighbors and families.

Local farmers played the game using a board and pins to simulate the processes of desertification and over-grazing. Photo: Grace Villamor 2013.

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Lead Institutions and Core Partners

- Center for Development Research (ZEF), University of Bonn
- Competence Center, WASCAL

Doctoral Research in this Area

Maurice D.M. Ahouansou: Hydrological Ecosystem Services (HES) and land use under climate change in West Africa: case study of a semi-arid watershed, North Benin; he is part of the GRP (KNUST).

Mhamadou Laouali Amadou (WASCAL GSP): Companion modelling approach for simulating the adaptation strategies of crop production system to climate change in the Atankwidi catchment (Upper East Northern Ghana).

Bernhard Baatuuwie (WASCAL GSP): Multi-dimentional and multi-scale indicative assessment of land degradation in Volta sub-basin.

Gülendam Baysal: Analyzing the Impact of Land Use/ Cover Change on Ecosystem Services.

Badmos Biola (WASCAL GSP): Modelling impacts and adaptation strategies of climate change on land use/ cover change in Vea Catchment, Ghana.

Justice Nana Inkoom: Interactions between different land uses and the impact of the land use pattern in the Upper East Region of Ghana.

Janina Kleemann: Expert-based modeling approaches of agricultural land use change in Upper East Region, Ghana.

HongMi Koo: Agricultural land use planning for enhancing ecosystem services using scenario-based assessment: Cases of Bolgatanga and Bongo districts in the Upper East Region, Ghana.

Aleza Koudjoukalo (WASCAL GSP): Management and Dynamics of Shea Parkland Agroforestry, Benin.

Michael Mensah: Impact of gender differences and land tenure to the resilience of Vea Catchment in Northern Ghana.

Kapoury Sanago (WASCAL GSP): Carbon dynamics of Parkland Agroforestry in Mali.

Boundia Thiombiano (WASCAL GSP): Developing actor-based nutrient cycles model for support building resilience of smallholder agro-ecosystems to climate change, Black Volta sub-basin.

Selected Publications

Belem, M., Manlay, R.J., Müller, J.P., and J.-L. Chotte 2011. „CaTMAS: A multi-agents model for the simulation of carbon resources dynamics of villages in West-Africa." *Ecological Modelling* 222(20-22): 3651-3661.

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Integrated Assessment

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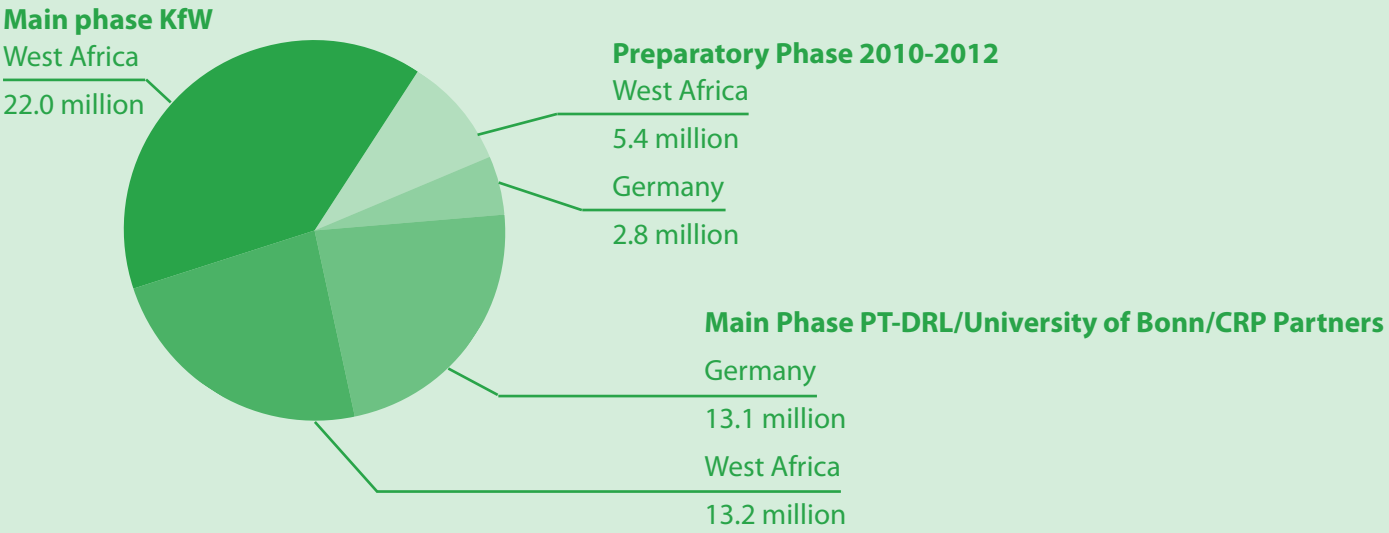
WASCAL Budget 2010-2016

