

“DAAD Qualitätsnetz Biodiversität”

Reconciling human livelihood needs and nature conservation in East African forest biodiversity hotspots

Abstract

Tropical forests are important habitats for endangered plant and animal species, but also provide various ecosystem services, which are crucial for the local human population. Most of the global forest biodiversity hotspots are located in developing countries, where human demographic pressure is exceptionally high. This has led to rapid transformation of pristine habitats and a reduction of ecosystem service provision by these formerly intact ecosystems. To establish efficient nature conservation programmes maintaining habitats of endangered species, as well as intact ecosystem services for the local human population, a combination of scientists and stakeholders from various disciplines has to collaborate. In our trans-disciplinary north-south, and south-south biodiversity network we combine scientists from the fields of (i) ecology, (ii) agro-ecology, as well as (iii) education, communication and management. The proposal focuses on joint-workshops, seminars and field work. Activities will take place in three selected forest model regions in south-east Kenya. We will discuss and develop new strategies for long-term nature conservation, implementing the usage of forest resources by the local human population. Our activities especially focus on uniting scientists and practitioners; we further intend to train and sensitize young students being the decision-makers of tomorrow in this highly fragile country.

Key-words: capacity building, communication, ecosystem functions, ecosystem services, education, forest biodiversity, human well-being, land-use patterns, nature conservation, population ecology, south-south collaboration

Background

Biodiversity is not equally distributed across the globe. Areas with exceptionally high levels of species richness and endemism can mainly be found in tropical regions along the equator (Zachos & Habel 2011, Stork & Habel 2013). Unfortunately, countries in this region often have an exceptionally high degree of demographic pressure, and thus an increasing need for the production of food and wood, their main source of energy (Cincotta et al. 2000). Ecosystems in areas of high agricultural value particularly suffer under this severe demographic pressure and pristine habitats are rapidly transformed into agricultural land. Hence, this pressure causes a **loss of many indigenous habitats and the fragmentation and degradation of remaining patches** (Pellikka et al. 2009). Increasing human demographic pressure and non-adapted agricultural techniques cause a severe loss of pristine forest habitats, and a depletion of natural resources. This trend has negative effects on animal and plant populations (Habel et al. 2014a, Husemann et al. 2014), as well as for the human well-being. In addition to these negative effects on the population structure of forest living organisms, degraded forests often provide reduced ecosystem functions. These coherences have been demonstrated for various **forested areas across East Africa**. For example, many highland forests act as important water catchments, making regional rainfall patterns strongly dependent on forested areas (Brown et al. 2005). Indigenous forests further provide habitats for endemic species, but also important ecosystem services, such as protection against soil erosion and against flooding events along rivers. Finally, forested areas store large amounts of carbon dioxide, provide fertile soil, shade, wood and various non-timber products like medicinal plants. The severe increase of the human population is causing a **conflict between an increasing need for land and natural resources and the protection of nature and ecosystem services**, especially in tropical forest regions. In consequence, we require targeted research to derive sustainable use and management scenarios in these fragile ecosystems (Entenmann et al. 2014).

Evidence based nature conservation (sensu Sutherland et al. 2004) is drawing on data derived from natural sciences (e.g. species behaviour, habitat dynamics, habitat configuration). However, it often **excludes human concerns, such as need for resource, cultural behaviours, and future expectations** (Schmitt 2011). However, experience has shown that conservation of nature is not possible when ignoring the socio-economic context. Thus, an awareness of the importance of biodiversity and ecosystem services provided by an intact environment and the presence of skills that enable people to get involved in the conservation of biodiversity and its sustainable use are important preconditions for the **participation of the human population** in biodiversity conservation programs. **Education and communication** with a focus on biodiversity are important success factors to strengthen biodiversity conservation (Manfredo 2008, Rieckmann & Timm 2010). It is crucial to assess **people's knowledge, awareness and willingness** to change their behaviour in order to develop successful environmental education and communication strategies. To reach the ultimate goal of integrating nature conservation and measures of increasing human well-being, transdisciplinary networks of scientists and stakeholders from various institutions and research fields should jointly elaborate **holistic strategies**.