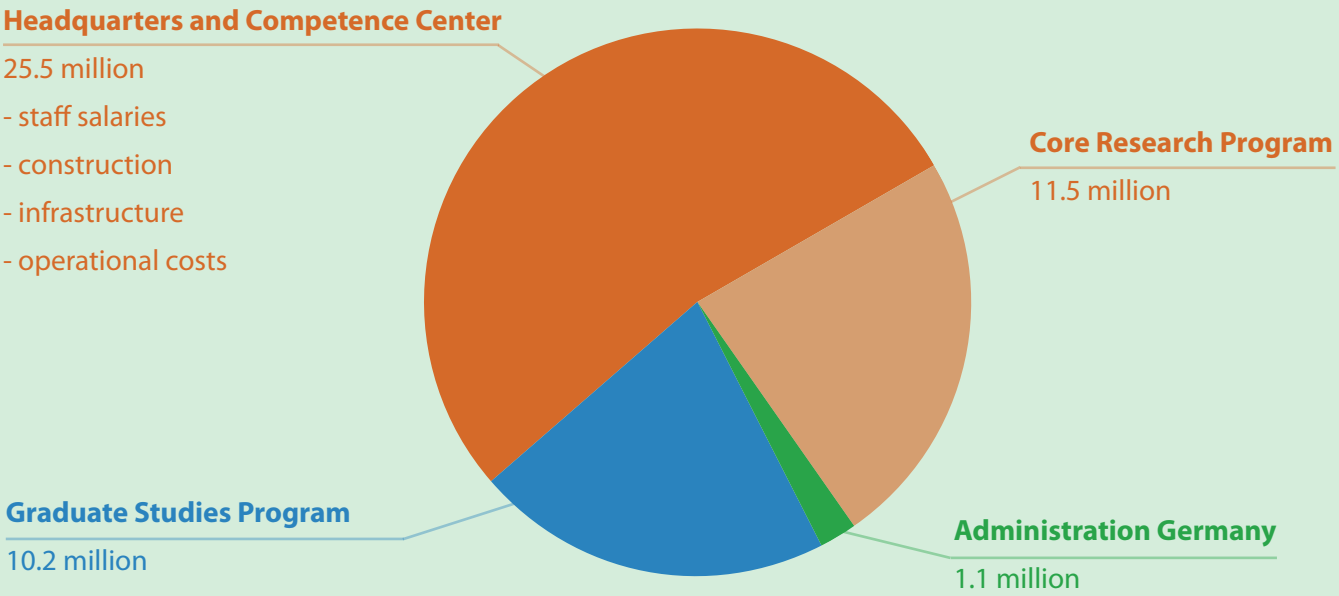
a. According to Phases

Preparatory phase 2010 - 2012	
via PT-DLR/University of Bonn	8.2 million Euro
Main phase 2012 – 2016	
via PT-DLR/University of Bonn/CRP Partners	26.3 million Euro
via KfW Group (starting from 2014)	22.0 million Euro
Total	56.5 million Euro

b. According to Region (2010-2016)



c. According to Programs (2012 - 2016)



6 Annex
Publications and Workshops

Publications

Adaawen, S.A. and P. Sow 2014. Migrations and social demands in the context of climatic and environmental change in North-East Ghana. *Sustainability* 6 (1): 375-398.

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Master and Diploma Theses

Dreier, Vanessa 2014. Environmental migration in Sub-Saharan Africa. A case study on Bialaba migrants from Northern Benin to Nigeria in search for productive land. Master Thesis, University of Bonn.

Wahren, Julia 2014. Climate Change Adaptation in the South-West Region of Burkina Faso: an Empirical Study. Master Thesis, Dresden University of Technology, School of International Studies (ZIS).

Germer, Michael 2013. Dissemination and uptake of climate forecasts in Burkina Faso. Stakeholder network in the Province of Ioba. Diploma Thesis, University of Bonn.

Koch, Robert 2013. Societies, Globalization and Development. Master Thesis, University of Bonn.

Training and Education Workshops

DKRZ, Hamburg, Germany organized a WASCAL **Regional Climate Modeling Workshop** with lectures on the topics "Optimization of WRF on DKRZ Blizzard" and "Strategies for long-term simulations in 2014", October 2013.

From 10 to 21 June 2013, UNU-EHS organized a **Training Module on Disaster Risk Reduction** in cooperation with UN OCHA ROWCA and the Togolese Red Cross, where ten students from the Master's Program Climate Change and Human Security in Lomé, Togo were trained in humanitarian coordination and emergency preparedness and response procedures. Lectures covered the important role of geo-information in analyzing and supporting all phases of the disaster management cycle as well as a better understanding of global and regional, in-situ and space-based observing systems around the world that contribute to the continuous monitoring of environmental risks and hazards.