Research framework and scientific cooperation

In collaboration with our Kenyan partner universities and model regions, we propose an **international transdisciplinary research network** to promote sustainable land-use management and land-use planning in the vulnerable forest areas of south-eastern Kenya through reconciliation of biodiversity conservation and use. The network aims at **strengthening the exchange between German and Kenyan scientists and students and invisions capacity building for the African partner universities** to foster essential research and teaching curricula related to sustainable land use management. We have selected three forest model regions differing in their natural history, degree of degradation,

way of land-usage, and the **current strategy of nature conservation**. All three regions are characterised by strong human land-use pressure, a severe loss of natural forest, the subsequent loss of pristine habitats for wildlife, and a rapid reduction of ecosystem services. The **long-term vision** of our activities is to consolidate the existing **North-South collaboration** between Technical University Munich (in the following TUM) and Kenyan Universities and to initiate a strong **South-South collaboration network amongst the Kenyan Universities**. Ultimately, we envisage a vibrant research and teaching network, including stakeholders and scientists from different disciplines and research fields to find solutions for **sustainable use of forest ecosystems in concert with biodiversity conservation implementing students as the future decision-makers**. We will combine approaches from the following three research fields:

- **Ecology:** Movement ecology of animal species; surveys on birds, arthropods and vegetation;
- **Agro-ecology and ecosystem services:** Analysis of land-use practices; detection of forest fragmentation patterns; quantification of ecosystem services via Rapid Ecosystem Function Assessment (REFA) (see Meyer et al. 2015);
- **Education, communication and management:** Surveys of livelihood parameters, awareness of biodiversity and ecosystem sensitivity, willingness to change resource utilization patterns; critical reflection of contrasting conservation strategies (integration and segregation of the local human population in conservation activities).

In the following we will describe our **methods which we will apply in each of the three model regions in the same way to compare parameters across all three regions:**

- (i) Information of land-cover, including forest patches and land-use, will be collected from high resolution aerial photographs derived from a camera placed at aerial vehicle (DJI observation drone); land-cover analyses will subsequently performed with the programme QGIS to evaluate the habitat configuration (habitat size, isolation, edge-size-ratios). This data will be combined with data from subsequent methods. Additional comparative analyses of land-cover changes will be performed based on historical aerial pictures. Based on this data we will select a specific study area for detailed ecological assessments and observations. A DJI observation drone will be provided by the Chair of Terrestrial Ecology, TUM.
- (ii) Analyses of the movement ecology of selected bird and mammal species will be done with radio tracking and acceleration sensors to assess movement behaviour, home range sizes and habitat demands. Based on the information we will develop habitat models to evaluate the ecological impact of habitat fragmentation, depending on the ecological amplitude and the dispersal behaviour of the respective targeted organism. Data will be collected with a tracking receiver. Subsequent calculations of species' specific home range sizes and movement behaviours will be performed in R. Equipment for field-work (receivers, antennas, transmitters) will be provided from the Chair of Terrestrial Ecology, and the Chair of Restoration Ecology, TUM.
- (iii) Assessment of plant diversity (woody species) and vegetation structure will be done using study plots (20m x 20m) and a stratified random sampling design. Stratification will be done in accordance with information obtained from method (i), based on e.g. the level of forest disturbance, forest protection status and accessibility by local people. For each plot, environmental factors, signs of human activities and phenology of woody plants will be described. Ordination techniques and cluster analysis will be used to identify vegetation patterns and the most relevant explanatory variables. The results will be evaluated in terms of bird diversity as well as in regards of land-use and conservation strategies.
- (iv) Rapid ecosystem function assessment methods (rapid arthropod sampling techniques and bioassays for ecosystem functions) will be used to quantify the potential of sites to deliver ecosystem services. Quantified potentials of

ecosystem services will be analysed with respect to land-cover and land-use information, as well as plant diversity and habitat connectivity.

- (v) Previously prepared and tested guided interviews will be used to administer questionnaires as instruments for collecting socio-economic data. The main goal is to obtain qualitative, typological data sets on current human needs and concerns, livelihood of people, awareness of biodiversity and ecosystem sensitivity, critical reflection of conservation strategies, the importance and connection between the forests, central legacies, and willingness to change land-use strategies, cultural background and further variables, such as biological knowledge. Participants will be selected using a typological method based on their relationship to the forest. The sample will therefore consist of data from people who deal with the forests on different levels such as professional, political or private levels, and from corresponding control groups.

Three model regions, three universities

For our activities we selected three forest model regions in south-eastern Kenya to conduct **research, workshops and teaching** (Fig. 1) in a multidisciplinary team. The selected forest regions differ in their original habitat size: the **Riparian gallery forests** around Kitui provide narrow habitat strips along rivers; the **Arabuko Sokoke** coastal forest represent medium-sized habitat strips along the East African coast of the Indian Ocean; and the **Taita Hill cloud forests** existed originally in large habitat patches on mountain tops. All three forest types suffer under severe and rapid habitat destruction due to favourable abiotic conditions for subsistence agriculture. The **three selected model regions** represent different conservation strategies: a strict segregation of land-use and nature conservation by National Parks, as well as participatory management regimes, or a complete lack of any conservation measures. Participants of this proposal have long-standing relationships via teaching and joint-research programmes with **three Kenyan universities, which are located close to the three selected field sites**. This situation creates the following **field-site-university-pairs** (see Fig. 1):

- Riparian gallery forests around Kitui - **South Eastern Kenya University (SEKU)**
- Arabuko Sokoke coastal forest - **Pwani University (PU)**
- Taita Hill cloud forests - **Taita Taveta University College (TTUC)**

For all regions institutional collaborations in teaching and joint-research programmes have existed for several years (see below). The geographic location of our three study regions with respective universities are displayed in Figure 1. The aim of this proposal is to consolidate a continuous exchange between TUM (and other German universities, i.e. Universities of Trier, Vechta and Halle), and the three Kenyan partner universities. The activities will promote **capacity-building on sustainable development**. In the following we will describe the selected **model regions and seven activities**.

1. Riparian gallery forests in cooperation with South Eastern Kenya University (SEKU); Riparian gallery forests are found along rivers, such as those in the semiarid regions of east Kenya close to Kitui city. Fertile soil, high-standing ground water level and trees for the production of charcoal, bricks, and timber for house construction makes these riparian ecosystem a favourable place to conduct subsistence agriculture (Teucher et al. 2014). In consequence, many people have settled along these rivers during the past decades. Today, a major proportion of these formerly interconnected gallery forests exists in small and isolated remnants, with negative effects on animal and plant population structures, as shown for the Kenyan endemic bird species Hinde's Babbler *Turdoides hindei* (Teucher et al. 2014). The selected gallery forests around Kitui city are not protected by any conservation status. This project will build on and further strengthen past activities that were conducted by scientists and students from TUM and SEKU in the fields of food security, agro-ecology, and

population ecology in this region. **TUM-SEKU** already hold a **Memorandum of Understanding (MoU)** for teaching and joint-research projects (APPENDIX I). The Principal Investigator (PI) of this proposal has already taught at SEKU several times (APPENDIX II), and organised various workshops, on “food security and biodiversity conservation” and “north-south collaboration in biodiversity research”; the outcome of these workshops, which has taken place at the SEKU campus, were published afterwards in international journals (see Habel et al. 2014b, 2015, see APPENDIX III and IV).