In March 2013 a WASCAL **Data Management Workshop** was held at the Competence Center in Ouagadougou, Burkina Faso and at the University of Augsburg, Germany in October 2013.

A **GISCAME User Workshop** took place in Ouagadougou, Burkina Faso. The aim of the workshop held in March 2013 was to evaluate the usability of GISCAME and the need for adjustments to the platform.

A WASCAL **Biodiversity Monitoring Workshop** was held on March 4-5, 2013 in Ouagadougou, Burkina Faso with 34 participants from 8 countries of the Biodiversity research program in West Africa and Germany.

Expert Workshops on Vulnerability and Risk Assessment: Expert workshops to generate a preliminary set of indicators for further vulnerability and risk assessment at the level of the catchment areas took place in Bolgatanga, Ghana (May 2013, 21 participants, D. Asare-Kyei, J. Kloos), and in Dano, Burkina Faso (June 2013, 18 participants, D. Asare-Kyei) supported by WASCAL associates on-site.

UNU-EHS organized an **Expert Workshop on Disaster Risk Reduction (DRR)** with experts from national ministries, international organizations, scientists and WASCAL staff members to discuss the institutional landscape related to DRR in Burkina Faso and Benin. The workshop was held in November 2012 in Ouagadougou, Burkina Faso.

Acronyms and Abbreviatons

2iE	Institute for Water and Environmental Engineering
ABM	Agent-based Modeling
ACMAD	African Centre of Meteorological Application for Development
AGRA	Alliance for the Green Revolution in Africa
AGRHYMET	Agrometeorology, Hydrology, Meteorology Regional Center
BIOTA	Biodiversity Monitoring Transect Analysis in Africa
BMBF	German Federal Ministry of Education and Research
CCE	WASCAL Graduate ResearchProgram on Climate Change and Energy
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Developpement
CORAF	Conference of the Agricultural Research Leaders in West and Central Africa
CNRST	National Center of Research and Technology, Mali
CSIR	Council for Scientific and Industrial Research
CRP	WASCAL Core Research Program
DFD	German Remote Sensing Data Center
DKRZ	German Climate Computing Center
DLR	German Aerospace Center
ECOWAS	Economic Community of West African States
ECOWAS/ WRCC	ECOWAS Water Resources Coordination Center
ESS	Ecosystem services
FARA	Forum for Agricultural Research in Africa
FUT-Minna	Federal University of Technology, Minna
FUTA	Federal University of Technology, Akure
GAIP	Ghana Agricultural Insurance Program
GCOS	Global Climate Observing System
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GRP	WASCAL Graduate Research Program
GLOWA	Global Change and the Hydrological Cycle
HES	Hydrological Ecosystem Services
IAM	Integrated Assessment Modeling
IFRA	Agricultural Training and Research Institute
ILRI	International Livestock Research Institute
INDEPTH	INDEPTH Network – Better Health Information for Better Health Policy
INERA	Institut National de l`Environnement et des Recherches Agricoles
INRAB	Institute for Agricultural Research Benin
INRAN	Institute for Agricultural Research Niger
IPCC	Intergovernmental Panel on Climate Change
IPR/IFRA	Institut Polytechnique Rural de Formation et de Recherche Appliquée de Katibougou
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
KfW	Kreditanstalt für Wiederaufbau (Engl.: Reconstruction Credit Institute)
KIT	Karlsruhe Institute of Technology
KNUST	Kwame Nkrumah University of Science & Technology
LEK	Local Ecological Knowledge
LUDAS	Land Use DynAmic Simulator
MDGs	Millennium Development Goals
MRP	WASCAL Master Research Program
NAPA	National Adaptation Program of Action
NGO	Non Governmental Organization
OIPR	Ivorian Office of Parks and Reserves
PT-DLR	Project Management Agency, German Aerospace Center
RIDF	Resource Integrated Development Foundation, Nigeria
RSSC	Regional Science Service Centers
SARI	Savanna Agricultural Research Institute
SES	Social-ecological systems
TRMM	Tropical Rainfall Measuring Mission
UAC	Université d'Abomey-Calavi, Bénin
UAM	Université Abdou Moumouni de Niamey
UCAD	Univesité Cheikh Anta Diop, de Dakar
UCC	University of Cape Coast, Ghana
UER	Upper East Region
UL	University of Lomé, Togo
UNFCCC	United Nations Framework Convention on Climate Change
UNU-EHS	United Nations University, Institute for Environment and Human Security
UN OCHA ROWCA	United Nations Office for the Coordination of Humanitarian Affairs, Regional Office for West and Central Africa
UTG	University of the Gambia
WMO	World Meteorological Organization
WRF	Weather and Research Forecasting
VBA	Volta Basin Authority
ZEF	Center for Development Research

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