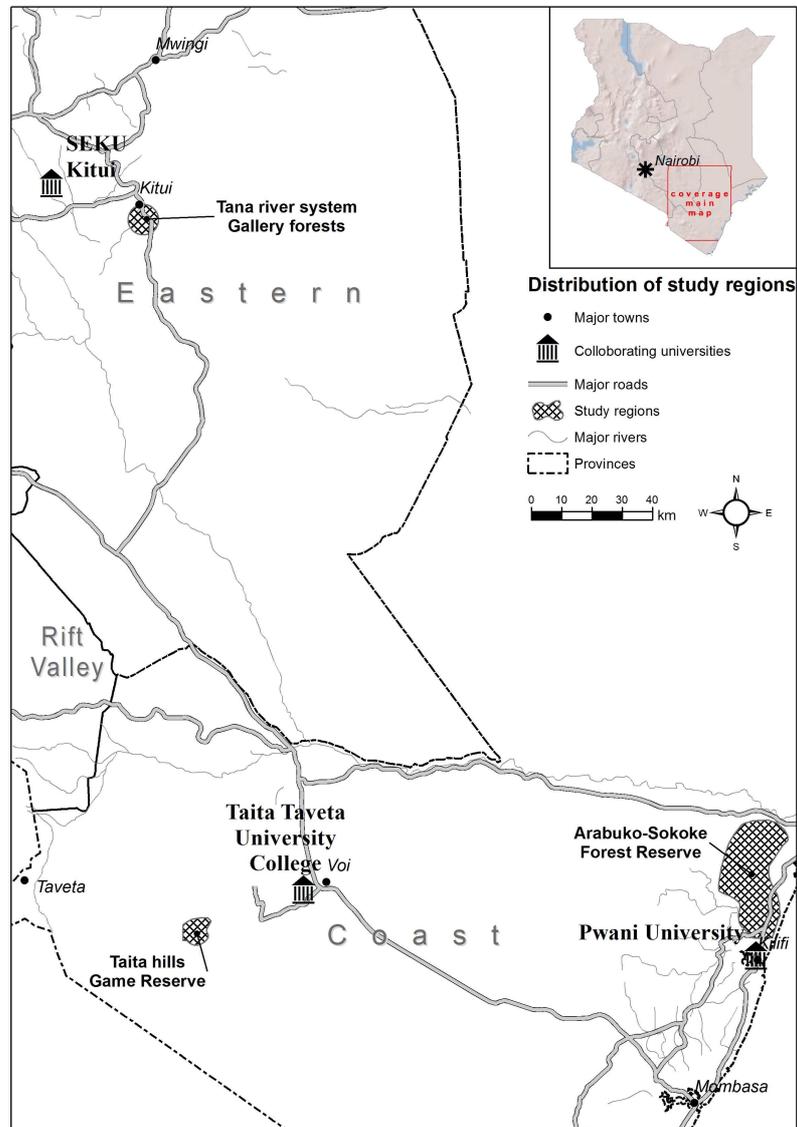


Figure 1: Distribution of study regions and the respective universities in south-eastern Kenya, with the gallery forest close to SEKU, the coastal forest Arabuko Sokoke close to PU, and the cloud forests of the Taita Hills with the neighbouring TTUC. Additional collaborations exist with the Kenyatta University and the National Museums of Kenya in Nairobi.

2. Lowland coastal Arabuko Sokoke forests of East Africa in cooperation with Pwani University; lowland coastal forests of East Africa covered the entire East African coastal sea shore of the Indian Ocean in former times. However, this forest cover was destroyed almost entirely during the past decades (Muriithi & Kenyon 2002) and most of the forest patches nowadays are small and geographically isolated. These remaining forest remnants are habitat for endemic and highly endangered species, such as the Sokoke Scopes Owl *Otus irenae*, the Golden Elephant Shrew *Rhynchocyon chrysopygus*, and various butterfly species (Muriithi & Kenyon 2002). Thus, this forest became classified as one of the global

biodiversity hotspots – named the East African Coastal Forest (Mittermeier et al. 2011). In the meanwhile, parts of the remaining forest were fenced and protected as National Park and received Forest Reserve status. Teaching and research activities were already conducted in the Arabuko Sokoke forest reserve and at the Pwani University by participants of this application. The long-lasting TUM-Pwani-collaboration is further supported by an existing MoU (APPENDIX V). An additional advantage is the existence of the “**TUM-field station**” located in Malindi, 30km north-east of Pwani University and 20 km north-east of the Arabuko Sokoke forest. This station can be used for various project activities and the accommodation of researchers and students during their stay (APPENDIX VI).

3. Cloud forests of the Taita Hills in cooperation with Taita Taveta University College; the cloud forests of the Taita Hills provide moist and cool climate and fertile soil - excellent preconditions for the production of food and cash crops. Thus, the forest cover became rapidly transformed into agricultural land during the past decades (Pellikka et al. 2005). In consequence, most of the highly endangered (Taita endemic) animal and plant species persist in small and isolated forest fragments, with negative effects on their viability – on community, species, and population level (Lens et al. 2002, Callens et al. 2011, Habel et al. 2014a). This region belongs to the **Eastern Afrotropical biodiversity hotspot** (Mittermeier et al. 2011). Most of the remaining forest patches are accessible by the local human population and deforestation remains a severe problem. Participatory forest conservation was conducted during the past decades, yet, with rather little success. Various biodiversity research projects were realized during the past years by the PI of this project (APPENDIX VII). The TUM already holds a MoU to the TTUC (APPENDIX VIII), as well as strong collaboration to Nature Kenya (Wundanyi branch, Taita Hills). Further activities from this application will enhance, continue and deepen the already existing cooperation in this region.

Work programme

We will collect **comparable data sets in each of the three model regions**, and will organise **workshops and seminars at the neighbouring universities during a four-year period**, with two activities per year (one in Kenya and one in Germany). Resulting data sets will be analysed afterwards at the three participating Kenyan universities, and at the TUM, Germany. **All activities in Kenya will cover a total duration of four weeks** (1 month) per stay, consisting of 3 days workshop at the beginning, subsequent fieldwork including field courses, and 3 days teaching and closing discussions at the end (and 2X0,5 days travelling). However, **MSc students will stay in the field for a total period of three months. Activities at the TUM will consist of 1 month data analysis and discussion**, with 2 days opening and 2 days closing workshops on selected topics (see below). For each activity, MSc students from Germany and Kenya will be involved. Furthermore, the **Kenyan PhD student Joslyn Muthio Nzau**, a very successful student who was previously funded by the DAAD (APPENDIX IX) will conduct her PhD thesis on human-wildlife conflicts in semi-arid regions around Kitui, East Kenya (one of our model regions) and thus, will be involved in various activities. An overview of all activities is provided in Table 1.

Activity #1 “Gallery forest”, Kenya, Kitui, SEKU, Nzeeu River, 4 weeks (March 2016); this activity aims at illustrating the relevance of gallery forests as ‘life lines’ in semiarid regions. In particular we will analyse the relevance of ecosystem services (soil, ground water, wood, shade) for the human population, and potential risks from over-exploitation of these resources. This first activity will start with an opening workshop on the **ecology and biogeography of gallery forests and delineate nature degradation of fragile ecosystems in semiarid regions of East Africa**. During field work we will perform studies on the movement ecology of selected bird species, such as *T. hindei*. We will perform a detailed assessment on the agro-ecological activities and studies on plant diversity and vegetation structure along gradients (disturbance, distance from river). A detailed survey will provide information on needs and potential of current land-use practices (methods described

in detail above). Participants will be scientists and students from SEKU and from the two other Kenyan universities, as well as from TUM and other German universities (see Supplementary Table 1 and 2). Fieldwork will be conducted by Kenyan and German scientists, as well as by PhD and MSc students.

Activity #2 “Gallery forest at TUM”, Germany, Freising, TUM, 1 month (August 2016); data analysis and discussion of the data collected in March 2016. Movement ecology data and land-use data; this will be offered as a lecture module held in particular for Kenyan and German MSc students, who will have collected data sets in the field in March 2016. Data from surveys will be analysed to understand whether and how different interest groups show different concerns, knowledge and reflection on conservation strategies and their personal interests. Participants will be students and scientists from SEKU and TUM (see Supplementary Table 1 and 2).

Activity #3 “Coastal forest”, Kenya, Malindi, Pwani University, Arabuko Sokokke forest, 4 weeks (March 2017); this activity aims at the efficiency and acceptance of diverging conservation strategies, and raises the question on how to protect highly endangered ecosystems and species - **gated conservation versus participatory conservation regimes**. We will analyse the movement ecology of selected endangered animal species, like *O. irenae* and *R. chrysopygus*. We will assess forest disturbance within the reserve and adjacent regions depending on accessibility and protection status (fenced, protected, unprotected forest patches) using high resolution aerial photographs. We will study the plant diversity and vegetation structure using study plots and a stratified random sampling design; guided interviews will focus on the acceptance of conservation areas by the local human population (for a detailed description of methods see above). Participants of activity #3 will be scientists and students from Pwani University and the two other Kenyan universities, as well as from TUM, and other German universities (see Supplementary Table 1 and 2). Fieldwork will mainly be conducted with MSc students from Kenya and Germany.

Activity #4 “Coastal forest at TUM”, Germany, Freising, TUM, 1 month (August 2017); data analysis and discussion. In these analyses we will focus on potential strategies to conserve forest fragments along the East Kenyan coast (gated conservation versus participatory conservation). This activity will be offered as a lecture module held at TUM in particular for MSc students, who will have collected data sets in the field in March 2017.

Activity #5 “Taita Hill cloud forest”, Kenya, Taita Taveta University College, 4 weeks (March 2018); this activity aims at illustrating the relevance of **forest corridors to guarantee long-term population and species persistence** within an agricultural matrix. We will perform movement ecology studies for endemic bird species in habitat patches differing in size and habitat quality. We will assess the land-use coverage by high resolution aerial photographs, and analyse the floristic diversity and vegetation structure of selected cloud forest patches using study plots and a stratified random sampling design. Stratification is done in coordination with other activities, and will take into consideration forest patch size and quality (e.g. edge-size-ratio); the method of guided interviews will primarily be the same as for the other activities in order to compare parameters across all three regions. Finally, we will critically evaluate the land-cover data and the need and exploitation of land by the local human population. Participants of these activities will be students and scientists from Taita Taveta University College and the other two Kenyan universities, as well as from TUM and other German universities (see Supplementary Table 1 and 2). Fieldwork will be conducted mainly with MSc students from both countries.

Activity #6 “Taita Hill cloud forest at TUM”, Germany, Freising, TUM, 1 month (August 2018); in our data analyses we will focus on the **design of corridors** for forest species; we will develop strategies to re-connect forest patches within the Taita Hills, incorporating human activities (ownership, plots for food crop). This activity will be offered as a lecture module held at TUM in particular for MSc students, who collected data sets in the field in

March 2018. As the Taita Hill cloud forest uses the concept of participatory forest conservation, which is different to the other two regimes, the second focus here will be to analyse, how this conservation strategy might show different effects upon different groups within the public (gated nature conservation versus participatory approaches). This activity will be offered as a lecture module held at TUM in particular for MSc students, who will have collected data-sets in the field in March 2018.

Activity #7 “Synthesis workshop“, Kenya, Kitui, SEKU, 1 week (March 2019); In this closing workshop we will present all collected data from the three study regions. We will **involve and reach local stakeholders such as universities, NGOs, community groups and governmental authorities** and evaluate the value of our approaches and data to raise awareness of conservation issues. In particular we will highlight the following aspects (in line with the three main research goals):

- (i) **Ecology;** discussion of biodiversity patterns of birds, arthropods and plants in relation to different habitat configuration (level of degradation, patch sizes);
- (ii) **Agro-ecology and ecosystem services;** natural resources used, delineating threshold values and potential strategies to improve livelihoods and quality, and to guarantee the resilience of ecosystems;
- (iii) **Education, communication and management;** current needs of the different groups within the public; (non-)acceptance and effects of conservations strategies of the public, e.g. advantages and disadvantages of integrating versus segregating the local human population.

Participants of this closing activity will be scientists and students from SEKU, PU and TTUC, as well as from TUM and other German universities. Additional representatives from developing organizations will be invited (see Supplementary Table 1 and 2).

Table 1: Overview of all seven activities; activities taking place in Kenya (grey X) and Germany (white X) in the respective study regions focusing on gallery forest, coastal forest and cloud forest.

| Year / Activity | Gallery forest | | Coastal forest | | Cloud forest | | Synthesis |
|-----------------|----------------|--------|----------------|--------|--------------|--------|-----------|
| | 3/2016 | 8/2016 | 3/2017 | 8/2017 | 3/2018 | 8/2018 | 3/2019 |
| #1 | X | | | | | | |
| #2 | | X | | | | | |
| #3 | | | X | | | | |
| #4 | | | | X | | | |
| #5 | | | | | X | | |
| #6 | | | | | | X | |
| #7 | | | | | | | x |

The Long-term impact

Solutions elaborated in the above described seven activities are facing very **recent challenges of Sub-Sahara Africa** – like **food security and ecosystem degradation**. Approaches selected here are bringing together disciplines from social sciences and natural sciences **towards transdisciplinary joint collaboration**. This proposal focuses on the combination of both, **theoretical methods** from natural and social sciences, as well as the **translation of these findings into conservation and agricultural practice**. With these activities we would like to underline that **nature conservation and improved human livelihood may not follow opposite goals**; Stakeholders are tracing a similar aim: the preservation of intact ecosystems (for human beings and endangered biota). North-south collaboration in this proposal will promote classical **capacity building**. Thus, we selected

comparatively **young Kenyan universities**, which are located in areas suffering under strong demographic pressure (semiarid regions of Kitui, coastal area, Taita Hills region). These young universities are still **improving their curricula and all are holding departments working with agriculture, social sciences and ecological research topics**. In addition to this north-south capacity building, we would like to establish a **south-south-biodiversity network** and link this network with local and national stakeholders and practitioners to translate newly developed ideas and strategies into practice. In specific, Kenyan (but also German) Master and PhD students will be qualified by these activities to create a strong and positive **backbone for future development (sustainable agriculture, improving food security, preservation of ecosystem services) in rural regions of Kenya** (and also adjoining countries). Scientists of all three Kenyan universities (and the German partners) are very interested to establish this network (with Germany and other Kenyan universities) and will support the realization of this proposal, ideas and activities by their own facilities (housing, university rooms etc.) and personnels.

References (Bold = Participants of this application)

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